Final Proof of Concept

Ballarat North PSP – Stormwater Drainage

Prepared for: Victorian Planning Authority
8 July 2025
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SMEC Company Details

Approved by	Sander van Hall
Address	Collins Square, Tower 4, Level 20, 727 Collins St, Melbourne, VIC, 3008, Australia
Phone	+61 3 9869 0885
Email	Sander.vanHall@smec.com
Website	www.smec.com
Signature	

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Executive Summary

SMEC has been engaged by the Victorian Planning Authority (VPA) to refine the stormwater drainage strategy based on the Integrated Water Management (IWM) Plan and prepare the functional designs for the Ballarat North Precinct Structure Plan (PSP). The outcomes of the stormwater drainage strategy will be used to inform the PSP land budget and the associated costing to deliver the drainage infrastructure works in the form of a Development Contributions Plan (DCP).

A literature review and contextual analysis (Stage 1) were conducted to understand the background work undertaken by the VPA and various consultants. The findings from this review helped inform the design basis. Subsequently, a preliminary drainage concept was developed and presented to the key stakeholders for initial feedback and support.

As part of the proof of concept (Stage 2) outlined in this report, SMEC has undertaken additional technical analysis (including hydrological, water balance, and hydraulic modelling) to corroborate the preliminary drainage strategy and provide confidence in the land budget allocated for stormwater drainage assets. The stormwater drainage strategy has been further refined with input from the VPA, and the required stormwater infrastructure has been identified and conceptually sized.

Site Context

Ballarat North PSP is located within the major river catchment of Hopkins River and within the sub catchment of Burrumbeet Creek. The PSP area is located within the City of Ballarat on the northern boundary of the existing urban extent of Ballarat. The PSP area is predominantly bounded by farming areas, and residential areas. The total site area is approximately 832 ha with a ‘Core Area’ of 567 ha and an ‘Expanded Area’ of 265 ha. The ‘Core Area’ was recognised by Ballarat City Council as the preferred next residential growth area and has been the subject of strategic technical assessments and engagement with landowners and relevant agencies over several years by Council. The ‘Core Area’ is the subject of this report.

The Ballarat North PSP area is generally split into four major catchments. The south east (SE) catchment is approximately 154 ha. The central (C) catchment is approximately 191 ha of which 48 ha is external catchment outside of the PSP boundary. The largest catchment is north west (NW) catchment and is approximately 212 ha. This catchment generally slopes towards western boundary of the site where it drains into the Burrumbeet Creek. A large external catchment traverses the PSP southern boundary from Burrumbeet Creek catchment.

Some of the key features of the PSP area include Ballarat Town Common, Mount Rowan, Ballarat Grammar Mount Rowan campus, Miners Rest wetland and former Wendouree tip site. Burrumbeet Creek and its tributary to the east are a prominent feature within the PSP area and is subject to a range of planning, engineering and environmental considerations. The site constraints including existing flooding, biodiversity assessments, have been identified to assist in developing the strategy.

Stormwater Drainage Strategy

A stormwater drainage strategy has been developed to address stormwater management requirements, including flood protection, IWM objectives where possible, compliance with relevant drainage authority design standards, and stormwater quality management. The strategy incorporates drainage assets and centralised stormwater treatment systems aligned with the IWM plan and the ‘Vision and Purpose’ of the PSP. Identified assets include a constructed waterway, retarding basins, wetlands and sediment ponds, along with provisions for supporting stormwater infrastructure such as pipelines, culverts and overland flow paths to manage and control runoff before it is discharged into Burrumbeet Creek.

The proposed locations of the stormwater infrastructure, waterways and outlet points are shown in the figure below.

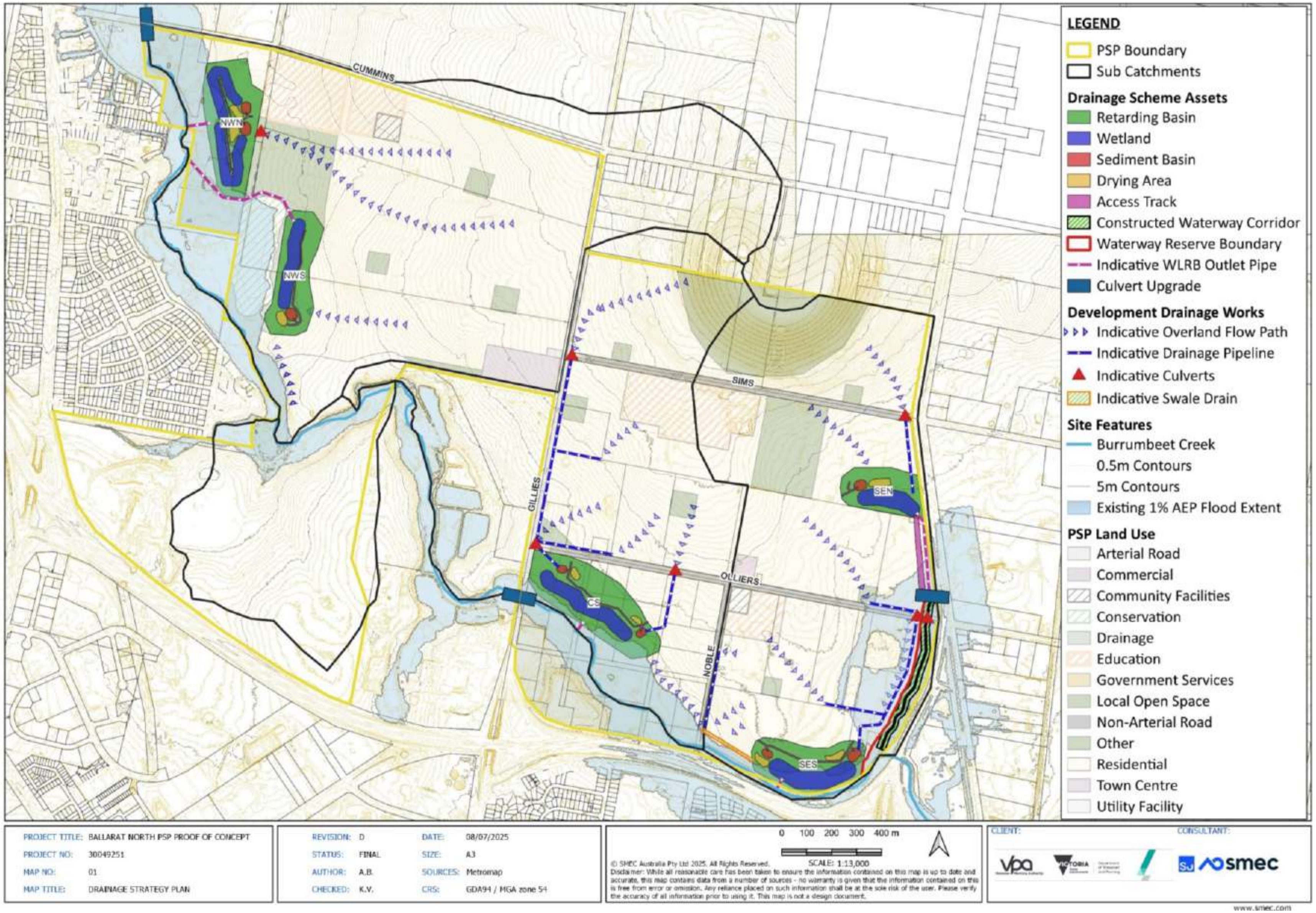


Figure 0-1-1 Ballarat North PSP area Preliminary Drainage Strategy

Integrated Water Management Strategy

The IWM Plan (Arup, 2024) recommends an alternative approach known as the 'Adaptive Plan.' This approach involves the provision of lot-scale rainwater tanks and precinct-scale WSUD wetlands, with the objective of harvesting stormwater for reuse in the irrigation of local open spaces.

Modelling shows that 29% of the non-potable water demand is supplied by a 2kL rainwater tank installed in every household within the PSP area, operating with approximately 71% reliability.

The water balance modelling conducted to date also suggests that 31% and 40% of the total runoff volume can potentially be harvested from wetland system for stormwater reuse with and without rainwater tanks in place. However, this outcome is contingent upon the availability of an equivalent water demand within the area.

Further evaluation of options will be required during the functional and detailed design phase to verify the water demand and storage needs. This will ensure that the harvested water can be appropriately stored for reuse and that the necessary infrastructure for transporting the water to support irrigation in the designated active open space, as outlined in the IWM plan, is properly planned.

Burrumbeet Creek Waterway Corridor Rehabilitation

It is recommended that the Burrumbeet Creek waterway corridor is revitilise through stabilisation of the existing creek form, and the reintroduction of native vegetation and trees along the riparian zones. Further studies such as hydro-ecological, geomorphological assessments, targeted flora and fauna survey will help identify and prioritise specific sections for enhancement. These items can be included in the DCP costs, as there is a clear nexus between the increased risk of creek deformation and future development within the PSP area, even though existing creek instabilities have already been caused by current land uses. The responsibility of setting the requirements and acceptance of the proposed in stream works ultimately lies with GHCMA as the waterway authority. Consultation with the traditional owners are also recommended to achieve the best outcome.

Flood Impact Assessment

Ballarat North PSP is situated within the Glenelg Hopkins Catchment Management Authority (GHCMA) regions. Ballarat North is subject to flooding along the Burrumbeet Creek floodplain in the 1% Annual Exceedance Probabilty (AEP). A hydrologic and hydraulic assessments have been completed in accordance with Australian Rainfall and Runoff (AR&R) (Ball et al., 2019) and GHCMA Guidelines. Specifically, climate change scenario modelling have been undertaken to define the 1% AEP flood extent. This has been used as the basis for the flood impact assessment.

The hydraulic modelling assessment has incorporated the proposed retarding basins, constructed waterway diversion and associated filling to assess the impacts on the floodplain under the developed conditions. The outcomes demonstrates that the PSP development with the proposed infrastructure does not result in any worsening of flood conditions in the 1% AEP event under climate change scenario.

Conclusion and Recommendation

The proof-of-concept outcomes has demonstrated that the proposed drainage infrastructure and mitigation works are technically feasible and meet the relevant requirements. The next phase of the project will involve the functional design of each proposed assets including constructed waterway, wetlands and retarding basins.

It is recommended that the outcomes be presented to the relevant authorities to confirm the key requirements, assumptions and critical concerns identified during the preliminary drainage strategy phase have been appropriately addressed.

1. Introduction

SMEC has been engaged by the Victorian Planning Authority (VPA) to refine the stormwater drainage strategy prepared by Arup in 2024 and prepare the functional designs for the Ballarat North Precinct Structure Plan (PSP). The outcomes of the stormwater drainage strategy will be used to inform the PSP and the associated costing to deliver the drainage infrastructure works in the form of a Development Contributions Plan (DCP).

Ballarat North PSP is divided into core and expanded areas, as shown in the **Figure 1-1** below. The study focuses primarily on the core area, with future-proofing considerations made for the expanded area.

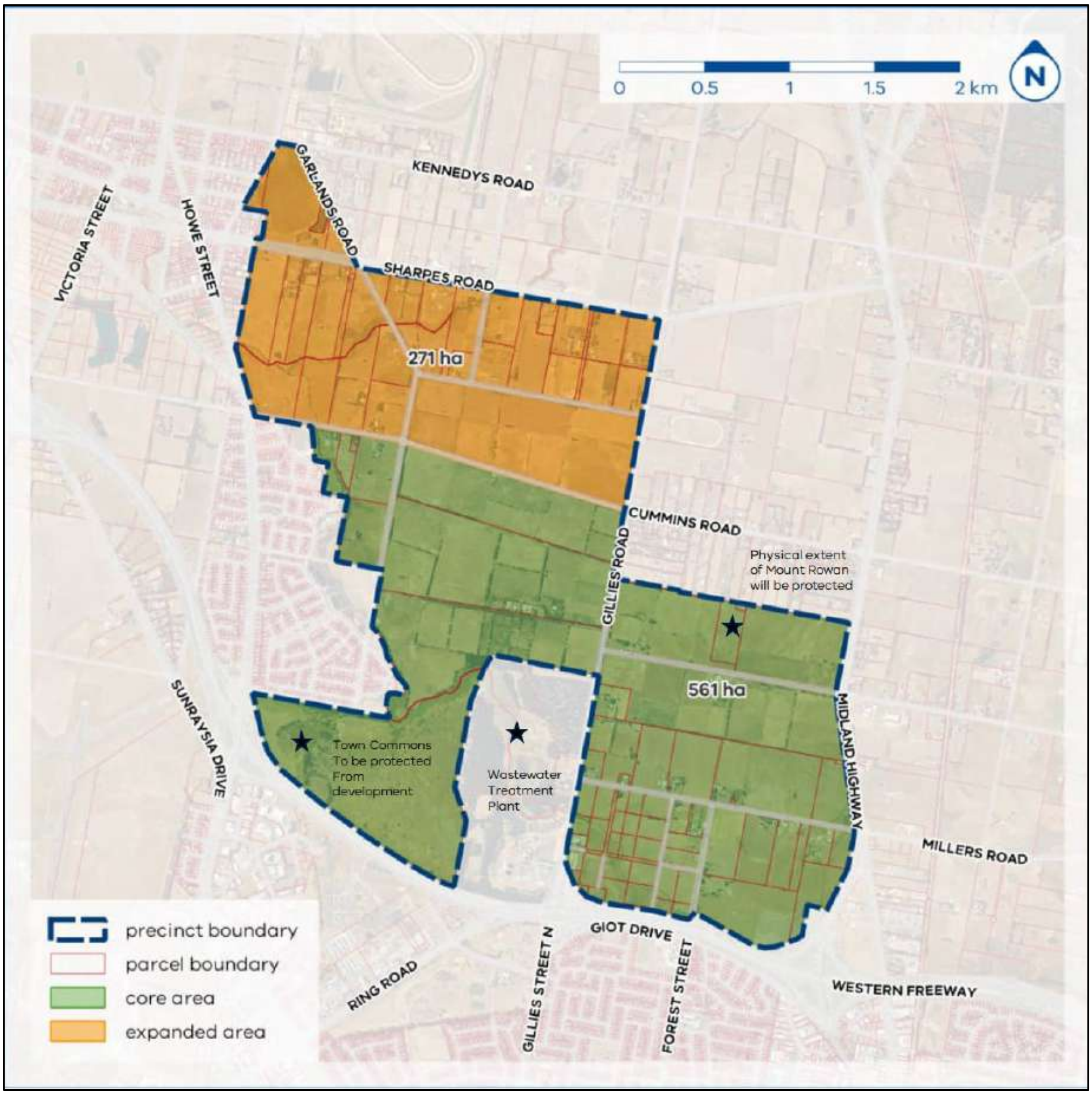


Figure 1-1 Ballarat North PSP Boundary

The PSP core area is approximately bounded by Cummins Road in the north, Midland Highway in the east, Burrumbeet Creek in the west, and Western Freeway in the south.

The scope of works encompasses a number of stages:

- Stage 1 - Literature Review and Contextual Analysis, Preliminary Drainage Concept
- Stage 2 – Stormwater Proof of Concept

- Stage 3 – Functional Design and Costing

A literature review was conducted to understand the background works undertaken by the VPA and various consultants. The findings from this review helped inform the design basis. Subsequently, a preliminary drainage concept was developed and presented to the key stakeholders for initial feedback and support.

This report describes the key outcomes and methodology related to various aspects of the drainage strategy development. The following report sections detail the key components:

- Key outcomes of the contextual analysis (Section 3 and 4)
- Waterway health (Section 5)
- Stormwater management objectives (Section 5)
- Existing conditions hydrology (Section 6)
- Outcomes of the stormwater proof of concept design for the developed conditions – infrastructure sizing (Section 7)
- Stormwater quality analysis and Integrated water management (Section 8 & 9)
- Flood impact assessment (Section 10)
- The detailed modelling methodology and results of the RORB and MUSIC modelling are provided in the Appendices.

The outcomes of Stage 2 (this report) is required to verify the drainage assets sizing and land allocation, which will then be further refined in the functional design (Stage 3) to ultimately inform the costing of the Ballarat North PSP and Development Contributions Plan.

2. Available Data

The following reports and digital data have been supplied by the VPA.

2.1 Reports

List of reports is presented in **Table 2-1**.

Table 2-1 Input Reports

Author	Year	Document Title
Arup	2024	Ballarat North PSP IWM & Drainage Assessment, Ballarat North PSP IWM Plan, Rev 03, 2 July 2024
Central Highlands Water, City of Ballarat, Corangamite CMA	2018	Ballarat City Integrated Water Management Plan, Final Report
Central Highlands Water	2018	Ballarat Potable Water Demand Target
Department of Environment, Land, Water and Planning	2017	Growling Grass Frog Habitat Design Standards
Ecology and Heritage Partners	2024	Ballarat North Precinct Structure Plan: Strategic Bushfire Development Report and Risk Assessment, Final, July 2024
GHD	2024	Adverse Amenity Impact Assessment, Ballarat North, Rev 0, 28 May 2024
Jacobs	2024	Land Capability Statement, Ballarat North Precinct Structure Plan 10 July 2024
Mesh	2024	Final Landscape and Visual Assessment, Ballarat North PSP, Version 1, May 2024
Spiire	2024	Memo - Drainage Strategy Asset Locations 10 July 2024
Stantec	2024	Ballarat North Precinct Structure Plan, Situational Analysis Report and Utility Servicing Assessment, Revision 03, 3 July 2024
Stantec	2024	Design Brief Report – Miners Rest Flood Mitigation Rev 02 31 January 2024
RBA	2024	Ballarat North PSP Historical (Post-Contact) Heritage Assessment, July 2024
State Government of Victoria	2014	Central Highlands Regional Growth Plan
Tree Logic	2024	Arboricultural Assessment and Report, Ballarat North – PSP, 6 August 2024
Urbis	2024	Ballarat North Precinct Structure Plan, Economic & Retail Assessment, Final Report, June 2024
Victorian Planning Authority	2023	Ballarat North Precinct Structure Plan, Vision & Purpose Survey Summary
Victorian Planning Authority	2024	Community Infrastructure and Open Space Needs Assessment, Ballarat North Precinct Structure Plan, June 2024

Victorian Planning Authority	2024	Draft Ballarat North Place Based Plan for future urban structure
Victorian Planning Authority	2024	Ballarat North Precinct Structure Plan - Co -Design Summary
Wadawurrung Traditional Owners	2024	Wadawurrung IWM Statement
Wadawurrung Traditional Owners	2024	Healthy Country Plan
Water Technology	2013	Burrumbeet Flood Investigation, Summary Study Report
Water Technology	2013	Burrumbeet Flood Investigation, Hydrologic and Hydraulic
WSP	2024	Ballarat North Precinct Structure Plan, Biodiversity Assessment Report, Rev C, 9 August 2024

2.2 Digital Data

List of available digital data is presented in **Table 2-2**.

Table 2-2 Digital Data

Source	Year	Description
Department of Environment, Land, Water and Planning	2024	3D Regional Towns LiDAR, 1m DEM, Provided by VPA, Accessed 10 September 2024. Elevation Data acquired between 2019-2020.
Department of Energy, Environment, and Climate Action	2024	**Error! Hyperlink reference not valid.**
Arup	2024	MUSICX - Ballarat North PSP IWM and Drainage Assessment
Arup	2024	RORB Model - Ballarat North PSP
Water Technology	2013	TUFLOW Model of Burrumbeet Creek
VPA	2025	GIS Shapefiles, Locality, Precinct Boundary, Existing Utilities, Landfill Site Shapefiles from Datashare
VPA	2025	Place-based plan (PBP) 23/06/2025

3. Contextual Analysis

3.1 Site Context

Ballarat North PSP area is located within the City of Ballarat on the northern boundary of the existing urban extent of Ballarat and south of the locality of Miners Rest as shown in **Figure 3-1**. The PSP area is predominantly surrounded by farming area to the north and east, and existing residential area to the west and south. It is bounded by Cummins Road to the north, Midland Hwy to the east, Western Fwy to the south, and Miners Rest residential area to the west. A key feature of the PSP is Burrumbeet Creek traversing along the southern portion of the PSP.

The total site area is approximately 567 ha and identified by Ballarat City Council as the preferred next residential growth area and has been the subject of appropriate strategic technical assessments and engagement with landowners and relevant agencies over several years by Council.

Ballarat North PSP has an average slope of approximately 3% and drains from north to south towards Burrumbeet Creek. Along the low point of the Creek, the terrain becomes relatively flat as it drains towards northwest of the PSP boundary. The site has an elevation varying from 516 to 420 m AHD. The highest point of the PSP site is north of Sims Road, and the lowest point is Burrumbeet Creek.

Ballarat Town Common is located in the southwest corner of the PSP which is identified as 'Crown Land' and is supposed to likely remain undeveloped. This catchment drains naturally towards north into Burrumbeet Creek.

The site is currently zoned as Urban Growth Zone. A number of planning overlays cover the PSP area including and not limited to Land Subject to Inundation (LSIO), Floodway Overlay, Environmental Significance Overlay (Schedule 2) and Erosion Management Overlay along the Burrumbeet Creek corridor.

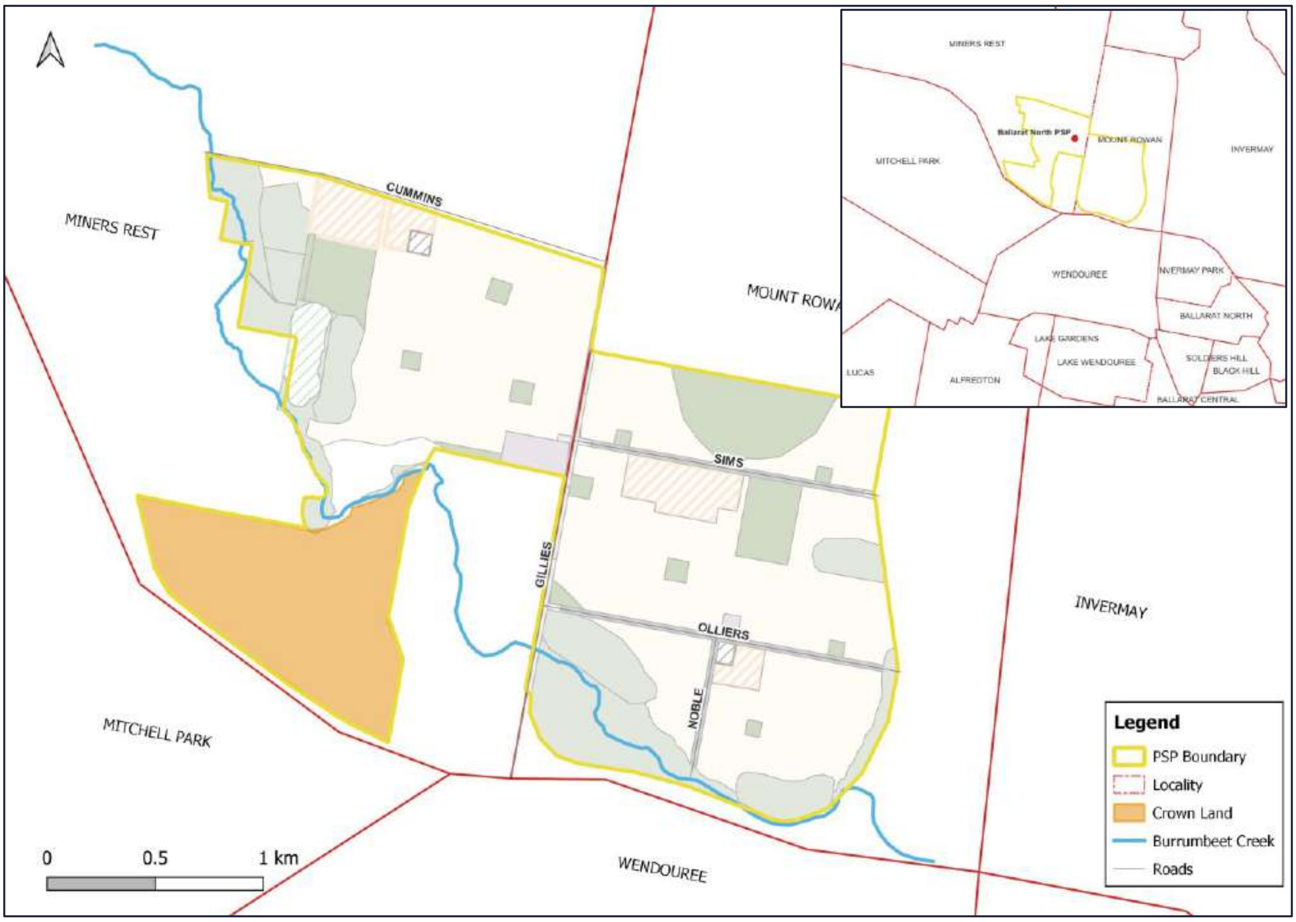


Figure 3-1 Ballarat North PSP Site Overview

3.2 Core Area Catchments

The Ballarat North PSP area is generally split into four major catchments. These catchments are described below and shown in Error! Reference source not found.

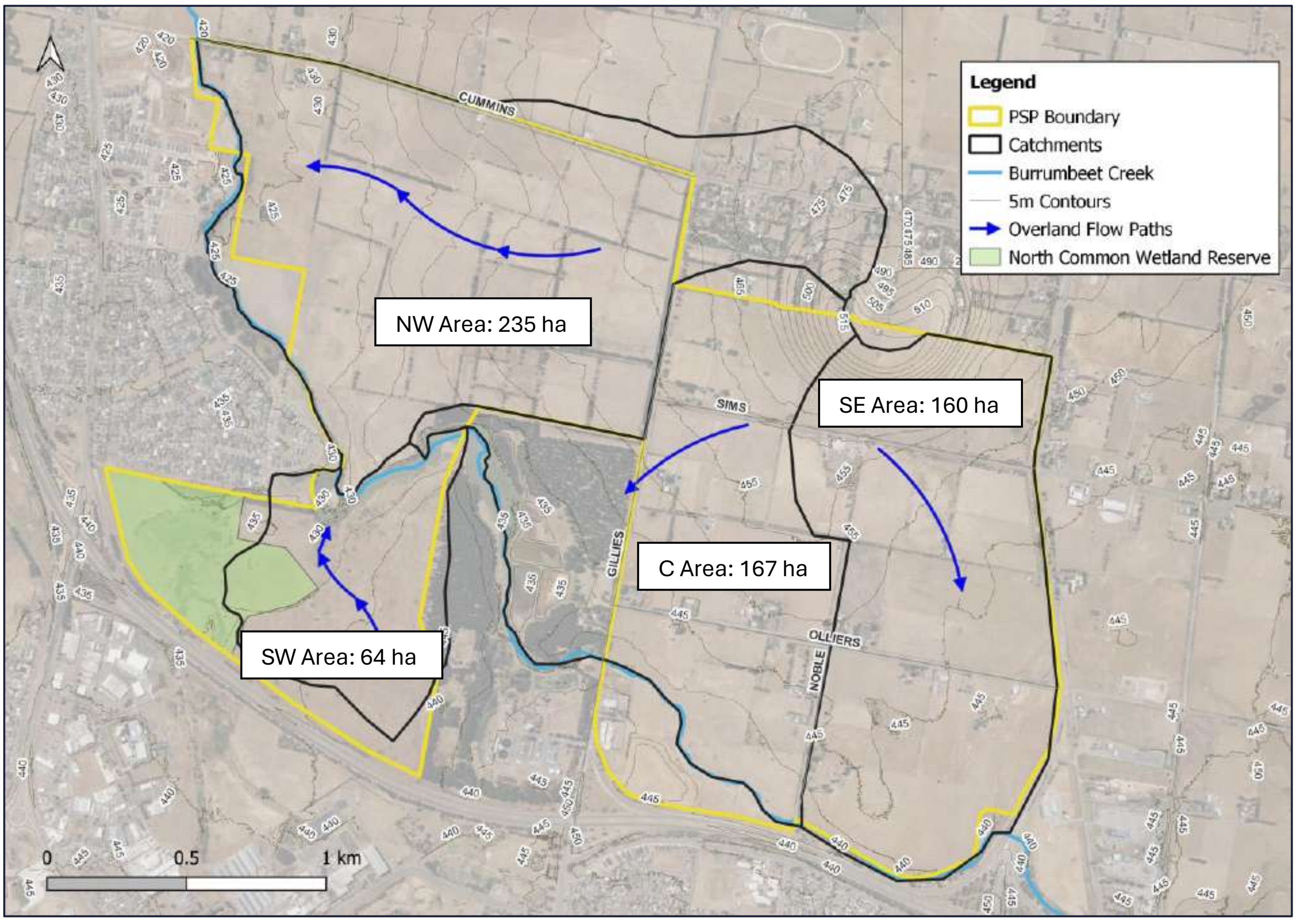


Figure 3-2 Catchment Split based upon Existing Overland Flow Paths

3.2.1 South East Catchment

The south east (SE) catchment is approximately 160 ha. The majority of the catchment is mainly large open paddocks which accommodates livestock grazing or otherwise underutilised rural land use. The direction of runoff is generally from north west to south east of the boundary. The highest point of SE catchment is north of Sims Road with the runoff draining towards south into the Burrumbeet Creek. The SE catchment elevation is varied from 520 m Australian Height Datum (AHD) to 440 m AHD.

3.2.2 Central Catchment

The central (C) catchment is approximately 167 ha of which 48 ha is external catchment outside of the PSP boundary. The majority of the external catchment is west of the Gillies Road. The C catchment is mainly open rural lands and slopes from north east to south west and south of the boundary towards Burrumbeet Creek. It has an elevation ranging from 520 m AHD to 435 m AHD. This catchment has multiple outlet locations along the creek interface.

3.2.3 South West Catchment

The south west catchment is approximately 64 ha which drains north into the Burrumbeet Creek. This catchment constitutes large open paddocks and environmental land, including part of the alignment of Burrumbeet Creek which runs through the North Common Wetland Reserve (see **Figure 3-2**), located on the southwest corner of the catchment boundary. This area is designated as Crown Land and is likely to remain undeveloped. Since there are no proposed developments in this area, there are no requirements for assets sizing and thus this catchment is excluded from ongoing modelling.

3.2.4 North West Catchment

The larger part of the PSP area is called north west (NW) catchment. The land use type is largely open space which is being used for livestock grazing and is approximately 235 ha in size. This catchment generally slopes towards western boundary of the site where it drains into the Burrumbeet Creek. The highest point elevation is 512 m AHD and lowest point is at 420 m AHD at the Burrumbeet Creek outlet (considered as the outlet of the entire PSP area). A rural residential external catchment of approximately 43 ha enters the catchment boundary to the east and north east.

3.2.5 External Catchment - Tributary of Burrumbeet Creek

There is a sizeable external catchment (990 ha) on the north and eastern side of the PSP boundary. Part of flows head east along Cummins Road and then turn south along the Midland Highway within the Mt Rowan locality. The remaining of the external catchment come from the Invermay locality to the east of the PSP boundary.

Flows coming from this external catchment will not impact the WLRB sizing. However, this external catchment has been included in the RORB model for sizing of the realigned constructed waterway. **Figure 3-3** below shows a snippet of the external catchment in the north and east of the PSP area.

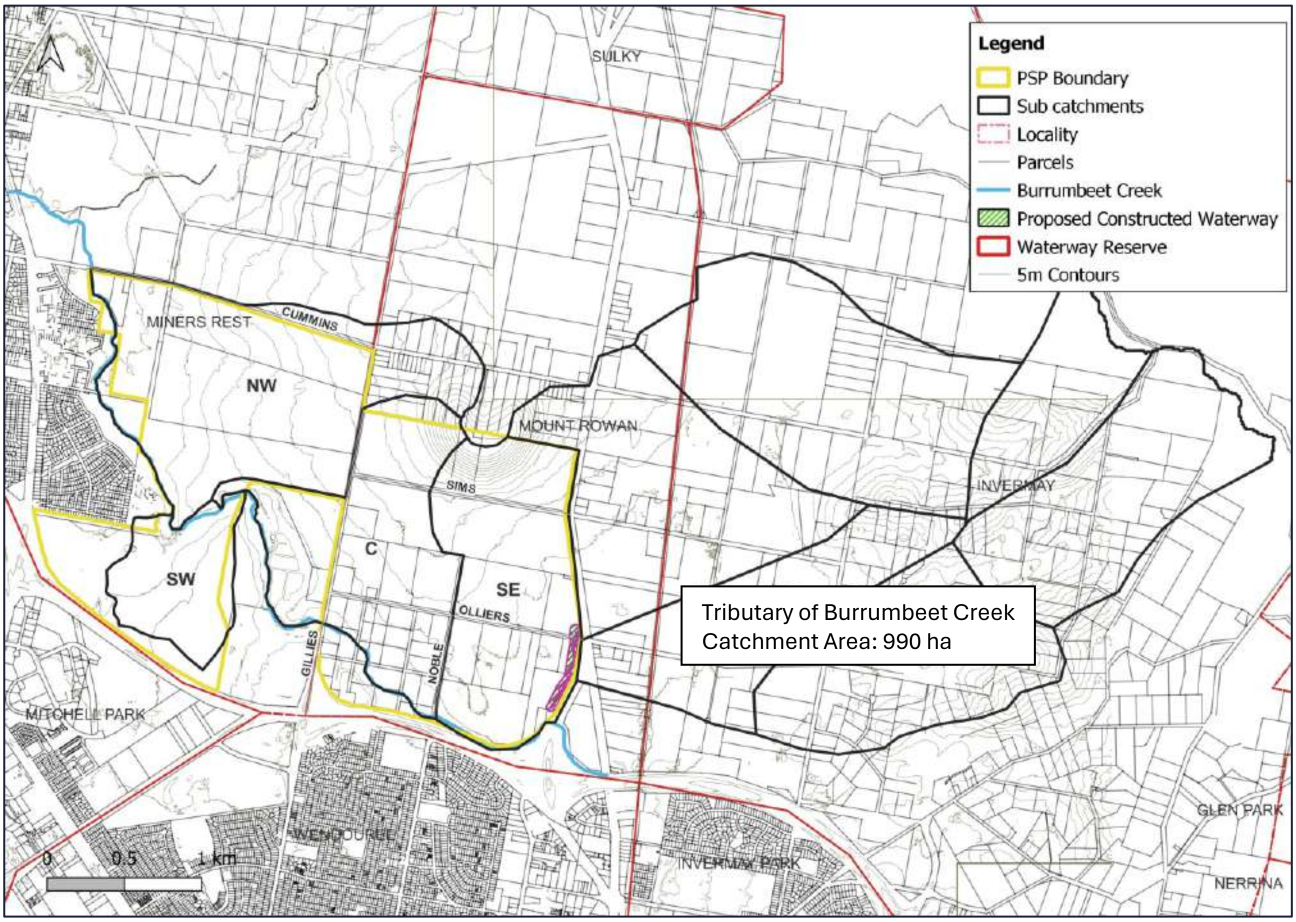


Figure 3-3 External Catchment to the Waterway

3.3 Expanded Area Catchment

The expanded area is bounded by Sharpes Road to the north, Howes Street to the west and Gilles Road to the east covering an area of 268 ha. This area generally drains towards north west into a separate tributary of Burrumbeet

Creek and is considered independent of the core area catchments. The catchment topography and direction of flow allows for drainage partitioning. The core area of the PSP has been prepared cognisant of the PSP expanded area. As such, the future drainage works within the core area does not preclude the expanded area to be investigated in the future. Catchment modelling for the core area will exclude the expanded area so that there is a clear division of catchment flows. The expanded area is shown in **Figure 3-4**.

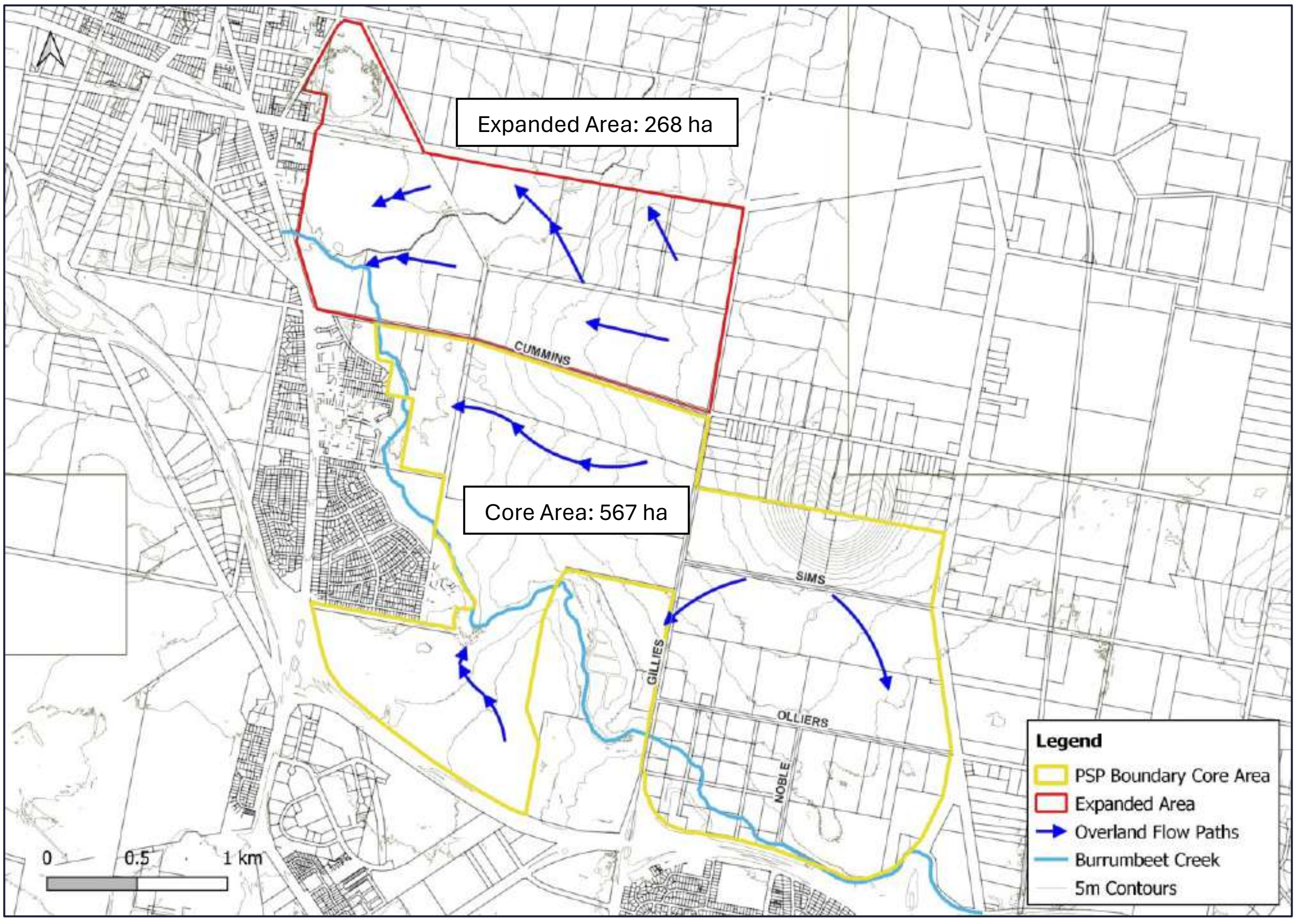


Figure 3-4 Ballarat North PSP Expanded Area

3.4 Planning Overlays

The following overlays as shown in **Figure 3-5** impacting the Ballarat North PSP area:

- The portion of the PSP area north of Sims Road is affected by the Significant Landscape Overlay (SLO) and Erosion Management Overlay (EMO). Any construction work (building or carry out works such as roadworks) is restricted in this area and a permit is required.
- The portion of the PSP area south of Sims Road is affected by the Specific Controls Overlay (SCO). This area is to be used or developed for Ballarat Grammar School Mount Rowan Campus as documented on the planning scheme map. Use or development of this area beyond the controls is prohibited or restricted.
- Bushfire Management Overlay (BMO) and Environmental Significance Overlay (ESO) (Schedule 4) on water reclamation plant site along the centre of the PSP boundary. The C, SW and NW catchments are partly affected by these overlays. The development of land in this area is affected by environmental constraints to ensure development is compatible with environmental values. Development is also only permitted where the risk to life and property from bushfire can be reduced to an acceptable level.
- The PSP area along the Burrumbeet Creek corridor is affected by the Land Subject to Inundation (LSIO), and Floodway Overlay (FO). This area is flood prone which is affected by the 1 in 100-year flood and therefore a permit is required to construct a building or carry out works.
- The NW catchment is partly affected by the Design and Development Overlay (DDO) connected to Ballarat Airport, west of the Ballarat North PSP boundary.
- There is a conservation area called seasonal herbaceous wetland along the Burrumbeet Creek to the west boundary of the NW catchment. Retention of the wetland habitat is recommended. (VPA, 2024).

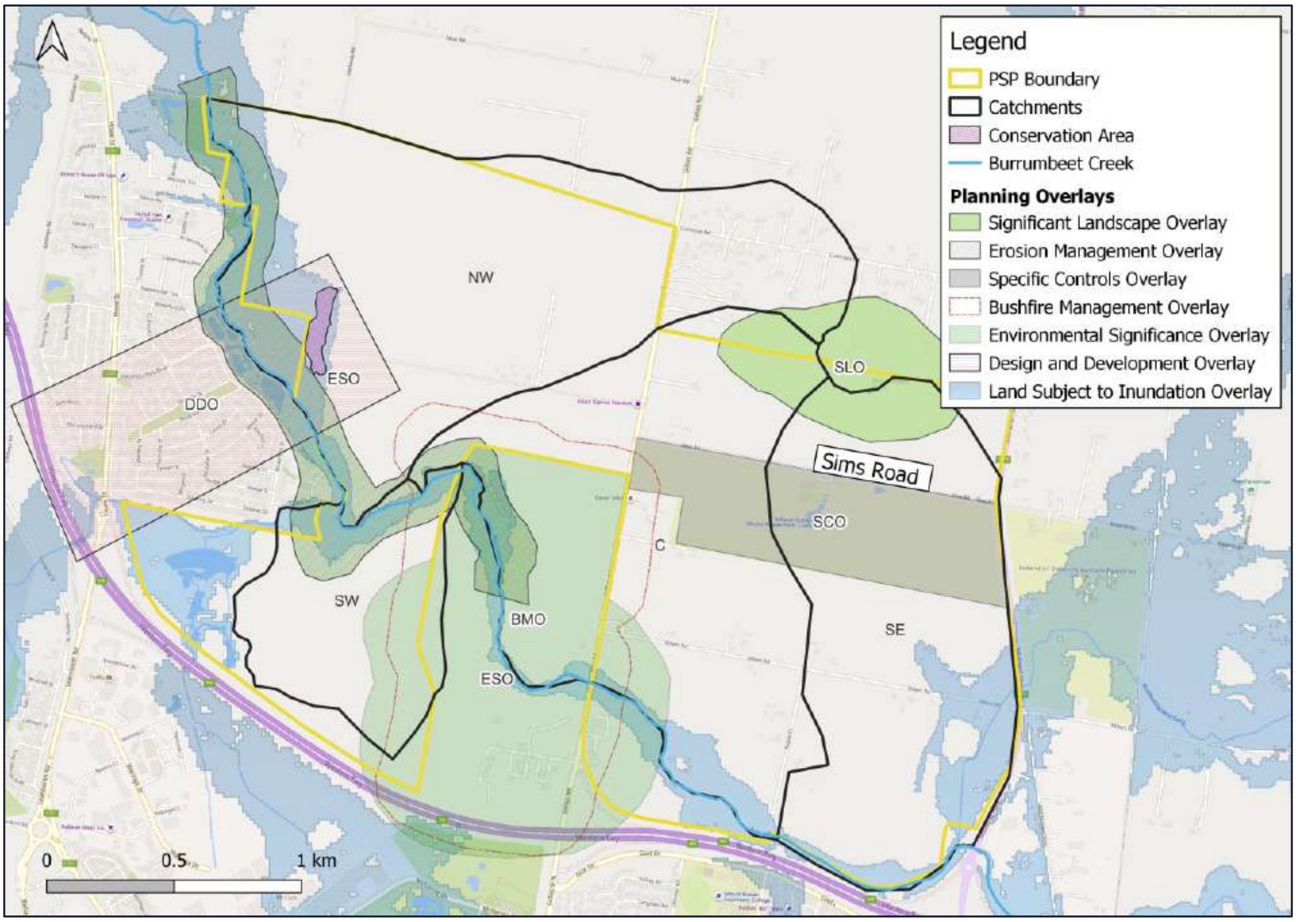


Figure 3-5 Planning Overlays for Ballarat North PSP (source: mapshare.vic.gov.au)

3.5 Site Visit

SMEC attended the site on 24 September 2024. The primary objectives and expected outcomes of the visit were to:

- Comprehend the site condition and constraints.
- Inspect the location of the four detention basins within the Ballarat North PSP area, as proposed in the IWM Plan (Arup, 2024), to check the suitability of these areas for the proposed treatments.
- Inspect the Burrumbeet Creek condition to assess the waterway health and any geomorphological change.

Refer **Figure 3-6** for the inspected locations on the site visit day.

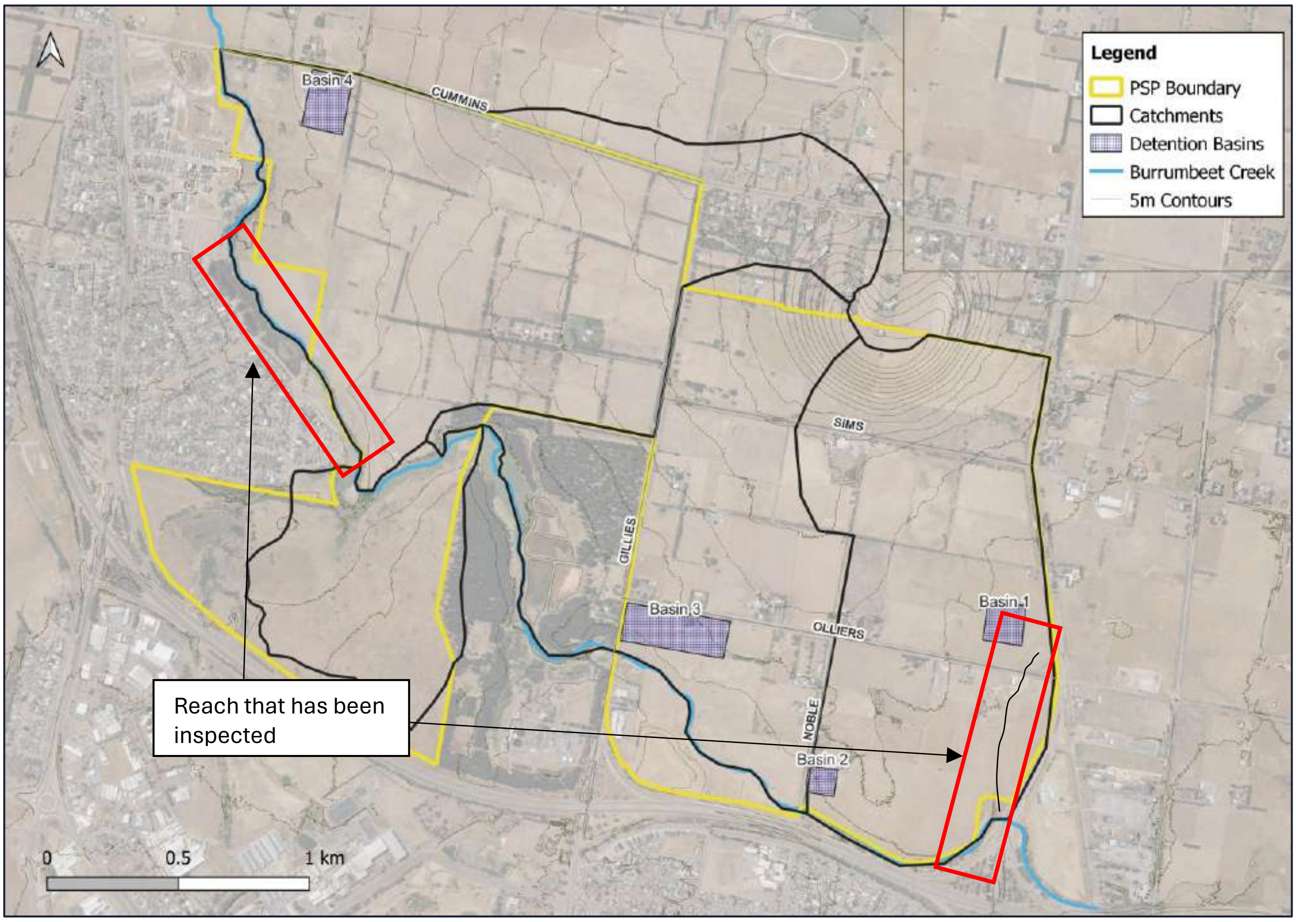


Figure 3-6 Site Visit Locations (24 September 2024)

The inspected locations of the detention basins proposed by Arup (2024) are shown in **Figure 3-7**.

Figure 3-7 Location of Detention Basin 1north of Olliers Road

Location of Detention Basin 2 east of Noble Ct adjacent to the Burrumbeet Creek

Location of Detention Basin 3 east of Gillies Road adjacent to the Burrumbeet Creek

Location of Detention Basin 4 south of Cummins Road

The unnamed tributary of Burrumbeet Creek was inspected on site running along the eastern boundary of the PSP area near Midland Hwy from north to south. This drain flows under Olliers Road through four (4) box culverts (approx. 1200mm (W) × 450mm (H)) and joins Burrumbeet Creek in the south with an average longitudinal slope of 0.004 m/m. The location and extent of this drain is illustrated in **Figure 3-8**.

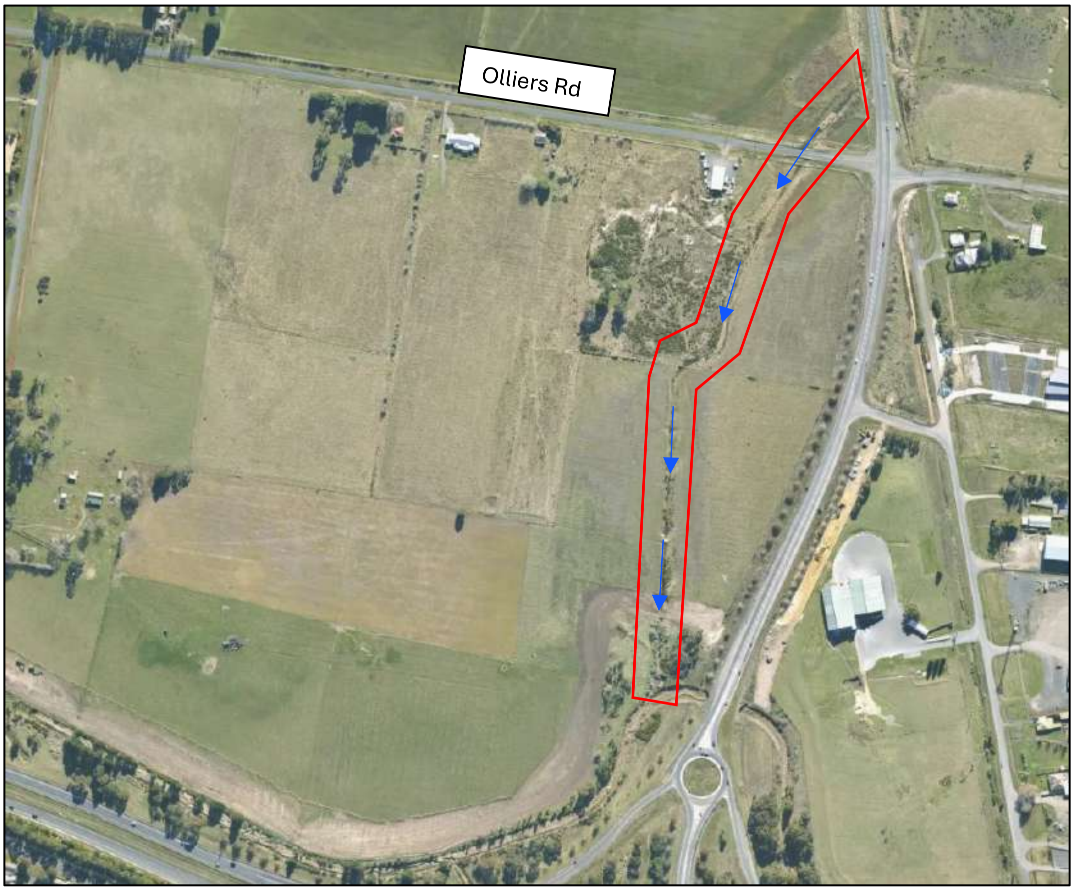


Figure 3-8 An unnamed drain (tributary of Burrumbeet Creek) near the eastern boundary of the PSP (source: Metromap)

The drain is in poor condition, with insufficient vegetation coverage on the banks to protect the channel from erosion. Although the channel has a relatively low longitudinal slope (average 0.004 m/m), there are clear signs of bank erosion. The primary cause of this active erosion is the lack of protective vegetation, likely compounded by an inadequate design that does not account for the channel's susceptibility to erosion.

Additionally, the drain contains patches of exotic vegetation, and there is little to no presence of native species such as trees, understory plants, or grasses, which are essential for stabilising the banks and supporting the ecosystem. **Figure 3-9** illustrates two photos from the channel condition with clear signs of bank erosion and exotic vegetation on banks.

Figure 3-9 Current condition of the unnamed drain near the eastern boundary of the PSP (looking downstream on the left and upstream on the right)

Burrumbeet Creek suffers from a lack of dense native riparian vegetation and a well-defined geomorphological form between the confluence of the unnamed drain and Burrumbeet Creek in the southeast corner of the PSP and south of Noble Court. The creek runs in a straight alignment for a long distance up to 407 m with no meandering alignment or proper geomorphological channel section. **Figure 3-10** and **Figure 3-11** illustrate the river condition within this stretch.

Figure 3-10 Channel straight alignment (source: Metromap)

Figure 3-11 Lack of native riparian vegetation in the channel corridor

Burrumbeet Creek has similar condition and issues west of Noble Court. Lack of vegetation is obvious on river banks in the river reach between Noble Court and Gillies Road. Error! Reference source not found. The river condition within this stretch is susceptible to erosion due to lack of vegetation on the river banks as a protective layer.

Figure 3-12 Lack of vegetation on river bank (source: Metromap)

Burrumbeet Creek is also in poor condition west of Gillies Road. The creek suffers from vertical and undermined riverbanks, as well as the presence of exotic vegetation (see **Figure 3-13**). The unstable banks indicate ongoing channel widening, which represents the second stage in a river channel's geomorphological cycle, following channel deepening. This suggests active erosion within the channel, causing a significant threat to the health of the waterway in this area.

Figure 3-13 Undermined bank and exotic vegetations (left), vertical bank and exotic vegetations (right)

3.6 Integrated Water Management

A review of the Integrated Water Management (IWM), Water Sensitive Urban Design (WSUD) elements completed in the earlier study by Arup (2024), are discussed below.

3.6.1 Review of the Arup (2024) Design Basis

- The IWM Plan report proposed that all development and detention basin works should be located outside the 1% AEP flood extent (including climate change). This is consistent with the asset locations in the Arup drainage layout plan. Refer **Figure 3-14** below for the IWM plan by Arup.

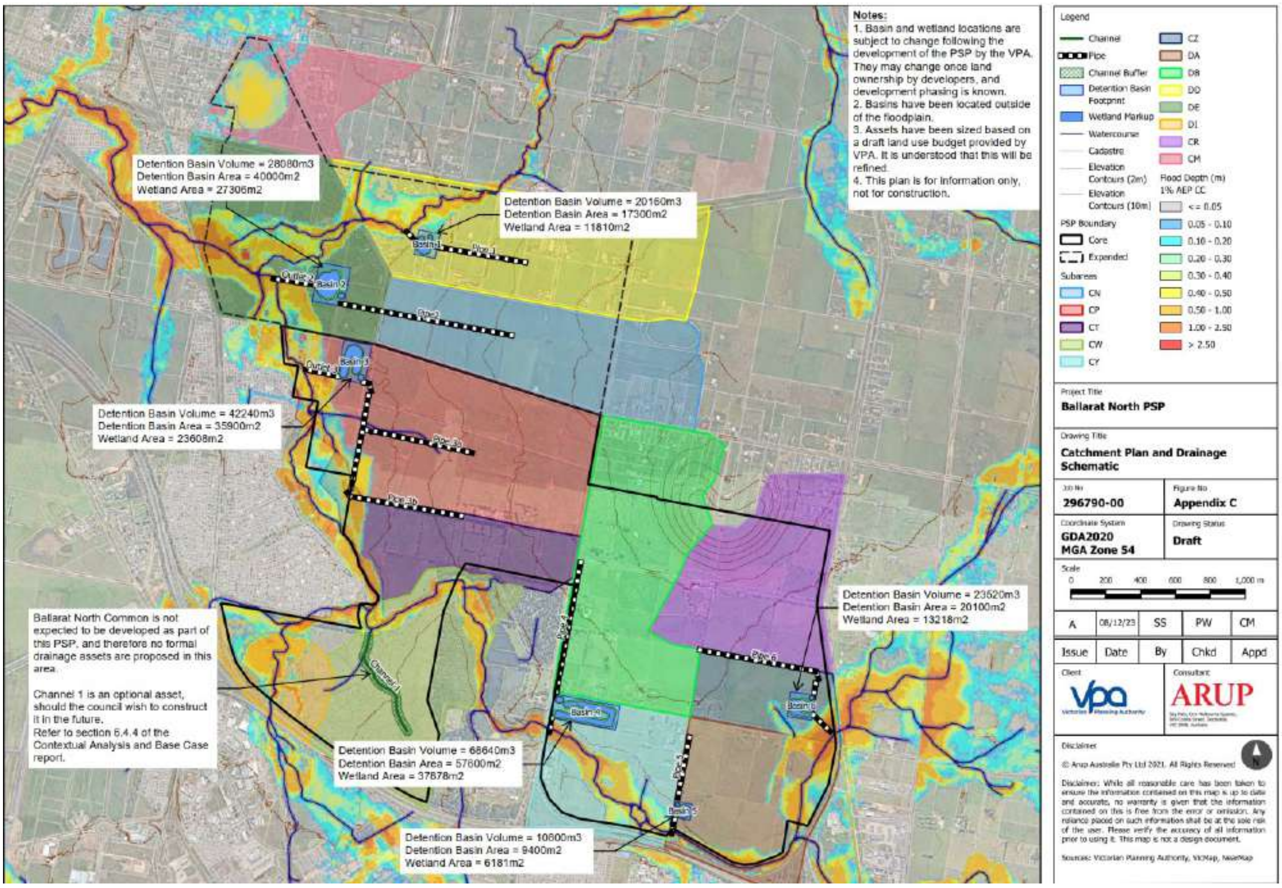


Figure 3-14 IWM Plan (Arup, 2024)

- A review of the initial drainage layout reveals challenges in design of RB and wetland infrastructure driven by elevation differentials between two and five meters. Such variation would result in significant excavation costs and land take to achieve appropriate batter slopes. It is preferable for retarding basins and wetlands to be located in flat terrain.
- It has been identified that the assets are not located at the most downstream point of the catchments. As a result, downstream catchment areas would be untreated and unattenuated unless additional infrastructure is included further downstream. Where possible it is best to locate centralised stormwater infrastructure close to the drainage outlet to minimise the number of assets required. Based on a review of the terrain and the site visit, there are opportunities to locate the future assets closer to the catchment outfalls.
- The landscape and visual amenity assessment (Mesh, 2024) is supportive of RBs, and wetlands located along the waterway corridor in flood prone land where possible to provide natural amenity, subject to floodplain requirements being met.

- Similar to the Water Technology (2013) modelling, a uniform climate change upscaling factor of 20% in the rainfall depth was adopted in the Arup model run. This factor was based on the climate scenario beyond the year 2100 and was consistent with practices at the time. The recent update to climate change guidance, as mentioned above, means that the hydrology was required to be update.
- A RORB rainfall runoff model was used to represent the developed conditions based on the draft Place Based Plan at the time. Based on the review of the model a number of aspects can be refined in the proof-of-concept stage. Some of these are as follows:
  - The subarea delineation will need to be redone to ensure there is a sufficient number of subareas upstream to provide a reasonable representation of the inflow hydrograph suitable for retarding basin sizing.
  - Refinement of the fraction of impervious area to reflect the latest land zonings in the developed conditions.
  - Reach length and slopes are to be recalculated based on the revised drainage layout.
- Arup (2024) states that the gap flows along the future roads can convey flows up to 10 m^3/s. This assessment is subject to the road design width and vertical slope. The terrain has an average longitudinal grade between 2-3% and can potentially convey a flow of this magnitude. The allowable gap flow will also need to consider flood safety criteria in residential streets used as floodway. If the road cannot convey the gap flows safely, then a formal overland flow path (easement) or constructed waterway may need to be designed into the landscape.
- This proof-of-concept design report has confirmed if provision for overland channel is required in the PSP land budget and are covered in Section 8.2

3.6.2 Innovation Pathway Pilot Project

Ballarat North PSP has been chosen as a pilot project for the VPA to implement the PSP 2.0 Process. This pilot project introduces a new Innovation Pathway for preparing structure plans. The five key areas of innovations are:

- Sustainable embedded energy networks
- Sustainable Subdivisions
- Biodiversity Corridors
- A new approach to waste management
- Social and affordable housing including diverse range of housing options.
- The Vision and Purpose Survey Summary has been prepared by the VPA with input from survey responses and is described in VPA (2023). The document describes the aspirations for the future community and the environment. Some of the key aspirations that can be achieved through the stormwater strategy development are:
- To facilitate a more sustainable form of subdivision
- To encourage housing that incorporates Environmentally Sustainable Design principles
- To apply a holistic approach to water and drainage management in the precinct and the surrounding area
- To appropriately manage flooding and inundation risks in the precinct
- To identify and plan for the optimal location and sizes of waterway assets to manage flooding and drainage in the precinct
- To protect the Ballarat Town Commons from development
- To establish streetscapes characterised by an abundant presence of canopy trees
- To make sure people have access to and can enjoy the Burrumbeet Creek
- To maintain and improve the biodiversity of the precinct, particularly around the Burrumbeet Creek and Ballarat Town Commons

- To ensure public access and enjoyment of Burrumbeet Creek.

3.6.3 Water Balance and Treatment Modelling

Arup (2024) describes water balance and pollutant modelling using MUSICX. A review of the model setup and assumptions has identified a number of items that can be refined. Generally, the treatment and stormwater harvesting performance outcomes meet the relevant requirements of the IWM strategy at the time of the analysis.

1) Update of fraction of impervious area based on the latest draft Place Based Plan.
2) The wetland areas and volumes are to be updated to reflect the revised drainage layout.
3) MUSICX outputs are difficult to assess in terms of inundation frequency analysis which is critical in wetland functional design. The proof-of-concept modelling will recreate the catchment model using MUSIC 6 version and in accordance with Melbourne Water MUSIC Guidelines (Melbourne Water, 2018).
4) The MUSICX model indicates that runoff from the entire residential area is captured in rainwater tanks. This representation is unrealistic as only a portion of the roof area will be connected to rainwater tanks. There is opportunity to refine the area entering the tanks to ensure the stormwater harvesting portion is not overestimated.
5) Consideration of the impacts of trees on infiltration and evapotranspiration targets can be assessed in the proof-of-concept stage.
6) The IWM Plan has clearly highlighted the preference for constructed wetlands as the primary treatment measure to meet best practice targets. It aligns with the objectives of a blue green corridor for the Burrumbeet Creek, increased amenity, and open space for the precinct.

- An analysis of a base case for water and pollutant balance modelling applicable for the PSP is described in Arup (2024). Water demands derived from CHW documents will be used in the concept proofing stage of the project.
- Residential potable water – 126.8 kL/hh/yr
- Residential non-potable water demand – 43.3 kL/hh/yr
- Commercial - 730 kL/ha/yr
- Passive Open Space – 2,000 kL/ha/yr
- Active Open Space – 5,000 kL/ha/yr

3.6.4 Stormwater Harvesting and Reuse

- A range of IWM portfolios were identified in Arup (2024) that could be implemented in the PSP to meet the wider catchment IWM objectives. Portfolio 1 is the base case scenario, Portfolio 2 aims to achieve the sustainability industry practice, Portfolio 3 aims to meet aspirational targets and Portfolio 4 as the Burrumbeet revitalisation. The recommendation was to attain Portfolio 4 which incorporates a centralised recycled water reuse scheme to service homes in the PSP area achieving a higher standard of service in terms of stormwater volume reduction targets. The same IWM opportunity was noted in the Ballarat City Integrated Water Management Plan (E2DesignLab, 2018) for the Northern Greenfield Investigation Area (Ballarat North PSP). Importantly, the feasibility of this option is subject to further investigation and development of a business case by CHW.
- The IWM report (Arup, 2024) provides a high-level direction for the PSP and is subject to stakeholder agreement prior to design and implementation (see **Figure 3-15**). The recommended Portfolio 4 and modelling completed to date does not include details of stormwater harvesting and reuse modelling to quantify the benefits (reduction in potable water demand) of the recycled water scheme option. <u>Information on the recycled water scheme is currently insufficient to allow Portfolio 4 to progress into functional design.</u> Additionally, the timing of the business case is unknown, resulting in critical knowledge gaps that hinder progress on the Portfolio 4 option.

Preferred portfolio of options	Base case (no IWM approach is taken)	Combined retarding basins and wetland to meet BPEM target and to control post development 1% AEP flows
		Stabilisation of Burrumbeet Creek
	Recommended IWM interventions	Recycled water to homes
		Precinct scale stormwater harvesting for open space irrigation
		Blue-green corridors in PSP
		Provide ecological refuge and resilience for flora and fauna residing within Burrumbeet Creek

Figure 3-15 IWM Portfolio 4

Until a decision is made, Arup (2024) recommends an alternative plan to be considered in the preparation of the PSP. The recommended Adaptive Plan portfolio is summarised as follows and shown in **Figure 3-16**. It is described as follows: "precinct scale wetlands connected to local stormwater harvesting to irrigate open spaces is delivered, and that blue-green corridors are incorporated into the land use plan for the PSP following key drainage pathways".

Alternative portfolio of options	Base case (no IWM approach is taken)	Combined retarding basins and wetland to meet BPEM target and to control post development 1% AEP flows
		Stabilisation of Burrumbeet Creek
		2kL rainwater tanks in homes
	Recommended IWM interventions	Precinct scale stormwater harvesting for open space irrigation
		Household raingardens
		Bioretention systems or passively irrigated trees in the streetscape
		Provide ecological refuge and resilience for flora and fauna residing within Burrumbeet Creek

Figure 3-16 Adaptive Plan

- The main differences between the two plans are stormwater harvesting using lot scale rainwater tanks for all developments or a centralised system to be controlled by CHW and the inclusion of a blue green corridor along Burrumbeet Creek.
- SMEC will be progressing the drainage strategy design and modelling based on the Adaptive Plan option noting that information on the recycled water scheme is currently insufficient to allow Portfolio 4 to progress into functional design. It is noted that confirmation from Central Highlands Water regarding proceeding with Adaptive Plan option in the agency validation phase is a key decision to provide certainty in the drainage strategy.
- SMEC will endeavour to develop an engineering solution that functionally serves both options in terms of location to allow for future proofing as best as possible noting the limited input available. Where possible the large centralised assets (RB and wetland) will be co-located to allow for interchangeability in systems including rainwater tanks or excluding recycled water. The aim is to have a consistent drainage layout for the two options. However, the exact modelling and volume can only be quantified once there is certainty in the recycled water scheme.
- There is uncertainty regarding the asset ownership and management of the future stormwater drainage assets. It is assumed that all drainage assets will be owned and managed by City of Ballarat with the exception of Burrumbeet Creek and any constructed waterways. In the case of the Portfolio 4, asset ownership of recycled water facilities would involve Central Highlands Water. Constructed waterways will likely become the responsibility of GHCMA. Confirmation of future asset ownerships should be agreed with all relevant parties.
- It is anticipated that asset ownership and maintenance agreements will be discussed and facilitated by the VPA in the agency workshop to obtain agreement between City of Ballarat, CHW, GHCMA and support

from other relevant stakeholders including the Traditional Owners of the Wadawurrung Country. The preparation of the draft concept plan will inform these discussions. The outcomes of the agency validation will provide feedback for the draft proof of concept stage of the project.

3.7 Waterway Health

Burrumbeet Creek and the unnamed drain near the eastern boundary of the PSP are in a poor condition from the waterway health perspective. The main issues observed during the site inspection are listed below:

- Lack of riparian vegetation in some reaches of the unnamed drain and Burrumbeet Creek (Section 3.7.1)
- Exotic and invasive vegetation on river banks (Section 3.7.1)
- Straightened channel alignment (Section 3.7.2)
- River water quality (Section 3.7.3)
- Active erosion (Section 3.7.4), and
- Growling Grass Frog habitat (Section 3.7.5).

Identified issues and potential solutions are discussed in the following sections.

3.7.1 Lack of Riparian Vegetation and Exotic Vegetation

Riparian vegetation is essential for maintaining a healthy waterway. A well-balanced mix of native trees, understory plants, and grasses along riverbanks helps prevent erosion by providing effective ground cover during floods and stabilising the soil through tree root systems.

Native riparian vegetation is highly adaptable to local environmental conditions, offering climate resilience and natural resistance to diseases and pests. Also, it supports a thriving habitat for aquatic and terrestrial flora and fauna, including invertebrates and amphibians.

In contrast, exotic vegetation can disrupt the ecosystem, introducing environmental challenges unfamiliar to local wildlife. Below are two key examples of issues that may arise due to the introduction of exotic vegetation:

- Native birds may not recognise exotic trees as suitable environments for nesting, leading to a decline in their use of shelter and feeding on insects that inhabit these non-native plants. In extreme conditions, this might lead to migration of native bird population or other native fauna.
- Exotic trees and shrubs may have different water requirements, often leading to excessive water uptake from waterways, which can disrupt the local hydrological balance.

Under existing conditions, the banks of Burrumbeet Creek and the unnamed drain near the eastern boundary are largely covered with exotic vegetation or remain bare for long stretches. This lack of appropriate vegetation increases the risk of erosion along the riverbanks.

Following urban development, the risk of erosion will increase due to hydrological changes in the catchment. Although current legislation mandates that peak flow rates under urbanised conditions match existing conditions, localised increases in flow rates between retardation points are still expected. In addition to flow rate, other factors contributing to the exacerbation of the risk of erosion include increased water volume and prolonged flow duration.

These factors highlight the critical role of in-channel and riparian vegetation in protecting the stability of the waterway and mitigating erosion.

3.7.2 Straightened Channel Alignment

Burrumbeet Creek follows a straight alignment from its confluence with an unnamed drain near the eastern boundary of the PSP and Noble Ct. While limited data is available on the channel bed, the site visit on 24 September 2024 confirmed the absence of pools and riffles. Naturally straight river alignments are extremely rare, typically occurring only in rocky channel beds. This rarity suggests that straight channels are inherently more susceptible to erosion. It is important to note that urban development can accelerate geomorphological changes, exacerbating erosion risks.

Beyond erosion concerns, a meandering channel form improves water quality and enhances aquatic habitats. Meanders promote better interaction between water and riparian vegetation at bends, as well as increased exchange between surface and groundwater through the hyporheic zone.

3.7.3 River Water Quality

Although there is no current data on the water quality of Burrumbeet Creek, it is likely to be poor due to high concentrations of nitrogen and phosphorus from agricultural fertiliser runoff. The presence of pathogen contamination and pesticides can be other potential issues under the current situation.

Urban development will alter the type and concentration of nutrients in the area. However, with proper planning and the implementation of stormwater treatment facilities, such as wetlands, surface water quality can be improved

3.7.4 Active Erosion

Active erosion was observed within Burrumbeet Creek during the site inspection. Vertical, collapsed embankment and undermined banks were observed frequently along the creek and drains discharging to the creek. There are multiple reasons as cause of erosion such as lack of proper vegetation coverage, lack of proper geomorphological alignment and channel and potentially hydraulic condition. See examples of active erosion in **Figure 3-17** and **Figure 3-18**.

Figure 3-17 Local Erosion on the right bank of the Unnamed Drain

Figure 3-18 Undermined River Bank

From a geomorphological perspective, the site observations suggest that the river is unstable and in the second phase of geomorphological evolution. The geomorphological evolution cycle and the channel widening process are illustrated in **Figure 3-19** and **Figure 3-20**.

As previously mentioned, in addition to peak flow, changes in surface water volume and event duration will further accelerate the geomorphological evolution of Burrumbeet Creek and its tributaries. Therefore, proper planning and design are essential to guide the creek toward an equilibrium state and mitigate future changes.

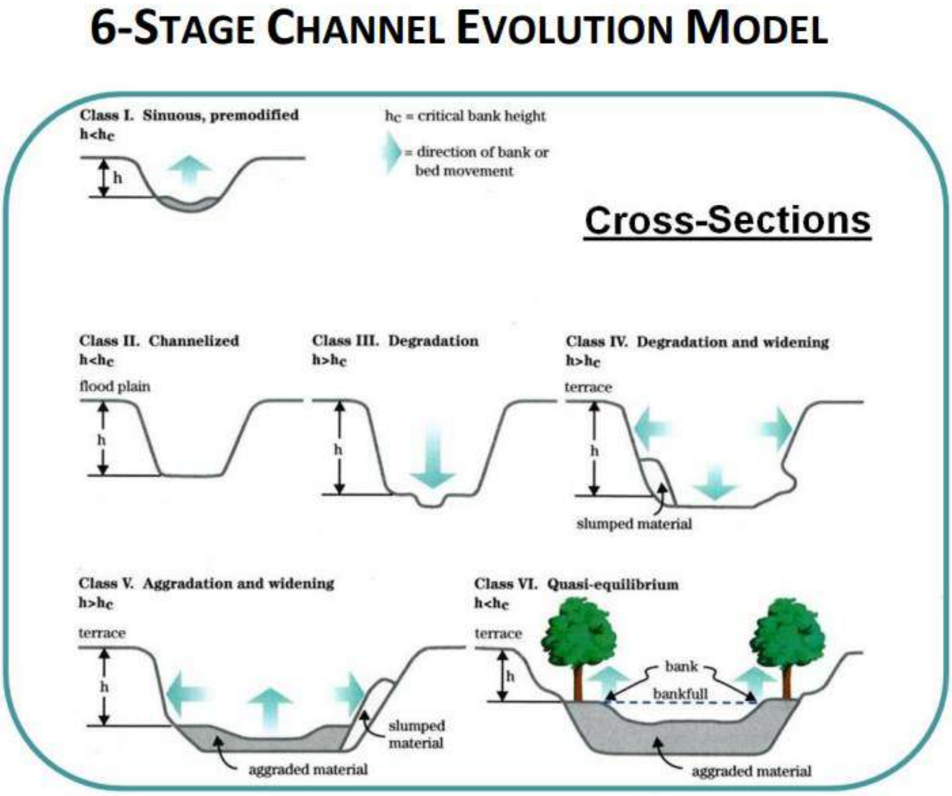


Figure 3-19 Six Stages of Channel Geomorphological Evolution Model (source: NSCEP, 1998)

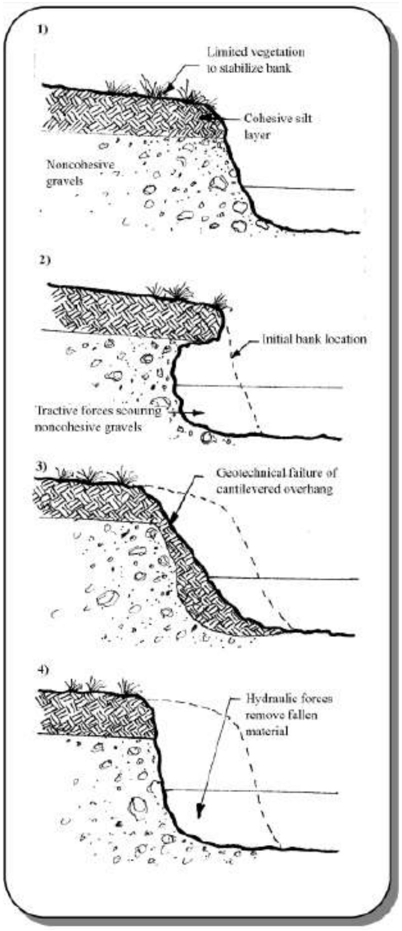


Figure 3-20 Channel Widening and River Bank Failure Process (source: NSCEP, 1998)

3.7.5 Growling Grass Frog habitat

Growling Grass Frog (GGF) is a threatened amphibian species with a declining population, which was once a common frog in south-eastern Australia. According to WSP (2024), no Growling Grass Frogs were recorded during the targeted survey in this area. However, they have suggested that under the right conditions, this species would be likely to utilise aquatic riparian habitat across the study area.

"No Golden Sun Moths, Growling Grass Frogs or Striped Legless Lizards were recorded during targeted survey. Based on the results of targeted surveys, Growling Grass Frog is considered unlikely to currently occur within the study area. However, the creeks and associated wetlands are connected with known habitat ~8.6 km upstream via the Burrumbeet Creek and Slattery Creek in Creswick State Forest. It is reasonable to assume that under the right conditions (e.g. high rainfall/flooding) this species would be likely to utilise aquatic riparian habitat across the study area whilst dispersing throughout the landscape."

Multiple factors have contributed to the reduction in the population of Growling Grass Frog, including loss of habitat, change in hydrological regime of waterways, poor water quality, disease including chytrid fungus, overshading of pools and dense terrestrial vegetation adjacent to their habitat.

The existing waterways, including drains, Burrumbeet Creek, and constructed wetlands do not provide suitable habitat for the GGF. The key factors preventing their migration to this area are listed below:

- Constructed wetlands designated to treat stormwater are not optimal as the high concentration of nutrients in stormwater entering these wetlands increases the risk of algal blooms and another disease that are fatal to the GGF.
- The design of conventional constructed wetlands designated to treat stormwater is not ideal for the GGF. For instance, GGF ponds require a specific water balance, shape and depth to guarantee water security for Growling Grass Frog and refuge areas for adult frogs as well as for eggs and tadpoles. Also, Growling Grass Frog wetlands require rocks around the minimum of 50% of the wetland perimeter.
- River channels with overgrown reeds and rushes are not suitable environments for GGF because of lack of areas with submerged vegetation, which is vital refuge areas for frog eggs and juveniles. Also, overgrown reeds and rushes reduce the water temperature, which increases the risk of disease such as chytrid fungus.
- A successful plan for GGF requires a cluster of wetlands with a preferred area of 7000 m^2 in size and the minimum size of 3000 m^2. The maximum distance between GGF should be 700 m.

To encourage the migration of the Growling Grass Frogs to this area, multiple ponds should be designed on the floodplains, offline from Burrumbeet Creek. Given the specific geometric requirements of the ponds and their water demands, these should be separate from conventional constructed wetlands designed for stormwater treatment.

Although the PSP itself is in its early stages and further design will be required to confirm the location and positioning of retarding basins and wetlands, it is unlikely that there will be enough space to accommodate additional GGF habitat in the Burrumbeet Creek floodplains.

4. Site Constraints

4.1 Flooding

A high-level review has been completed of the available flood modelling information. Burrumbeet Creek is the main drainage outfall for the PSP area providing flood conveyance, amenity and a biodiversity corridor. It has also been identified as one of the main opportunities for enhancement and rehabilitation. It is understood that the current Flood Overlay (FO) and Land Subject to Inundation Overlay (LSIO) are based on the 2013 flood modelling outcomes. Refer **Figure 4-1**.

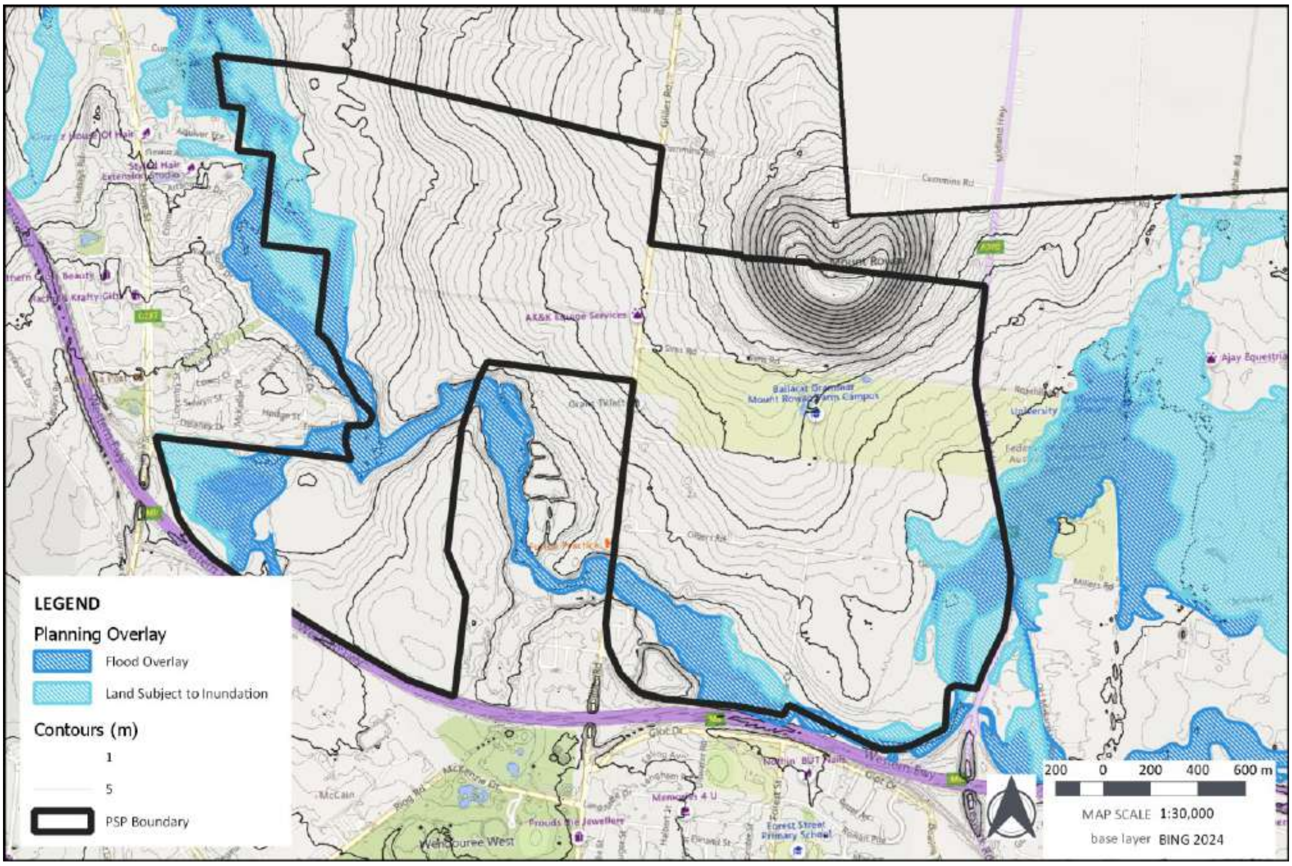


Figure 4-1 Flood Overlay and Land Subject to Inundation

Glenelg Hopkins Catchment Management Authority (GHCMA) has previously commissioned a flood study of the Burrumbeet Creek which is documented in Water Technology (2013). GHCMA has advised the VPA that the flood extents documented in the report are now out of date and are supportive of an update to be completed in collaboration with the City of Ballarat. The update will incorporate catchment alterations and guideline updates including:

- New major drainage infrastructure.
- Any increase in impervious areas that has occurred due to new developments.
- Updates to the technical practice in hydrological analysis including Design Rainfall Depth and Losses updates (Bureau of Meteorology, 2016) and Climate change factor guidance (AR&R, 2024).
- Validation of the model using historical major flood event data that may be available subsequent to the previous study.

The currency of the defined 1% Annual Exceedance Probability (AEP) flood extent impacts the Ballarat North PSP scope of works as it defines the development exclusion zone. The existing Burrumbeet Creek flood study was used to assist in providing recommendation relevant to the Ballarat North PSP as summarised below:

4.1.1 Implications of using the Existing Flood Extent

- The Burrumbeet Creek flood modelling described in Water Technology (2013) was grounded on a joint calibration of the hydrologic (RORB) and hydraulic model to a gauging station at Burrumbeet Lake. A TUFLOW model was utilised for the hydraulic modelling to produce the flood extents for various probability events. Four calibration events (1981, 2000, 2010 and 2011) were selected to calibrate the models. Model parameters were determined based on the outcomes of the calibration. Losses were derived using literature current at the time. The resulting design flows were reported to have a good match to the flood frequency curve derived from the gauging station.
- Since the model parameters have been derived using a calibration process, an update to the flood study is unlikely to change those parameters. However, the most recent 2016 design rainfall depths are lower relative to those applied in the study described in Water Technology (2013).
- A desktop assessment has been completed to identify any catchment changes subsequent to 2013 with the potential to impact hydrology modelling. No features were identified in aerial imagery or terrain data across the Ballarat North PSP core and catchments with the potential to result in substantial changes to 2013 flood extents.

4.1.2 2024 Climate Change Consideration Update

- The latest Climate change guidance (AR&R, 2019) will result in increased flood levels and extents relative to the previous modelling. According to Water Technology (2013), the previous climate change scenario modelling generally resulted in 0.5 m increase in flood depth along the Burrumbeet Creek above the 2013 existing conditions.
- The new Climate change guidance (AR&R, 2019) recommends application of an upscaling factor for all design storms. Further, the scaling factor varies with the adopted planning time horizon and climate condition. The updated guidance was released in September 2024 and the updated flood modelling will not be completed in time for the PSP preparation. It is emphasised that this knowledge gap has an impact on the flood extent definition and ultimately the areas that can be developed.
- The recent update to climate change guidance means that the hydrology is required to be update as follows:
  - 2016 Intensity Frequency Duration (IFD) curves must be adjusted to represent the future climate conditions, recognising that global temperatures have increased subsequent to the period over which data used to derive the IFD was collected. The uplift factors are derived from the Datahub (Ball et al, 2019).
  - Adopting a global temperature increase depending on the potential future development options and emissions pathways (from very low, to very high emissions), to assess the future climate change scenario. Based on GHCMA flood modelling guidelines (GHCMA, 2024), a worst-case scenario (4.5° Celsius increase in global temperature) should be adopted.
  - Selecting a future timeframe for which the climate change scenario is assessed. It is considered typical to adopt 100 years design life assessment for stormwater infrastructure. The 2100-year horizon has been adopted as per GHCMA guidelines.
- SMEC recommended that a preliminary estimate of the flood extent (with climate change) be prepared and adopted for the basis of design. Due to limited timeframes in the VPA program, a coarse but conservative approach has been adopted to produce a flood extent. The preliminary flood extent has buffer to allow for uncertainties and was grounded on conservative assumptions. The preliminary estimate was presented to GHCMA for in principle support prior to proceeding to the draft drainage layout phase. The intention was that the comprehensive flood study should be investigated in parallel to the preparation of the PSP and to be incorporated in the final stages of the PSP preparation.

- As part of the literature review, SMEC completed the above exercise and presented the methodology and outcomes to GHCMA in the form of Technical Memo. The results of the sensitivity analysis shows that there are minor variations to the 1%AEP flood extents in the Ballarat North PSP area. SMEC conservatively adopted the Scenario 3 flood extent (green line in **Figure 4-2**) as the basis of preliminary design which was considered a reasonable and conservative interim approach. Scenario 3 is the result of peak outflows from the climate change scenario (2100-year horizon and 4.5 degrees increase in global warming) multiplied by two.

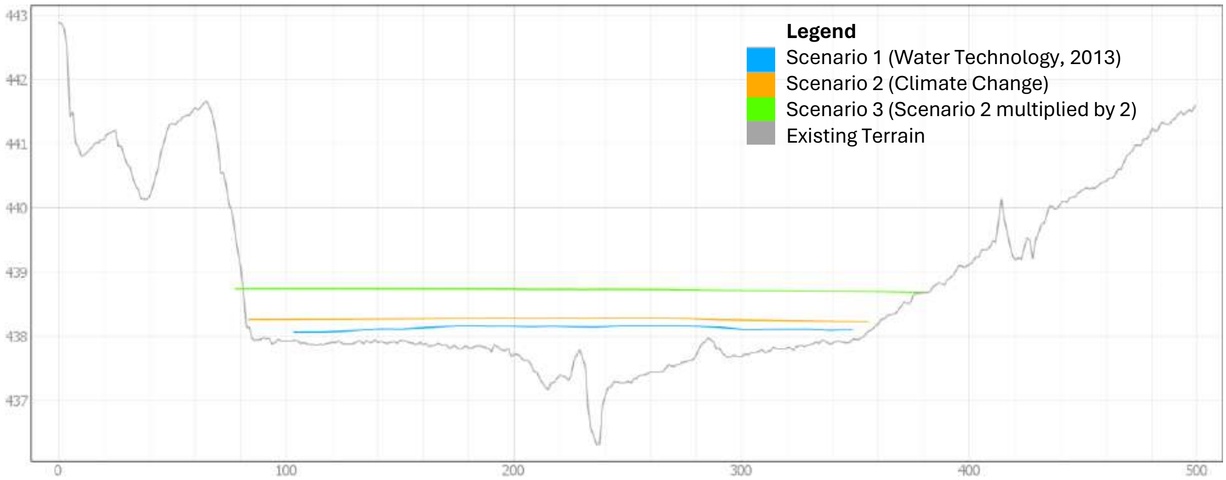


Figure 4-2 Cross Section Location 4

- GHCMA ultimately provided in principle support subject to further model refinement in later phase of the project. This allowed the PSP preparation to progress. A copy of the Technical Memorandum and in principle support from GHCMA are included as **Appendix E**.
- The proof-of-concept Stage 2 further refined the hydraulic modelling to reduce the uncertainties and therefore reduced the preliminary flood extents. The refinement of the hydraulic modelling is discussed in Section 11.

4.1.3 Flood Mitigation Option within the Catchment

- Water Technology (2013) investigated flood mitigation measures to reduce flood impacts to properties. One option worth noting was the proposed construction of a retarding basin for Burrumbeet Creek upstream of Gillies Road. During the stakeholder workshop held on the 27 November 2024, GHCMA confirmed that this option is no longer being considered. Instead, flood mitigation investigation in Miners Rest a few hundred kilometres downstream were being explored. Refer to an extract of the Water Technology (2013) report presenting the mitigation option in **Figure 4-2**.

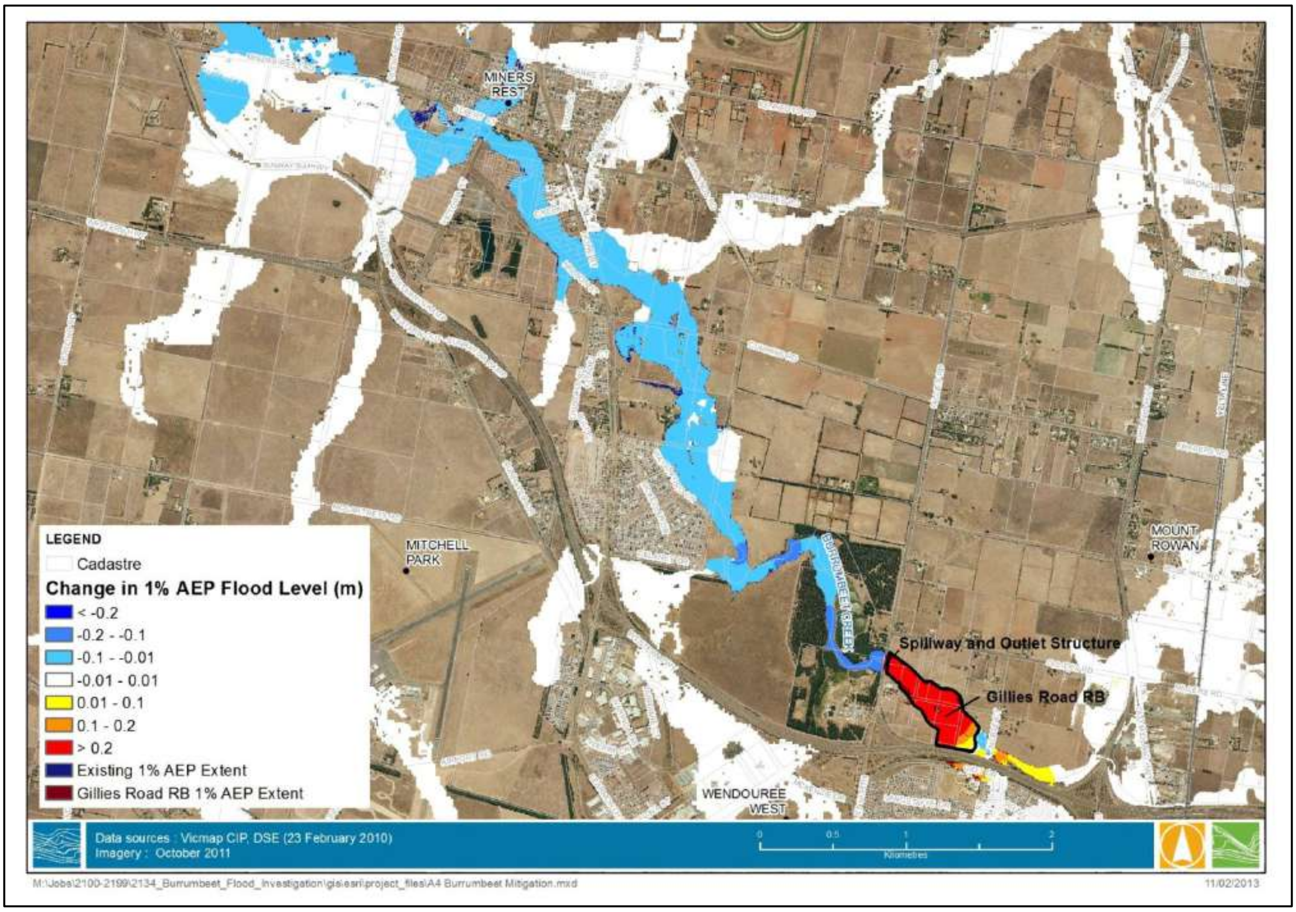


Figure 4-3 Potential Gillies Road RB from Water Technology (2013)

4.1.4 Miners Rest Flood Mitigation - Stantec (2024)

- A report detailing the flood mitigation strategies for Miners Rest is described in Stantec (2024). The report was prepared for the City of Ballarat. The investigation identified and assessed flood mitigation options to reduce the number of properties subject to flooding from Burrumbeet Creek. The study area is located approximately 700 metres downstream from the Ballarat North PSP core area boundary. The mitigation options include levees, channel widening and regrading of Burrumbeet Creek.
- A high-level review of the potential implications of the mitigation options for the PSP core area suggests little impact on the proposed drainage systems. Any changes to Burrumbeet Creek at Miners Rest will have hydraulic implications for the creek itself but the peak flood level is unlikely to be significantly different since there is at least two meters fall downstream to Miners Rest and that there are culvert structures at Cummins and Victoria Street that provide key hydraulic controls for Burrumbeet Creek and the PSP area upstream.
- The proposals suggest that engineering and widening the Creek cross sections are feasible options to increase flood conveyance and flood storage. Progression of these options is subject to additional investigations of the geology, feature levels and vegetation to define site constraints.
- The Miners Rest Flood Mitigation investigation is currently not confirmed. It is noted that GHCMA has not been involved in any consultation relating to this investigation. Should this option proceed to the next stage, consultation with the GHCMA will need to occur. At this point in time, no further information have been provided by Council to indicate this mitigation option will proceed. In relation to the PSP development, it is expected that the hydrologic and hydraulic regime will not be significantly impacting the Ballarat North PSP flood extent. It is envisaged in the functional design phase that the project team will continue the consultation with GHCMA and the City of Ballarat to ensure any flood mitigation strategies for Miners Rest will not significantly affect the outcomes of the Ballarat North PSP drainage strategy.

4.2 Biodiversity

4.2.1 Burrumbeet Creek Rehabilitation

Various reports including the IWM report (Arup, 2024), Biodiversity assessment report (WSP, 2024) and Land capability statement (Jacobs, 2024) describe the flora and fauna within the PSP core area. Some of the key considerations are listed below.

- Burrumbeet Creek is understood to have a low strategic biodiversity score and is in 'Poor' condition. A targeted Growling Grass Frog survey did not record any sightings in the area of study (WSP, 2024). The report also states there is limited value in the retention of sporadic occurrences of low-quality remnant native vegetation. Nonetheless, it is recommended by the report to avoid and minimise works in the creek and natural wetlands.
- As summarised in Arup (2024), Burrumbeet Creek provides potential habitat for fauna species protected under the Environmental Protection and Biodiversity Conservation (EPBC) Act, namely Golden Sun Moth, Striped Legless Lizard and Growling Grass Frog.
- WSP (2024) recommends adopting the Melbourne Water Waterway Corridor Guidelines (Melbourne Water, 2013) in setting an appropriate setback from the Creek. The guidelines set a fixed minimum width to allow for core riparian zone and vegetated buffer on either side of the waterway hydraulic width.
- GHCMA is responsible for the adoption of the appropriate corridor setback for Burrumbeet Creek. There are opportunities to consider an alternative setback requirement specific to the area based on the floodplain form and the interface with the future stormwater assets proposed to service the development.
- Erosion is a pertinent risk that has been identified in a number of documents and overlays including the Erosion Management Overlays and Land Capability Statement (Jacobs, 2024).
- As an outcome of the VPA's pitching session in July 2023, various agencies have highlighted the opportunities to improve the state of the existing waterway.
- Arup (2024) which is informed by the strategic objectives, recommends that the Burrumbeet Creek corridor is enhanced to provide ecological refuge and resilience for flora and fauna, or to reintroduce lost species to the creek.
- A design response to address Burrumbeet Creek objectives will require consultation with the relevant agencies (City of Ballarat, GHCMA and Traditional Owners) and agreement on the appropriate interventions to be included in the stormwater drainage strategy and the PSP Development Contribution Plan.
- The Wadawurrung Traditional Owners have expressed their concerns about the water usage from the catchment. The Cultural flows have been highlighted as an important resource for the Traditional Owners in terms of spiritual, cultural, environmental, social and economic importance. Working together with the Wadawurrung will be important to achieve the goals of the Wadawurrung Healthy Country Plan.
- A statement by the Wadawurrung Traditional Owners has been made in relation to the Ballarat North PSP. "While treated storm water can be used to support environmental flows and systems, treated storm water must not to be used as Cultural Water - it should be used as the re-allocation source for systems in place, freeing up licenses and reducing extraction from natural systems, allowing passing flow management and future water entitlements to be handed back to Traditional Owners.".

4.2.2 Growling Grass Frog

- Based on the information reviewed to date, there is no clarity in terms of a Growling Grass Frog (GGF) Corridor for this section of the Burrumbeet Creek. However, it has been identified as a potential location for enhancement to encourage GGF migration in the future.
- WSP (2024) reports, "No Golden Sun Moths, Growling Grass Frogs or Striped Legless Lizards were recorded during targeted survey. Based on the results of targeted surveys, Growling Grass Frog is considered unlikely to currently occur within the study area. However, the creeks and associated

wetlands are connected with known habitat ~8.6 km upstream via the Burrumbeet Creek and Slattery Creek in Creswick State Forest. It is reasonable to assume that under the right conditions (e.g. high rainfall/flooding) this species would be likely to utilise aquatic riparian habitat across the study area whilst dispersing throughout the landscape."

- Therefore, while GGF habitat is not a primary objective for this site rehabilitation of the waterway and improvement of the riparian zone provides an appropriate environment to facilitate GGF migration. SMEC believe this is a preferential objective dependent on the satisfaction of the following criteria:
- GGF is sensitive to the quality of water within their habitat. According to Growling Grass Frog Habitat Design Standard (DELWP, 2017), "Stormwater and other nutrient rich water sources are less optimal (for GGF habitat and water source) as they might increase the risk of algal blooming". As such, the constructed wetlands for stormwater quality are not recommended for GGF habitat.
- GGF require multiple wetlands as they need to move between these water bodies. Therefore, the limited space within this floodplain presents a challenge for to inclusion of GGF habitat which would be in addition to the WSUD wetlands.
- Water with good quality should be provided from different water sources including, portable, high-quality groundwater and treated stormwater. Whereas the primary goal of the PSP is treating stormwater runoff.
- Wetlands located within retarding basins provide a challenge for GGF migration between wetlands.
- Connectivity of suitable habitat for the GGF between their current habitat, located 8.6 km upstream, and this site is crucial for their migration. However, the presence of multiple road crossings that are not GGF-friendly makes migration to this site unlikely.
- Therefore, due to the absence of GGF at this location, the lack of suitable habitat between their current upstream habitat and this site, and the limited space for additional GGF-specific wetlands, SMEC do not recommend including GGF ponds in this floodplain.

4.3 Other Opportunities and Constraints

Further opportunities, constraints and gaps in the knowledge identified in the literature review are listed below.

- Existing underground infrastructure has been reviewed at a high level as described in Stantec (2024). The review has not identified any critical services that could impact the viability of the drainage infrastructure.
- No geomorphologic studies have been undertaken within the core area. At this stage no allowance has been made for intrinsic geomorphologic values requiring protection along Burrumbeet Creek and its tributaries.
- The Ballarat Town Commons are within the PSP core area but do not contain any developable areas. As such no drainage works have been allowed for. The concept plan presented in Arup (2024) identifies a potential waterway channel alignment to mitigate the risk of erosion from overland runoff. SMEC will review this proposal if design intervention is required.
- The concept design presented in Arup (2024) excluded consideration of land ownership. The refined stormwater strategy will consider the land ownership in the arrangement of drainage assets. The implementation and delivery of the ultimate drainage works is an important consideration at the concept stage. Further input will be sought from key stakeholders and developers during the consultation period to ensure the final stormwater strategy has considered development staging and deliverability of the overall system.
- Potential for land contamination has been identified in the PSP area (Jacobs, 2024). Specifically, there is an old landfill located south of the creek line. The RBs and Wetland will be located outside of the old landfill.
- The hydrogeology has been considered at a high level (Jacobs, 2024). No specific details have been provided but shallow groundwater could be encountered in the low-lying parts of the catchment. The land capability assessment (Jacobs, 2024) has also identified the risk of dispersive and sodic soils within the area of investigation. Site-specific assessments were recommended and will be further considered in

functional design through allowances for site mitigation strategies or design interventions where possible. However, as a starting point the concept design phase will be based on a standard design. At the time of writing, the information on these matters is limited.

- An arboricultural assessment is documented in Tree Logic (2024) and recommends avoiding highly rated trees as a priority where possible.
- The outcome of the proof of concept will identify the potential changes to the draft Place Based Plan. These will be discussed with the VPA regarding the risks and opportunities of the PSP layout and locations of proposed assets.
- The co-design workshop has considered the ideal locations for activity centres and businesses, and how infrastructure will be delivered for the precinct and their timeframes. This is just to name a few. The locations of active and passive open spaces will be an important consideration for the future placement of the constructed wetlands to meet the aspirations of stormwater harvesting for active space irrigation.

5. Stormwater Management Objectives

5.1 Drainage Requirements

The Ballarat City Council requires that all new developments be designed to meet the standards and guidelines set forth in the Australian Rainfall and Runoff (AR&R) Guidelines (Ball et al., 2019) and the Infrastructure Design Manual (IDM) (LGIDA, 2019). Additionally, the design outcomes must comply with the provisions of the *Planning and Environment Act 1987*.

The IDM requires new developments to:

- Provide drainage capacity equivalent to 20% AEP for minor drainage system in residential areas for Council drainage systems
- Be protected from major flooding equivalent to the 1% AEP event, where all new lots shall be above the 1% AEP flood level, and buildings are at least 300mm above the 1%AEP flood level.

In developing the precinct, it is a requirement to ensure there is no adverse change to the stormwater peak discharges from the site outfall boundaries for critical storms up to the 1% AEP event and ultimately prevent any adverse impacts to downstream properties. To meet this requirement, it is typical to manage the stormwater flows as follows:

- Collect and control stormwater flows via provisions of underground drainage systems, overland flow paths and drainage channels or waterways.
- Retain the peak flow from developed conditions to match the existing conditions within the catchment, before discharging to the catchment outlet, through the provision of retarding basin infrastructure.

5.2 Stormwater Quality

The minimum requirements for urban stormwater quality treatment is set out in the *Best Practice Environmental Management Guidelines for Urban Stormwater* (BPEMG) document (CSIRO, 1999). The requirement is stipulated in the Victorian Planning Provisions under Clause 56.07 Integrated Water Management. The guideline document sets a minimum target of stormwater pollutant reduction as follows:

- 80% Total Suspended Solids
- 45% Total Phosphorus
- 45% Total Nitrogen
- 70% Gross Pollutants or Litter

Water Sensitive Urban Design (WSUD) principles are applied to the development in order to meet these requirements which generally involves provision of sedimentation basins, bioretention systems and constructed urban wetlands.

5.3 Stormwater Volume Management

The EPA Publications - Urban Stormwater Management Guidance (1739.1) (EPA, 2021) provides the guidance on the management of urban stormwater which includes guidelines on volume reduction targets. The aim of the document is to set minimum and aspirational targets for stormwater runoff volume reduction by infiltration and stormwater harvesting and reuse where possible. It also provides guidance on the areas with higher priority to the rest of the urban catchments. For Ballarat North PSP, where the average annual rainfall is around 600 mm the target is 29% harvesting and evapotranspiration, and 7% infiltration.

5.3.1 Precinct Structure Plan 2.0 Guidance

- The VPA has prepared PSP guidance with the aim to 'lift the bar' by encouraging higher standards of design and development. With respect to IWM, the following targets were included.
  - T14– All streets containing canopy trees should use stormwater to service their watering needs.
  - T17– IWM solutions should meaningfully contribute towards the actions and targets of the relevant Catchment Scale Public Realm & Water Plans and any relevant water-related strategy, plan, or guideline.
- National Construction Code (NCC) 2022 in Schedule 2. There are no specific requirements for provision of rainwater tanks. However, there is a strong push by the State Government to improve the water efficiency of all buildings subject to regulatory impact statement and stakeholder and community consultation.
- Ballarat Potable Water Demand Target – Supplementary Guide describes the compulsory potable water use target of 124 litres per person per day for residential developments within the PSP area. Central Highlands Water (CHW) does not mandate specific solutions with the onus being on the developer to demonstrate the target is met. An example is provided which includes installing a 2-kL rainwater tank with water efficiency devices. Ballarat City Council accepts this as a minimum base case for residential developments.
- Furthermore, a condition is placed on planning permits that the owner must demonstrate to the satisfaction of CHW how the subdivision incorporates the principles of WSUD and IWM of the Ballarat City IWMP to achieve potable water reduction targets. Where this involves a requirement for future owners of the lots to install and maintain rainwater tanks the owner must enter into an agreement with CHW and City of Ballarat under Sections 173 of the Planning and Environment Act 1987 to record this requirement, unless an alternative means of recording the requirement is agreed to CHW's satisfaction.

6. Existing Condition

6.1 Hydrology

The catchment hydrologic model, RORB, was employed to estimate runoff hydrographs for the catchment. RORB (Laurenson et al., 2010) is a nonlinear rainfall runoff and stream flow routing model for calculation of flow hydrographs in drainage and stream networks. The model requires catchments to be subdivided into subareas, connected by conceptual flow reaches.

The latest RORB model (Water Technology, 2013) was adopted as a base case model and modified to represent the PSP catchment at a smaller scale. The RORB model k_c parameter was adjusted through a calibration process, and the calibration compared the peak flow of the combined model just downstream of the Ballarat North PSP against the peak flow at the same location of the base case Water Technology model. **Appendix A-1** details the RORB model parameters and calibration methodology.

Figure 6-1 below shows the existing condition RORB model setup for the Ballarat North PSP. By definition the existing conditions represent the catchment as it currently is without any new developments. The PSP area has been subdivided into sub catchments SE, C, and NW, and SW. As mentioned before, SW catchment is a regional open space and most likely to remain undeveloped and thus is removed from modelling. The sub catchment characteristics such as areas and fraction imperviousness are presented in **Appendix A-1**.

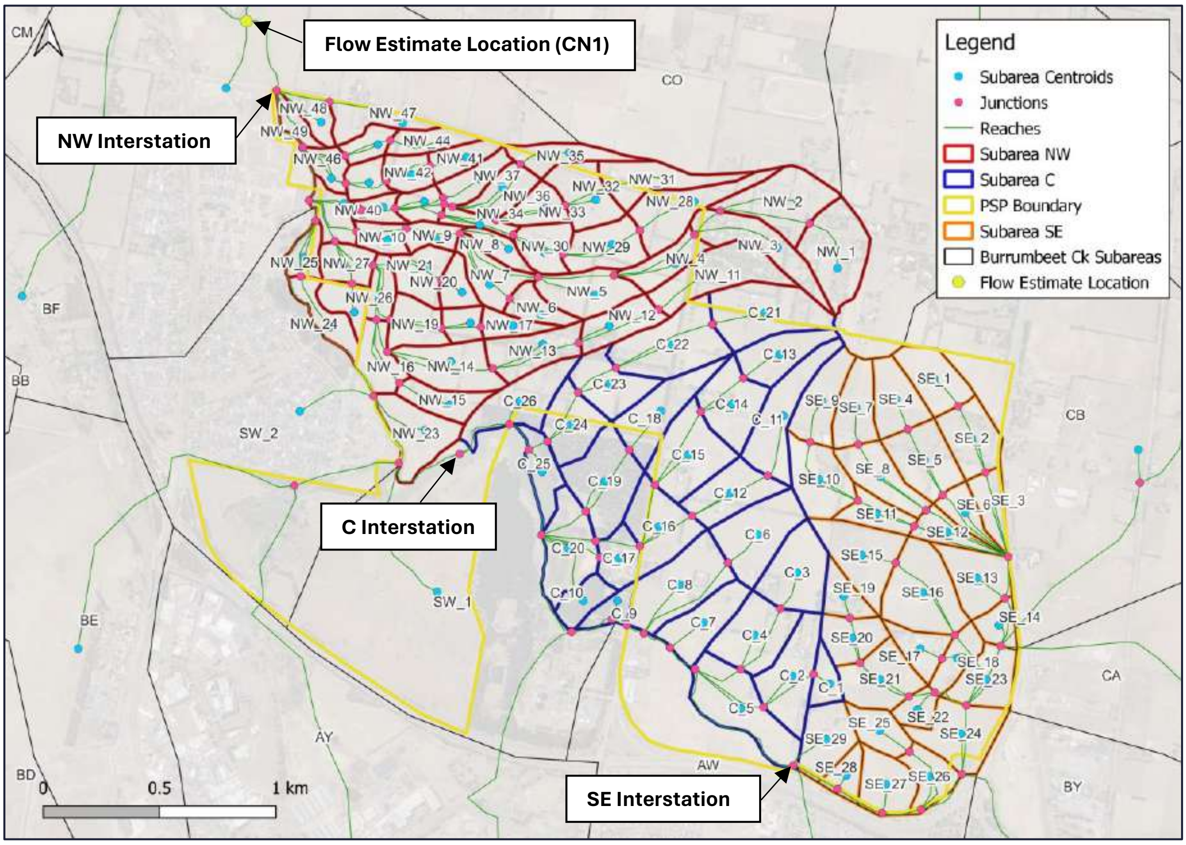


Figure 6-1 Ballarat North PSP Existing Condition RORB Model Setup

The RORB model was simulated for the 10% AEP and 1% AEP, and the peak flows are outlined in **Table 6-1** and **Table 6-2**. The flow estimate locations are shown in **Figure 6-1** above.

Table 6-1 Existing Condition 10% AEP Results

Flow Estimate Location	Peak Flow (m^3/s)	Critical Duration (hrs)
SE Interstation	2.5	1.5
C Interstation	3.6	1.5
NW Interstation	1.8	4.5
CN1	25.6	4.5

Table 6-2 Existing Condition 1% AEP Results

Flow Estimate Location	Peak Flow (m^3/s)	Critical Duration (hrs)
SE Interstation	4.7	2
C Interstation	6.8	1.5
NW Interstation	4.1	4.5
CN1	58.6	9

6.1.1 Climate Change Scenario

A scenario where climate change factors are taken into consideration have been modelled. Ball et al. (2019) defines the industry standard for completing design event rainfall runoff estimation and associated flood modelling. Guidance in climate change consideration has recently been updated in September 2024 (Version 4.2). The updates incorporate changes the uplift factors to be adopted for rainfall runoff model procedures. The uplift factors are dependent on the global temperature increase and future horizon being assessed.

The climate change scenario modelling adopted for this project is based on an increase in global temperature of 4.5 °C in the year 2100 horizon. This is consistent with the Glenelg Hopkins CMA guidelines (GHCMA, 2024) which has been adopted by Ballarat City Council for the purposes of the Ballarat North PSP drainage strategy.

The climate change uplift factors vary depending on the storm duration and AEP. A summary table of the uplift factors applicable to the site location is illustrated in **Table 6-3**. Detailed climate change factors are included in **Appendix A-2**.

Table 6-3 Data hub Climate Change Consideration Uplift Factors (AR&R v4.2, 2019)

SSP5-8.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.2	1.18	1.17	1.16	1.14	1.13	1.13	1.12	1.11	1.11
2040	1.26	1.24	1.22	1.2	1.18	1.17	1.16	1.15	1.14	1.14
2050	1.34	1.31	1.29	1.26	1.24	1.23	1.21	1.2	1.18	1.18
2060	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2070	1.52	1.47	1.43	1.4	1.36	1.34	1.31	1.29	1.27	1.26
2080	1.63	1.57	1.52	1.48	1.43	1.4	1.37	1.35	1.33	1.31
2090	1.77	1.69	1.64	1.58	1.52	1.49	1.45	1.42	1.39	1.37
2100	1.86	1.77	1.71	1.64	1.58	1.54	1.5	1.47	1.43	1.41

The outcome of this scenario for the 10% AEP and 1% AEP storm events is presented in **Table 6-4** and **Table 6-5**.

Table 6-4 10% AEP Existing Flow Estimates Comparison with the Impact of Climate Change

Flow Estimate Location	Peak Flow (m^3/s)	Critical Duration (hrs)
SE Interstation	4.6	1.5
C Interstation	6.8	1.5
NW Interstation	3.2	1.5
CN1	40.1	4.5

Table 6-5 1% AEP Existing Flow Estimates Comparison with the Impact of Climate Change

Flow Estimate Location	Peak Flow (m^3/s)	Critical Duration (hrs)
SE Interstation	9.8	1
C Interstation	14.4	1
NW Interstation	7.8	2
CN1	107.6	4.5

The values outlined in tables above provide the basis of the allowable peak discharge in the developed conditions to mitigate the increased peak flows from the catchment as a result of the PSP development. This assessment will be covered in Section 7 and 10 of the report where the retarding basin sizing and flood impacts are assessed for current climate conditions and the future climate change conditions.

7. Stormwater Drainage Strategy

7.1 General

The stormwater drainage strategy has been further refined, considering various constraints, site context analysis, IWM objectives, and the strategic vision for the Burrumbeet Creek waterway. The strategy maintains the concept of centralised assets positioned alongside the waterway corridor consistent with the blue green corridor concept in the IWM plan. A major/minor drainage system is proposed to manage the flow conveyance of the PSP which is consistent with the Infrastructure Design Manual (LGIDA, 2019).

It is noted that the future internal road network and subdivision layout is not yet known at the PSP level and will ultimately determine the direction of flows. However, the strategy as discussed below provides the overarching plan on how to direct the stormwater runoff into the proposed drainage infrastructure.

The Burrumbeet Creek waterway and its tributaries provide opportunity to interface the water sensitive urban design (WSUD) features together with active open spaces. Future developers of the new estates are encouraged to integrate the blue green corridor with the urban design. For example, the proposed tributary realignment Section 7.2.1.3 could be designed in parallel with a main boulevard and provide a high impact amenity feature for the new estate’s main entrances. The proposed wetland/RBs have been located adjacent of activity centres, schools and parkland. It is expected that the shared paths would be integrated with the proposed WSUD assets.

Section 7.2 discusses the proposed strategy for each sub-catchment while the details of the retarding basin and wetland sizing are discussed in Section 7.4 and Section 8.1 respectively.

7.2 Strategy Basis

The PSP area can be split into four sub catchments SE, C and NW, and SW. Each catchment outfalls separately on the northside of Burrumbeet Creek with exception to SW which drains from the soutside of the Creek. A combined wetland/retarding basin system (WLRB) are proposed to capture flows up to and including the 1% AEP event prior to discharging to the Burrumbeet Creek. As mentioned, SW (Town Commons) is earmarked to remain as a nature reserve and as such, no hard drainage assets are required for this catchment.

The overall drainage strategy layout plan is illustrated in Error! Reference source not found.. General notes in preparation of the drainage strategy are:

- Note that SW catchment is a regional open space and identified as a Crown Land and thus is less likely to develop. Therefore, there is no proposed infrastructure assets for this catchment.
- SMEC have provided the indicative drainage pipelines as part of the drainage strategy. Existing sewer invert levels and diameters in the southern part of the PSP along the Burrumbeet Creek have provided by CHW, however sewer mains depths are unknown to review potential clash between the sewer mains and proposed drainage. This is while the indicative future sewer alignments have a of 2-6 m. SMEC believe that there is less likely a clash between the proposed drainage and existing/future sewer mains. Having said that, potential clashes need to be confirmed in the functional design once the drainage pipes have been designed and upon receiving more accurate data about the depths of the sewer mains by CHW.

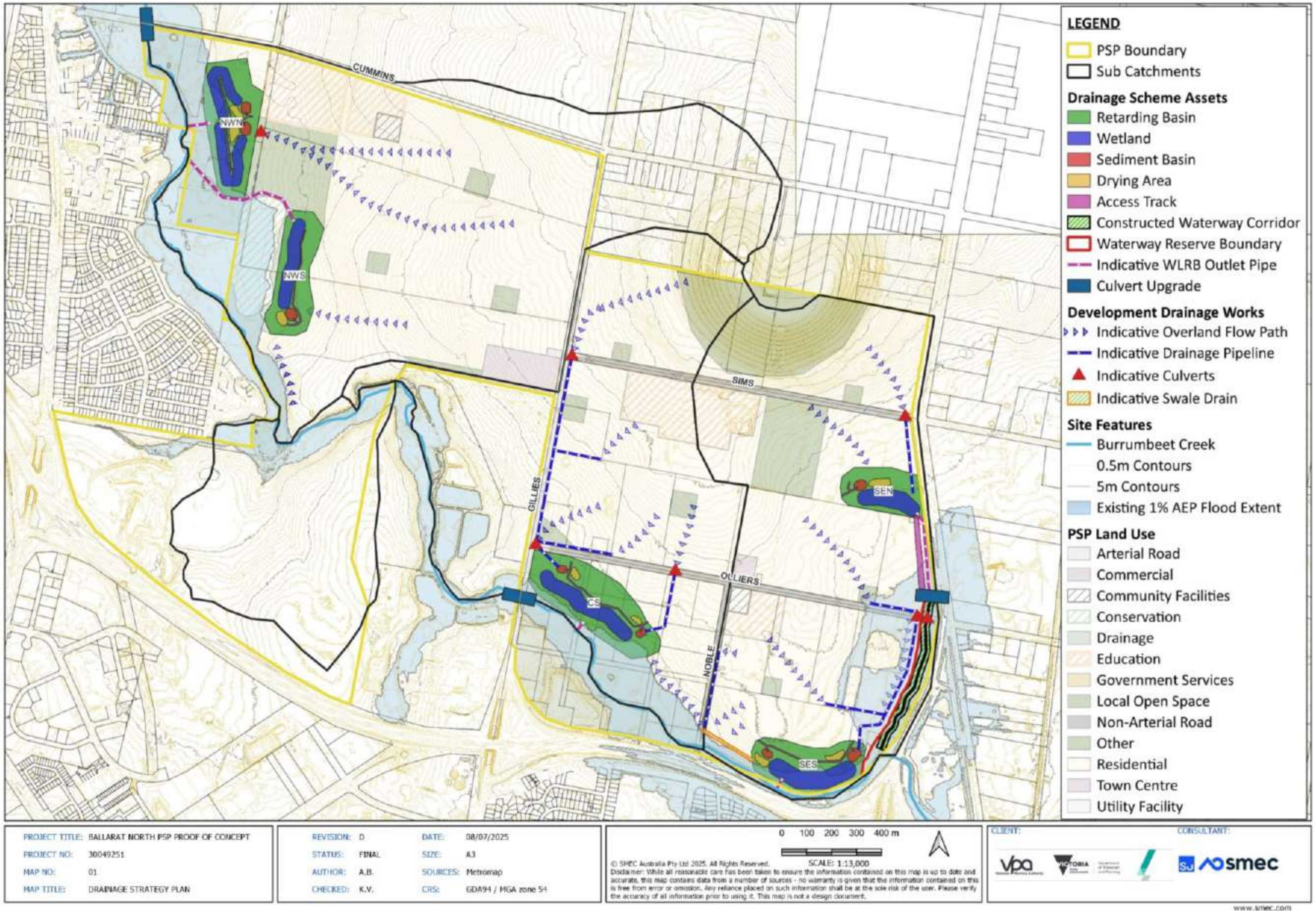


Figure 7-1 Proposed Stormwater Drainage Strategy

The proposed drainage strategy for each of the sub catchments are explained below:

7.2.1 SE Catchment

7.2.1.1 SEN & SES

- Two WLRBs are proposed for sub-catchment SE. One located within the education zoning and is identified as SEN in the plan. SEN has been sized for the eastern catchment of the future School (Ballarat Grammar Mount Rowan campus) and northern areas of Sims Road. The retarding basin is sized to attenuate no more than the existing conditions peak flow at the same location. Once the flows have been attenuated, it is intended to convey this flow via underground drainage pipe into the proposed constructed waterway.
- SEN will provide stormwater treatment via wetland and the treated water be discharged into the realigned constructed waterway (tributary of Burrumbeet Creek).
- SES has been sized to treat the remaining area and retard the flows back to existing conditions.
- A portion of the sub catchment draining towards Noble Court is proposed to be diverted east towards SES. This can be achieved through the provision of minor drainage pipe and major overland flow path (swale drain) to convey the flows through to WLRB SES.
- There is a minor encroachment of the 1% AEP flood extents (with climate change) to the WLRB SES footprint. The intention is to refine the retarding basin design by cut and fill in the functional stage to ensure there is no flood storage loss that could cause an increase in flood levels.

7.2.1.2 Trunk Drainage Design

- Major culverts are required to cross Olliers Rd and provide connection for the realigned constructed waterway. The sizing of the culverts is presented in Section 7.5.
- Runoff from the remaining of catchment SE between Noble Court and Midland Highway is proposed to be conveyed towards southeast into a drainage pipe along the west side of the future waterway realignment all the way to SES.
- It is proposed that this drainage pipe will capture the 20% AEP flow and any gap flows (flows between 1% AEP and 20% AEP storm events) will be conveyed towards SES via overland flow path within the road reserves adjacent of the constructed waterway. No outfall connection into the proposed constructed waterway are proposed except for the pipe outlet from SEN. This concept provides a simple and consistent strategy where all runoff are treated and retarded at prior to discharging into the waterway.
- As an alternative, the trunk drainage can be designed to capture the 20% AEP flow with the gap flows allowed to overtop into the constructed waterway. This gap flow will be then conveyed by the waterway and discharged into Burrumbeet Creek without retardation. The future developer can investigate and confirm if this option is feasible since it depends on the subdivision design. Hydrological analysis (RORB modelling) will be required to ensure flows are adequately retarded back to the predevelopment levels.

  Figure 7-1shows the indicative pipe and culvert infrastructure required for each parcel to connect into the centralised WLRB.

7.2.1.3 Waterway Diversion (CW1)

- An unnamed waterway (hereafter called CW1) near the eastern boundary of the PSP (see the current location and extent of this waterway in **Figure 3-8**) is proposed to be re-located along the eastern boundary of the PSP area shown in **Figure 7-1**. Based upon the low value of the existing drain, there is an opportunity to reconstruct the waterway into an improved form and condition, whilst also providing floodplain containment into a narrower constructed waterway. The realignment allows for a better use of the land which would otherwise be difficult to develop, specifically the area in between the existing waterway and Midland Road.
- It is noted as a general principle that GHCMA do not support the realignment of waterways or floodplain topography changes for the purposes of large-scale development. However, GHCMA may consider

proposals if it can be demonstrated that there is an unequivocal advantage for both waterway and floodplain health. GHCMA, has requested that the advantage of the proposed realignment is presented against the original alignment in relation to other benefits outside of lot development yield. Furthermore, the Biodiversity Assessment Report (WSP, 2024) states that there are high value vegetation are evident in the current alignment.

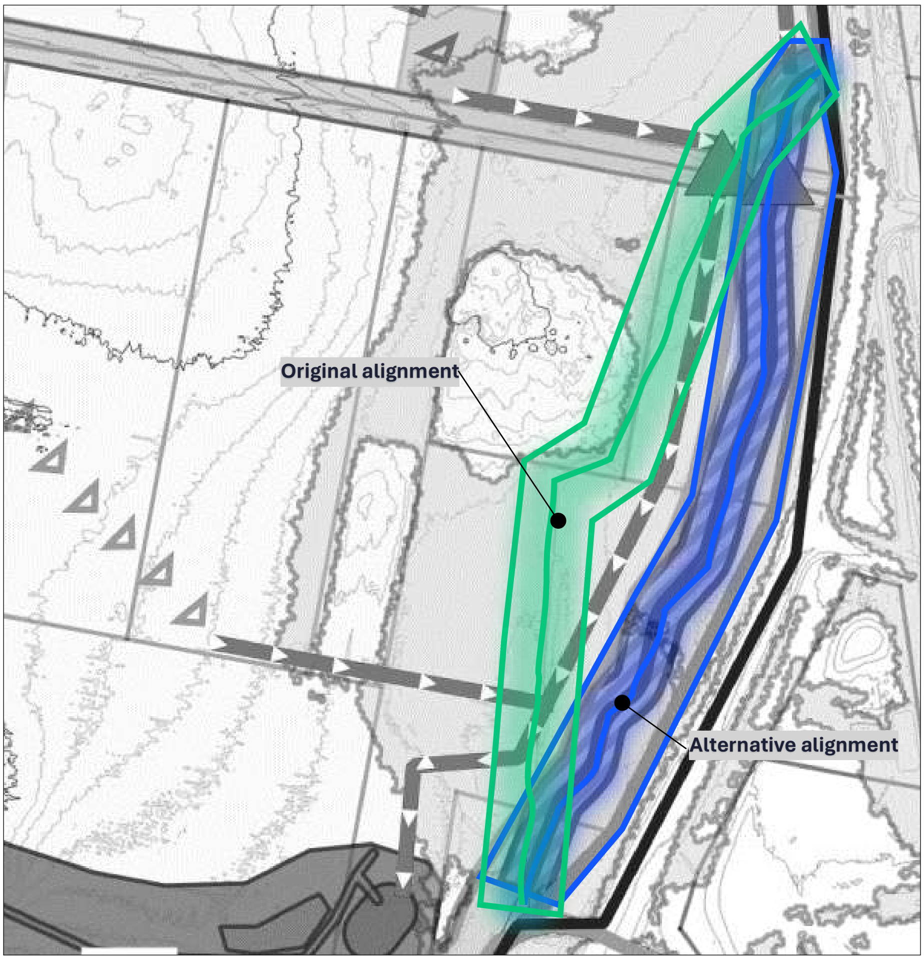


Figure 7-2 Waterway Realignment Option assessment

- In an attempt to address the above concerns from GHCMA at POC stage, commentary on the advantages of the proposed realignment (adjacent Midland Highway in blue line) (Refer to **Figure 7-3**) against the current waterway alignment (green line), and their likely outcomes are described below.
    - From a hydraulic perspective there is minimal difference between the two alignments in terms of length and typical cross-sectional width. Both options will need to meet a specific hydraulic capacity and will likely result in similar hydraulic width and ultimately corridor width. The waterway bend radius will be smaller at the upstream section of the reach in the alternative alignment.
    - The main difference between the two options will be the interface to either side of the waterway and connectivity over the waterway. In the original alignment, it is likely that there will be a road interface on both sides and potentially pedestrian or traffic crossing over the waterway. The alternative alignment abuts to Midland Highway and is unlikely to require a crossing over the waterway.
    - From a visual amenity standpoint, the alternative constructed waterway alignment would be visible from the main road (Midland Hwy) and provides an opportunity for a shared user path between the waterway corridor and Midland Highway contributing to the 'blue green corridor' vision for the PSP.

- From a bulk earthworks perspective, the proposed realignment would require significant filling of the floodplain and excavation to offset the flood storage. It is expected that the cost of the filling would not be included in the DCP costs but would be borne by the developer benefiting from the additional developable land that would otherwise be floodplain storage.

- The external catchment entering the PSP at Midland Highway culverts is approximately 990 ha and will be conveyed by the proposed constructed channel. The existing culverts are not proposed to be modified as part of the PSP drainage strategy.
- Filling is required to the west of the waterway and as a result flood storage is required to be offset in the design of the waterway. A proof-of-concept design has been completed to show this is feasible and the modelling outcomes are discussed in Section 10 of the report. The final fill level is subject to design of the future development.
- A reserve corridor width of approximately 60 m is required based on the hydraulic and flood storage requirement. The hydraulic width will be refined in functional design and the final corridor width to be adopted will be finalised then.
- Minor flows will be piped underground to the WLRB with proposed overland gap flows to be contained within the road reserves and directed to the retarding basins. An assessment of the typical capacity of the road reserve to carry the gap flows have been completed. The details are reported in **Appendix C**.
- Overland flows (gap flows between the 20% AEP and 1% AEP storm events) within and discharging from the site is required to be safely convey via the road reserves.

Summary of the drainage and WSUD details within the SE catchment is presented in **Table 7-1**.

Table 7-1 SE Catchment Drainage and WLRB Details

Asset ID	Upstream Catchment Area (ha)	Treatment Type	Drainage Reserve (ha)	Description
SEN	51	Retarding Basin/Wetland	5.4	Located within the future education zone. Downstream pipe is sized for 1%AEP (retained flows)
SES	98	Retarding Basin/Wetland	7.6	Located next to Burrumbeet Creek.
CW1	990	Constructed Waterway	4.4	660 m waterway length 60 m wide reserve
Culvert	1070	Major Culvert	n/a	8 no DN1950 pipe

7.2.2 C Catchment

7.2.2.1 CS

- One WLRB is proposed for sub-catchment C which is identified as CS. This asset is located along the Burrumbeet Creek floodplain on the east side of the Gillies Rd where the terrain is flatter and is best suited from engineering perspective. The drainage reserve sizing is provided in **Table 7-2**.
- Minor flows within this catchment will be piped underground to the WLRB with proposed overland gap flows to be contained within the road reserves and directed to the retarding basin. An assessment of the typical capacity of the road reserve is in **Appendix C**.
- There are two sediment basins, and a centralised wetland proposed for CS.
- Major culverts are required to cross Sims Rd and Olliers Rd. The sizing of the culverts is presented in Section 7.5.

- There is a minor encroachment of the 1% AEP flood extents (with climate change) to the WLRB CS footprint. The intention is to refine the retarding basin design by cut and fill in the functional stage to ensure there is no flood storage loss that could cause an increase in flood levels.
- It is noted that there is a significant tree within the retarding basin footprint as reported by Tree Logic (2024). This will be reviewed in the functional design to minimise harm to this tree.

Summary of the WSUD details within the C catchment is presented in **Table 7-2**.

Table 7-2 C Catchment WLRB Detail

Asset ID	Upstream Catchment Area (ha)	Treatment Type	Drainage Reserve (ha)	Description
CS	107	Retarding Basin/Wetland	11.4	Two incoming catchments on each end of the wetland

7.2.3 NW Catchment

7.2.3.1 NWN & NWS

- Two WLRBs are proposed for sub-catchment NW which are identified as NWN and NWS. Both centralised assets are located along the Burrumbeet Creek floodplain on the western boundary of the PSP.
- Minor flows will be piped underground to the WLRB with proposed overland gap flows to be contained within the road reserves and directed to the retarding basins. An assessment of the typical capacity of the road reserve to carry the gap flows have been completed. The details are reported in **Appendix C**.
- There are two wetlands, and two sediment basins proposed for NWN to reduce the risk of high inundation frequency. This configuration will be confirmed in functional design once the inundation frequency analysis is completed.
- There is a minor encroachment of the 1% AEP flood extents (with climate change) to the WLRB NWN footprint. The intention is to refine the retarding basin design by cut and fill in the functional stage to ensure there is no flood storage loss that could cause an increase in flood levels.
- Major culverts are required to cross the north-south connector streets. The sizing of the culvert is presented in Section 7.5.
- NWN is proposed to be located immediately west of the connector road.
- Opportunities for passive irrigation of the Active Open Space (AOS) adjacent to the NWN and NWS have been considered and discussed in Section 9.2.4.
- The outfall connection from NWS to the creek has been realigned to avoid traversing the Seasonal Herbaceous Wetland (SHW).

- CHW has indicated that a future sewer alignment may clash with the proposed stormwater assets. Refer to **Figure 7-3**. The concept design is largely determined by the terrain’s low point and has limited opportunity to be relocated elsewhere. Therefore, it is important that consultation and negotiation with CHW are continued to potentially relocate the future sewer alignment to avoid the potential maintenance issue with the sewer, proposed wetland and retarding basin. It is noted that vertical clearance is likely to not be an issue since the sewer is expected to be deep enough below the wetland as per CHW comments. Although, the sewer cannot be too deep since it has to connect to the existing sewer pump station at Cummins Road.

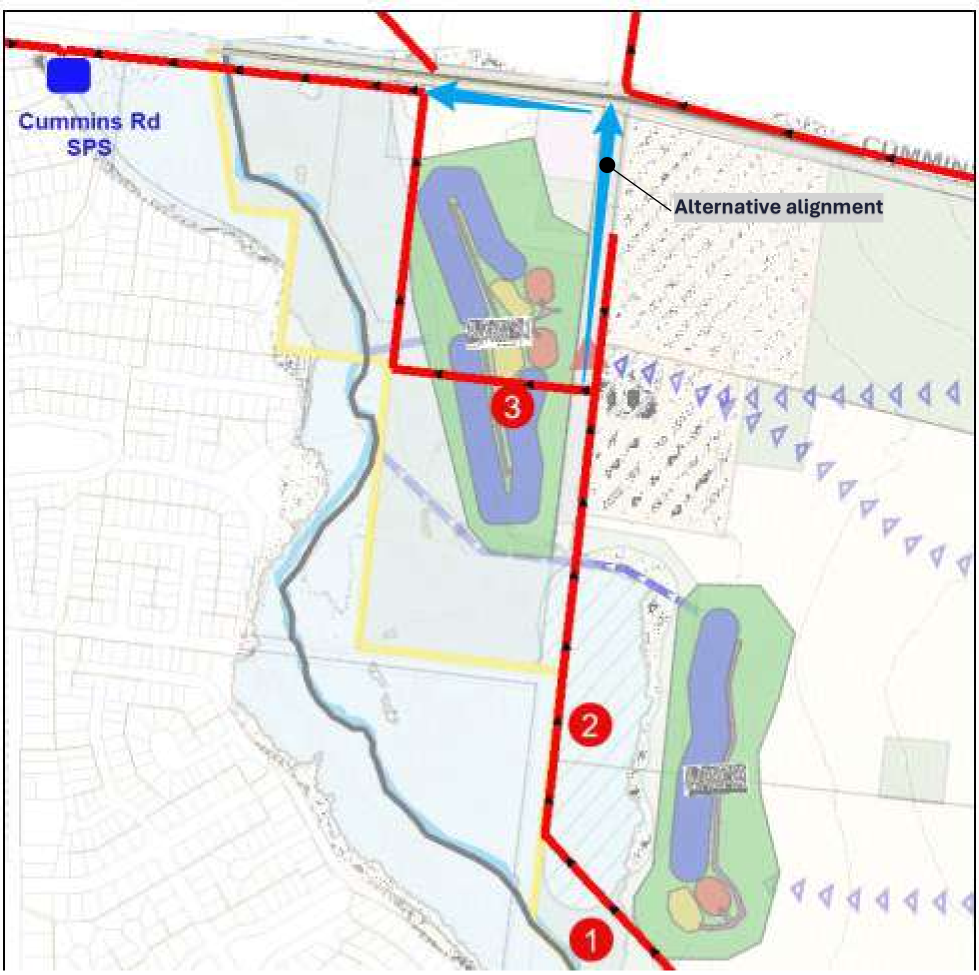


Figure 7-3 Potential alternative sewer alignment for RBWL NWN (indicative trunk sewer alignment provided by CHW).

Summary of the WSUD details within the NW catchment is presented in **Table 7-3**.

Table 7-3 NW Catchment WLRB Details

Asset ID	Upstream Catchment Area (ha)	Treatment Type	Drainage Reserve (ha)	Description
NWN	120	Retarding Basin/Wetland	9.8	Treatment wetland split into two inlets within one RB to reduce risk of high inundation frequency
NWS	70	Retarding Basin/Wetland	7.4	Located next to Seasonal Herbaceous Wetland. Pipe outlet into Burrumbeet Creek in between SHW and RB NWN

7.2.3.2 Seasonal Herbaceous Wetland

- NWS is proposed to be located adjacent and avoiding the Seasonal Herbaceous Wetland (SHW) conservation area which has a buffer of 50 m. The water requirements of the SHW is currently unknown in terms of the hydrological regime that is required to maintain the conservation area. These are expected to be investigated once the development is underway. The construction of the drainage assets will likely modify the frequency of stormwater runoff entering the SHW. The impacts of this will need to be investigated. By locating the wetland near the SHW, there is opportunity to supply water into the SHW if it is deemed necessary.

- The PSP area along the Burrumbeet Creek corridor is affected by the Land Subject to Inundation (LSIO), and Floodway Overlay (FO). These areas are flood prone which is impacted by the 1% AEP flood. All new lots will be set or filled to a minimum of 300 mm from overland flow paths and 600 mm above the 1% AEP flood level if adjacent the creek which is to be determined during the design stage.
- Overland flows (gap flows between the 20% AEP and 1% AEP storm events) within and discharging from the site is required to be safely conveyed via the road reserves.
- Any roads or access ways proposed to act as a stormwater overland flow path will be designed and constructed to comply with the floodway safety criteria of the Guidelines for Development in Flood Affected Areas (DELWP, 2019), or where appropriate to Council's requirements and standards.
- Catchment NW includes external catchment of approximately 42 ha extending east of Gilles Road and north Cummins Road. This area has been taken into consideration in the sizing of the assets, noting that some area north of Cummins Road may ultimately be managed and captured by the drainage strategy for the expanded area.

7.2.4 SW Catchment

- SW catchment is currently earmarked to remain as a nature reserve referred to as Ballarat Town Commons. No development is proposed in this catchment. As such, no drainage works are required to manage the existing runoff.
- The SW catchment is Crown Land and contains the existing North Common Wetland.
- The previous IWM study by Arup (2024) identified an optional channel works to manage overland flow path within the reserve that could be delivered by Council should they wish to do so. It is understood that these works would not be included in the DCP. The Proof-of-Concept design has not found any reason or justification to pursue this further.

7.3 Developed Condition

A developed conditions catchment RORB model has been created for the entire PSP area to represent the increase in peak runoff resulting in increased impervious areas from the development. Subsequently, the retarding basin size and storage were determined to ensure the resulting outflow is no more than the existing conditions. This model encapsulates all the four sub-catchments and the external catchment of the Burrumbeet Creek system. The extent of the developed conditions RORB model for the Ballarat North PSP area is shown in **Figure 7-4**.

Note that SW catchment is a Crown Land and is likely to remain undeveloped and therefore no infrastructure assets have been provisioned for this area. Hence, this catchment has not been further split up and has been excluded from the ongoing modelling.

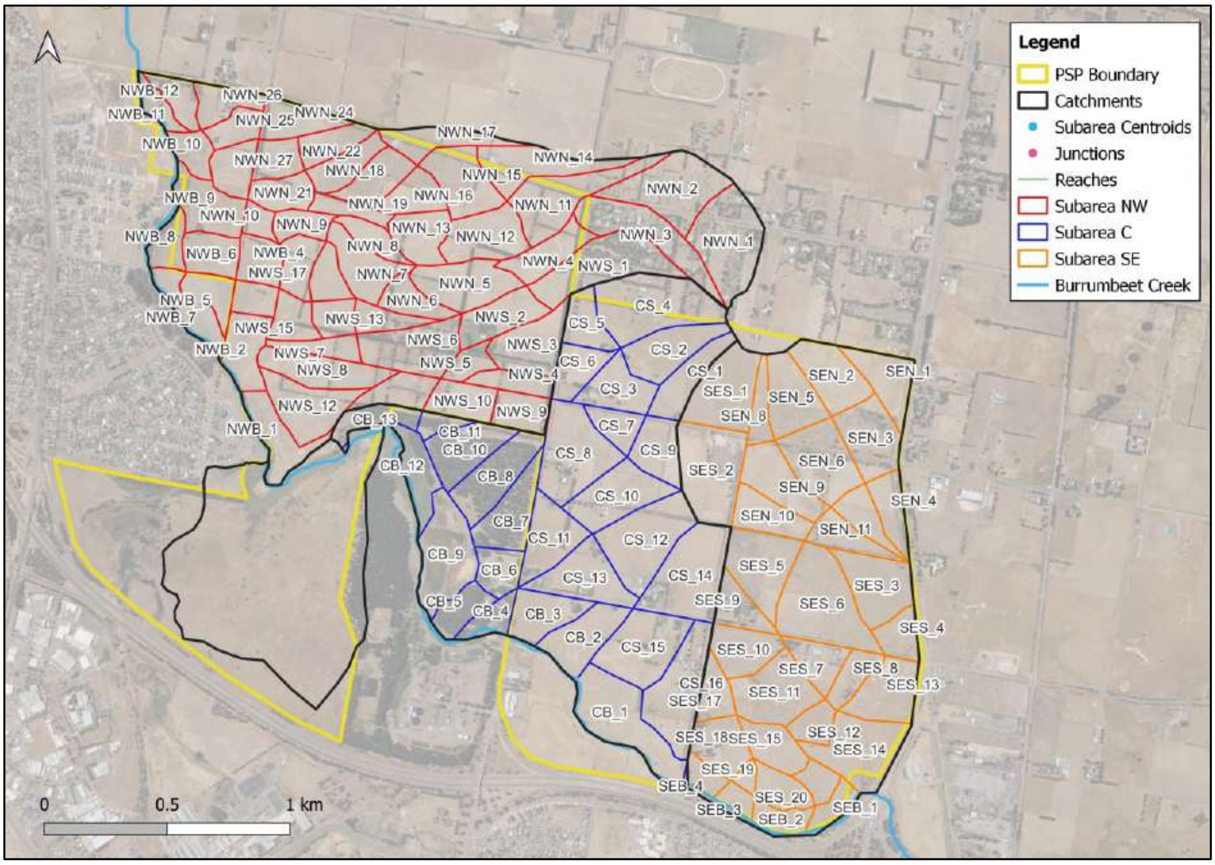


Figure 7-4 Ballarat North PSP Developed Condition RORB Model Setup

The RORB model was simulated for the 10% AEP and 1% AEP and the peak inflows are outlined in **Table 7-4** and Table **7-5**.

Table 7-4 10% AEP Developed Condition Flow Estimates

Flow Estimate Location	Peak Inflow (m^3/s)	Critical Duration
SEN	5.3	30min
SES	6.4	30min
CS	6.9	45min
NWN	4.8	45min
NWS	3.9	45min

Table 7-5 1% AEP Developed Condition Flow Estimates

Flow Estimate Location	Peak Inflow (m^3/s)	Critical Duration
SEN	8.2	20min
SES	10.3	30min
CS	11.1	30min
NWN	8.4	1hour
NWS	6.3	1hour

A scenario where climate change factors are taken into consideration as per the AR&R guidelines (Ball et al., 2019) has been modelled. The outcomes for the 10% AEP and 1% AEP events are shown in **Table 7-6** and **Table 7-7.**

Table 7-6 10% AEP Developed Flow Estimates with Climate Change

Flow Estimate Location	Peak Inflow (m^3/s)	Critical Duration
SEN	9.6	30min
SES	12.2	30min
CS	13.1	30min
NWN	9.9	1hour
NWS	7.4	45min

Table 7-7 1% AEP Developed Flow Estimates with Climate Change

Flow Estimate Location	Peak Inflow (m^3/s)	Critical Duration
SEN	16.1	20min
SES	21.2	30min
CS	22.9	30min
NWN	17.7	1hour
NWS	12.7	45min

The details of the developed conditions RORB modelling methodology and parameters are provided in **Appendix A**. The storage and retardation modelling outcomes are discussed in the following section.

7.4 Retarding Basin Sizing

The retarding basin (RB) areas were determined by adopting the area required for wetland and sediment basin (including access tracks) as the base area of the RB.

The current locations of the WLRBs have been optimised based on the site inspection and site topography constraints. Some 3d design has been considered to account for batter slopes in determining the footprint at POC. The outlet levels have also been checked at a high level. The design and footprints will be further considered in the functional design. The general location is not expected to change in the next phase.

The height, storage volume and outlet structures of the RBs were iterated until the critical peak outflow is less than the existing conditions. Further refinement of the RB design will be undertaken in particular the design levels and outlet configurations in the functional design phase of the project.

The outcomes of the retarding basin (RB) sizing for each sub-catchment is summarised in **Table 7-8**.

Table 7-8 Retarding Basin Outcomes (1% AEP)

Asset ID	Existing Condition Peak Flow (m^3/s)	Inflow (m^3/s)	Outflow (m^3/s) (Duration)	Storage (m^3)	Outlet Configuration	Drainage Reserve Area (ha)
SEN	1.8	8.2	0.6 (9hr)	24,200	1∅1050mm	5.4
SES	4.7	10.3	1.4 (9hr)	45,400	1∅1350mm	7.6
CS	6.8	11.1	1.1 (9hr)	50,000	1∅1350mm	11.4
NWN	3.9	8.4	0.4 (9hr)	58,300	1∅600mm	9.8
NWS	1.4	6.3	0.6 (9hr)	35,000	1∅900mm	7.4

The assessment was repeated for the climate change scenario as shown in **Table 7-9**.

Table 7-9 Climate Change Results (1% AEP)

Asset ID	Existing Conditions Peak Flow (m^3/s)	Inflow (m^3/s)	Outflow (m^3/s) (Duration)	Storage (m^3)
SEN	3.7	16.1	1.1 (4.5hr)	33,700
SES	8.7	21.2	2.4 (9hr)	66,600
CS	10.6	22.9	1.7 (9hr)	70,900
NWN	7.5	17.7	0.5 (9hr)	89,300
NWS	6.7	12.7	1.0 (9hr)	50,200

The outcome of the analysis confirms the requirements to retard the flows back to existing conditions can be met by the retarding basins proposed and the combination of these does not increase the peak flows along Burrumbeet Creek.

7.5 Major Culverts

A number of cross drainage culverts must be constructed underneath the future roads to convey 1% AEP flows considering future climate change. The details of the culverts are presented in **Table 7-10**. These will be investigated further in the functional design phase.

Table 7-10 Major Culverts Information

Asset ID	Road Name	Contributing Catchment Area (ha)	1% AEP Design Flow (m^3/s)	Culvert Size (mm)
CUL1	Sims Rd (Connector Rd)	16.6	4.2	2∅1350
CUL2	Sims Rd (Connector Rd)	32.5	8.5	2∅1800
CUL3	Olliers Rd	18.5	5.6	2∅1650
CUL4	Olliers Rd	9.8	3.6	2∅1200
CUL5	Olliers Rd	77.0	18.3	4∅1800
CUL6	UNNAMED Rd	109.1	15.7	4∅1800
CUL7	Olliers Rd (Waterway)	1070.0	33.7	8∅1950

The locations of the culverts and their contributing catchment areas are shown in **Figure 7-5**.

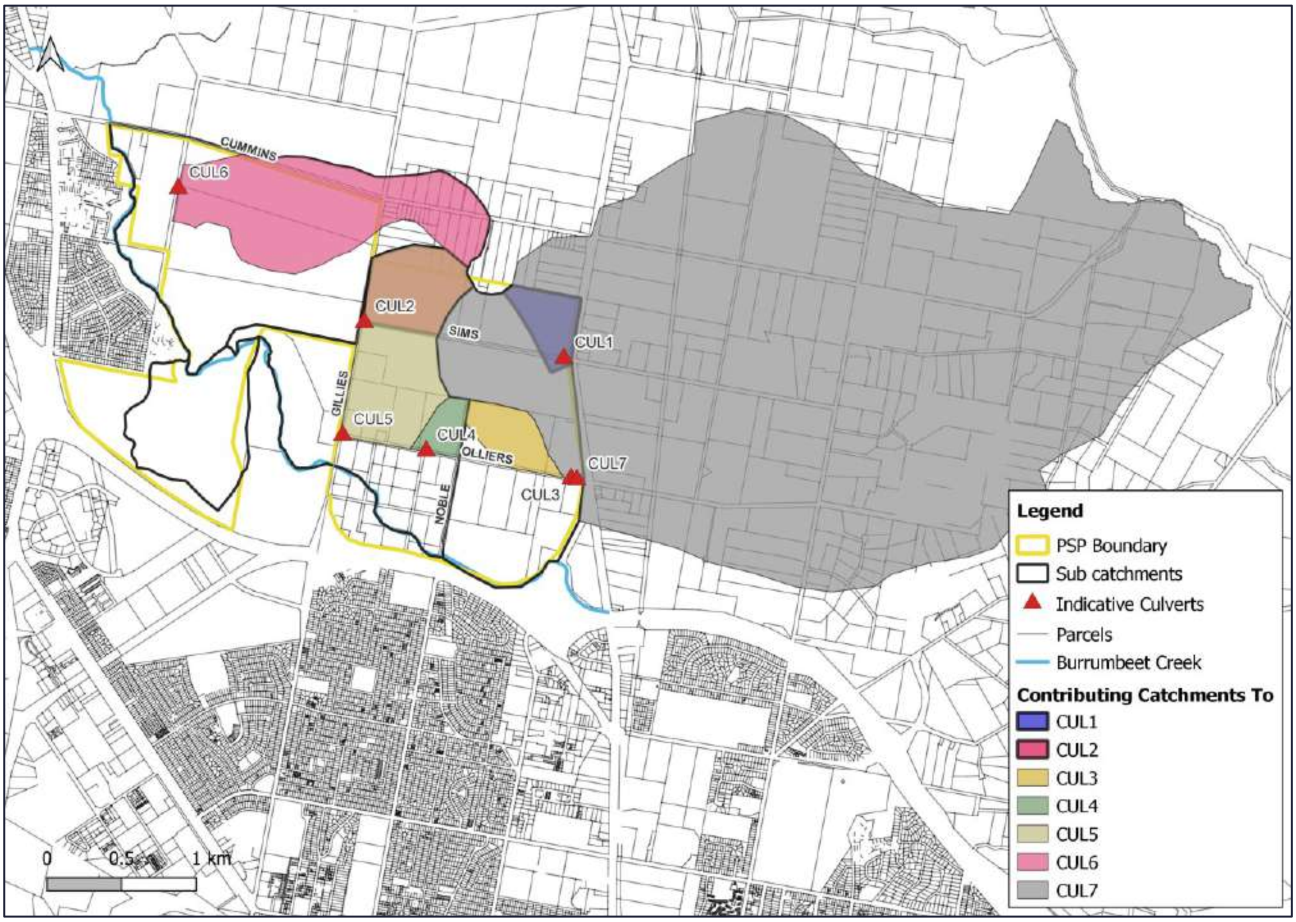


Figure 7-5 Major Culverts

8. Stormwater Quality Analysis

The combined WLRB was designed in accordance with Melbourne Water (2020) including sediment basins, wetlands, and dewatering areas components. Refer **Appendix A-2** for Water Quality Analysis and MUSIC modelling details and following section about sediment basins and wetlands sizing.

Figure 8-1 below shows the locations and names of the sediment basins and wetlands and the internal catchment that are flowing into these assets. These catchment areas have been used for water quality modelling.

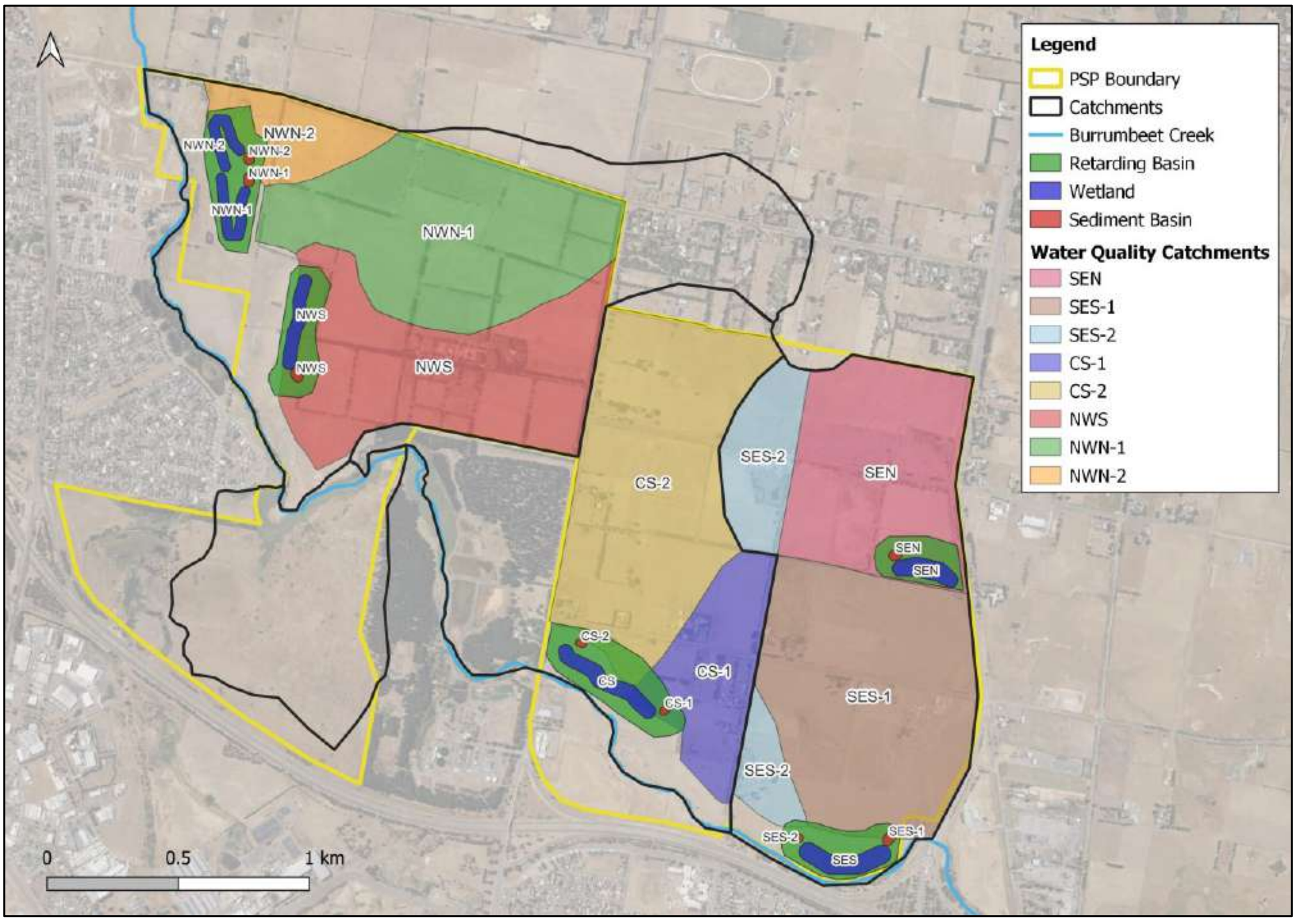


Figure 8-1 Layouts of the Wetlands and Sediment Basins

8.1 Stormwater Quality Assets Sizing

8.1.1 Sediment Basin Sizing

The sediment basins were sized to ensure a minimum 95% capture efficiency for suspended solids is achieved at the design flow. The design flow was estimated using rational calculations. Two scenarios of the sediment basins being empty and full were considered and the minimum areas of the sediment basins at NWL that satisfy this requirement were adopted.

The procedure involves the use of the Fair and Geyer equation to size the sediment basins. The design sediment loading of 1.6 m^3/ha/year and gross pollutant loading rate of 0.4 m^3/ha/year were applied for developed conditions. **Table 8-1** details input parameters used for sizing the basins.

Table 8-1 Sediment Basins Design Parameters

Parameters	SEN	SES-1	SES-2	CS-1	CS-2	NWS	NWN-1	NWN-2
4EY Design Flow (m3/s)	0.6	0.3	0.1	0.1	0.6	0.6	0.5	0.2
Surface Area at NWL (m^2)	750	1,000	300	600	1,100	700	750	300
Extended Detention Depth (m)	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Permanent Pool Volume (m^3)	750	1,000	300	600	1,100	700	750	300
Fraction of Solids Removed (%)	96	99	99	99	98	96	97	97
Minimum Storage Volume (m^3)	490	730	250	270	730	620	650	170
Minimum Drying Area (m^2)	980	1,450	500	540	1,450	1,230	1,300	330
Notional detention Time (hrs)	12	12	12	13	12	12	12	12

8.1.2 Wetland Sizing

The sizes of the wetlands were initially obtained from MUSIC model to ensure best practice water quality objectives have been met. **Appendix A-2** shows the snippet of the MUSIC model layout for the developed condition. The wetland system for the NW southern catchment (NWS) is located approximately 30 m east, increasing its setback from the Seasonal Herbaceous Wetland (SHW) to avoid encroachment on the conservation area. Details of the wetlands modelled in MUSIC are provided in **Table 8-2**.

Table 8-2 Wetlands Design Parameters

Parameters	SEN	SES	CS	NWS	NWN-1	NWN-2
Surface Area (m^2)	16,000	25,000	21,000	16,000	15,000	5,000
Extended Detention Depth (m)	0.35	0.35	0.35	0.35	0.35	0.35
Average Depth (m)	0.40	0.40	0.40	0.40	0.40	0.40
Permanent Pool Volume (m^3)	4,800	7,500	6,300	4,800	4,500	1,740
Notional Detention Time (hrs)	72	72	72	72	72	72

Table 8-3 to **Table 8-8** shows the treatment effectiveness for each of the wetlands.

Table 8-3 SEN Treatment Efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	387,000	6,850	82.3
Total Phosphorus (TP)	81.5	23.3	71.4
Total Nitrogen (TN)	584	285	51.1
Gross Pollutants	7,900	435	94.5

Table 8-4 SES Treatment Efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	63,800	8,480	86.7
Total Phosphorus (TP)	136	33.9	75
Total Nitrogen (TN)	1000	480	52.2
Gross Pollutants	13,500	0	100

Table 8-5 CS Treatment Efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	76,200	13,100	82.8
Total Phosphorus (TP)	159	46.9	70.6
Total Nitrogen (TN)	1150	621	45.9
Gross Pollutants	15,500	0	100

Table 8-6 NWS Treatment Efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	55,700	10,500	81.1
Total Phosphorus (TP)	117	36.8	68.5
Total Nitrogen (TN)	826	454	45
Gross Pollutants	11,000	0	100

Table 8-7 NWN-1 Treatment Efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	51,800	9,630	81.4
Total Phosphorus (TP)	109	33.5	69.3
Total Nitrogen (TN)	781	426	45.4
Gross Pollutants	10,500	0	100

Table 8-8 NWN-2 Treatment Efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	10,600	1,330	87.4
Total Phosphorus (TP)	23.1	5.51	76.1
Total Nitrogen (TN)	170	76.7	54.8
Gross Pollutants	2,290	0	100

8.1.3 Treatment Train Effectiveness

As per the MUSIC modelling results, the removal efficiency of proposed treatment nodes in the PSP area is shown in **Table 8-9**.

Table 8-9 Reduction in Pollutant Loads

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	308,000	59,600	80.6
Total Phosphorus (TP)	651	207	68.3
Total Nitrogen (TN)	4,800	2,630	45.2
Gross Pollutants	62,200	1,960	96.8

The results demonstrates that BPEMG can be achieved by the proposed wetland and sediment basin assets.

9. Integrated Water Management Strategy

9.1 General

This section of the report describes the Integrated Water Management (IWM) water balance modelling completed for Ballarat North PSP. The intent of this IWM plan is to quantify the potential stormwater runoff volume that can be harvested from the PSP development.

IWM is a holistic plan that encompasses various components of the water cycle. The WSUD component has been addressed in Section 8 of this report. This section focuses on the water balance modelling, with an emphasis on the potential for rainwater and stormwater harvesting from the PSP catchment.

9.2 Adaptive Plan

The development of the PSP is expected to span several years, during which time opportunities for the implementation of IWM will continue to evolve. One major opportunity, which is yet to be confirmed, is the potential stormwater harvesting scheme by CHW.

The IWM study conducted by Arup (2024) to inform the PSP recommends an alternative approach known as the 'Adaptive Plan' which involves installation of 2kL rainwater tanks in all residential dwellings as well as the provision of precinct-scale wetlands for stormwater harvesting for open space irrigation.

The supplementary lot scale IWM recommendations include implementation of household raingardens, and passively irrigated trees. The modelling of these features have not been quantified at this point but can be included in the functional design phase.

Additionally, Burrumbeet Creek corridor enhancement was identified to be a key recommendation of the IWM initiatives.

9.2.1 Water Demands

SMEC have used the previous land use budget provided by VPA to calculate water demands for the PSP area. VPA has provided the latest place-based plan (PBP) with the updated land budget on 23/06/2025 and thus, the water demand calculation is subject to change based on the changes on the new land budget. SMEC however believe that the changes are insignificant after PBP revision. To estimate the expected water demands for the PSP, the assumptions are outlined in **Table 9-1**.

Table 9-1 Water demand Assumptions

Type	Water Demand	Unit	Reference
Residential Potable Water Demand	126.9	kL/hh/yr	CHW,2018
Residential Non-Potable Water Demand (includes toilet flushing and garden irrigation)	43.3	kL/hh/yr	CHW,2018
Active Open Space	5,000	kL/ha/yr	Arup, 2024
Passive Open Space	2,000	kL/ha/yr	Arup, 2024

The total water demand for residential lots and open spaces within PSP area has been estimated and is illustrated in **Figure 9-1**. The total water demand within the PSP area is estimated to be 3,650 kL/day (1,332 ML/year). The full list of analysis assumptions is provided in **Appendix D**.

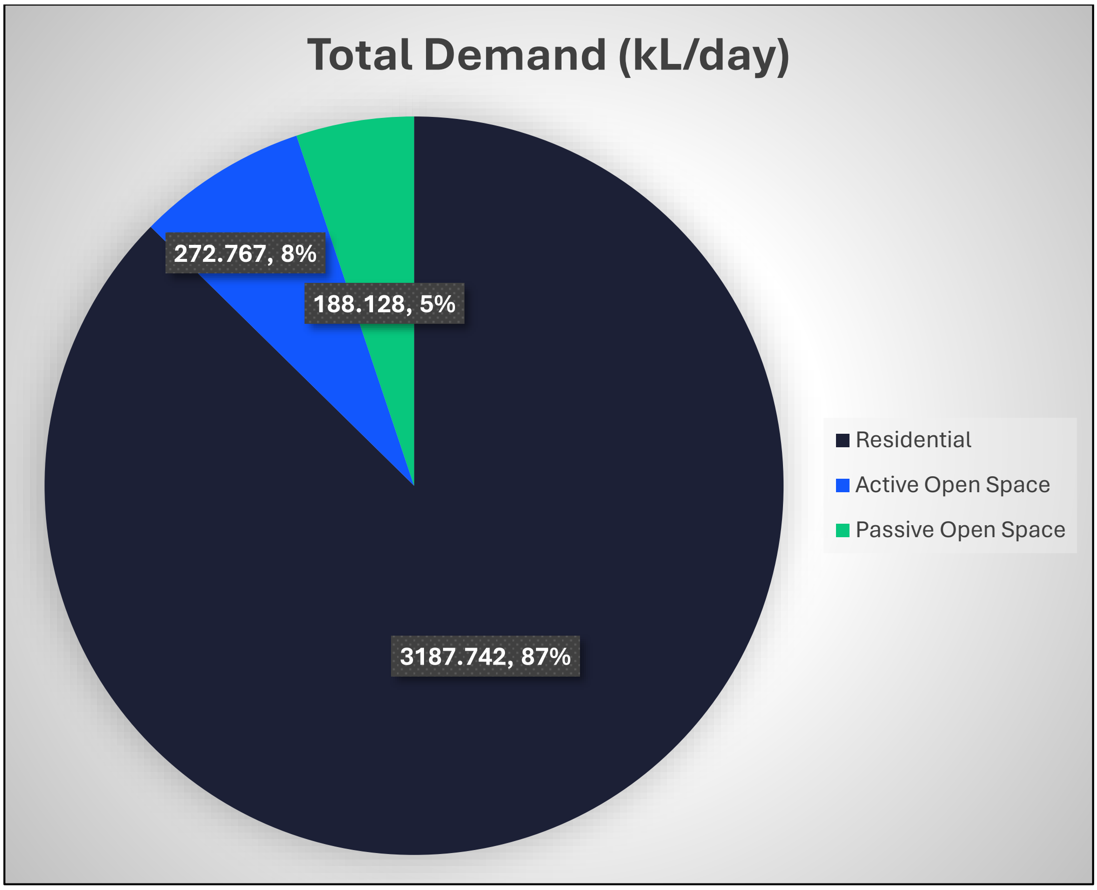


Figure 9-1 PSP Water Demand

9.2.2 Rainwater Harvesting

Rainwater can be collected from rooftops and directed into tanks for household use in meeting non-potable needs, such as toilet flushing, and outdoor irrigation. According to the Supplementary Guide (CHW, 2018), all new residential dwellings are required to install a minimum 2kL rainwater tank to help reduce dependence on potable water. A MUSIC model was developed to determine the magnitude of stormwater able to be generated and captured from residential roof areas within the PSP area. The snippet of the MUSIC model is shown in **Appendix D.** Additional information regarding assumptions and water demands are provided in the following sections.

9.2.2.1 Model Assumptions

The following assumptions have been made in setting up the MUSIC model.

- Impervious fraction values are taken from MW MUSIC Guidelines and estimated based on land use budget shapefile provided by VPA for the Ballarat North PSP.
- Rainwater is to be harvested only from residential roofs within Ballarat North PSP area.
- 80% of roof areas is assumed to be drained to a rainwater tank, and 20% would bypass.
- 2kL rainwater tanks are installed in every household, and that it will be reused for toilet flushing, and garden irrigation.
- Average number of people per household in Ballarat North area is 2.2 (ABS, 2021). This figure has been used for toilet flushing reuse demand calculations.
- Toilet flushing demand is assumed to be 20 L/person/day for residential lots.
- Irrigation reuse demand is assumed to be 2 ML/ha/yr for passive open spaces (residential gardens).

9.2.2.2 Reliance on Rainwater Harvesting

The Ballarat Potable Water Demand Target Supplementary Guidelines (CHW, 2018) specify a mandatory potable water target of 124 L/person/day within the PSP area and recommend the implementation of WSUD measures to achieve this goal. In line with these guidelines, 29% of the non-potable water demand is supplied by a 2kL rainwater tank, operating with approximately 71% reliability.

9.2.3 Stormwater Harvesting from Wetlands

The objective of this approach is to harvest stormwater from wetlands for local open space irrigation purposes. The effectiveness of this measure to the volume reduction and infiltration targets is known to be much larger in comparison to smaller lot scale initiatives. The estimation of the stormwater runoff volume available from wetlands within the PSP area has been assessed in two scenarios:

- Scenario A – Rainwater tanks installed
- Scenario B – Rainwater tanks not installed

The water balance model (MUSIC) created to assist with sizing of the WSUD wetland treatment areas was utilised to estimate the stormwater runoff volume available from wetlands within the PSP area in the developed conditions.

9.2.3.1 Model assumptions

The following assumptions have been made in setting up the MUSIC model.

- The volume available for harvesting from wetlands is sensitive to the wetlands' configuration. It is assumed that only *excess flows* (bypass and weir overflow) can be harvested to ensure wetland planting is not compromised.
- Model calibration has not been employed in this assessment to validate the runoff volumes outcomes. It is judged likely that the runoff volumes produced by the model may not be accurate and further validation may be warranted should these proceed to design or cost benefit analysis study. For the purposes of this high-level assessment the model outcomes are considered appropriate.
- No storage has been included in the model. This would potentially overestimate the volumes being harvested.
- Water demand for each wetland systems has not been determined at this stage.
- These assumptions can be refined once the functional design phase for each wetland has been completed.

9.2.3.2 Scenario A - Rainwater Tanks Installed

The stormwater runoff volume generated from the existing catchment and the increased runoff volume from the full development of the PSP area are shown in **Table 9-2**. This is a 248% increase from existing condition. The total volume of runoff that can be harvested from wetlands is estimated to be approximately 315 ML/yr which is 31% of the total runoff volume increase. This is above the target of 29% as per EPA (2021).

Table 9-2 Water Balance Model Results – Scenario A

Water Balance Metrics	Mean Annual Volume (ML/yr)
Existing Condition	698
Developed Condition	1,730
Increase in Runoff Volume	1,032
% increase	248%
Stormwater Runoff available for Harvesting from Wetlands	315

The breakdown of the mean annual volume that can be extracted from each wetland is shown in Table 9-3 below.

Table 9-3 Breakdown of Potential Harvested Runoff Volume from Wetlands – Scenario A

Wetlands	Mean Annual Volume Harvested (ML/yr)
SEN	27.7
SES	63.1
CS	98.3
NWS	55.5
NWN-1	63.4
NWN-2	6.6
TOTAL	315

9.2.3.3 Scenario B - Rainwater Tanks Not Installed

The total volume of runoff that can be harvested from wetlands is estimated to be approximately 407 ML/yr which is 40% of the total runoff volume increase in the absence of rainwater tanks. This is above the target of 29% as per EPA (2021). The breakdown of the mean annual volume that can be harvested from each wetland is shown in **Table 9-4**.

Table 9-4 Breakdown of Potential Harvested Runoff Volume from Wetlands – Scenario B

Wetlands	Mean Annual Volume Harvested (ML/yr)
SEN	35.8
SES	88.1
CS	127.8
NWS	69.4
NWN-1	79.0
NWN-2	6.7
TOTAL	407

9.2.4 Potential for Active Open Space Irrigation

There is an active open space (see **Figure 9-2**) within the PSP area that can be irrigated using the available runoff volume harvested from the adjacent wetlands, NWN-1 and NWS. Results below show that there is an adequate amount of volume available from each of the wetlands to irrigate the adjacent active open space. Following assumptions have been made:

- The assessment has only been carried out for Scenario A with inclusion of rainwater harvesting tanks in place.
- Irrigation reuse demand is assumed to be 5 ML/ha/yr for the active open space.

Percentage of harvested stormwater required for irrigation of the active open space is estimated as shown in **Table 9-5**.

Further evaluation of options will be required during the functional and detailed design phase to verify the water demand and storage needs. This will ensure that the harvested water can be appropriately stored for reuse and that the necessary infrastructure for transporting the water to support irrigation in the designated active open space, as outlined in the IWM plan, is properly planned.

Table 9-5 Harvested Stormwater Required for Active Open Space Irrigation

Parameter	Value
Active Open Space Area (ha)	10.5
Total Irrigation Demand (ML/yr)	52.5
Available Harvested Stormwater (ML/yr) from NWN-1 Wetland	63.4
% of Harvested Stormwater Required for Irrigation	83%
Available Harvested Stormwater (ML/yr) from NWS Wetland	55.5
% of Harvested Stormwater Required for Irrigation	95%

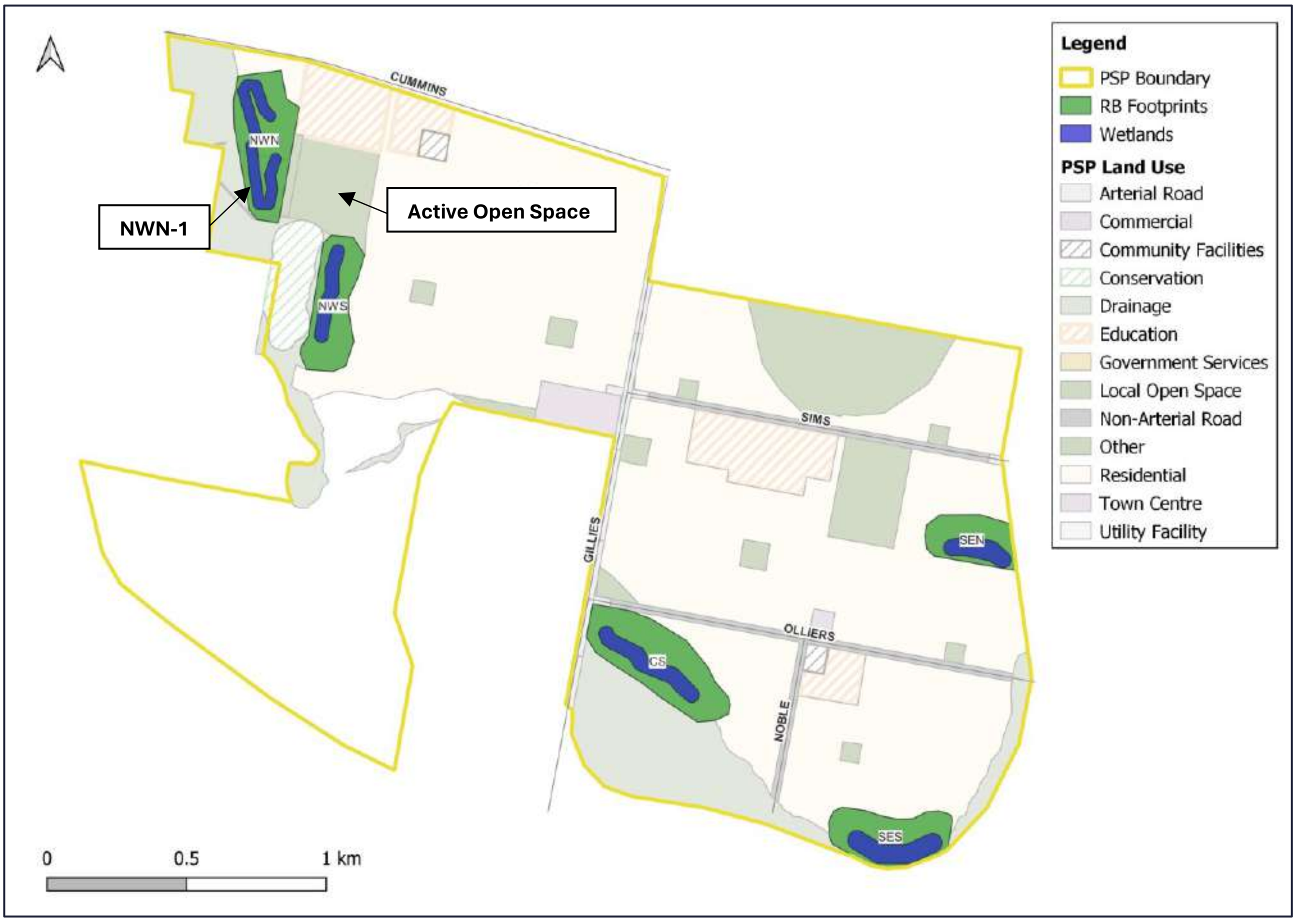


Figure 9-2 Location of the Active Open Spaces within the PSP area

9.2.5 Burrumbeet Creek corridor improvements

This report (Section 3.7), along with the previous IWM study has identified the risks of further erosion of Burrumbeet Creek under current conditions, a risk likely to be exacerbated by future conditions due to increased runoff volume, and increased frequency and duration from urban runoff despite a reduction in peak runoff rate during the 10% and 1% AEP flood event.

To address this, it is recommended that this section of the Burrumbeet Creek waterway corridor is revitilise through stabilisation of the existing creek form, and the reintroduction of native vegetation and trees along the riparian zones.

Further studies such as hydro-ecological, geomorphological assessments, targeted flora and fauna survey will help identify and prioritise specific sections for enhancement. These items can be included in the DCP costs, as there is a clear nexus between the increased risk of creek deformation and future development within the PSP area, even though existing creek instabilities have already been caused by current land uses. The responsibility of setting the requirements and acceptance of the proposed in stream works ultimately lies with GHCMA as the waterway authority. Consultation with the traditional owners are also recommended to achieve the best outcome.

9.3 Summary and Recommendations

Modelling shows that 29% of the non-potable water demand is supplied by a 2kL rainwater tank installed in every household within the PSP area, operating with approximately 71% reliability. The water balance modelling conducted to date also suggests that 31% and 40% of the total runoff volume can potentially be harvested from wetland system for stormwater reuse with and without rainwater tanks in place. However, this outcome is contingent upon the availability of an equivalent water demand within the area. There is an opportunity to reuse the water for irrigation purposes for the active open space near WLRB NWN-1.

Further evaluation of options will be required during the functional and detailed design phase to verify the water demand and storage needs. This will ensure that the harvested water can be appropriately stored for reuse and that the necessary infrastructure for transporting the water to support irrigation in the designated active open space, as outlined in the IWM plan, is properly planned.

Similarly for the Burrumbeet Creek, further assessments such as geomorphological, and flora and fauna assessments are recommended to be undertaken to better understand the interventions possible for the creek to ultimately meet one of the key IWM initiatives identified for the PSP.

10. Flood Impact Assessment

10.1 Defining the Existing Conditions Extent

Correspondence from Glenelg Hopkins Catchment Management Authority (GHCMA) to the VPA has flagged that the available 1% Annual Exceedance Probability (AEP) flood extents of Burrumbeet Creek are out of date. The current flood study upon which the flood mapping is based is described in Water Technology (2013). The current flood mapping does not accurately represent the recent changes in the catchment including new major drainage infrastructure and increases in development area.

The Flood Overlay (FO) and Land Subject to Inundation Overlay (LSIO) based on the current flood study are overlaid on the Ballarat North PSP in **Figure 10-1**. The changes in modelling practice subsequent to the current flood study include revised design rainfall depths and climate change impact estimation techniques.

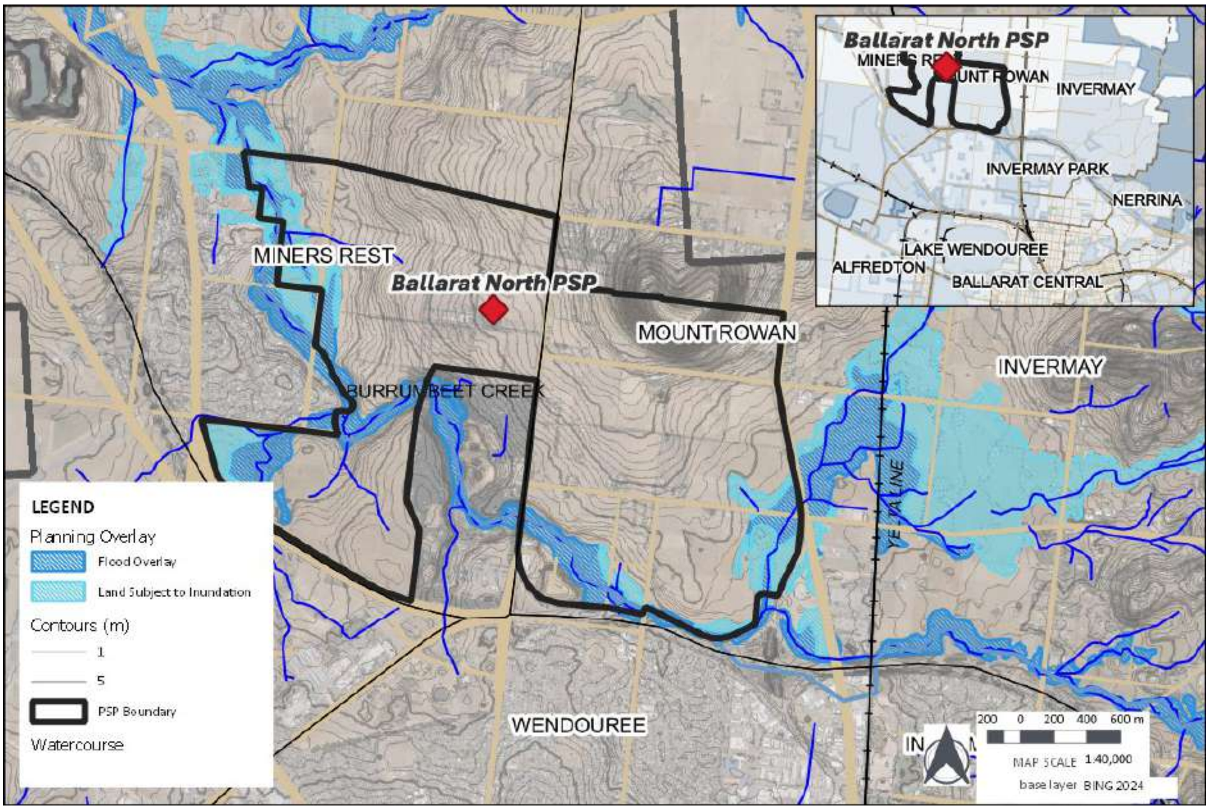


Figure 10-1 Ballarat North PSP and Burrumbeet Creek Flood Overlays

The flood extent defines the development exclusion zone, and an estimate of the updated zone is required to provide certainty for development planning purposes. Furthermore, defining the existing conditions base case is also necessary in order to assess the impact of the development conditions.

10.1.1 Interim Flood Extent

SMEC was tasked with preparing a methodology to delineate an interim flood inundation extent in advance of a more detailed future flood study to be completed at a later time. The methodology and outcomes was presented for in principal agreement to GHCMA. The intent of the interim methodology is to define the 1% AEP flood extent inclusive of climate change applying a simple, conservative analysis. The detail of this assessment is documented in a Technical Memo (30049251-181-TM-001) provided in **Appendix E**.

Subsequent to the interim flood outcomes and development of the RORB models, the TUFLOW model was refined to be more accurate, and the methodology and outcomes are presented below.

10.1.2 Methodology

10.1.2.1 Inputs

The models supplied by VPA were modified by SMEC. More recent terrain data were sourced from publicly available sources. These includes:

- Burrumbeet Creek – rainfall runoff model – RORB (Refer to Section 6)
- RORB sub catchment and reaches in GIS format (shapefiles)
- Burrumbeet Creek - 2d hydraulic model - TUFLOW
- Terrain (LiDAR) data 2019 (Geoscience Australia, 2024)

10.1.2.2 2024 Climate Change Consideration Update

Ball et al. (2019) defines the industry standard for completing design event rainfall runoff estimation and associated flood modelling. Subsequent to completion of the current flood study in 2013, Ball et al. (2019) has been updated in 2019 (Version 4.1) and more recently in September 2024 (Version 4.2). The updates incorporate changes to design rainfall and then, in 2024, changes to climate change impact estimation procedures.

For the purpose of the flood impact assessment, the existing conditions including climate change was simulated as it produces the critical and higher flood levels.

10.1.2.3 Limitations

- The model does not include all the underground drainage information on the south side of the Western Freeway. The existing residential area is indicated as flood prone. It is likely that the severity of the flood in this area may be overstated in the SMEC model since the culvert size under the freeway were based on site observations. Therefore, the size and capacity have not been verified.
- Similarly for the downstream areas in Miners Rest, the Council drainage system have not been included in the hydraulic modelling. However, since this area is downstream of the PSP site, the flood impact assessment should not be significantly influenced by the lack of drainage data.

10.1.3 Hydrology

The design rainfall and climate change conditions adopted for this assessment is consistent with the requirements of AR&R and GHCMA Flood Modelling Guidelines and Specifications (GHCMA, 2024). These are summarised in **Table 10-1**.

Table 10-1 Rainfall Depth and Climate Change Uplift factor

Scenario	Scenario Description	Design Rainfall Depth Source	Adopted Time Horizon	Global Climate Condition	Design Rainfall Depth Uplift Factor
Existing Condition	Latest Climate Change Consideration	BoM IFD 2016 w/ uplift as per Ball et al. (2019)	2100	SSP8.5 4.5 degrees °C increase	1.47[1]

1. For critical duration of 12 hours

The future climate change scenario is based on an increase in global temperature of 4.5 °C in the year 2100 horizon. The climate change uplift factors vary depending on the storm duration and AEP. A summary table of the uplift factors applicable to the site location is illustrated in **Table 10-2**. Detailed climate change factors are included in **Appendix A-2**.

Table 10-2 Data hub Climate Change Consideration Uplift Factors (AR&R v4.2, 2019)

SSP5-8.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	**1.2**	**1.18**	**1.17**	**1.16**	**1.14**	**1.13**	**1.13**	**1.12**	**1.11**	**1.11**
2040	1.26	1.24	1.22	1.2	1.18	1.17	1.16	1.15	1.14	1.14
2050	**1.34**	**1.31**	**1.29**	**1.26**	**1.24**	**1.23**	**1.21**	**1.2**	**1.18**	**1.18**
2060	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2070	1.52	1.47	1.43	1.4	1.36	1.34	1.31	1.29	1.27	1.26
2080	1.63	1.57	1.52	1.48	1.43	1.4	1.37	1.35	1.33	1.31
2090	**1.77**	**1.69**	**1.64**	**1.58**	**1.52**	**1.49**	**1.45**	**1.42**	**1.39**	**1.37**
2100	1.86	1.77	1.71	1.64	1.58	1.54	1.5	1.47	1.43	1.41

The RORB (Laurenson et al., 2010) model sub area and reaches and parameters (delay and losses) are described **Appendix A** of this report. A summary of the model parameters is shown in **Table 10-3**.

Table 10-3 RORB model parameters

Parameter	Value
Delay (k_c)[1]	46
Non-linearity (m)	0.8
Initial Loss (mm)	17.25
Continuing Loss (mm/hr)	5.33

Note 1: The primary delay adopted. k_c was adjusted for smaller sub catchment using interstations.

10.1.3.1 Outcomes

The 1% AEP peak flow estimated at Burrumbeet Creek within the PSP area (CN1) and at the catchment outlet are summarised in **Table 10-4.**

Table 10-4 Design Flow 1%AEP

Scenario	1% AEP Peak Flow (m^3/s)	
	Miners Rest (CN1) (Duration)	Lake Burrumbeet Gauge-Outlet
Existing Conditions	107.6 (4.5hr)	262

The RORB catchment model setup and locations of the reported peak flows are shown in **Figure 10-2**.

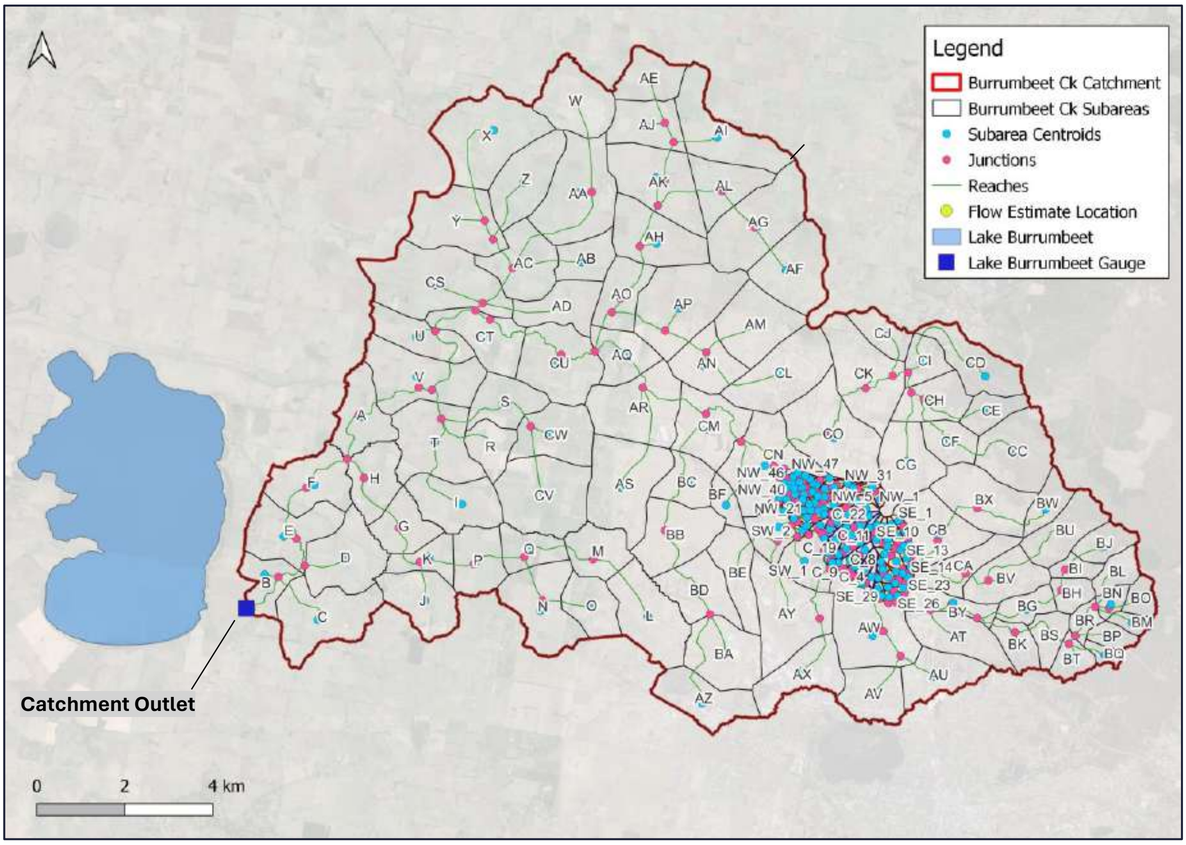


Figure 10-2 RORB Catchment Model

A range of storm durations and corresponding critical temporal pattern were selected for hydraulic simulation based on the peak flows at key locations (road crossings, along Burrumbeet Creek and proposed RB outlet) within the PSP. In particular at Miners Rest (CN1) and external catchment inflow location at Midland Road.

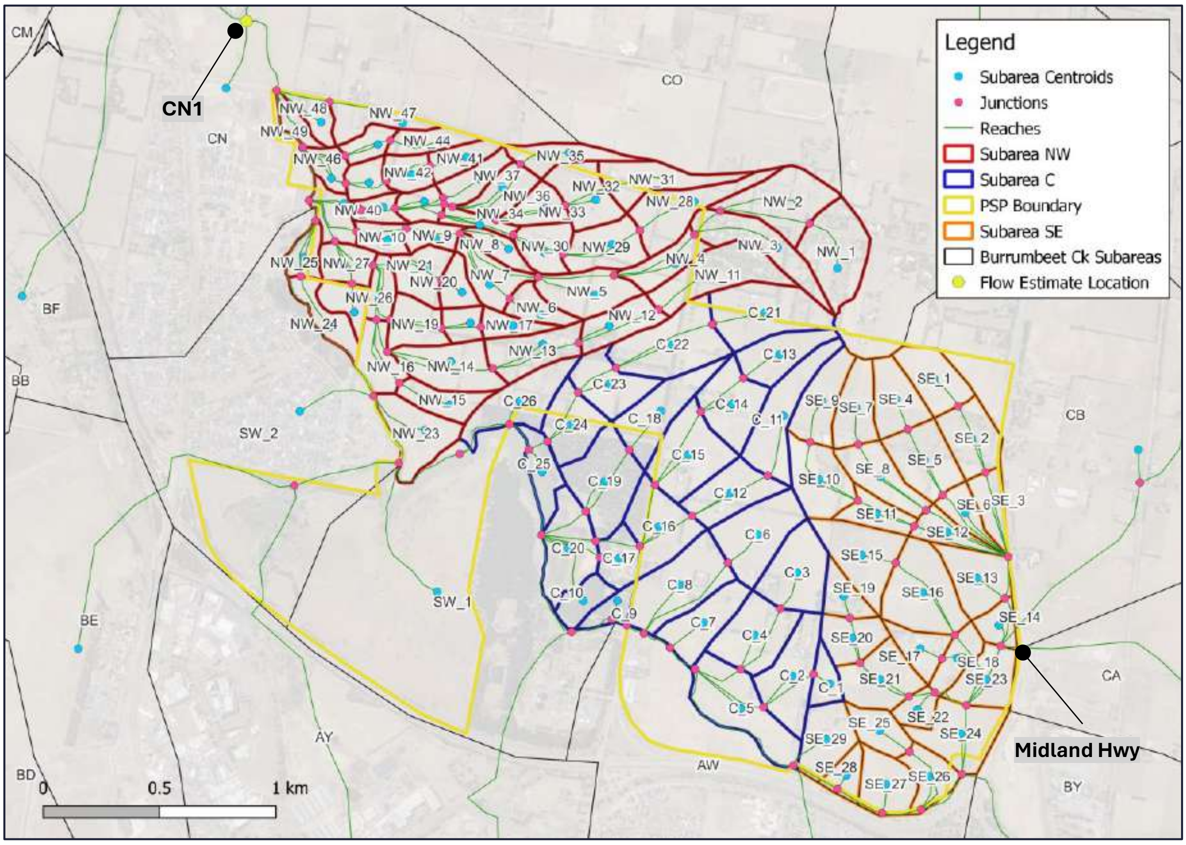


Figure 10-3 Peak Flows at Key Locations – Existing Condition

Table 10-5 outlines the storm events selected for the hydraulic simulation.

Table 10-5 Hydraulic Simulation Storm Events

Storm Duration	Temporal Pattern
1 hr	TP27
2 hr	TP28
4.5 hr	TP28
9 hr	TP26
12 hr	TP21
24 hr	TP21

10.1.4 Hydraulic Modelling

A 2d hydraulic model (TUFLOW) was setup to determine the maximum flood extents from various storm events for the 1% AEP. The TUFLOW model was setup and ran as follows:

- Inflow hydrograph at the upstream end of the model domain and for individual reach and tributary entering the Creek.
- Outflow boundary condition based on longitudinal slope.
- 5 m grid size based on 2019 LiDAR of 1m resolution.
- HPC computation scheme with sub-grid-sampling (SGS) enabled.
- Roughness definition (materials file) were modified to refine the area covering the PSP.

- Model extent is limited to the Burrumbeet Creek reach covering the PSP area and 2 km downstream into Miners Rest.
- The inflow hydrograph to the hydraulic model was extracted from the hydrologic model at a location shown in **Figure 10-4**. This represents more accurate representation of inflows for each sub catchment and tributaries.
- Major culvert structures at road crossings have been included in the TUFLOW model.

The TUFLOW model domain is shown in **Figure 10-4**.

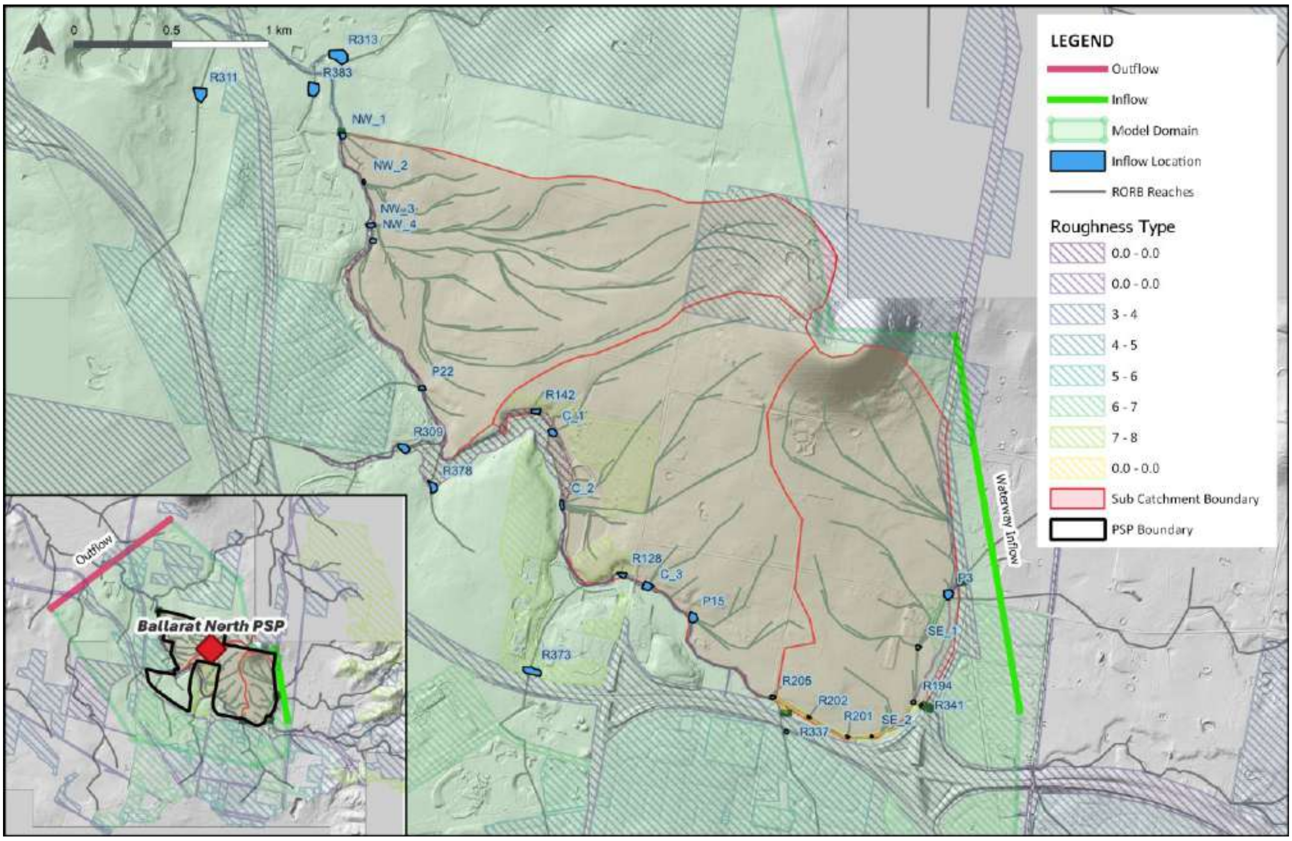


Figure 10-4 TUFLOW Model Setup Existing Conditions

10.1.5 Existing Conditions Extent Results

The results of the various storm events were combined to create the maximum flood extent. The 1% AEP flood extent of the existing conditions scenarios are provided in **Figure 10-5** and **Appendix F**.

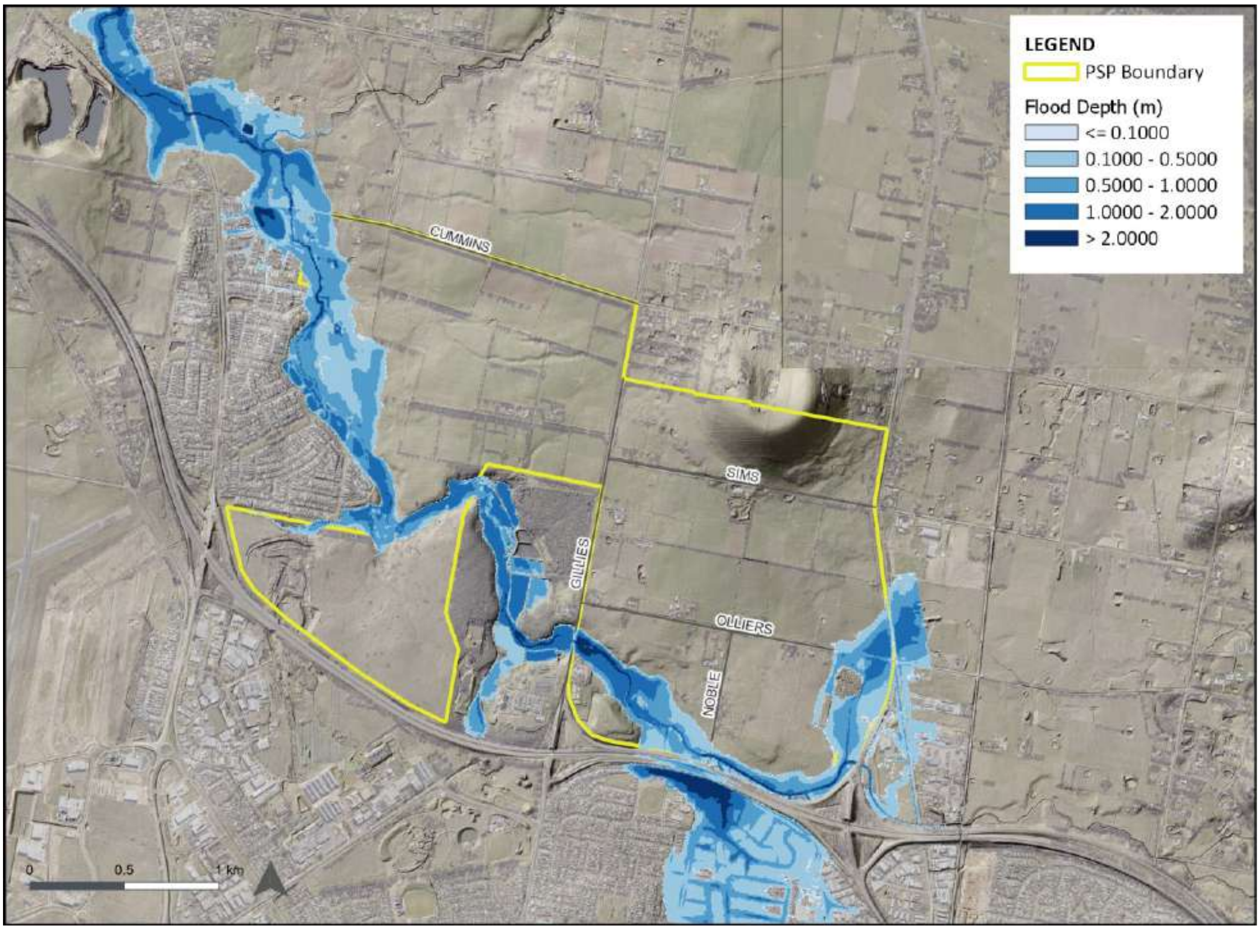


Figure 10-5 Existing Condition Flood Impact Assessment – 1% AEP

10.2 Developed Condition

10.2.1 Waterway Diversion

A waterway diversion is proposed on the eastern boundary of the PSP. The design intent is to fill the adjacent flood prone land to the west as described in Section 7.2.1. A design tin of the proposed waterway realignment have been created based on a typical constructed waterway with a pilot channel and benching.

For the proof-of-concept stage, the waterway profile has been determined to meet the hydraulic capacity requirements initially. In the functional design phase, the waterway profile will be further refined to be consistent with the Constructed Waterway Design Guidelines (Melbourne Water, 2019). A typical waterway profile and fill levels compared to the existing terrain is shown in **Figure 10-6**.

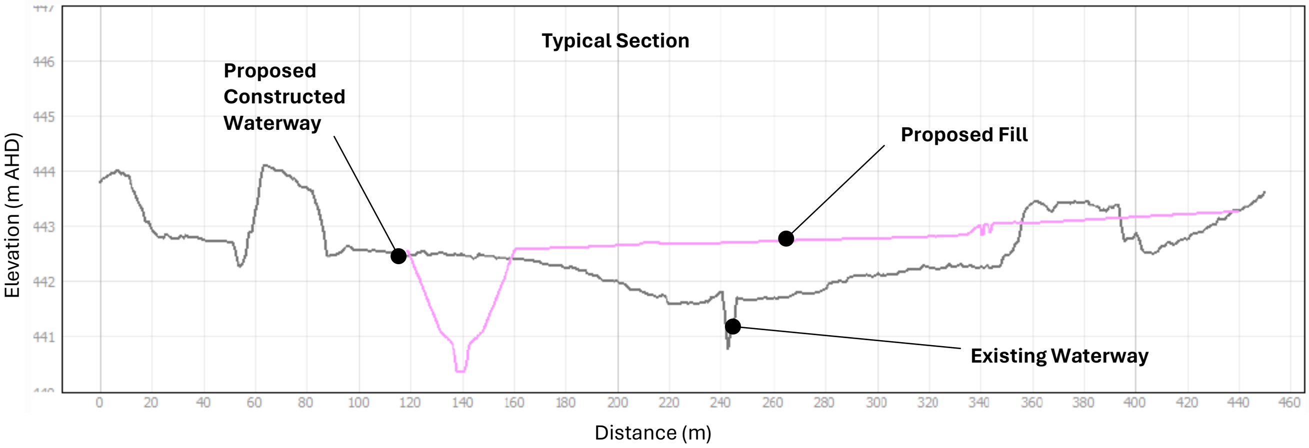


Figure 10-6 Typical waterway Profile

The alignment of the waterway diversion is shown in **Figure 10-7**. It is noted that the waterway diversion is proposed to extend into the confluence of Burrumbeet Creek. This will be further refined in the functional design phase.

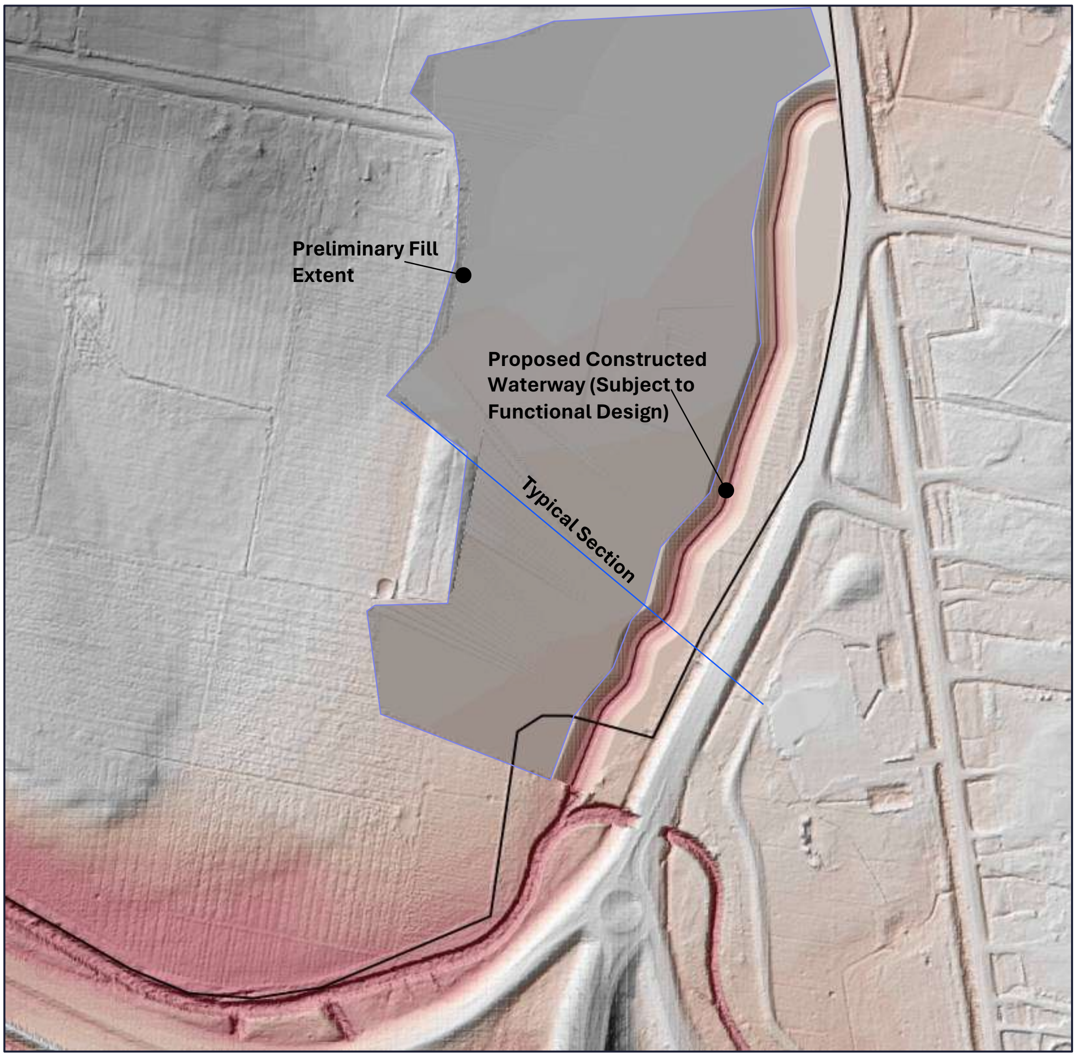


Figure 10-7 Alignment of the Waterway Diversion

10.2.1.1 Limitations

- The model does not include the 3d modelled surface of the proposed retarding basin and wetland. This work will be completed in the functional design phase. It is envisaged that the flood storage will need to be maintained by cut and fill balance near the proposed WLRB. The modelling will be updated once the 3d surface is developed.

10.2.2 Inflow Conditions

The developed conditions model was simulated with the inflow locations representing the peak outflow from the retarding basins. This is in addition to the external and adjacent subarea flows into Burrumbeet Creek. **Figure 10-8** shows the inflow locations matching the developed conditions RORB model.

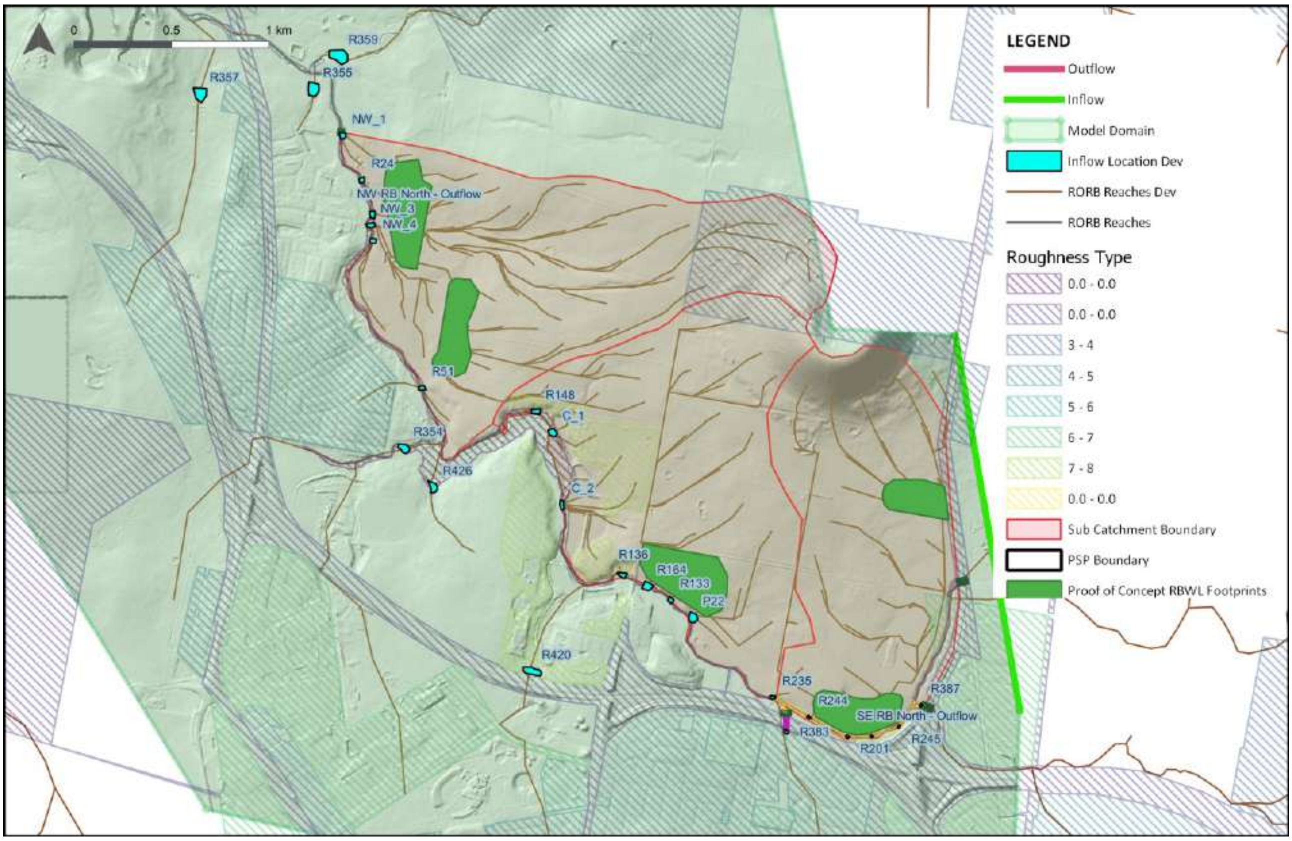


Figure 10-8 TUFLOW Model Inflow Locations - Developed Conditions

10.2.3 Results

The results of the same storm events modelled in the existing conditions were combined to create the maximum flood extent. The 1% AEP flood extent of the developed conditions scenarios are provided in **Figure 10-9** and **Appendix F**.

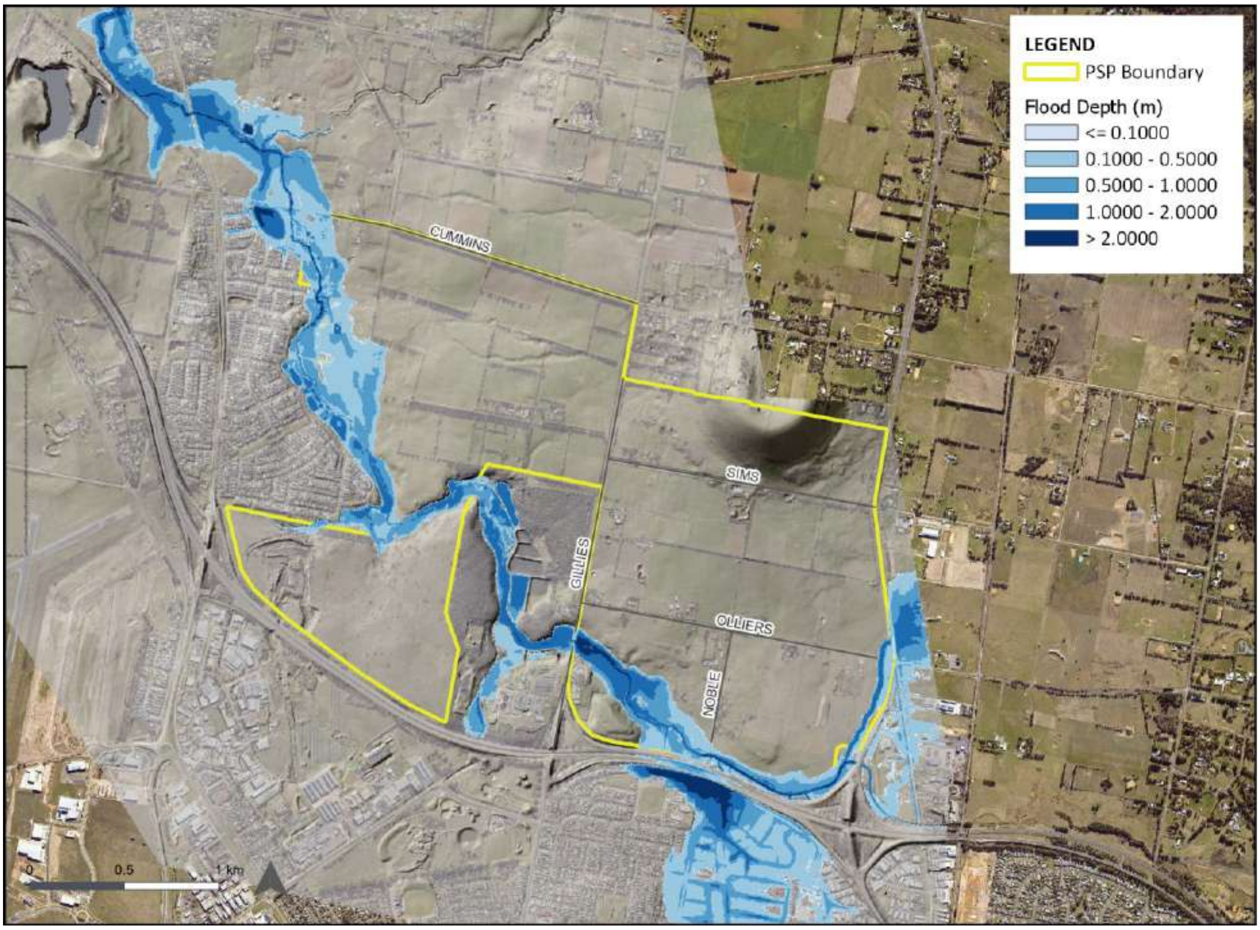


Figure 10-9 Developed Condition Flood Impact Assessment – 1% AEP

10.2.4 Impacts Assessment Result

The difference in flood levels were compared between the existing and developed conditions which is presented in an afflux map. The results are provided in **Figure 10-10**Figure 10-10 and **Appendix F**.

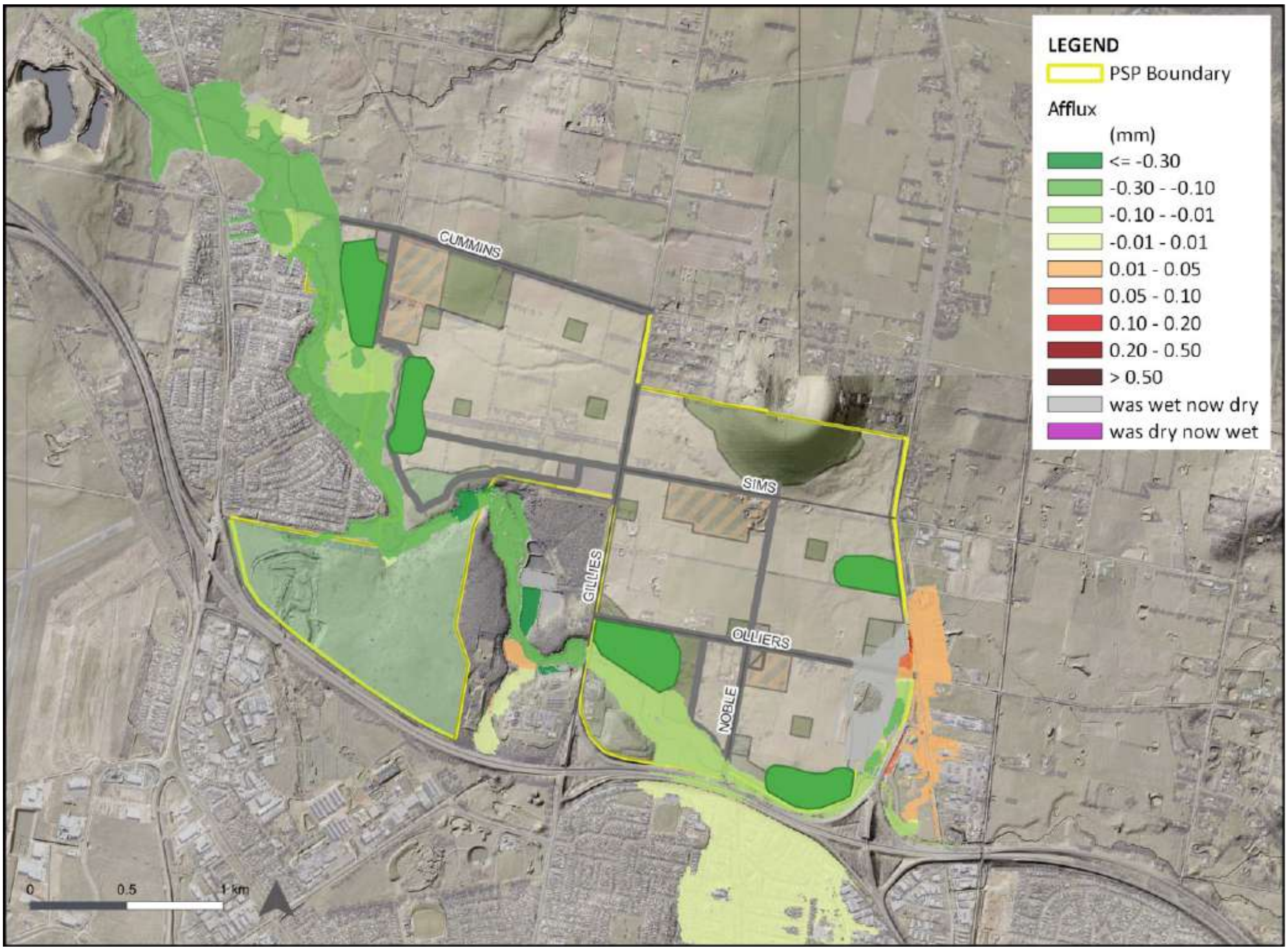


Figure 10-10 Flood Impact Assessment - Afflux

The afflux maps shows the developed conditions flood level within Burrumbeet Creek is lower by up to -0.3m. However, upstream of Midland Hwy there is an increase of about 30mm. This is caused by the culvert constriction and the waterway. This will be further refined in the functional design stage to avoid any flood increases.

The outcomes demonstrates that there is no worsening of flood conditions in the 1%AEP with climate change as a result of the PSP development. The results provides proof that the provisions of flood mitigation measures (retarding basins and waterway realignment) can appropriately mitigate the impacts of the increased peak runoff from the PSP development.

11. Conclusion and Recommendations

The proof-of-concept outcomes has demonstrated that the proposed drainage infrastructure and mitigation works are technically feasible and meets the relevant requirements.

The next phase of the project will involve the functional design of each proposed asset, including constructed waterway, outfall drains, major culverts, wetlands and retarding basins. A 3D modelling exercise will be undertaken to further validate and refine the proposed drainage strategy, ultimately informing costs estimates for inclusion in the Development Contributions Plan.

It is recommended that the outcomes be presented to the relevant authorities to confirm that the key requirements, assumptions and critical concerns identified during the preliminary drainage strategy phase have been appropriately addressed.

It should be noted that the outcomes of the proof-of-concept are subject to change as the project progresses into the functional design phase, which will consider terrain constraints in greater detail. Additional hydraulic modelling, including shear stress assessments, will be required to inform the design of the waterway realignment and assess the impacts to Burrumbeet Creek. Further design considerations for the wetland assets, such as the inundation frequency analysis, will confirm whether adjustments to the wetland area is required. While some refinements are anticipated, the fundamental principles of the drainage strategy are not expected to change significantly.

12. References

ABS (2021). [2021 Ballarat North, Census All persons QuickStats | Australian Bureau of Statistics]

Arup (2024). Ballarat North PSP IWM & Drainage Assessment, Ballarat North PSP IWM Plan, Rev 03, 2 July 2024.

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) (22019). (AR&R) Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia (Geoscience Australia), Version 4.2, 2019.

Babister, M., Trim, A., Testoni, I. & Retallick, M. 2016. The Australian Rainfall & Runoff Datahub, 37th Hydrology and Water Resources Symposium Queenstown NZ

Central Highlands Water, City of Ballarat, Corangamite CMA (2018). Ballarat City Integrated Water Management Plan, Final Report.

Central Highlands Water (2018). Ballarat Potable Water Demand Target.

CSIRO (1999). Urban Stormwater: Best Practice Environmental Management Guidelines, CSIRO Publishing, Melbourne.

Department of Environment, Land, Water and Planning (2019). Guidelines for Development in Flood Affected Areas. February 2019.

Department of Environment, Land, Water and Planning (2017). Growling Grass Frog Habitat Design Standards.

E2DesignLab (2018). Ballarat City Integrated Water Management Plan, Final Report, 16 February 2018.

Ecology and Heritage Partners (2024). Ballarat North Precinct Structure Plan: Strategic Bushfire Development Report and Risk Assessment, Final, July 2024.

GHD (2024). Adverse Amenity Impact Assessment, Ballarat North, Rev 0, 28 May 2024.

Geoscience Australia (2024). Elvis LiDAR Elevation. Accessed on September 2024.

Glenelg Hopkins Catchment Management Authority (2024). Flood Modelling Guidelines and Specifications, August 2024.

Jacobs (2024). Land Capability Statement, Ballarat North Precinct Structure Plan 10 July 2024.

Laurenson,E.M, Mein,R.G. and Nathan,R.J (2010). RORB – Version 6.15, Runoff Routing Program, User Manual, Department of Civil Engineering, Monash University, Clayton, Australia.

Local Government Infrastructure Design Association (LGIDA) (2019). Infrastructure Design Manual. Version 5.30, IDM 2019.

Melbourne Water (2023). MUSIC (Model for Urban Stormwater Improvement Conceptualisation) Guidelines – October 2023.

Melbourne Water (2013). Waterway Corridors, Guidelines for greenfield development areas within the Port Philip and Westernport Region, October 2013.

Melbourne Water (2018). MUSIC Guidelines - Input parameters and modelling approaches for MUSIC users in Melbourne Water's service area, 2018.

Mesh (2024). Final Landscape and Visual Assessment, Ballarat North PSP, Version 1, May 2024.

National Serive centre for Environmental Publications (NSCEP) (1998). Stream Corridor Restoration: Principles, Processes, and Practices.

RBA (2024). Ballarat North PSP Historical (Post-Contact) Heritage Assessment, July 2024.

Spiire (2024). Memo - Drainage Strategy Asset Locations 10 July 2024.

Stantec (2024). Ballarat North Precinct Structure Plan, Situational Analysis Report and Utility Servicing Assessment, Revision 03, 3 July 2024

Stantec (2024). Design Brief Report – Miners Rest Flood Mitigation Rev 02 31 January 2024.

State Government of Victoria (2014). Central Highlands Regional Growth Plan.

Tree Logic (2024). Arboricultural Assessment and Report, Ballarat North – PSP, 6 August 2024.

Urbis (2024). Ballarat North Precinct Structure Plan, Economic & Retail Assessment, Final Report, June 2024.

Victorian Planning Authority (2023). Ballarat North Precinct Structure Plan, Vision & Purpose Survey Summary.

Victorian Planning Authority (2024). Community Infrastructure and Open Space Needs Assessment, Ballarat North Precinct Structure Plan, June 2024.

Victorian Planning Authority (2024). Draft Ballarat North Place Based Plan for future urban structure.

Victorian Planning Authority (2024). Ballarat North Precinct Structure Plan - Co -Design Summary.

Victorian Planning Authority (2024). Final Landscape and Visual Assessment.

https://mapshare.vic.gov.au/vicplan/

Wadawurrung Traditional Owners (2024). Wadawurrung IWM Statement.

Wadawurrung Traditional Owners (2024). Healthy Country Plan.

Water Technology (2013). Burrumbeet Flood Investigation, Summary Study Report.

Water Technology (2013). Burrumbeet Flood Investigation, Hydrology and Hydraulics, October 2013.

WSP (2024). Ballarat North Precinct Structure Plan, Biodiversity Assessment Report, Rev C, 9 August 2024.

Appendix A

Hydrology

A-1 RORB Modelling

A-1-1 General

In order to mitigate the impacts of increased runoff from the development, an existing condition design flow estimate is required to set the base case hydrology for the Ballarat North PSP area. As there are no local flow gauges near the site, there are uncertainties in the existing peak runoff that would be expected from the site. The nearest flow gauge available is located 21 km downstream from the PSP area at Bo Peep Gauge near Lake Burrumbeet.

In the absence of local data, the procedures set out in Australian Rainfall & Runoff (AR&R) guidelines (Ball et al., 2019) have been adopted to quantify a target peak flow. Water Technology (2013) describes the flood study for the larger Burrumbeet Creek catchment and has been considered in setting the model parameters. The 2013 flood study is comprehensive and includes hydrologic and hydraulic calibration to actual flood events. The snippet of the Water Technology (2013) existing conditions hydrologic model (RORB) model setup is illustrated in **Figure A-1-1** below. This model was adapted as a reference to represent the PSP area at a smaller scale.

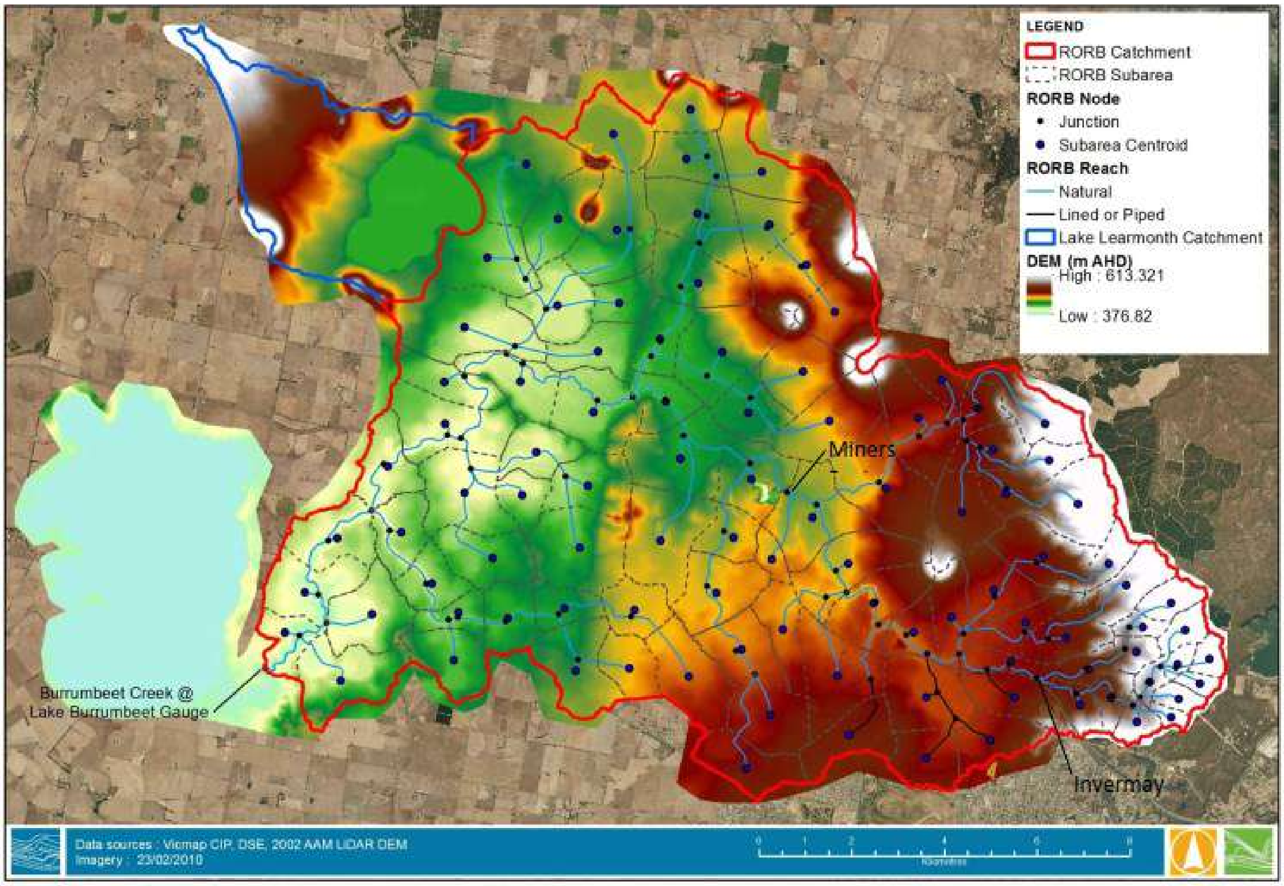


Figure A-1-1 Water Technology RORB Model Setup (Water Technology, 2013)

A-1-2 Existing Condition

The runoff-routing model, RORB (Version 6.45) was used to determine the magnitude of design flows in accordance with the latest version of AR&R (Ball et al., 2019). The larger model created by Water Technology (2013) was subdivided to smaller subareas representing the Ballarat North PSP area at a scale appropriate for the PSP. The PSP area has been subdivided into subareas SE, C, and NW. The graphical representation of the modified existing condition RORB model setup is shown in **Figure A-1-2**.

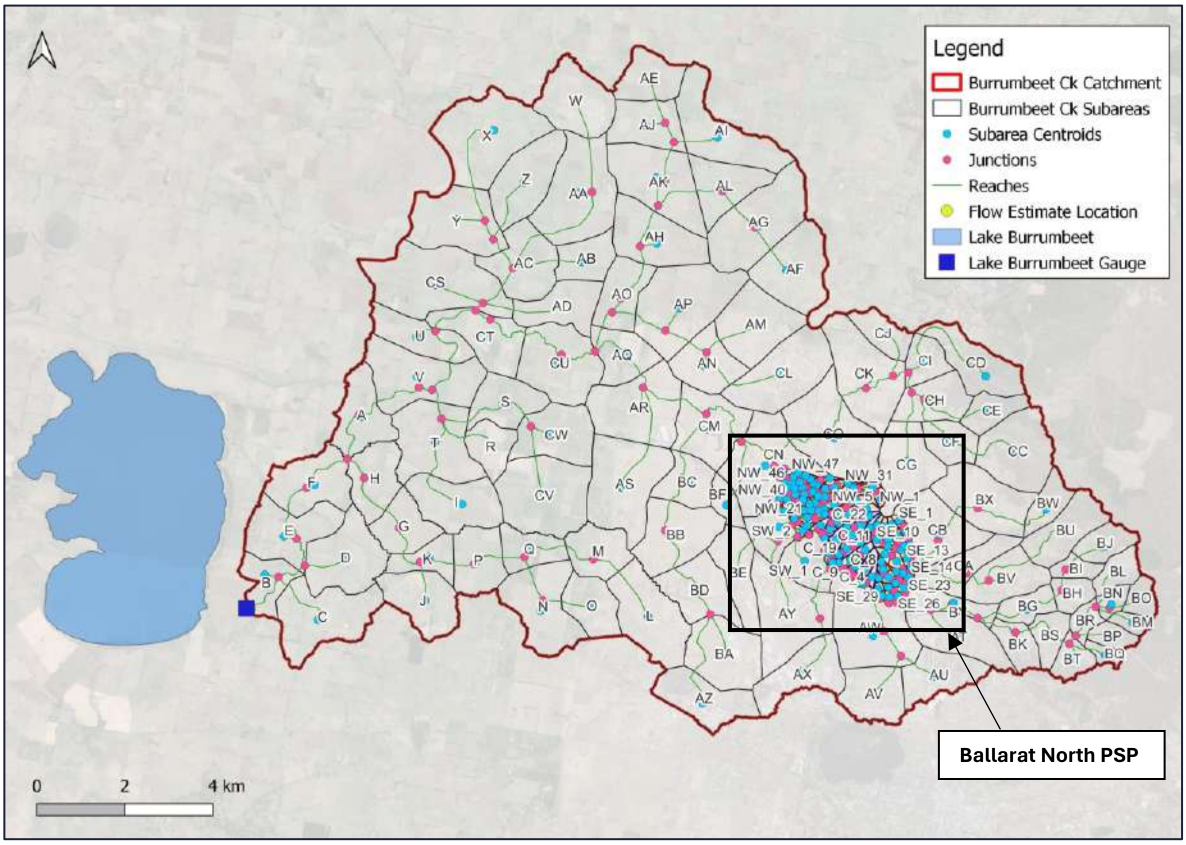


Figure A-1-2 Existing Condition RORB Model Setup

The magnified view of the Ballarat North PSP is shown in **Figure A-1-3**.

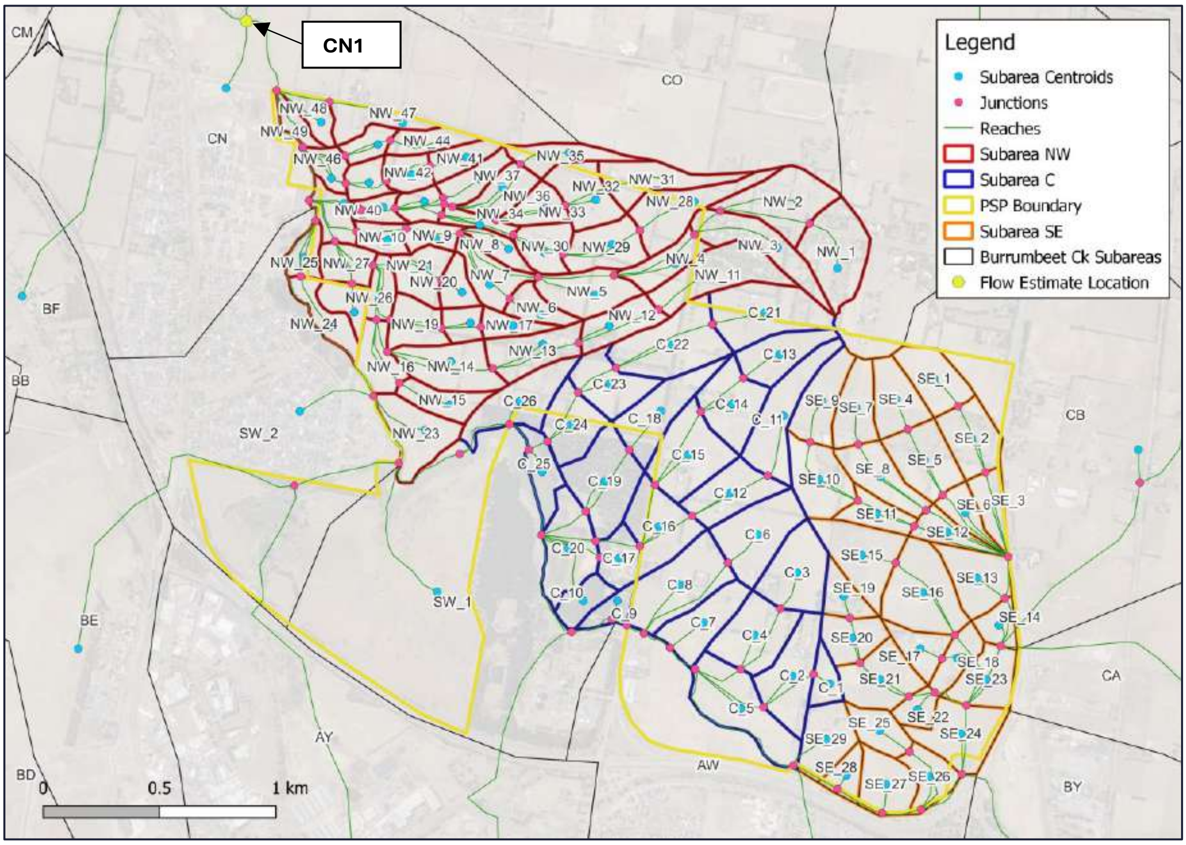


Figure A-1-3 Ballarat North PSP Existing Condition RORB Model Setup in QGIS

The sub catchment characteristics within the Ballarat North PSP area for the existing condition are presented in **Table A-1-1** below.

Table A-1-1 Existing Condition Ballarat North PSP Sub catchment Characteristics

Sub catchment	Sub catchment Area (km^2)	Fraction Imperviousness
NW	2.1	0.1
C	1.9	0.1
SE	1.5	0.1

A-1-3 Model Parameter Calibration

Design Rainfall Depth

Rainfall depths were obtained from the Australian Bureau of Meteorology (BoM) 2016 Rainfall IFD Data System. Areal reduction factors, and temporal patterns were adopted from the ARR Datahub. Given that the combined RORB model exceeds 75 km^2, areal temporal patterns must be applied. However, areal temporal patterns for durations less than 9 hours were not available and thus temporal patterns have been applied for durations up to and including 9 hours with areal temporal patterns have been applied for duration of 12 hours and above.

Pre-burst rainfalls have been applied using the in-built functionality of RORB. Median pre-burst data downloaded from the ARR 2016 Datahub was read into RORB and applied in a single increment prior to the design storm.

Delay Parameter (k_c)

Due to the modification of the model setup which results in smaller subareas for the three sub catchments, it is required to adjust the delay parameter (k_c) to ensure the delay response is consistent with the larger catchment model. Three interstation were included to allow the adjustment of the k_c parameter to match the existing conditions outcome of the Water Technology (2013) flood study. Once this has been achieved, this model would be used as the base case model.

To determine an appropriate k_c value for the PSP area, k_c/d_{ave} for the larger Burrumbeet Creek RORB model was calculated and k_c values for each of the subareas NW, C, and SE within the Ballarat North PSP were estimated based on the known d_{ave} values. The following k_c values were adopted as presented in **Table A-1-2**.

Table A-1-2 Adopted k_c Values

Catchment	Average Flow Distance (d_{ave}) (km)	Delay Parameter (k_c)
NW	1.19	2.87
C	0.61	1.43
SE	0.70	1.64
Burrumbeet Ck Outlet	19.55	46.00

Loss Parameter

The initial and continuing loss factors were adopted from Water Technology (2013) and verified at the downstream node of the Ballarat North PSP to provide a similar flow as to Burrumbeet Creek existing conditions peak flow. Water Technology has adopted a variable initial loss factor for various storm durations. The loss values are based on (Hill et al, 1998) Loss parameters adopted for RORB modelling is presented in **Table A-1-3**.

‘m’ value is also assumed to be 0.8.

Table A-1-3 Loss Parameters

Parameter	Duration	Value
IL (mm)	10 min	1.9
	15 min	2.3
	20 min	2.6
	25 min	2.9
	30 min	3.1
	45 min	3.7
	1 hour	4.2
	1.5 hours	4.9
	2 hours	5.5
	3 hours	6.4
	4.5 hours	7.5
	6 hours	8.2
	9 hours	9.4
	12 hours	10.2
	18 hours	11.5
	24 hours	12.4
	30 hours	13.1
	36 hours	13.7
	48 hours	14.5
	72 hours	15.7
CL (mm/hr)		3.7

A-1-4 Outcomes

Critical durations were determined using ensemble analysis for the different storm events. The temporal patterns that generate the closest peak flow to the median of all temporal patterns were adopted as the critical temporal pattern.

The RORB modelling results for the 10% AEP and 1% AEP storm events for the existing condition are outlined in **Table A-1-4 and Table A-1-5**. The validation point was selected to be at CN1 just downstream of the PSP boundary as shown in **Figure A-1-3**. Utilising the Water Technology (2013) loss parameters with the adjusted k_c values for each of the sub catchments within the PSP area provides a similar peak flow for the combined model.

Table A-1-4 Existing Condition RORB Model Results – 10% AEP

Model	Peak Flow (m^3/s)	Critical Duration (hrs)
SE Interstation	2.5	1.5
C Interstation	3.6	1.5
NW Interstation	1.8	4.5
Combined Model Existing Condition (CN1)	25.6	4.5

Table A-1-5 Existing Condition RORB Model Results – 1% AEP

Model	Peak Flow (m^3/s)	Critical Duration (hrs)
SE Interstation	4.7	2
C Interstation	6.9	1.5
NW Interstation	4.1	4.5
Combined Model Existing Condition (CN1)	58.6	9

A-1-5 Comparison to Regional Flood Estimates

A summary of the RFFE results are provided in **Table A-1-6**. As shown below, adjusting the k_c values for the SE and C sub catchments results in flows that closely align with the RFFE estimation tool.

Table A-1-6 Existing Condition RORB Model Results for the Ballarat North PSP

Model	RFFE	RFFE 5% Limit	RFFE 95% Limit
SE 1% AEP Flow (m^3/s)	4.7	1.5	15.3
C 1% AEP Flow (m^3/s)	6.0	1.9	19.3
NW 1% AEP Flow (m^3/s)	6.6	2.1	21.3

A-1-6 Developed Condition

RORB model was setup using a plug-in for the Ballarat North PSP under developed condition. Similar to the existing condition RORB model, this model was combined with the larger Burrumbeet CK RORB model provided by Water Technology (2013) and run for the 1% AEP storm event with the adjusted Kc values to determine the 1% AEP peak flow at the downstream node (CN1) of the Ballarat North PSP outlet.

Details of sub catchment characteristics within the Ballarat North PSP area for the developed condition are presented in **Table A-1-7**.

Table A-1-7 Developed Condition Ballarat North PSP Sub catchment Characteristics

Sub catchment	Sub catchment Area (km2)	Fraction Imperviousness
NW	2.34	0.45
C	1.65	0.41
SE	1.55	0.53

The new place-based plan (PBP) was provided by VPA on 23/06/25 and the overall fraction imperviousness for each of the sub catchments based on the updated PBP was calculated. **Figure A-1-4** below shows the fraction imperviousness map for the PSP area.

The changes on the new PBP are listed below:

- NW School/AOS layout has been revised. The AOS is now closer to the NWN and NWS basins.
- AOS has been relocated from central catchment to southeast catchment.
- Mount Rowan extent has been slightly reduced (small increase to NDA in central and southeast catchment).
- Waterway diversion has been added to the PBP. See Section 7.2.1.3 for more details.

Drainage basins have also been added to the new PBP as per shown on the drainage strategy plan provided by SMEC.

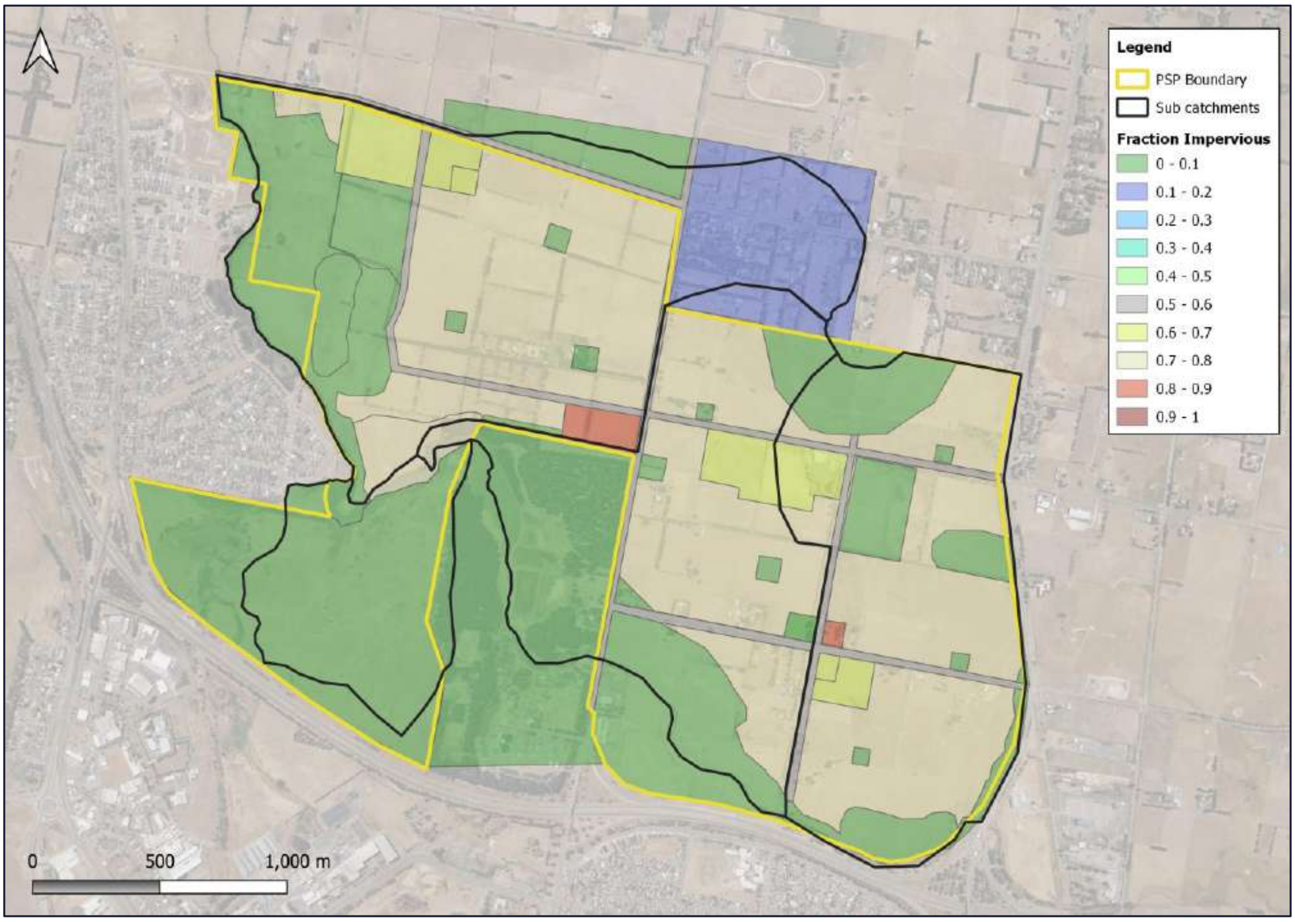


Figure A-1-4 Ballarat North PSP Area Fraction Impervious Map

It must be noted that changes on the PBP layout plan will impact (although slightly) the calculated fraction imperviousness for major sub catchments. The RORB and MUSIC modelling will require to be amended based upon the updated fraction imperviousness. However, SMEC believe that changes on the fraction imperviousness will not change the RB footprints and less likely impact the sizing of the water quality assets. Additional modelling needs to be discussed with VPA and will be done in the functional design report upon confirmation.

Figure A-1-5 shows the snippet of the developed condition RORB model. RORB catg and par files for the existing condition are provided in conjunction with this report.

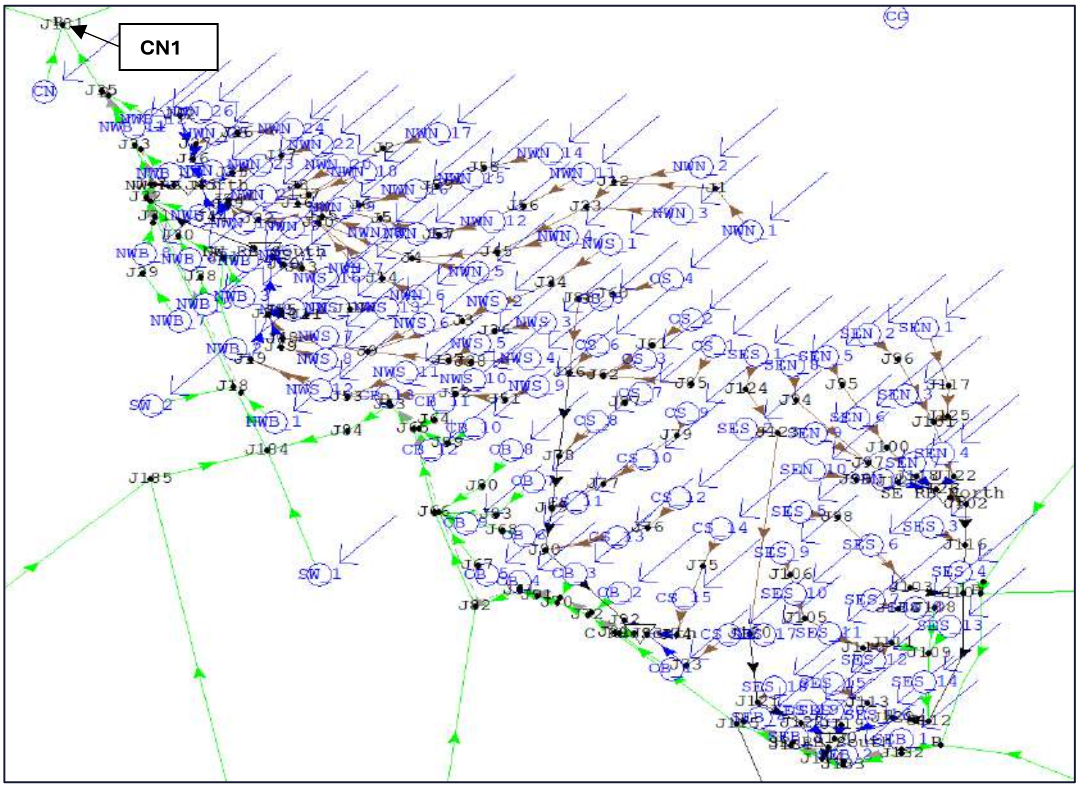


Figure A-1-5 Developed Condition RORB Model Setup – Ballarat North PSP area

The developed condition RORB modelling results at the downstream node (CN1) of the Ballarat North PSP for the 10% AEP and 1% AEP events are outlined in **Table A-1-8**.

Table A-1-8 Developed Condition RORB Model Results at CN1

Model	Peak Flow (m^3/s)	Critical Duration (hrs)
10% AEP		
Combined Model Developed Condition	23.6	4.5
1% AEP		
Combined Model Developed Condition	55.3	9

A-1-7 Retarding Basin Sizing

Multiple retarding basins for the subareas SE, C, and NW have been designed to retard developed condition flows back to the existing condition flows under the 1% AEP storm event (see **Figure A-1-6**). The layout of the retarding basins is subject to change at the functional design stage.

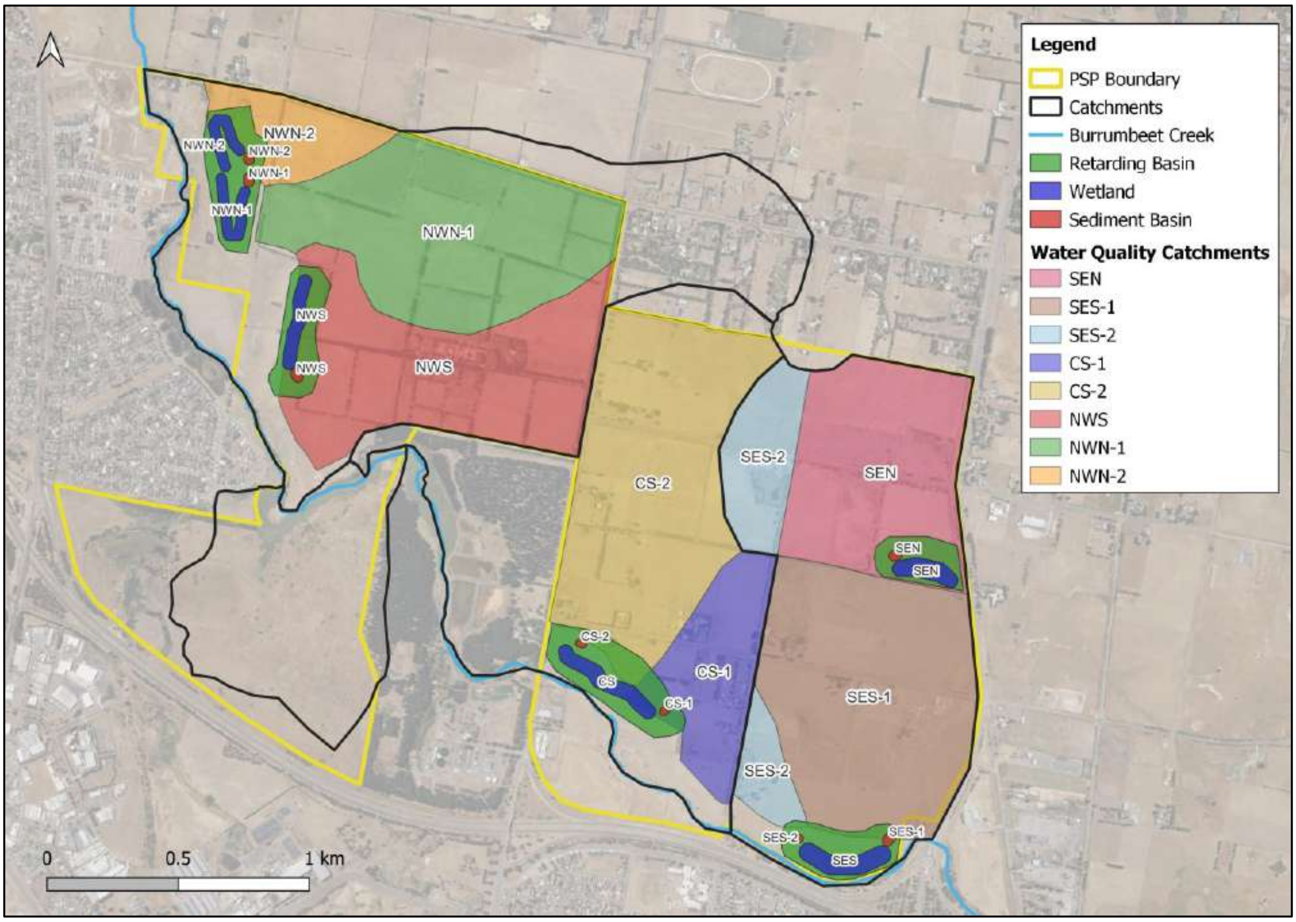


Figure A-1-6 Approximate Layout of the Retarding Basins

Details of the retreading basins are presented in **Table A-1-9.**

Table A-1-9 Details of the Retarding Basins within the Ballarat north PSP

RB Name	1% AEP Flood Level (m AHD)	Spillway Level (m AHD)	Storage (m^3)
SEN	443.5	444.3	24,200
SES	441.0	441.5	45,400
CS	436.6	437.2	50,000
NWN	423.8	424.5	58,300
NWS	427.5	428.3	35,000

A-1-1 RORB Results

10% AEP Design Flows

The RORB model 10% AEP flow estimates downstream of the retarding basins are presented in **Table A-1-10** and compared with those of existing condition.

Table A-1-10 10% AEP Flow Estimates Comparison

Flow Estimate Location	Existing 10% AEP Flow (m^3/s) & Critical Duration (hr)	Developed 10% AEP Flow (m^3/s) & Critical Duration (hr)
SEN	0.9 (1.5hr)	0.3 (9hr)
SES	2.5 (1.5hr)	0.5 (9hr)
CS	3.6 (1.5hr)	0.4 (9hr)
NWN	1.5 (4.5hr)	0.3 (9hr)
NWS	0.7 (1.5hr)	0.3 (9hr)
Ballarat North PSP DS (CN1)	25.6 (4.5hr)	23.6 (4.5hr)

1% AEP Design Flows

The RORB model 1% AEP flow estimates downstream of the retarding basins are presented in **Table A-1-11** and compared with those of existing condition.

Table A-1-11 1% AEP Flow Estimates Comparison

Flow Estimate Location	Existing 1% AEP Flow (m^3/s) & Critical Duration (hr)	Developed 1% AEP Flow (m^3/s) & Critical Duration (hr)
SEN	1.8 (2hr)	0.6 (9hr)
SES	4.7 (2hr)	1.4 (9hr)
CS	6.8 (1.5hr)	1.1 (9hr)
NWN	3.9 (3hr)	0.4 (9hr)
NWS	1.4 (2hr)	0.6 (9hr)
Ballarat North PSP DS (CN1)	58.6 (9hr)	55.3 (9hr)

A-1-2 Climate Change Sensitivity Analysis

The sensitivity of flood behaviour to projected Climate Change was tested for the SSP 5-8.5 for the year 2100. The increased rainfall intensity was simulated in the RORB model. The adjustment factors of 1.19 and 1.44 have been applied for the initial loss and continuous loss, respectively.

The RORB model 10% AEP and 1% AEP flow estimates downstream of the retarding basins with the impact from climate change on existing and developed conditions are presented in **Table A-1-12** and **Table A-1-13**.

Table A-1-12 10% AEP Flow Estimates Comparison with the Impact of Climate Change

Flow Estimate Location	Existing 10% AEP Flow (m^3/s) & Critical Duration (hr)	Developed 10% AEP Flow (m^3/s) & Critical Duration (hr)
SEN	1.6 (1.5hr)	0.5 (9hr)
SES	4.6 (1.5hr)	1.1 (9hr)
CS	6.8 (1.5hr)	0.9 (9hr)
NWN	2.7 (1.5hr)	0.3 (9hr)
NWS	1.2 (1.5hr)	0.5 (9hr)
Ballarat North PSP DS (CN1)	40.1 (4.5hr)	46.3 (3hr)

Table A-1-13 1% AEP Flow Estimates Comparison with the Impact of Climate Change

Flow Estimate Location	Existing 1% AEP Flow (m^3/s) & Critical Duration (hr)	Developed 1% AEP Flow (m^3/s) & Critical Duration (hr)
SEN	3.7 (2hr)	1.1 (4.5hr)
SES	8.7 (1.5hr)	2.4 (9hr)
CS	10.6 (1hr)	1.7 (9hr)
NWN	7.5 (2hr)	0.6 (9hr)
NWS	6.7 (2hr)	1.0 (9hr)
Ballarat North PSP DS (CN1)	107.6 (4.5hr)	100.0 (4.5hr)

Table A-1-14 below presents the peak elevation, and the storage required for each of the retarding basins under 1% AEP storm event as opposed to the base design event.

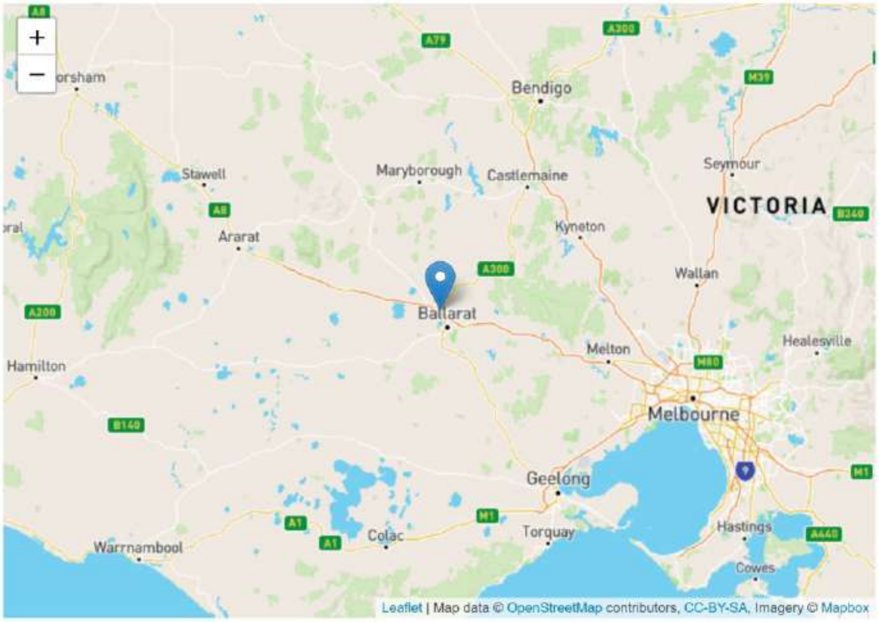
Table A-1-14 1% AEP Flood Level and Storage Changes as a result of Climate Change

RB Location	1% AEP Flood Level (m AHD)	Spillway Level (m AHD)	Storage (m^3)
SEN	443.8	444.3	33,700
SES	441.5	441.5	66,600
CS	436.9	437.2	70,900
NWN	424.2	424.5	89,300
NWS	427.8	428.3	50,200

A-2 Data Hub Climate Change Factors

Input Data

Longitude	143.828
Latitude	-37.506
Selected Regions (clear)	
Climate Change Factors	show



Loss Factors

Initial Loss (Adjustment Factors)

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2030	**1.05**	**1.05**	**1.05**	**1.05**
2040	1.05	1.06	1.06	1.07
2050	**1.06**	**1.07**	**1.07**	**1.08**
2060	1.06	1.07	1.09	1.1
2070	1.06	1.08	1.1	1.12
2080	1.06	1.09	1.12	1.14
2090	**1.06**	**1.09**	**1.13**	**1.17**
2100	1.06	1.1	1.15	1.19

Continuing Loss (Adjustment Factors)

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2030	**1.1**	**1.1**	**1.1**	**1.11**
2040	1.12	1.12	1.13	1.14
2050	**1.12**	**1.15**	**1.16**	**1.18**
2060	1.13	1.17	1.19	1.23
2070	1.13	1.18	1.23	1.28
2080	1.13	1.2	1.27	1.33
2090	**1.13**	**1.21**	**1.31**	**1.39**
2100	1.12	1.22	1.34	1.44

Temperature Changes (Degrees, Relative to 1961-1990 Baseline)

Year	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
2030	**1.2**	**1.2**	**1.2**	**1.3**
2040	1.3	1.4	1.5	1.6
2050	**1.4**	**1.7**	**1.8**	**2.1**
2060	1.5	1.9	2.2	2.5
2070	1.5	2.1	2.5	3
2080	1.5	2.2	2.9	3.5
2090	**1.5**	**2.4**	**3.3**	**4.1**
2100	1.4	2.5	3.6	4.5

Layer Info

Time Accessed	27 October 2024 11:03PM
Version	2024_v1
Note	Updated climate change factors for IFD Initial loss and continuing loss based on IPCC AR6 temperature increases from the updated Climate Change Considerations (Book 1: Chapter 6) in ARR (Version 4.2). ARR recomends the use of Current and near-term (2030 midpoint). Medium-term (2050 midpoint) and Long-term (2090 midpoint)

Appendix B

Stormwater Quality

B-1 MUSIC Modelling

B-1-1 General

The objective of stormwater quality modelling is to achieve "best practice" set out in the Best Practice Environmental Management Guidelines for Urban Stormwater (BPEMG) document (CSIRO, 1999). The best practice water quality targets are detailed in **Table B-1-1**.

Table B-1-1 Best Practice Water Quality Targets

Pollutant	% Target Reduction
Total Suspended Solids	80
Total Phosphorus	45
Total Nitrogen	45
Gross Pollutants	70

B-1-2 Proposed Works

SMEC has identified the following works for provision of stormwater quality treatment:

- Sediment basins to treat up to and including 4EY (3-month ARI) flows for each of the sub catchments.
- Wetlands to treat up to and including 4EY (3-month ARI) flows for each of the sub catchments.

B-1-3 MUSIC Model Setup

The proposed stormwater treatment devices to meet these objectives have been modelled using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) Version 6 and the Melbourne Water MUSIC Guidelines (Melbourne Water, 2023).

The MUSIC model requires the specification of subarea parameters, and meteorological data (rainfall and evaporation). The parameters for the MUSIC model were adopted in accordance with the Melbourne Water MUSIC Modelling Guidelines (2023).

Subarea Parameters

Suitable source nodes and effective impervious areas (EIA) were assigned to the land uses. EIA calculation is subject to change based on the new PBP provided by VPA on 23/06/2025. MUSIC model update as a result of EIA change needs to be discussed with VPA for confirmation. **Table B-1-2** provides a breakdown of the subareas and their %EIA used to develop MUSIC model for the Ballarat North PSP area.

Table B-1-2 Subarea Parameters

Subarea ID	Area (ha)	EIA (%)
SEN	51	63
SES-1	73	52
SES-2	25	55
SEB	7	3
CS-1	27	59
CS-2	74	62
CSB	23	7
NWN-1	67	64
NWN-2	17	52
NWS	64	72
NWB	35	13

Climate Data

Rainfall data was adopted from station 089002 at "Ballarat" for the designated project location. Details of climate data are summarised in **Table B-1-3**.

Table B-1-3 Meteorological Data

Station Name – MELBOURNE REGIONAL OFFICE	
Station ID	086071
Data Period	01/01/1952 – 31/12/1961
Number of Years	10
Average Annual Rainfall (mm)	708
Average Annual Evapotranspiration (mm)	995
Time Step (min)	6

B-1-4 Proposed Treatment Train

A combined treatment train of the sediment basins and wetlands has been proposed for the PSP area to meet best practice water quality objectives.

To ensure consistency between the hydrologic and water quality analysis, the MUSIC model was schematised with the same subarea configuration as the RORB model. A layout of the MUSIC model layout for the developed condition is shown in **Figure B-1-4**. Treatment feature parameters are detailed in Section 0. The layouts of the water quality catchments is shown in **Figure 8-1**.

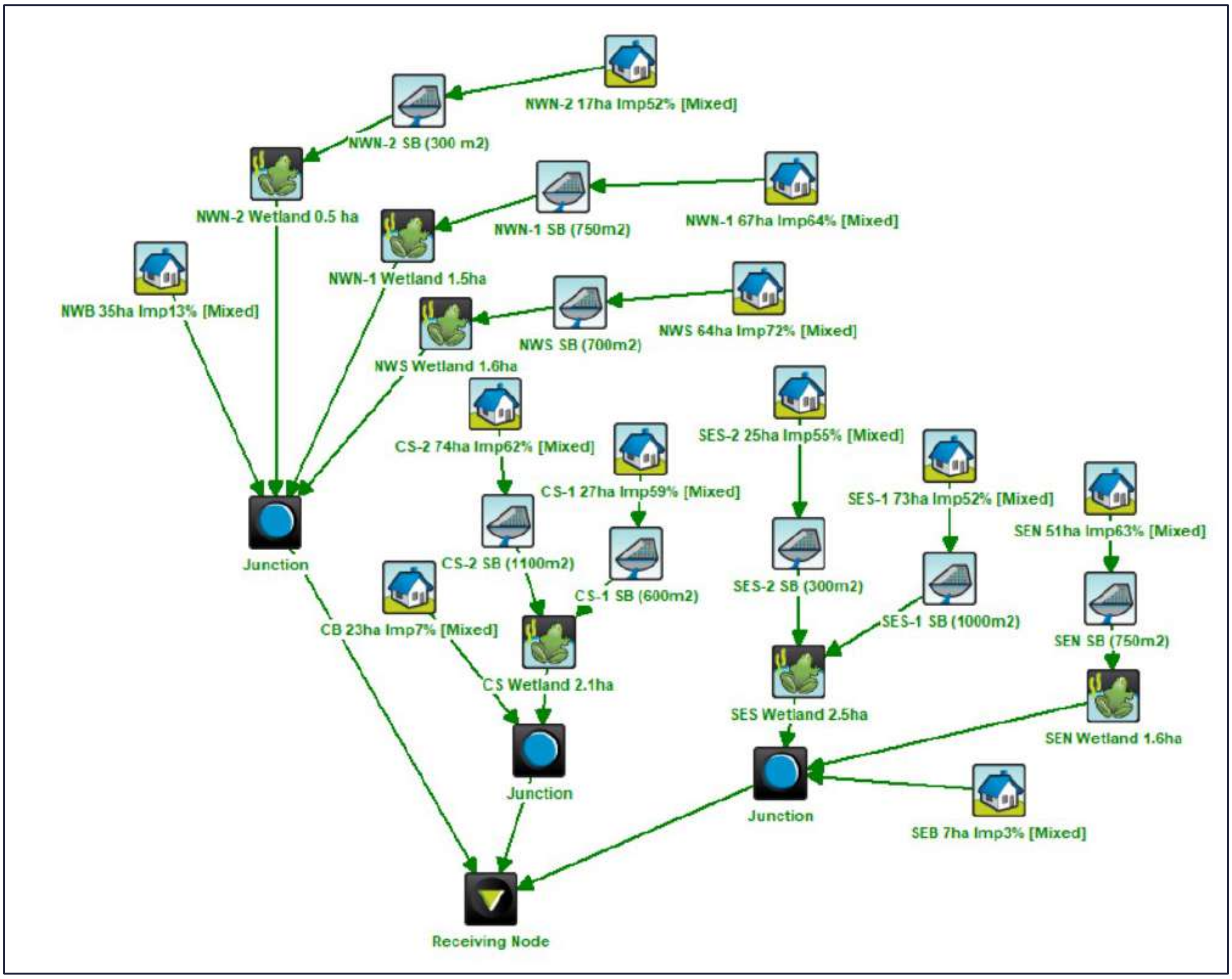


Figure B-1-4 MUSIC Model Schematic Layout

B-1-5 Stage Storage Inputs

For this version of the MUSIC modelling, custom stage-storage relationships have not been used. However, custom stage-storage relationships will be determined in 12d and applied to the MUSIC model at later stage to include pipe and weir flows and storage volumes.

B-1-6 Treatment Areas

Table B-1-4 and **Table B-1-5** below shows the sediment basins and wetlands treatment areas for each asset proposed within the PSP.

Table B-1-4 Sediment Basins Treatment Areas

Parameters	SEN	SES-1	SES-2	CS-1	CS-2	NWS	NWN-1	NWN-2
Surface Area at NWL (m^2)	750	1,000	300	600	1,100	700	750	300

Table B-1-5 Wetlands Treatment Areas

Parameters	SEN	SES	CS	NWS	NWN-1	NWN-2
Surface Area (m^2)	16,000	25,000	21,000	16,000	15,000	5,000

B-1-7 Wetlands Treatment Effectiveness

Tables below show the treatment effectiveness for each of the wetlands.

Table B-1-6 SEN Treatment Efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	387,000	6,850	82.3
Total Phosphorus (TP)	81.5	23.3	71.4
Total Nitrogen (TN)	584	285	51.1
Gross Pollutants	7,900	435	94.5

Table B-1-7 SES Treatment Efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	63,800	8,480	86.7
Total Phosphorus (TP)	136	33.9	75
Total Nitrogen (TN)	1000	480	52.2
Gross Pollutants	13,500	0	100

Table B-1-8 CS Treatment Efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	76,200	13,100	82.8
Total Phosphorus (TP)	159	46.9	70.6
Total Nitrogen (TN)	1150	621	45.9
Gross Pollutants	15,500	0	100

Table B-1-9 NWS Treatment Efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	55,700	10,500	81.1
Total Phosphorus (TP)	117	36.8	68.5
Total Nitrogen (TN)	826	454	45
Gross Pollutants	11,000	0	100

Table B-1-10 NWN-1 Treatment Efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	51,800	9,630	81.4
Total Phosphorus (TP)	109	33.5	69.3
Total Nitrogen (TN)	781	426	45.4
Gross Pollutants	10,500	0	100

Table B-1-11 NWN-2 Treatment Efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	10,600	1,330	87.4
Total Phosphorus (TP)	23.1	5.51	76.1
Total Nitrogen (TN)	170	76.7	54.8
Gross Pollutants	2,290	0	100

B-1-8 Treatment Train Effectiveness

As per the MUSIC modelling results, the removal efficiency of proposed treatment nodes in the PSP area is shown in **Table B-1-12**.

Table B-1-12 Reduction in Pollutant Loads

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	308,000	59,600	80.6
Total Phosphorus (TP)	651	207	68.3
Total Nitrogen (TN)	4,800	2,630	45.2
Gross Pollutants	62,200	1,960	96.8

Appendix C

Overland Flow Assessment

C-1 Overland Flow Capacity within Road Reserve

An assessment has been completed whether any additional channel or waterway is required to safely convey the major flow path shown in the preliminary drainage concept plan. In doing so, the road overland flow capacity has been estimated using the PC Convey software tool. **Figure C-1-1** below shows the locations of the roads for which the overland flow capacity has been estimated.

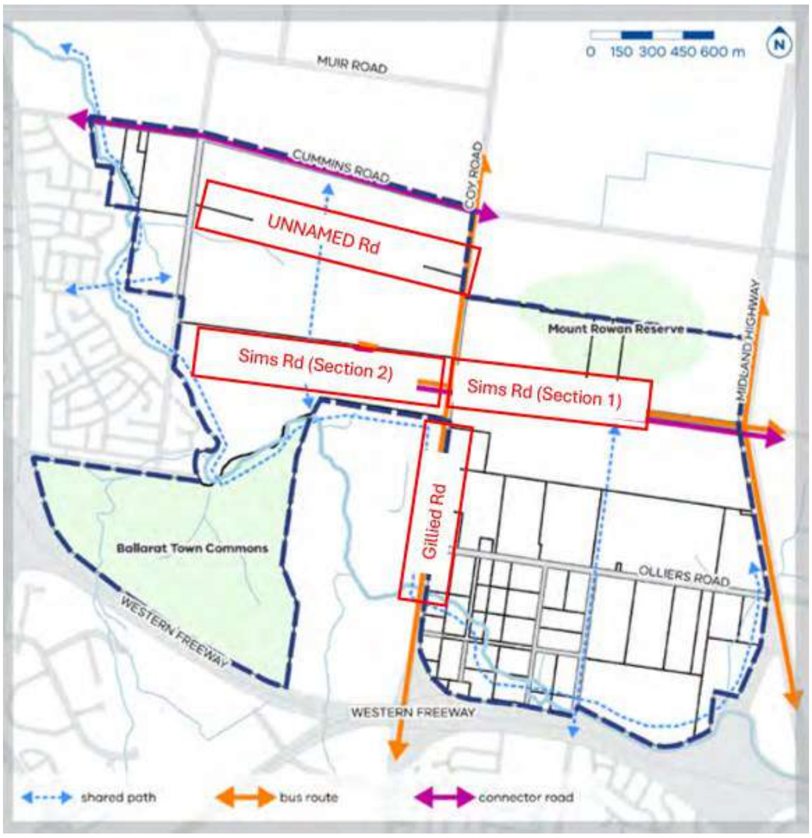


Figure C-1-1 Locations of the Roads

Sims Rd (Section 1) has a longitudinal grade of 1.4%, Gillies Rd has a grade of 1.8% and Sims Rd (Section 2) and UNNAMED Rd have a grade of 2.2%.

A typical road profile for a 24 m (without median) and 34 m (with median) reserve widths as proposed in IDM (LGIDA, 2019) was used to estimate the maximum overland flow capacity that can be contained within the road reserve (see **Figure C-1-2**).

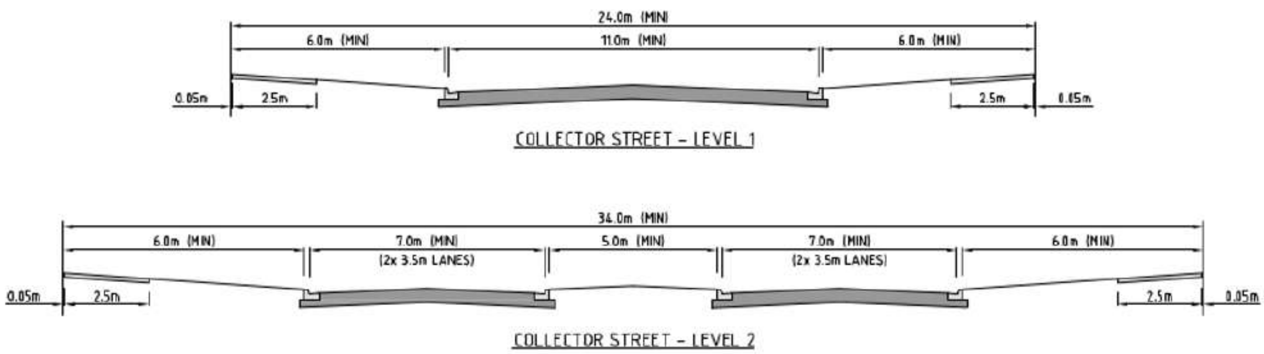


Figure C-1-2 Road Profiles Access Place and Street/Collector Level 1 (top image) and Level 2 (bottom image) (IDM,2020)

There are two types of road cross section that are 'with and without median strip' that can be assessed. When a median strip is present, as long as the average depth and velocity parameters are met, the overland flow can increase to the footpath with the freeboard requirement met within the lot. This means that the entire road reserve can take overland flows. This is while a road profile without a median strip can significantly take less overland flow because the freeboard must be catered for in the road itself. For this assessment, it is assumed that the roads have median strips and thus the reserves can also take overland flows.

The PC Convey results for the road profiles Level 1 and Level 2 with median strip are presented below. The road grades are assumed to be 1%, 2% and 3% in the software tool.

Table C-1-1 PC Convey Results for the Level 1 Collector Street (without median)

Road Grade (%)	Maximum Flow (m^3/s)	Average Depth (D_{ave}) (m)	Average Velocity (Vave) (m/s)	Dave x Vave (m^2/s)
1	5.3	0.160	1.47	0.23
2	7.5	0.160	2.08	0.33
3	9.2	0.160	2.55	0.41

Table C-1-2 PC Convey Results for the Level 2 Collector Street (with median)

Road Grade (%)	Maximum Flow (m3/s)	Average Depth (D_{ave}) (m)	Average Velocity (Vave) (m/s)	Dave x Vave (m^2/s)
1	8.9	0.175	1.56	0.27
2	12.5	0.175	2.21	0.39
3	15.4	0.175	2.71	0.47

The gap flows between the 1% and 20% AEP storm events generated within each of the roads shown in **Figure C-1-1** have been calculated using RORB and compared with the PC Convey results to ensure the aforementioned roads have enough capacity to contain gap flows safely. All roads are assumed to be Level 2 (with median) except for the UNNAMED Rd. The summary of the calculations is presented below.

Table C-1-3 Road Overland Flow Capacity

Road Name	Road Grade (%)	1% AEP Flow (m^3/s)	20% AEP Flow (m^3/s)	Gap Flow (m^3/s)	Capacity Range* (m^3/s)
Sims Rd (Sec. 1)	1.4	4.2	1.9	2.3	8.9-12.6
Gillied Rd	1.8	7.0	3.3	3.7	8.9-12.6
Sims Rd (Sec. 2)	2.2	2.9	1.3	1.5	12.6-15.4
UNNAMED Rd	2.2	7.1	3.1	3.9	7.6-9.3

*Capacity range has been adopted from PC Convey results for the Level 2 Collector Street based upon varying road grades. The exception is UNNAMED Rd which is assumed to be Level 1 Collector Street.

As shown in the table above, the overland flow capacity estimated for each of the roads are well beyond the gap flows and thus the roads can contain the overland flow capacity safely.

The overland flow road capacity has also been estimated with the impact of the climate change. Results as presented in **Table C-1-4** below show that Sims Rd and Gillies Rd have sufficient capacity to contain the gap flows between the 1% and 20% AEP storm events safely however the UNNAMED Rd cannot contain the entire gap flows within its road reserve given that it is assumed to be Level 1 with less overland flow capacity as opposed to Level 2 Collector Street. Thus, it is recommended that this road shall be widened to be able to contain the gap flows. This calculation should be confirmed in the functional design phase of the subdivision.

SMEC will investigate the swale drain option in the functional design if subdivision road widening is feasible. VPA must confirm whether road widening is feasible.

Table C-1-4 Road Overland Flow Capacity with the impact of the Climate Change

Road Name	Road Grade (%)	1% AEP Flow (m^3/s)	20% AEP Flow (m^3/s)	Gap Flow (m^3/s)	Capacity Range (m^3/s)
Sims Rd (Sec. 1)	1.4	8.4	2.4	5.9	8.9-12.6
Gillied Rd	1.8	14.5	4.2	10.3	8.9-12.6
Sims Rd (Sec. 2)	2.2	5.9	1.6	4.30	12.6-15.4
UNNAMED Rd	2.2	14.8	4.3	10.5	7.6-9.3

Appendix D

Integrated Water Management Strategy

D-1 IWMS Summary Tables

Site Information

Table D-1-1 Lot Balance

Lot Size (m2)	Number of lots	Occupancy
0-300	0	
300-500	6,826	2.2
>500	0	
Total	6,826	

Table D-1-2 Land Budget

Parameter	Unit	Value	Percentage
Residential	ha	273.03	56.6
Active Open Space	ha	19.91	4.1
Passive Open Space	ha	34.33	7.1
Commercial	ha	6.29	1.3
Education	ha	28.98	6.0
Transport	ha	17.78	3.7
Drainage	ha	88.88	18.4
Other	ha	12.80	2.7
Total	ha	482.00	100.0

MUSIC Model Inputs

Table D-1-3 Lot Balance

Parameter	Unit	Value
Rainfall station	Station # and location	086071 - Melbourne
Date period	Year starting to year ending	1952 - 1961
Time step	Minutes	6

Analysis Assumptions

Table D-1-4 Water Demand Assumptions

Parameter	Unit	Value
Residential		
Potable water demand (per lot)	L/day	348
Non-potable water demand incl irrigation (per lot)	L/day	119
Active Open Space		
Irrigation rate for active open space	ML/ha/year	5
Passive Open Space		
Irrigation rate for passive open space	ML/ha/year	2

Table D-1-5 Reuse Demand Assumptions

Parameter	Unit	Value
Residential		
Toilet reuse demand (per lot)	L/day	44
Irrigation reuse demand (per lot)	L/day	75
Rainwater tank volume (per lot)	kL	2
Uptake rate of rainwater tank installed for residential lots	%	100
Total reuse supplied	KL/day	640
Total reuse supplied	ML/year	233.7

Table D-1-6 Site Total Water Demand Assumptions

Parameter	Unit	Value
Residential		
Total site water demand	ML/year	1163.5
Total site rainwater tanks installed	no.	6826
Total site rainwater supplied	ML/year	233.7
Total site stormwater supplied	ML/year	0
Total site alternative water supplied	ML/year	62.8
Total site potable water reduction from alternative water supplied	%	25
Total site potable water demand (after alternative supply)	ML/year	867.0

D-2 MUSIC Modelling Layout

The snippets of the MUSIC model incorporating rainwater harvesting tanks are shown in the figures below.

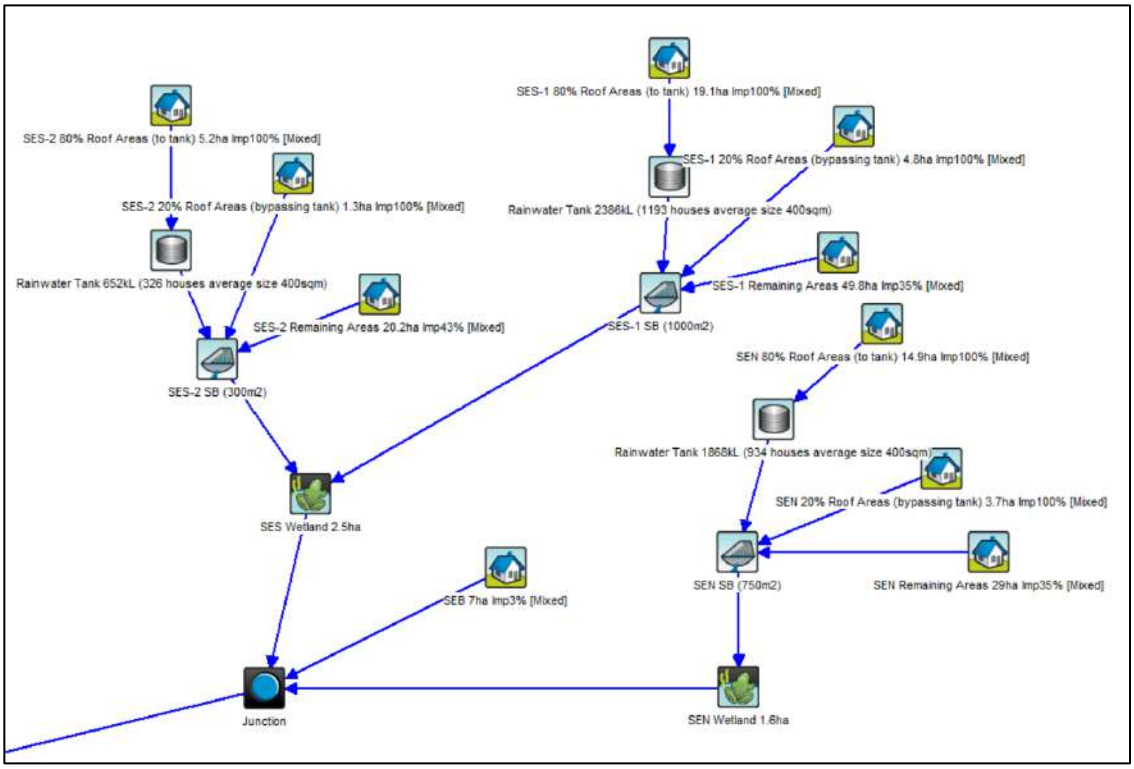


Figure D-2-1 MUSIC Model Layout – nodes for SE north and south catchments

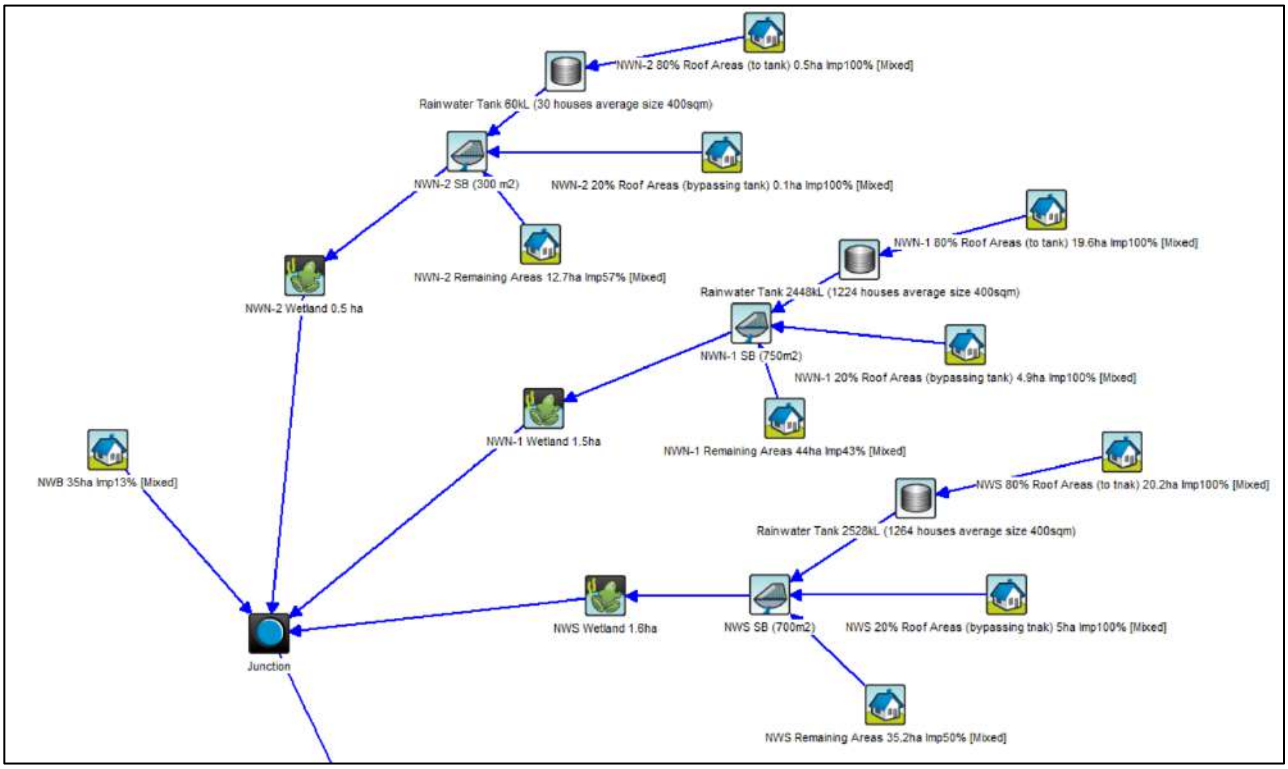


Figure D-2-2 MUSIC Model Layout – nodes for NW north and south catchments

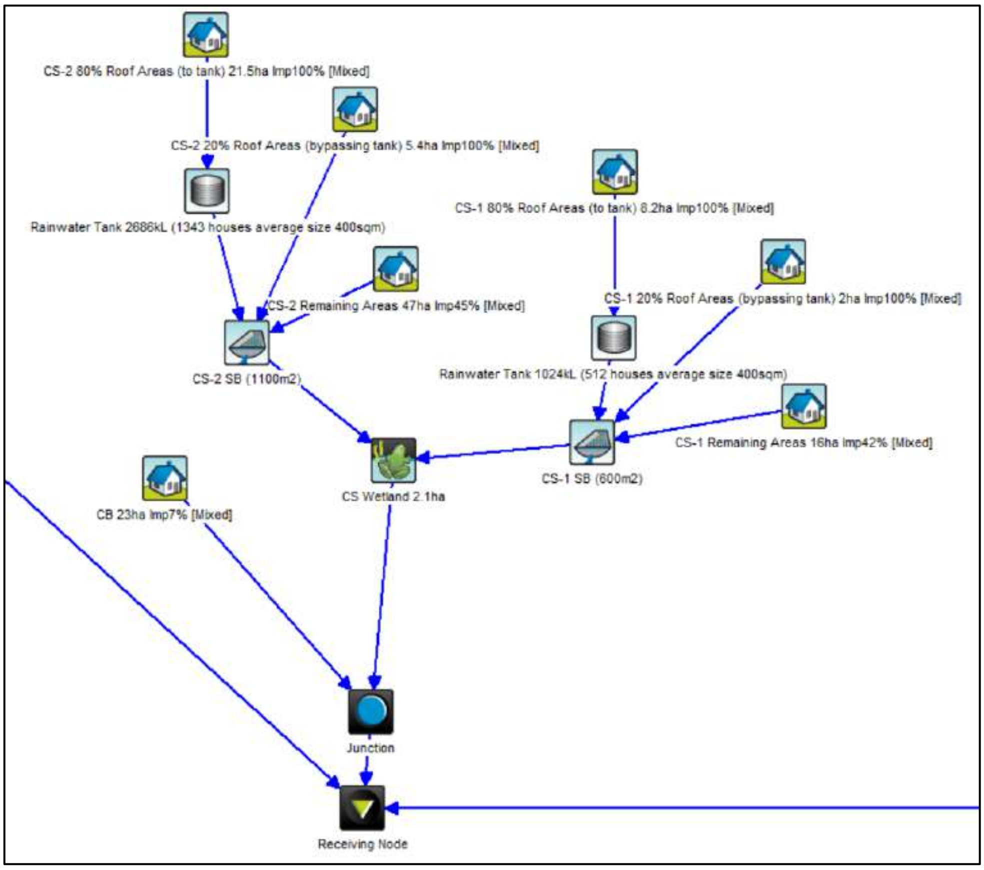


Figure D-2-3 MUSIC Model Layout – nodes for C south catchment

Appendix E

Technical Memo - GHCMA

Technical Memorandum

Memo No.	181-TM-001	Date of Issue	30 October 2024
Subject	Burrumbeet Creek Interim Flood Extent	Discipline	Flood Modelling
Project Title	Ballarat North PSP Stormwater Functional Design	Project No.	30049251
Document No.	30049251-181-TM-001	Revision	0
Author	Karl Velasco – Associate Engineer Water Resources / Project Manager		
Reviewed by	Tim Rhodes – Technical Principal Water Resources	Approved by	Sander van Hall – Project Director
Prepared for	Robert Marks - Victorian Planning Authority	Attention to	Glenelg Hopkins Catchment Management Authority
Attachments	• Appendix B - Depth Maps • Appendix C - Meeting File Note – VPA/SMEC/GHCMA/CoB – Brief to GHCMA on SMEC's approach to address limitations in 2013 Burrumbeet Creek flood mapping in assumptions for Ballarat North PSP drainage strategy		

1. Introduction

SMEC has been engaged by the Victorian Planning Authority (VPA) to prepare a stormwater drainage strategy for the Ballarat North Precinct Structure Plan (PSP). The subject site is located approximately 7 km north of Ballarat as shown in **Figure 1-1**.

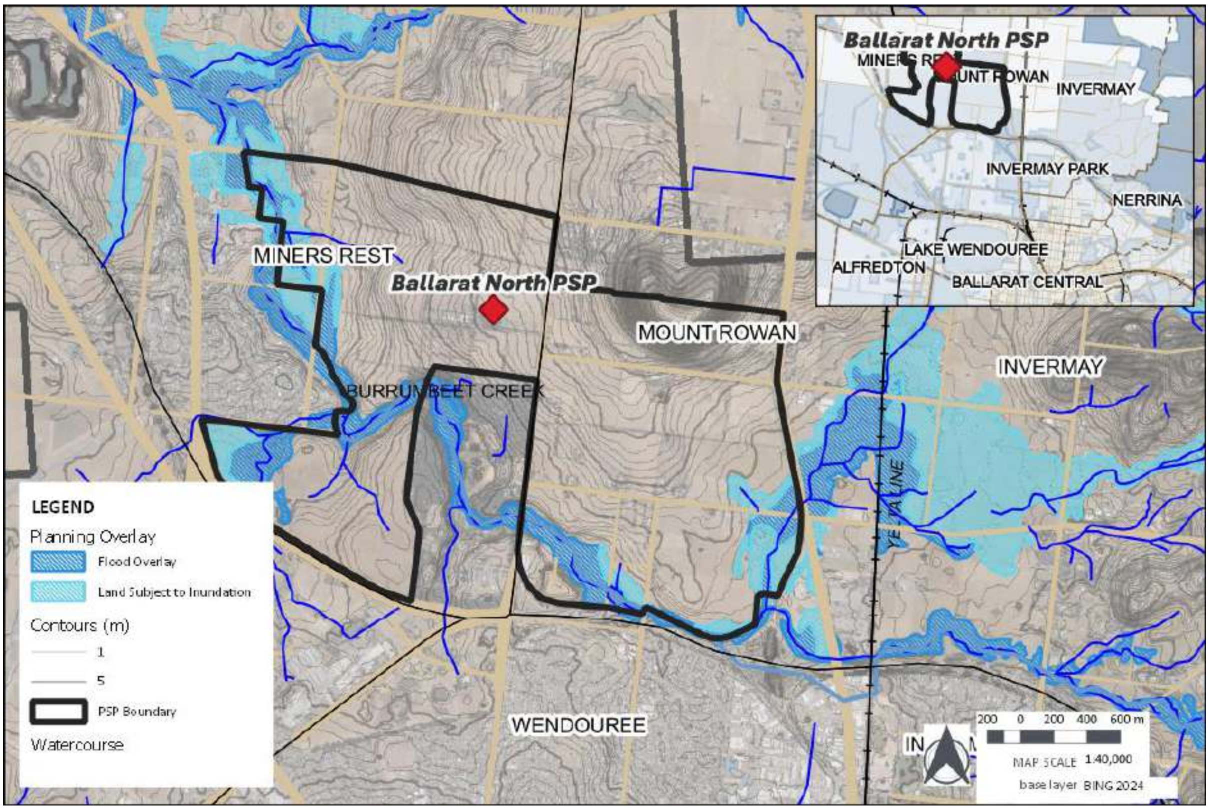


Figure 1-1 Ballarat North PSP and Burrumbeet Creek Flood Overlays

Correspondence from Glenelg Hopkins Catchment Management Authority (GHCMA) to the VPA has flagged that the available 1% Annual Exceedance Probability (AEP) flood extents of Burrumbeet Creek are out of date. The current flood study upon which the flood mapping is based is described in Water Technology (2013). The current flood mapping does not accurately represent the recent changes in the catchment including new major drainage infrastructure and increases in development area. The Flood Overlay (FO) and Land Subject to Inundation Overlay (LSIO) based on the current flood study are overlaid on the Ballarat North PSP in **Figure 1-1**. The changes in modelling practice subsequent to the current flood study include revised design rainfall depths and climate change impact estimation techniques.

The flood extent defines the development exclusion zone and an estimate of the updated zone is required to provide certainty for development planning purposes.

1.1 Consultation with GHCMA

SMEC was tasked with preparing a methodology to delineate an interim flood inundation extent in advance of a more detailed future flood study to be completed by others. The methodology requires input and in principal agreement from GHCMA.

The intent of the interim methodology is to define the 1% AEP flood extent inclusive of climate change applying a simple, conservative analysis. The method is to incorporate the latest modelling guidance with a buffer to allow for uncertainties. The interim flood extent is to be updated at the time when outputs from a revised Burrumbeet Creek flood study become available. GHCMA has indicated that they are currently planning to commission a new flood study in collaboration with the City of Ballarat (CoB).

A meeting involving SMEC, VPA, GHCMA, and CoB was held on 13th September 2024, where the proposed approach and modelling outcomes were discussed and generally supported by GHCMA (Refer to Meeting File Note in **Appendix C**).

2. Methodology

2.1 Inputs

The current flood study (Water Technology, 2013) was supplied by VPA inclusive of the associated models and data as follows:

- Burrumbeet Creek – rainfall runoff model – RORB
- RORB sub catchment and reaches in GIS format (shapefiles)
- Burrumbeet Creek - 2d hydraulic model - TUFLOW
- Terrain (LiDAR) data used in the 2013 TUFLOW model

2.2 2024 Climate Change Consideration Update

Ball et al. (2019) defines the industry standard for completing design event rainfall runoff estimation and associated flood modelling. Subsequent to completion of the current flood study in 2013, Ball et al. (2019) has been updated in 2019 (Version 4.1) and more recently in September 2024 (Version 4.2). The updates incorporate changes to design rainfall and then, in 2024, changes to climate change impact estimation procedures.

2.3 Hydrology

The interim modelling methodology assesses the sensitivity of the flood extent to the hydrological inputs. Three scenarios were evaluated as follows:

1. Older (current) assessment – based on outcomes presented in Water Technology (2013) procedures, inclusive of climate change factors at the time.
2. Future conditions – based on Ball et al. (2019) procedures, inclusive of climate change.
3. Sensitivity - Hydrograph from Scenario 2 increased by a factor of 100%.

The results were compared with the climate change scenario outcomes presented in Water Technology (2013). The design rainfall depths and uplifts adopted for each scenario are summarised in **Table 2-1**.

Table 2-1 Hydrological Sensitivity Scenarios

Scenario Number	Scenario Description	Design Rainfall Depth Source	Adopted Time Horizon	Global Climate Condition	Design Rainfall Depth Uplift Factor
1	Previous 2013 Climate Change Consideration	BoM IFD 1987	n/a	n/a	1.2
2	Latest Climate Change Consideration	BoM IFD 2016 w/ uplift as per Ball et al. (2019)	2100	SSP8.5 4.5 degrees °C increase	1.47[1]
3	Scenario 2 hydrograph increased by 100%	n/a	n/a	n/a	n/a

1. For critical duration of 12 hours

Scenario 2 is the future climate change scenario based on an increase in global temperature of 4.5 °C in the year 2100 horizon. The climate change uplift factors vary depending on the storm duration and AEP. A summary table of the uplift factors applicable to the site location is illustrated in **Table 2-2**. Detailed climate change factors are included in **Appendix A**. Scenario 3 is a sensitivity run where the flow rate from Scenario 2 is doubled to assess the sensitivity of the outcomes to input variability.

Table 2-2 Data hub Climate Change Consideration Uplift Factors (AR&R v4.2, 2019)

SSP5-8.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.2	1.18	1.17	1.16	1.14	1.13	1.13	1.12	1.11	1.11
2040	1.26	1.24	1.22	1.2	1.18	1.17	1.16	1.15	1.14	1.14
2050	1.34	1.31	1.29	1.26	1.24	1.23	1.21	1.2	1.18	1.18
2060	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2070	1.52	1.47	1.43	1.4	1.36	1.34	1.31	1.29	1.27	1.26
2080	1.63	1.57	1.52	1.48	1.43	1.4	1.37	1.35	1.33	1.31
2090	1.77	1.69	1.64	1.58	1.52	1.49	1.45	1.42	1.39	1.37
2100	1.86	1.77	1.71	1.64	1.58	1.54	1.5	1.47	1.43	1.41

The RORB (Laurenson et al., 2010) model sub area and reaches were maintained from the original Burrumbeet Creek model. The routing parameters were maintained, and losses were updated from the Bureau of Meteorology (2016). A summary of the model parameters is shown in **Table 2-3**.

Table 2-3 RORB model parameters

Parameter	Value	Source
Delay (k_c)	46	Water Technology (2013)
Non-linearity (m)	0.8	Water Technology (2013)
Initial Loss (mm)	17.25	BoM Data hub (Ball et al., 2019)
Continuing Loss (mm/hr)	5.33	BoM Data hub (Ball et al.,2019)

For Scenario 2 the initial and continuing losses were adjusted according to the latest Climate Change guidance. Refer to **Appendix A** for the loss adjustment factors adopting 4.5 °C increase and year 2100.

The 1% AEP peak flow estimated at Burrumbeet Creek within the PSP area (Node 156) and at the catchment outlet are summarised in **Table 2-4.** The critical storm duration at the site is the 12-hour storm event.

Table 2-4: Design Flow 1%AEP

Scenario	1% AEP Peak Flow (m^3/s)	
	Node 156	Lake Burrumbeet Gauge-Outlet
1	Not reported	93
2	53	131
3	106	262

The RORB catchment model setup and locations of the reported peak flows are shown in **Figure 2-1**.

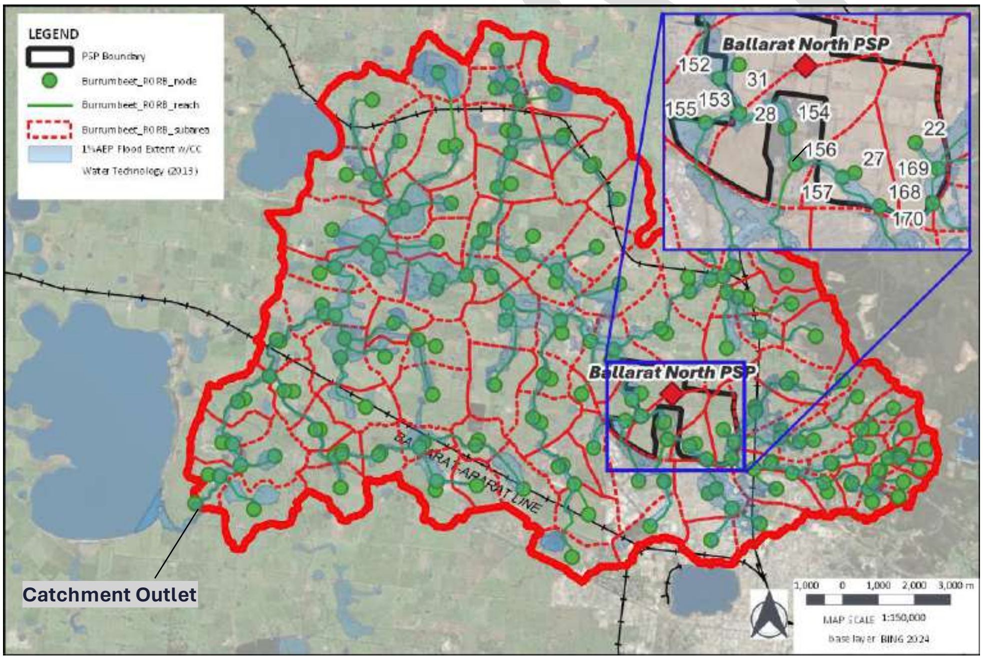


Figure 2-1 RORB catchment model

2.4 Hydraulic Modelling

A simple 2d hydraulic model was setup to determine the sensitivity of the flood extents from various hydrologic scenarios mentioned above. The TUFLOW model was setup and ran as follows:

- Inflow hydrograph at the upstream end of the model domain.
- Outflow boundary condition based on longitudinal slope.
- 5 m grid size based on 2019 LiDAR of 1m resolution.

- HPC computation scheme with sub-grid-sampling (SGS) enabled.
- Roughness definition (materials file) were maintained as per the original model.
- Model extent is limited to the Burrumbeet Creek reach covering the PSP area.

The TUFLOW model domain is shown in **Figure 2-2**.

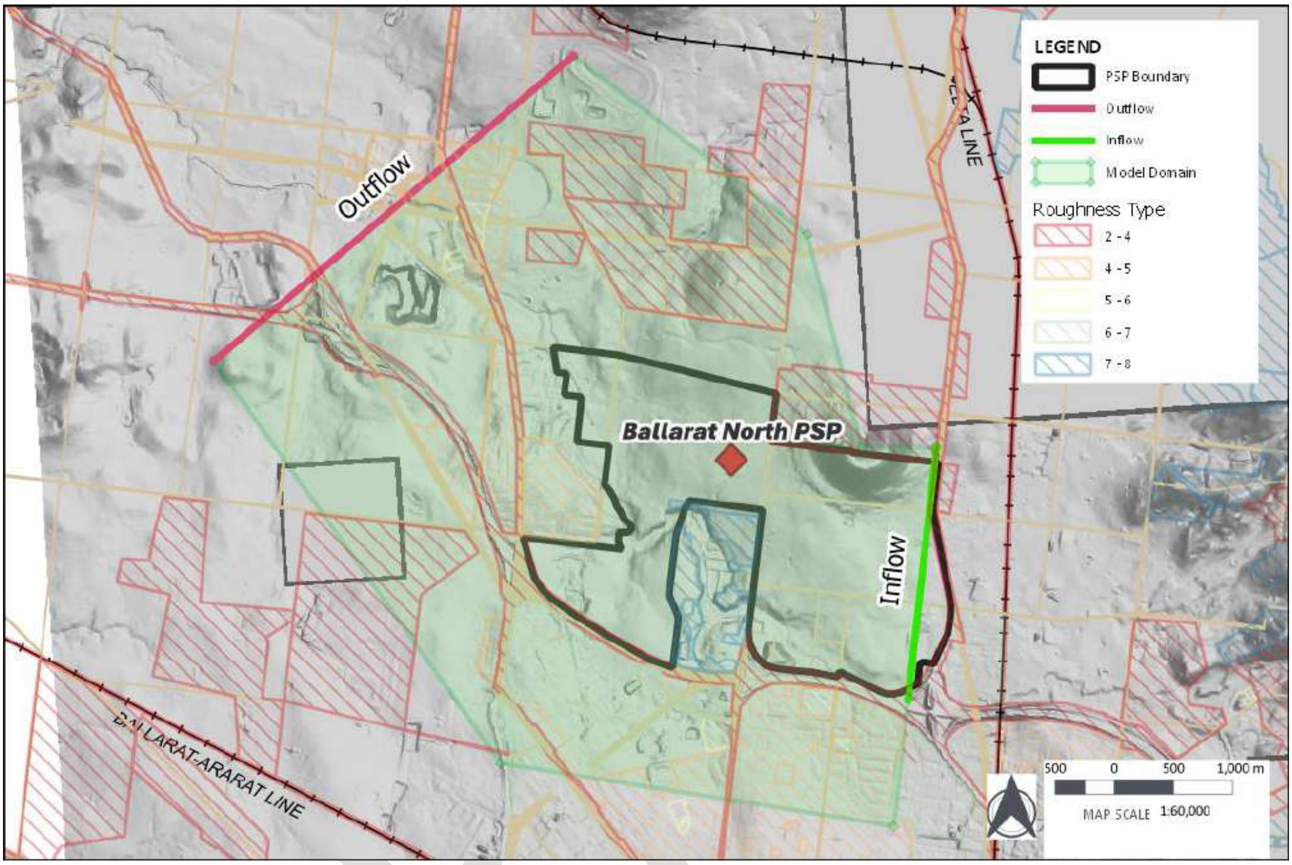


Figure 2-2 TUFLOW Model Setup

Limitations

The following limitations are noted:

- The model does not include the inflows from minor tributaries along Burrumbeet Creek. This has the potential to result in less inflow downstream of the model domain and therefore lower flood levels.
- The inflow hydrograph to the hydraulic model was extracted from the hydrologic model at a location halfway between the PSP upstream and downstream reaches. This represents an average flow along Burrumbeet Creek. A more accurate representation would be to include a series of inflows at the location of each tributary.
- Major culvert structures at road crossings were not included in the TUFLOW model. This can influence the flood extents considerably in the local area.
- One storm duration (12hr) was simulated based on the critical storm duration from Burrumbeet Creek. There is a potential for the flood extent from the northern tributary to be larger if the shorter durations were simulated.

3. Results

3.1 1%AEP Flood Extent with Climate Change

The 1% AEP flood extent from the three scenarios are shown in **Appendix B – Map 1**.

Comparison

- The outcomes indicate that the flood extent area does not vary substantially between scenarios 1 and 2. The flood depth of the 2013 flood study (Scenario 1) and Scenario 2 does not vary greater than 1 m across the model domain. Largest deviation can be seen in the areas where there are road culverts.
- The areas where the flood line are closer together indicates the waterway banks are relatively steeper. The areas where the extents are notably wider the flooding extends in the floodplains.
- The sensitivity run of scenario 3 gives the largest flood extent from all scenarios. <u>It is recommended to adopt this flood extent as the basis of design for the preparation of the Ballarat North PSP drainage strategy</u>. Adopting this scenario allows for the simplifications and uncertainties that has not been accounted for in the assessment. This is considered a conservative approach in the interim as the updates to the flood study is expected to be less than scenario 3.

Cross sections

A number of cross sections are provided in **Figure 3-1** to **Figure 3-4** illustrating the maximum flood depth relative to the topography of Burrumbeet Creek and the floodplain. The right-hand side interfaces to the Ballarat North PSP development area. The approximate distance of Scenario 2 (orange) to Scenario 3 (green) extent is 30 m at one of the critical cross sections in location 7. Refer to **Figure 3-4.**

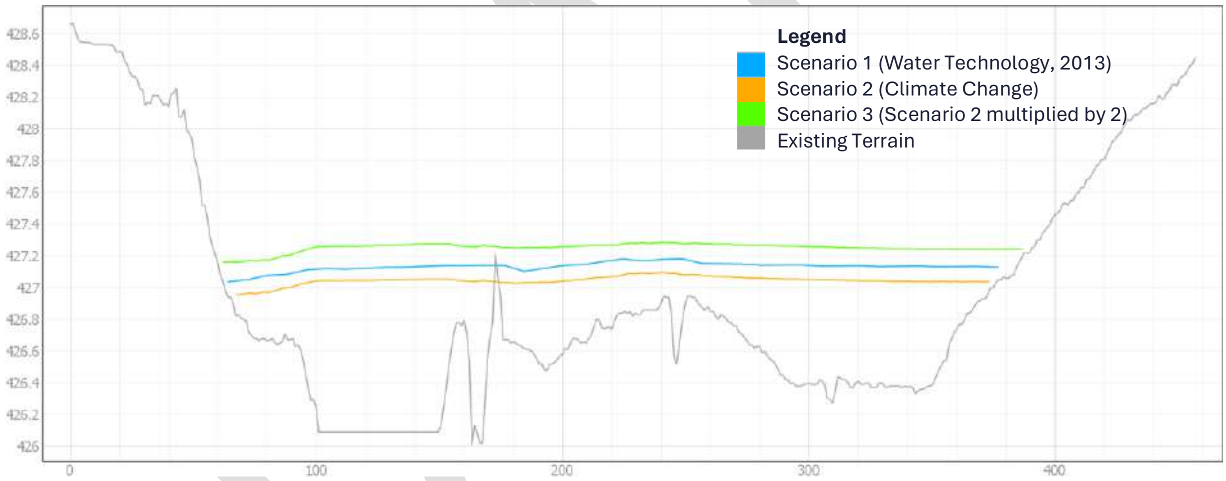


Figure 3-1 Cross section location 2

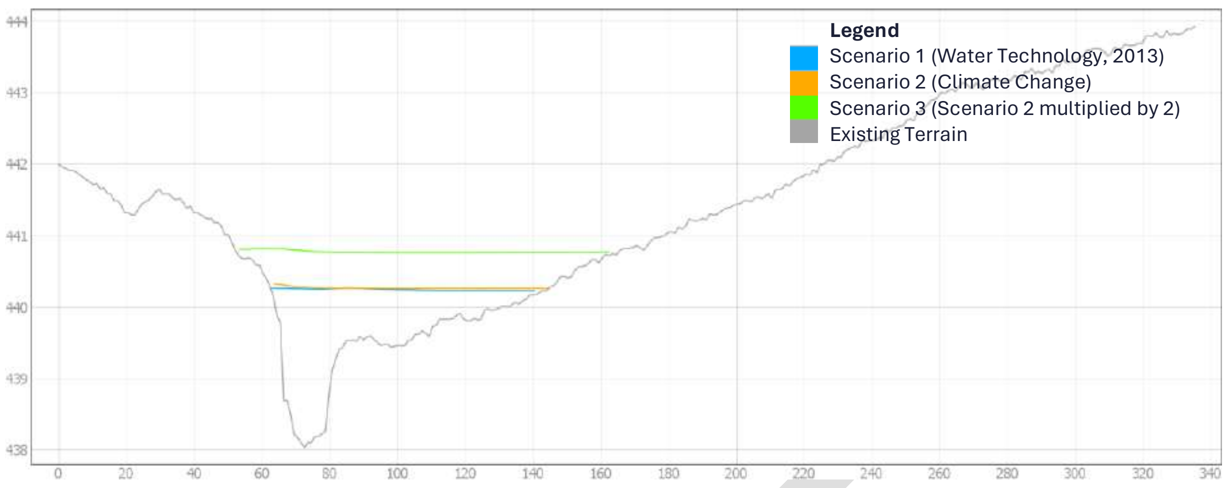


Figure 3-2 Cross section location 3

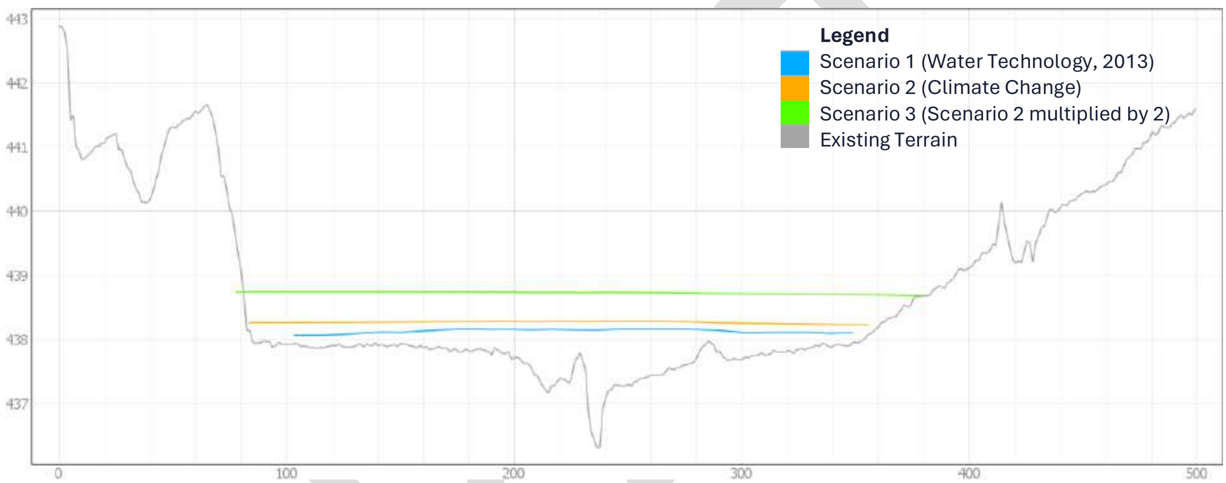


Figure 3-3 Cross section location 4

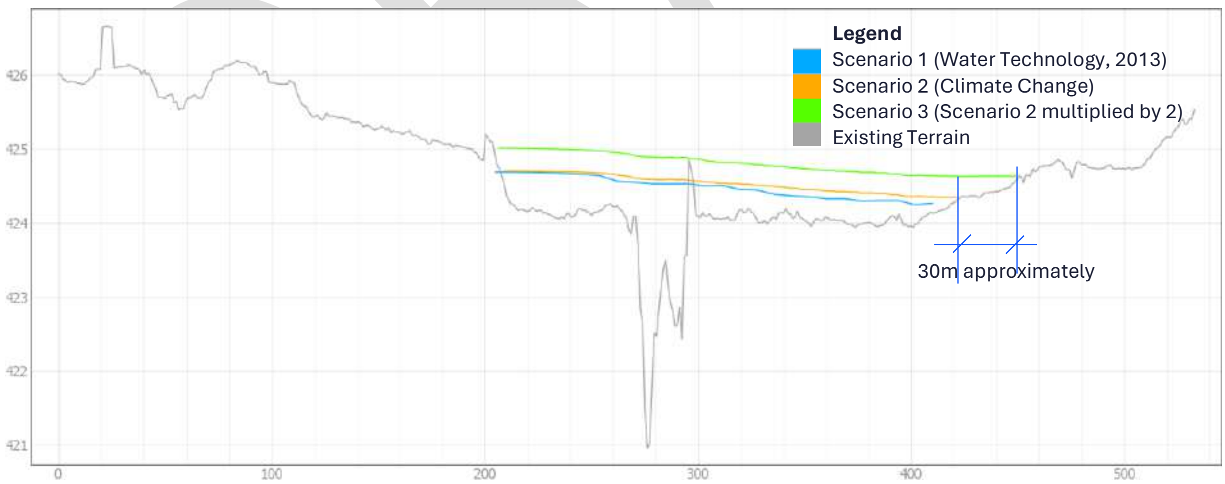


Figure 3-4 Cross section location 7

4. Conclusion

A coarse hydrologic and hydraulic analyses have been completed to understand the sensitivity of climate change impacts and recent updates to AR&R on the flood inundation extent. The results shows there are minor variations to the 1%AEP flood extents in the Ballarat North PSP area. SMEC proposes to adopt the Scenario 3 flood extent to be used as the basis of design which is considered a reasonable and conservative interim approach. It is recommended that the impending flood study be progressed in parallel with the PSP development and be incorporated in the Ballarat North PSP. Glenelg Hopkins CMA's in-principle support to the above methodology and outcomes are required to provide confidence in the next phase of the project.

5. References

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) (2019), (AR&R) Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia (Geoscience Australia), Version 4.2, 2019.

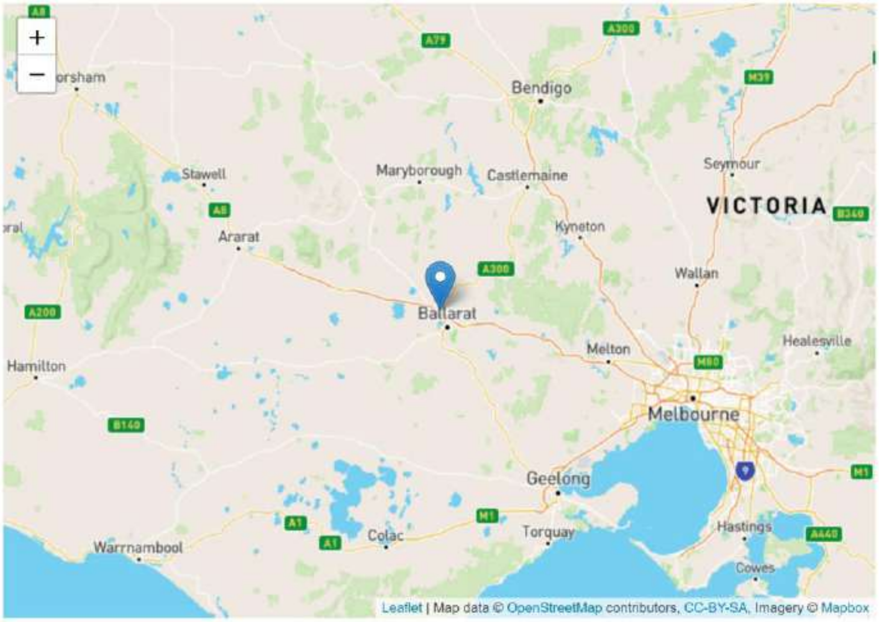
Laurenson,E.M, Mein,R.G. and Nathan,R.J (2010), RORB – Version 6.15, Runoff Routing Program, User Manual, Department of Civil Engineering, Monash University, Clayton, Australia.

Water Technology (2013), Burrumbeet Flood Investigation, Summary Study Report.

Appendix A – Data Hub Climate Change Factors

Input Data

Longitude	143.828
Latitude	-37.506
Selected Regions (clear)	
Climate Change Factors	show



Loss Factors

Initial Loss (Adjustment Factors)

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2030	**1.05**	**1.05**	**1.05**	**1.05**
2040	1.05	1.06	1.06	1.07
2050	**1.06**	**1.07**	**1.07**	**1.08**
2060	1.06	1.07	1.09	1.1
2070	1.06	1.08	1.1	1.12
2080	1.06	1.09	1.12	1.14
2090	**1.06**	**1.09**	**1.13**	**1.17**
2100	1.06	1.1	1.15	1.19

Continuing Loss (Adjustment Factors)

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2030	**1.1**	**1.1**	**1.1**	**1.11**
2040	1.12	1.12	1.13	1.14
2050	**1.12**	**1.15**	**1.16**	**1.18**
2060	1.13	1.17	1.19	1.23
2070	1.13	1.18	1.23	1.28
2080	1.13	1.2	1.27	1.33
2090	**1.13**	**1.21**	**1.31**	**1.39**
2100	1.12	1.22	1.34	1.44

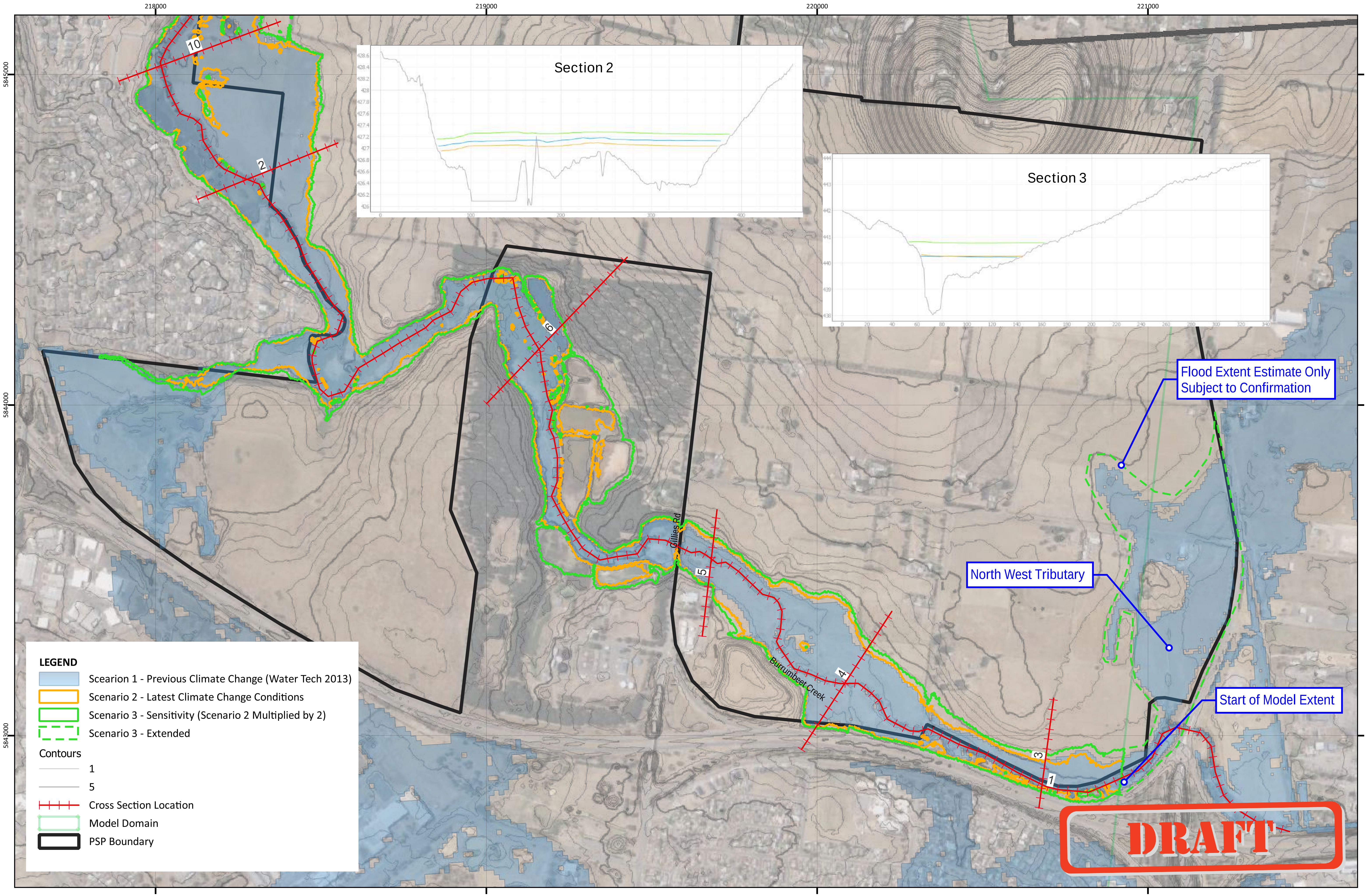
Temperature Changes (Degrees, Relative to 1961-1990 Baseline)

Year	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
2030	**1.2**	**1.2**	**1.2**	**1.3**
2040	1.3	1.4	1.5	1.6
2050	**1.4**	**1.7**	**1.8**	**2.1**
2060	1.5	1.9	2.2	2.5
2070	1.5	2.1	2.5	3
2080	1.5	2.2	2.9	3.5
2090	**1.5**	**2.4**	**3.3**	**4.1**
2100	1.4	2.5	3.6	4.5

Layer Info

Time Accessed	27 October 2024 11:03PM
Version	2024_v1
Note	Updated climate change factors for IFD Initial loss and continuing loss based on IPCC AR6 temperature increases from the updated Climate Change Considerations (Book 1: Chapter 6) in ARR (Version 4.2). ARR recomends the use of Current and near-term (2030 midpoint). Medium-term (2050 midpoint) and Long-term (2090 midpoint)

Appendix B – Flood Extent Map



MAP 1A 1% AEP FLOOD EXTENT

BURRUMBEET CREEK SENSITIVITY ASSESSMENT

BALLARAT NORTH PSP STORMWATER AND DRAINAGE

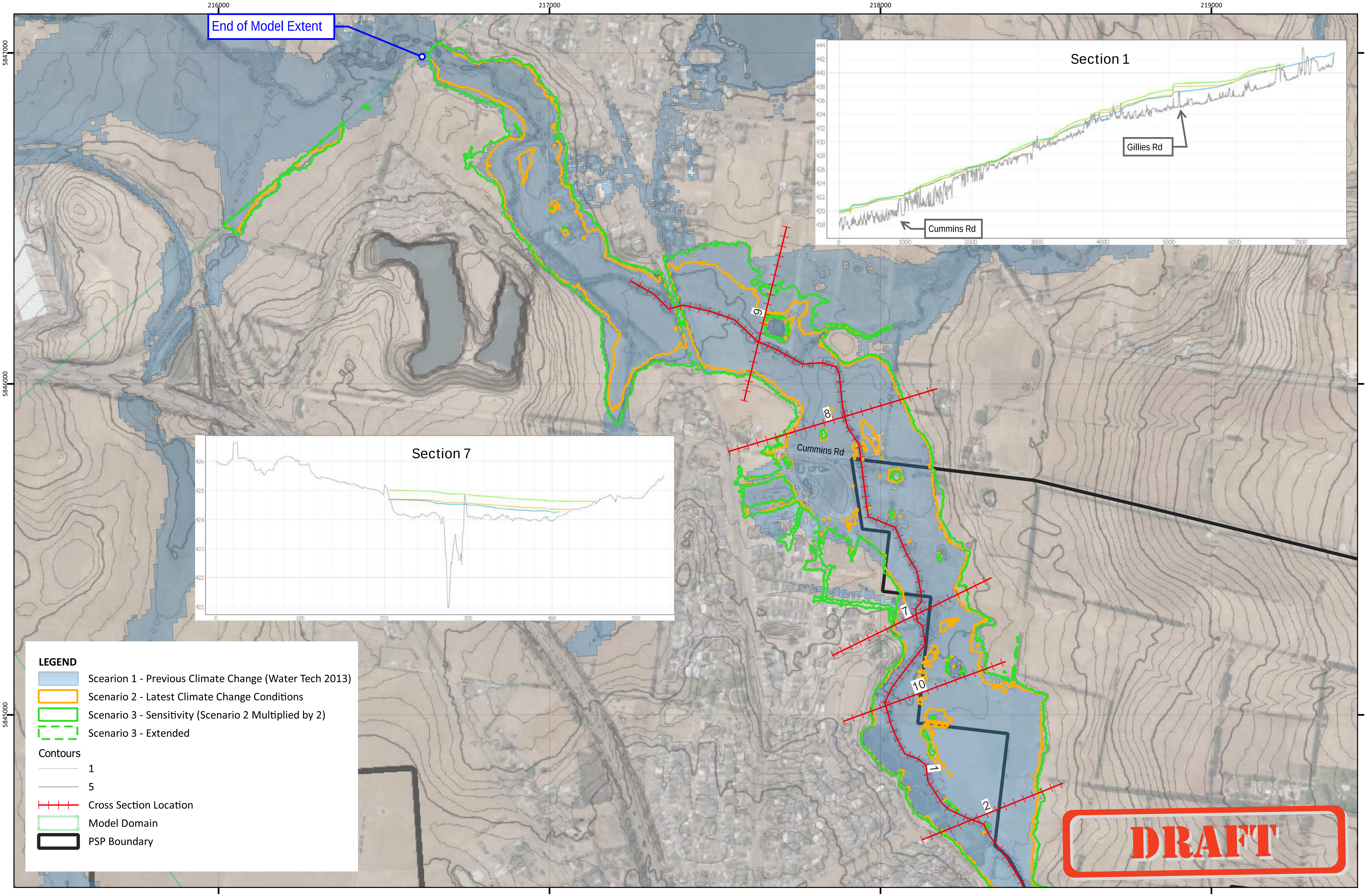
client: Victorian Planning Authority

consultant: smec

PROJECT NO	30049251
DATE	30 Oct 2024
REVISION	Draft
CREATED BY	KV
aerial imagery	BING MAPS

100 0 100 200 300 m

MAP SCALE	1:10,000
PAGE SIZE	A3
DATUM	GDA94
PROJECTION	MGA Zone 55



MAP 1B 1% AEP FLOOD EXTENT

BURRUMBEET CREEK SENSITIVITY ASSESSMENT

BALLARAT NORTH PSP STORMWATER AND DRAINAGE

client: Victorian Planning Authority

consultant: smec

PROJECT NO	30049251
DATE	30 Oct 2024
REVISION	Draft
CREATED BY	KV
aerial imagery	BING MAPS

100 0 100 200 300 m

MAP SCALE	1:10,000
PAGE SIZE	A3
DATUM	GDA94
PROJECTION	MGA Zone 55

Appendix C – Meeting File Note

VPA/SMEC/GHCMA/CoB – Brief to GHCMA on SMEC's approach to address limitations in 2013 Burrumbeet Creek flood mapping in assumptions for Ballarat North PSP drainage strategy

<table>
<tr><td>Date:</td><td>13 September 2024</td><td>Time:</td><td>11:00am – 12:00pm</td></tr>
<tr><td>Meeting Location:</td><td colspan="3">MS Teams</td></tr>
<tr><td>Attendees:</td><td colspan="3">Peter Robertson (Glenelg Hopkins CMA)

Karl Velasco (SMEC)
Tim Rhodes (SMEC)
Hamid Ghajarnia (SMEC)

Sam Brown (CoB)
Mario De La Pena (CoB)
Derylle Hastings (CoB)</td></tr>
<tr><td>VPA Attendees:</td><td colspan="3">Noor Syuhada Shamsul, Andrew Nguyen, Rob Marks, April Chan</td></tr>
<tr><td rowspan="3">Aspects Discussed</td><td colspan="3">1. Welcome and introductions</td></tr>
<tr><td colspan="3">2. Rob provided history of discussions between VPA and GHCMA then introduced SMEC to present their approach to limitations with the 2013 Burrumbeet Creek flood mapping data.</td></tr>
<tr><td colspan="3">3. SMEC shared GIS mapping of the results of a preliminary model that has new assumptions applied to bring the flood mapping up to date (as best as possible). SMEC noted:
a. They have considered hydrology and hydraulics
b. The purpose of this model was to get a sense of the variables they would get compared to the 2013 data
c. This model is not a detailed product, further detail and refinement will occur to inform the PSP
d. SMEC adopted 2100 timeframe and SSP8.5 climate change scenario
e. Rainfall has been increase to 47% with flows up to 55% greater than 2013 data
i. This was applied to a basic TUFLOW model
ii. The result is less than +500mm to the water level compared to the 2013 flood mapping.
f. Model is updated to recent ARR guidelines and takes climate change into consideration.
g. The model is a rough indication of future flood levels and will be refined as the project progresses.
i. Red outline in SMEC model shows the existing data
ii. Green outline in SMEC model shows SMEC's proposed flood extents.
1. SMEC noted green outline is beyond what could be expected from climate change and is a suitable</td></tr>
</table>

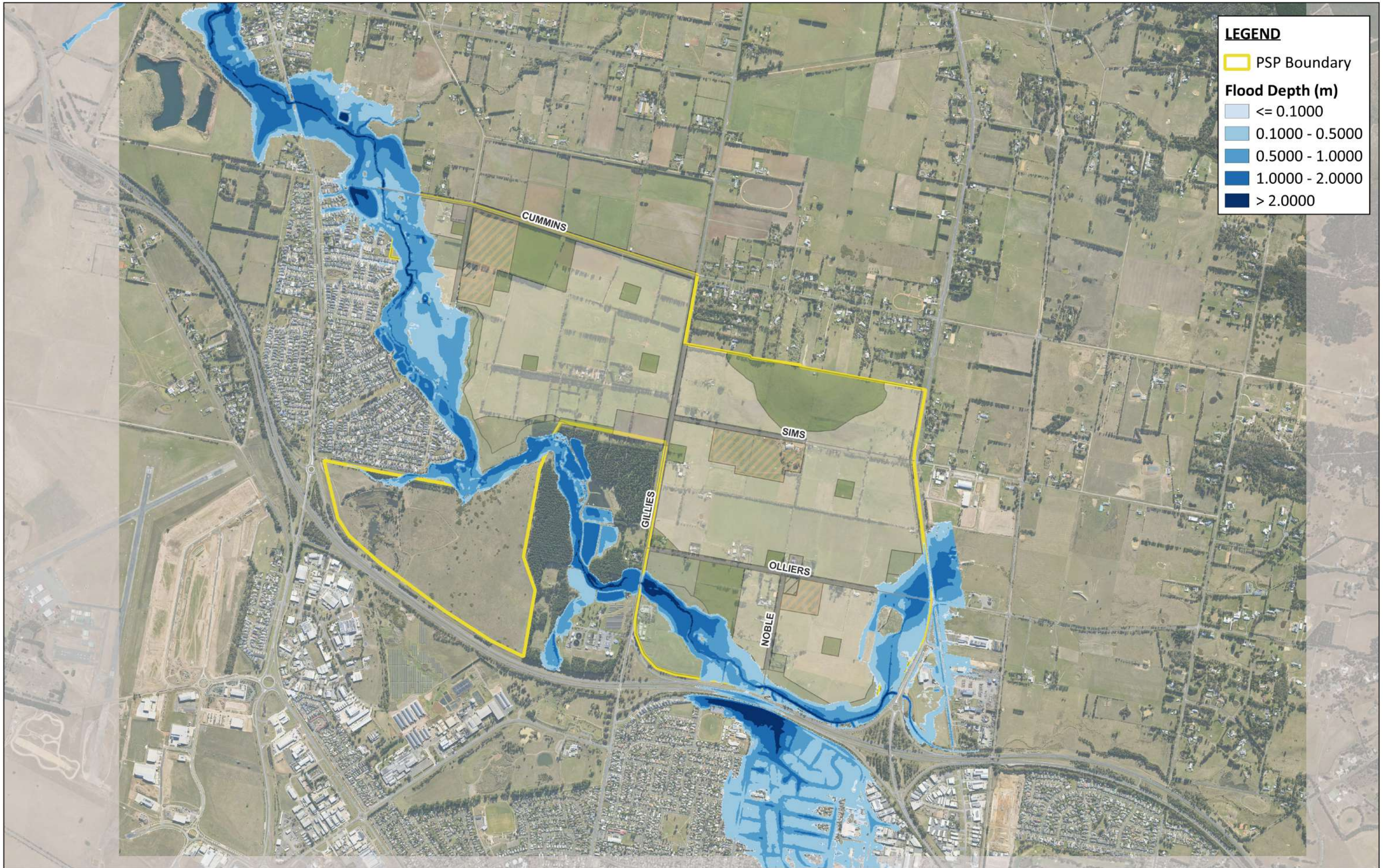
	‘development line’ to apply a buffer to account for the 2013 data limitations. h. Limited extent as they do not have data for flows from the east as Midland Hwy i. Minor tributaries and culverts not considered at this stage
	4. GHCMA supported the principles of SMEC’s approached and supported these as an appropriate means to progress the PSP, subject to a document outlining SMEC’s approach being provided to GHCAM for review.
	5. GHCMA noted that work is underway by CoB in Miners Rest (West of Howe St) that is also relevant, led by Vaughan Notting (CoB). Mario (CoB) noted he will follow up with Vaughan on the scope of this work and the timing.
	6. SMEC sought GHCMA advice on waterway corridor widths and noted if there’s no guidance, they would adopt the MW guidelines. GHCMA emphasised the main objective of the CMA in this regard is to ensure no development in any flood prone areas. SMEC noted that if any development is proposed in these areas, SMEC will provide options and mitigations for consideration by the CMA (such as waterway manipulation, cut & fill)

Next Steps and Actions	**1. SMEC to prepare summary document outlining:**
	• Brief description of the limitations of the 2013 flood mapping for application in the Ballarat North PSP
	• Summary of the assumptions applied to SMEC’s model, including:
	  ○ Aspects yet to be considered in the model such as minor tributaries and culverts
	  ○ Timeframes
	  ○ Climate change scenario
	  ○ Rainfall and flow increases
	  ○ Resulting water level
	  ○ ARR guidelines
	• SMEC’s recommendation for how the approach can/should be applied for the PSP
	2. GHCMA to review SMEC’s document and advise VPA/SMEC whether the approach is supported by GHCMA and if suitable to progress the PSP.

Prepared by	Robert Marks

Appendix F

Flood Impact Assessment Maps



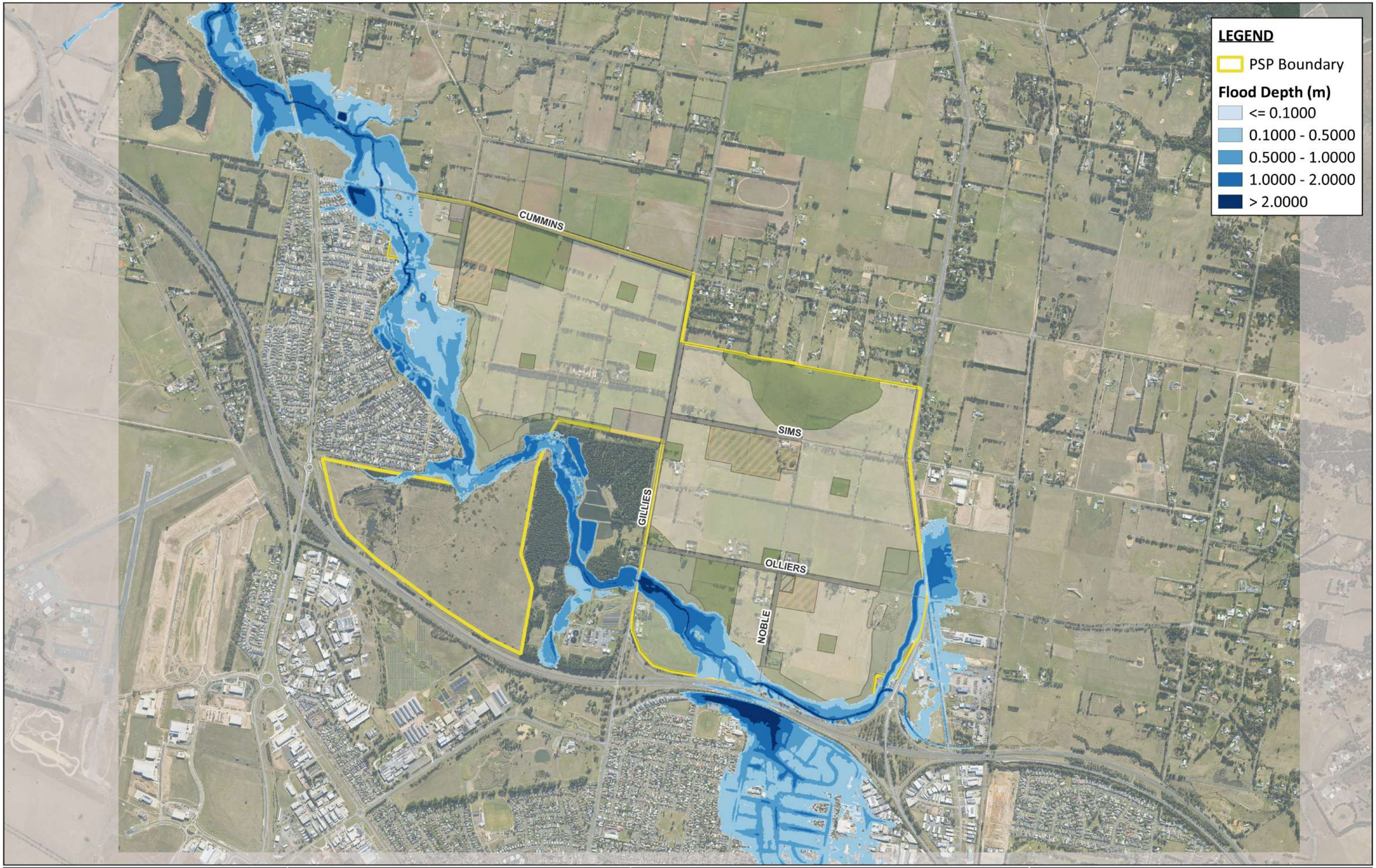
PROJECT TITLE:	BALLARAT NORTH PSP PROOF OF CONCEPT	REVISION:	A	DATE:	11/04/2025
PROJECT NO:	30049251	STATUS:	DRAFT	SIZE:	A3
MAP NO:	02	AUTHOR:	K.V.	SOURCES:	Metromap
MAP TITLE:	FLOOD IMPACT ASSESSMENT - EXISTING 1% AEP	CHECKED:	A.B.	CRS:	GDA94 / MGA zone 54

0 200 400 600 800 m

SCALE: 1:20,000

CLIENT:

CONSULTANT:



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PROJECT NO:	30049251	STATUS:	DRAFT
MAP NO:	03	AUTHOR:	K.V.
MAP TITLE:	FLOOD IMPACT ASSESSMENT - DEVELOPED 1% AEP	CHECKED:	A.B.

DATE:	11/04/2025
SIZE:	A3
SOURCES:	Metromap
CRS:	GDA94 / MGA zone 54

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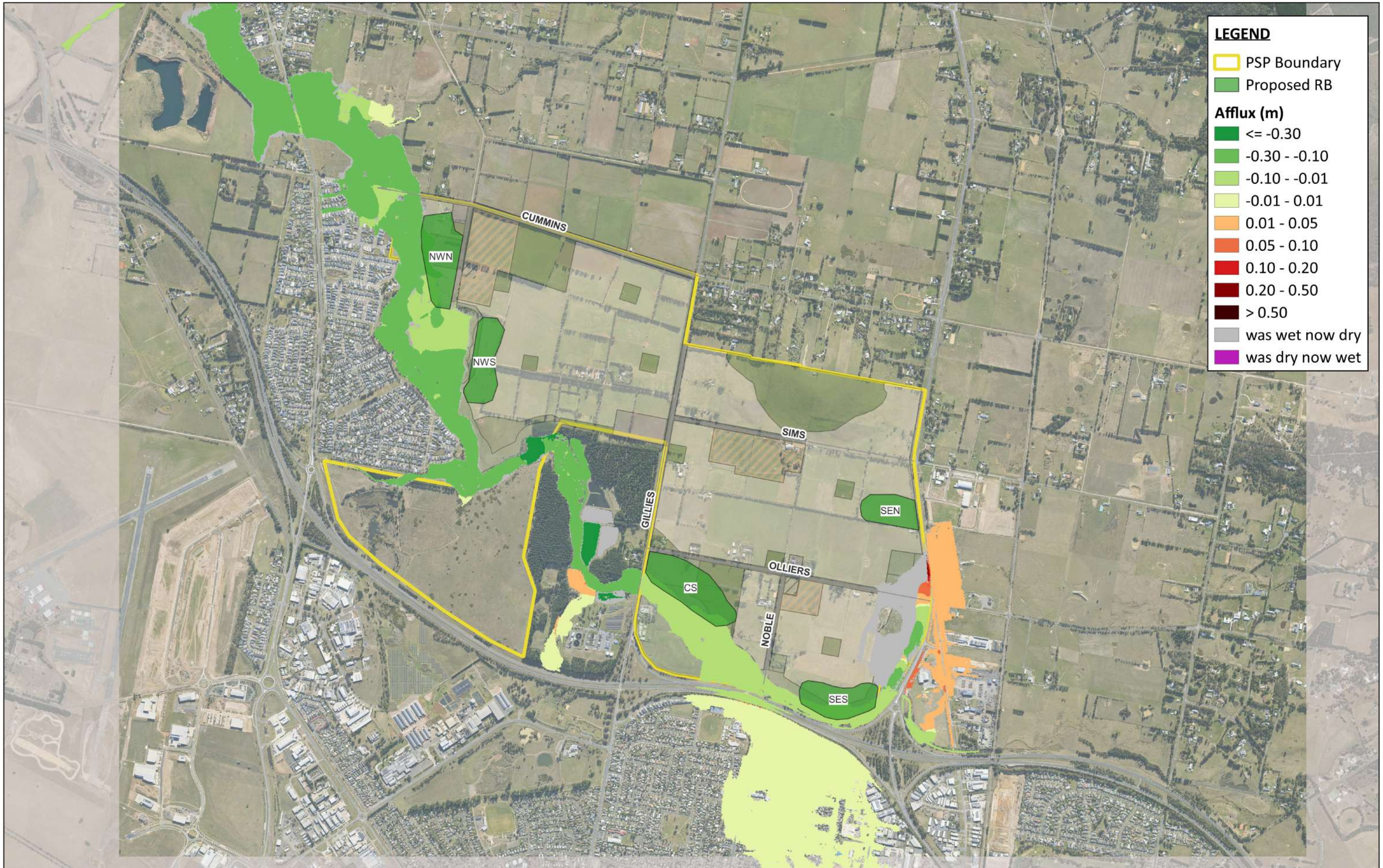
SCALE: 1:20,000

CLIENT:

CONSULTANT:



PROJECT TITLE:	BALLARAT NORTH PSP PROOF OF CONCEPT	REVISION:	A	DATE:	11/04/2025
PROJECT NO:	30049251	STATUS:	DRAFT	SIZE:	A3
MAP NO:	04	AUTHOR:	K.V.	SOURCES:	Metromap
MAP TITLE:	FLOOD IMPACT ASSESSMENT - AFFLUX 1% AEP	CHECKED:	A.B.	CRS:	GDA94 / MGA zone 54

0 200 400 600 800 m

SCALE: 1:20,000

CLIENT:

CONSULTANT:

www.smec.com

an SJ company

SMEC Australia

Wurundjeri Country, Collins Square, Tower 4, Level 20
727 Collins St Melbourne VIC 3008

PO Box 23027, Docklands, VIC, 8012

Phone: +61 3 9514 1500

Email: melbourne@smec.com

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