Wonthaggi North East Precinct Structure Plan and Development Contributions Plan

PROOF OF CONCEPT REPORT

September 2021

alluvium

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

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

This report has been prepared by Alluvium Consulting Australia Pty Ltd for the Victorian Planning Authority under the contract titled 'D/21/3212 – WONTHAGGI NORTH EAST PRECINCT STRUCTURE PLAN AND DEVELOPMENT CONTRIBUTIONS PLAN – STORMWATER DRAINAGE FUNCTIONAL DESIGNS AND COSTINGS'.

Authors:	Kieran Port, Dylan Brand, Olivia Blair-Holt, Caroline Carvalho, Jonathan Ho
Reviewed:	Caroline Carvalho
Approved:	Stuart Cleven
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Author/s	Dylan Brand Kieran Port Caroline Carvalho Olivia Blair-Holt Jonathan Ho
Reviewed	Caroline Carvalho
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Abbreviations

Alluvium	Alluvium Consulting Australia Pty Ltd
BCSC	Bass Coast Shire Council
BPEMG	Best Practice Environmental Management Guidelines
DCP	Development Contributions Plan
DETV	Department of Education and Training, Victoria
Engeny	Engeny Water Management Pty Ltd
PSP	Precinct Structure Plan
TSS	Total Suspended Solids
TP	Total Phosphorus
TN	Total Nitrogen
VPA	Victorian Planning Authority
WGCMA	West Gippsland Catchment Management Authority
WNEP	Wonthaggi North East Precinct
VPA	Victorian Planning Authority

1 Introduction

Alluvium Consulting Australia Pty Ltd (Alluvium) has been engaged by the Victorian Planning Authority (VPA) in partnership with Bass Coast Shire Council (BCSC) to undertake a suite of stormwater drainage functional designs and associated cost estimates for the Wonthaggi North East Precinct Structure Plan (PSP) and Development Contributions Plan (DCP).

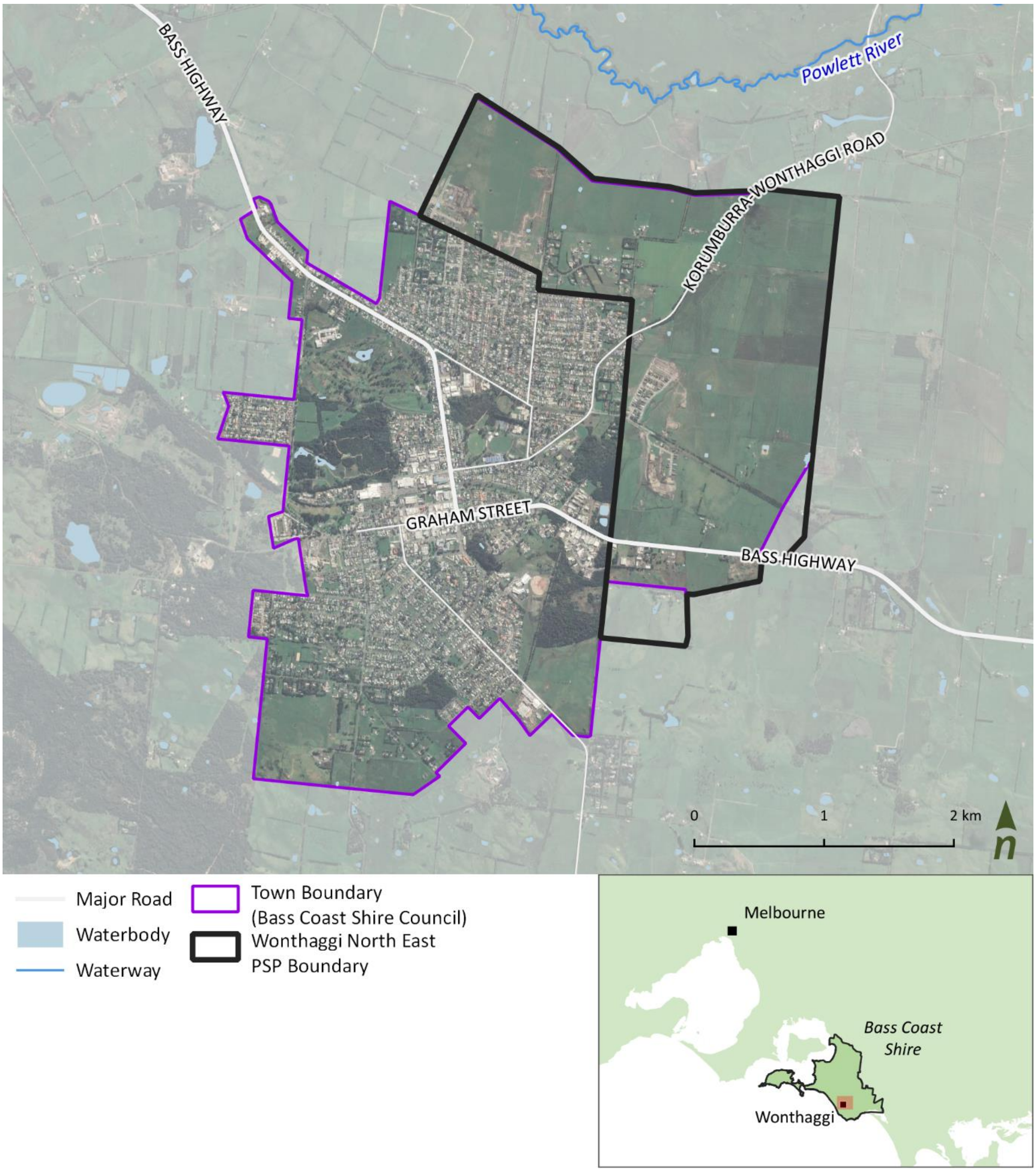


Figure 1. *Site location*

This Report – Proof of Concept (PoC)

The following 'Proof of Concept' report documents the site context for the proposed development precinct, previous drainage investigations and modelling, and background and site investigations which will influence future stormwater drainage options. Stakeholder feedback on previous work has also been considered. Alluvium has reviewed the various iterations of the Stormwater Management Plan ('drainage strategy') undertaken by Engeny (October 2019 through to September 2021), including the *Impact and Proposed Mitigation Works Strategy* (Engeny, March 2021) and various data and model outputs and revisions.

Building on this existing work, Alluvium has provided an alternative concept for the Wonthaggi North East PSP for the VPA and Council consideration.

The recommendations are based on potential efficiencies in land take, asset performance and long term protection, capital costs and lifecycle management costs – all of which are particularly important in such a complex drainage environment in order to allow development to proceed viably and sustainably.

Engeny Consultants previously provided Bass Coast Shire Council with a drainage strategy for the Wonthaggi North East PSP – *Stormwater Management Plan* (October 2019). Following the June 2020 planning scheme amendment process for the PSP (Amendment C152), Engeny was engaged to prove PSP concepts further, specifically in relation to the proposed wetland-retarding basin (WLRB1) and the ultimate outfall from the precinct to the downstream at Powlett River (to the north) - *Impact and Proposed Mitigation Works Strategies* (March 2021). More recently, a final version of the drainage strategy (September 2021) was provided and has been considered in this Proof of Concept (PoC) Report including stakeholder feedback.

The intent of this study (Alluvium) is to:

- review previous strategies
- analyse previous modelling and concepts
- confirm the required stormwater management assets in an integrated manner
- and ultimately develop the concept designs into functional designs for the PSP.

This allows the VPA and stakeholders to gain confidence that the system can adequately function as intended, as well as more accurately identifying the required infrastructure, land take, capital investment costs, maintenance requirements and associated costs for the PSP.

Ultimately, this project will allow for the finalisation of the Precinct Structure Plan (PSP) and the Development Contributions Plan (DCP) for the Wonthaggi North East Precinct.

Following acceptance by the VPA of this report, with agreement on the proposed concepts / assets for the precinct, Alluvium will progress these to functional designs.

2 Background

Wonthaggi North East PSP covers approximately 632 hectares of land located to the north-east of the existing Wonthaggi township, just south of the Powlett River, and intersected with the majority of land north of Bass Highway and west of Kirrak Road. The proposed precinct boundary is provided in Figure 3. The precinct is predicted to provide up to 5,000 new homes potentially, to respond to population growth estimates for the town from 8,000 to 20,000 residents, over the next 30 to 50 years. The Wonthaggi North East PSP represents 40% of the Wonthaggi township.

The precinct consists of three major outfalls, two of which outfall north into the Powlett River, and one to the west of the existing township. The topography of the PSP area is generally flat and ranges in elevation from 13m AHD on the northern Heslop Road boundary to 32m AHD at a central highpoint in the precinct.

Bass Coast Shire Council is the local drainage authority for all urban land in the region, while West Gippsland Catchment Management Authority (WGCMA) is the rural drainage and floodplains manager. Together, with Traditional Owners, broader community and landowners, these are the key stakeholders to this project.

Engeny was engaged by the Bass Coast Shire Council in 2019 to undertake modelling, stormwater drainage investigations and development of the Stormwater Management Plan that will inform the precinct designs. The associated DCP (VPA, Nov 2020) identified 29 functional water assets (Figure 2, left) for capture, conveyance and management of stormwater quantity and quality, which includes:

- Two (2) 'internal' constructed waterways (west alignment and east alignment towards Kirrak Rd)
- Four (4) treatment wetlands, two (2) of which have integrated retarding basin (RBs) function
- 11 sediment basins
- and 12 culverts
- potential for additional (TBC).

The Engeny work developed the proposed assets to a conceptual level with associated high level cost estimates.

On behalf of the Bass Coast Shire Council, Engeny was engaged by the VPA to revise the 2019 drainage strategy following feedback during the amendment process. This Strategy was completed and provided to Alluvium in August 2021 and a later revised final version September 2021. This latest drainage strategy provides further refinement of the proposed stormwater drainage infrastructure for the Wonthaggi North East PSP and has now been used to inform this Proof of Concept (PoC) Report.

A number of changes have occurred in the Strategy since its earlier direction to present time (Figure 2 left versus right), particularly to the wetland/retarding basin assets, and consideration of further assets (additional SBs up to 16) and assets associated with the precinct's ultimate outfall to the Powlett River. The modelling and conceptual design of the final strategy (Sept 2021) was used to inform this revised PoC report.

Therefore, the suite of functional designs for the Alluvium study is outlined below. The Main Outfall to Powlett (MOP) River is a new functional design added to the package of works. A number of previously identified assets have been integrated with other systems, some recommended as 'redundant', bringing the total number of individual asset functional designs to 23, as follows:

- 2 constructed waterways - *same*
- 4 wetland-retarding basins – *2 additional WLs to be designed as integrated RB systems*
- 7 sediment basins – *these are independent SBs requiring individual designs. 5 SBs will now be integrated into the 4 WLRB designs (Note: WLRB-1A & WLRB-1B is split); 2 SBs are considered obsolete (SB 8 & 9); 2 SBs of limited contribution to PSP and deemed redundant (SB1 & SB14); SB13 is still missing from the strategy layout; SB5 considered unlikely to progress.*
- 9 culverts – *C1 and C3 are critical assets for the two constructed waterways; C2 and C4 are missing from the revised layout and presumed to be existing assets (now named Bass Highway culverts and McGibbonys Rd culvert respectively); C5-C7 have been renamed to C4-C6 respectively; C8-C11 are*

missing from the revised strategy layout, however, are critical for the WLRB outfalls and considered in this PoC, and C12 in north-west corner of precinct.

- 1 main outfall (and associated infrastructure) – *this is an additional (expected) asset for functional design. Details of this asset were not available at the time of this Report, therefore not discussed in detail.*

These are explained in more detail in Section 6.1 of this report.

This report accounts for all work undertaken to date, namely:

- a review of all background and supporting material to inform this study
- a review of Engeny's stormwater strategy versions, and modelling work undertaken
- analysis of all data, GIS, topography, flood models, MUSIC models and concepts – to test / prove
- recommendations as to the most cost-effective approach to ensure –
    - asset intended functionality and constructability
    - development viability without compromising stormwater function, environmental, social or cultural values
    - and broader outcomes of liveability for the current and future communities.

Underlying these analysis considerations is the desire to provide robust, sustainable assets which adequately:

- capture, retard, detain, treat and convey stormwater safely
- protect and further enhance receiving environments and local biodiversity
- deliver improved landscape and neighbourhood amenity outcomes
- provide future community services related to community connectivity, comfort, health and wellbeing and broader liveability outcomes.

Any proposed land use changes should provide for multiple benefits and multiple community-based outcomes, beyond just stormwater management and function alone. This consideration, amongst others, are foundational principles being applied to the development of the functional design package for the Wonthaggi North East PSP.

Given the number of strategy iterations and concept design changes and re-modelling that has been undertaken to date, the table below attempts to reconcile and/or provide a quick tracking of what, when and how information has influenced Alluvium's PoC Report.

It should be noted that:

- naming conventions of each proposed asset varies across the documentation
- proposed asset locations and inter-relationships between assets varies across the documentation.

Table 1 (below) was created to summarise each proposed asset for the PSP and connect (track) these across the various versions of the Engeny Strategy (i.e. Oct 2019, March 2021, August 2021, September 2021), as well as the various background information, documents and model outputs / updates provided by the VPA (and Engeny) in relation to the PSP and DCP.

Table 1. Summary of assets and revision updates from Engeny Strategy (revised, September 2021) to this Proof of Concept Report (Alluvium)

	As per DCP Assets		As per ENGENY – FINAL REVISED STRATEGY				Proposed Updates as per ALLUVIUM - PROOF OF CONCEPT		
Funct. Design #	DCP Asset ID	Asset type	Dimensions/ footprint	Asset Description (Naming)	Issue	Sept 2021 Strategy ID	Proposed changes	Alluvium PoC ID	Reference
1	DR1	Constructed Waterway	Length (m) – TBC	Western Waterway (DR1)	Low sinuosity, leading to high velocity flows and channel scouring, and impacts on wetland performance / vegetation degradation	DR1	Increase sinuosity to lower velocities and reduce bed scour / protect downstream assets / ensure long term increase in ecological value of new waterway	W-WW	Stormwater Conveyance (Waterways
2	DR2	Constructed Waterway	Length (m) – TBC	Eastern Waterway (DR2)	Low sinuosity, leading to high velocity flows and channel scouring, and impacts on wetland performance / vegetation degradation	DR2	Remove 90-degree bend at d/s to prevent short circuit / asset failure Increase sinuosity to lower velocities and reduce bed scour / protect downstream assets / ensure long term increase in ecological value of new waterway	E-WW	Stormwater Conveyance (Waterways
3	WLRB 1	Wetland and Retarding Basin	Treatment Area 58,000 (m^2)	Wetland and Retarding Basin 1	System is online which will lead to wetland scour, poor performance and vegetation losses Advised by Engeny 13 Aug wetland is retarding approx. 200mm above NWL Sept 2021 – WL retarding 320mm above NWL	WL1	Re-orient asset from 'online' system to 'offline' system (from waterways) to protect from wetland failure Altered wetland form to improve performance / function and protect wetland integrity / vegetation survival Wetland split to manage catchments size / waterway inflows (two inlet zones) to WLRB-1A (east) and WLRB-1B (west)	WLRB-1A (east) WLRB-1B (west)	Stormwater Quantity Management (Retarding Basins) and Stormwater Quality Treatment (Wetlands, Sediment Basins)

	As per DCP Assets		As per ENGENY – FINAL REVISED STRATEGY				Proposed Updates as per ALLUVIUM - PROOF OF CONCEPT		
4	WLRB 2	Wetland and Retarding Basin	Treatment Area 8,000 (m^2)	Treatment Wetland	Advised by Engeny 13 Aug wetland is retarding approx. 100mm above NWL Sept 2021 – WL retarding 170mm above NWL	WL2	Now treatment and retarding function	WLRB2	Stormwater Quantity Management (Retarding Basins) and Stormwater Quality Treatment (Wetlands, Sediment Basins)
5	WLRB 3	Wetland and Retarding Basin	Treatment Area 13,220 (m^2)	Wetland and Retarding Basin 3	Advised by Engeny 13 Aug wetland is retarding approx. 100mm above NWL Sept 2021 – WL retarding 144mm above NWL	WL3	New concept to improve function and performance to BPEM	WLRB3	Stormwater Quantity Management (Retarding Basins) and Stormwater Quality Treatment (Wetlands, Sediment Basins)
6	WLRB 4	Wetland and Retarding Basin	Treatment Area 5,850 (m^2)	Treatment Wetland	Advised by Engeny 13 Aug wetland is retarding approx. 100mm above NWL Sept 2021 – WL retarding 166mm above NWL	WL4	Now treatment and retarding function	WLRB4	Stormwater Quantity Management (Retarding Basins) and Stormwater Quality Treatment (Wetlands, Sediment Basins)
-	SB1	Sediment Basin	Treatment Area 520 (m^2) Footprint 2875 (m^2)		Same location	SB1	Recommend omit as small contributing catchment / negligible impact to PSP	N/A	Stormwater Quality Treatment (Wetlands, Sediment Basins)
7	SB2	Sediment Basin	Treatment Area 810 (m^2) Footprint 4290 (m^2)		Same location	SB2	Upsize - proposed treatment area: 1,000 (m^2)	SB2	Stormwater Quantity Management (Retarding Basins) and Stormwater Quality Treatment (Wetlands, Sediment Basins)

	As per DCP Assets		As per ENGENY – FINAL REVISED STRATEGY			Proposed Updates as per ALLUVIUM - PROOF OF CONCEPT		
8	SB3	Sediment Basin	Treatment Area 700 (m^2) Footprint 2670 (m^2)	Same location	SB3	Upsize - proposed treatment area: 1,500 (m^2) This is a critical SB as it is located at the headwaters of the proposed W-WW	SB3	Stormwater Quantity Management (Retarding Basins) and Stormwater Quality Treatment (Wetlands, Sediment Basins)
9	SB4	Sediment Basin	Treatment Area 850 (m^2) Footprint 4440 (m^2)	Moved to upstream (further south) location; reduce size	SB4	To be resized & remodelled as relocated further upstream as per Engeny strategy. Proposed treatment area: 1,300 (m^2)	SB4	Stormwater Quantity Management (Retarding Basins) and Stormwater Quality Treatment (Wetlands, Sediment Basins)
-	SB5	Sediment Basin	Treatment Area 880 (m^2) Footprint 4380 (m^2)	Sept strategy suggest remove	SB5	Removed - Consistent with Engeny & considered obsolete to PSP.	N/A	Stormwater Quantity Management (Retarding Basins) and Stormwater Quality Treatment (Wetlands, Sediment Basins)
10	SB6	Sediment Basin	Treatment Area 1030 (m^2) Footprint 5070 (m^2)	Same location	SB6	Upsized Proposed treatment area: 1,400 (m^2)	SB6	Stormwater Quantity Management (Retarding Basins) and Stormwater Quality Treatment (Wetlands, Sediment Basins)
11	SB7	Sediment Basin	Treatment Area 980 (m^2) Footprint 4900 (m^2)	Same location	SB7	Upsized - proposed treatment area: 1,400 (m^2)	SB7	Stormwater Quantity Management (Retarding Basins) and Stormwater Quality Treatment (Wetlands, Sediment Basins)
-	SB8	Sediment Basin	Treatment Area 1230 (m^2) Footprint 5990 (m^2)	Double ID – this is now the wetland inlet zone	SB8	Removed. New WLRB1B design incorporates primary treatment (sediment forebay) therefore this independent SB is not required – obsolete to PSP.	N/A	

	As per DCP Assets		As per ENGENY – FINAL REVISED STRATEGY			Proposed Updates as per ALLUVIUM - PROOF OF CONCEPT		
-	SB9	Sediment Basin	Treatment Area 700 (m^2) Footprint 5990 (m^2)	Upstream of Western waterway	SB9	Removed. New WLRB1A design incorporates primary treatment (sediment forebay) therefore this independent SB not required – obsolete to PSP.	N/A	
Now part of #4 design NEW asset (25 Aug)	No ID	Sediment Basin		New SB as inlet to WL1	No ID	This sediment basin is already part of Alluvium's new WLRB1 concept design and has been sized accordingly to eliminate the need for SB8 and SB9.	N/A	
Now part of #5 design	SB10	Sediment Basin	Treatment Area 1080 (m^2) Footprint 4100 (m^2)	Now part of WL2	SB10	Relocated / integrated to be primary treatment / inlet zone for WLRB2 therefore does not require an Asset ID	N/A	
Now part of #6 design	SB11	Sediment Basin	Treatment Area 920 (m^2) Footprint 2800 (m^2)	Now part of WL3	SB11	Relocated / integrated to be primary treatment / inlet zone for WLRB3 therefore does not require an Asset ID	N/A	
Now part of #7 design	SB11A	Sediment Basin	Treatment Area 900 (m^2) Footprint 4320 (m^2)	Now part of WL4	SB11A	Relocated / integrated to be primary treatment / inlet zone for WLRB4 therefore does not require an Asset ID	N/A	-
12	SB12	Sediment Basin	Treatment Area 500 (m^2) Footprint 2620 (m^2)	North-west corner of precinct	SB12	Unchanged	**SB12**	Stormwater Quantity Management (Retarding Basins) and Stormwater Quality Treatment (Wetlands, Sediment Basins)

	As per DCP Assets		As per ENGENY – FINAL REVISED STRATEGY				Proposed Updates as per ALLUVIUM - PROOF OF CONCEPT		
-	SB13	Sediment Basin	-	-	Missing from strategy layout 2021 (Engeny)	Missing from new layout	Removed - assumed not required	N/A	
-	SB14	Sediment Basin	Treatment Area 500 (m^2) Footprint 2500 (m^2)			SB14	Removed - recommended obsolete due to small catchment area.	N/A	
13	SB15	Sediment Basin	Treatment Area 500 (m^2) Footprint 2500 (m^2)			SB15	Upsized - proposed treatment area: 1,500 (m^2) This is a critical SB as it is located at the headwaters of the proposed E-WW	SB15	Stormwater Quantity Management (Retarding Basins) and Stormwater Quality Treatment (Wetlands, Sediment Basins)
-					New SB for revised WLRB1 - unnamed	NEW unnamed	Integrated as part of WLRB1 – not an independent asset design	N/A	
14	CU1	Culvert		Outfall to DR1	Missing from new layout	No ID	Assumed no change – critical to W-WW	CU1	6.5 Culvert Crossings
-	CU2	Culvert		Outfall to DR1	Renamed Bass Highway/ CDS unit (culverts 18-19)	now Bass Highway/ CDS unit (culverts 18-19)	Existing CDS Unit & highway culverts (18-19)	N/A	6.5 Culvert Crossings
15	CU3	Culvert		Outfall to DR2	Missing from new layout	No ID	Assumed no change – critical to E-WW	CU3	6.5 Culvert Crossings
-	CU4	Culvert		Outfall to DR1	Inconsistent naming/ already existing	now McGibbonys (culverts 22-23)	Existing asset Assumed no functional design required	N/A	6.5 Culvert Crossings
16	CU5	Culvert		Outfall to DR1	Renamed C4	Now C4 (culverts 23-23A)	Assumed no change	CU5	6.5 Culvert Crossings
17	CU6	Culvert		Outfall to DR1	Renamed C5	Now C5 (culverts 23B-23C)	Assumed no change	CU6	6.5 Culvert Crossings

	As per DCP Assets		As per ENGENY – FINAL REVISED STRATEGY			Proposed Updates as per ALLUVIUM - PROOF OF CONCEPT		
18	CU7	Culvert	Outfall to DR1	Renamed C6	Now C6 (culverts 24-24A)	Assumed no change	CU7	6.5 Culvert Crossings
19	CU8	Culvert	Outfall to main outfall		Missing from new layout	Assumed no change – critical to WLRB1 outfall to Main Outfall Powlett (River)	CU8	6.5 Culvert Crossings
-	CU9	Culvert	Outfall to main outfall	Existing	Missing from new layout	Assumed no functional design required existing asset – critical to WLRB2 outfall to main outfall – design to account for asset's existing levels	N/A	6.5 Culvert Crossings
20	CU10	Culvert	Outfall to North Heslop Rd		Missing from new layout	Assumed no change – critical to WLRB3 outfall to Heslop Rd	CU10	6.5 Culvert Crossings
21	CU11	Culvert	Outfall to North Heslop Rd		Missing from new layout	Assumed no change – critical to WLRB4 outfall to Heslop Rd	CU11	6.5 Culvert Crossings
22	CU12	Culvert	Outfall to North Heslop Rd		Missing from new layout	Assumed no change – related to SB12 in north-west corner of precinct to account for untreated inflows to PSP assets.	CU12	6.5 Culvert Crossings
23 NEW		Main Outfall	Precinct ultimate outfall		Main Outfall to Powlett River	No change – critical asset– Main Outfall to Powlett (MOP) River	MOP	
Total Assets to Design	**DCP = 29**						**Alluvium = 23 designs**	

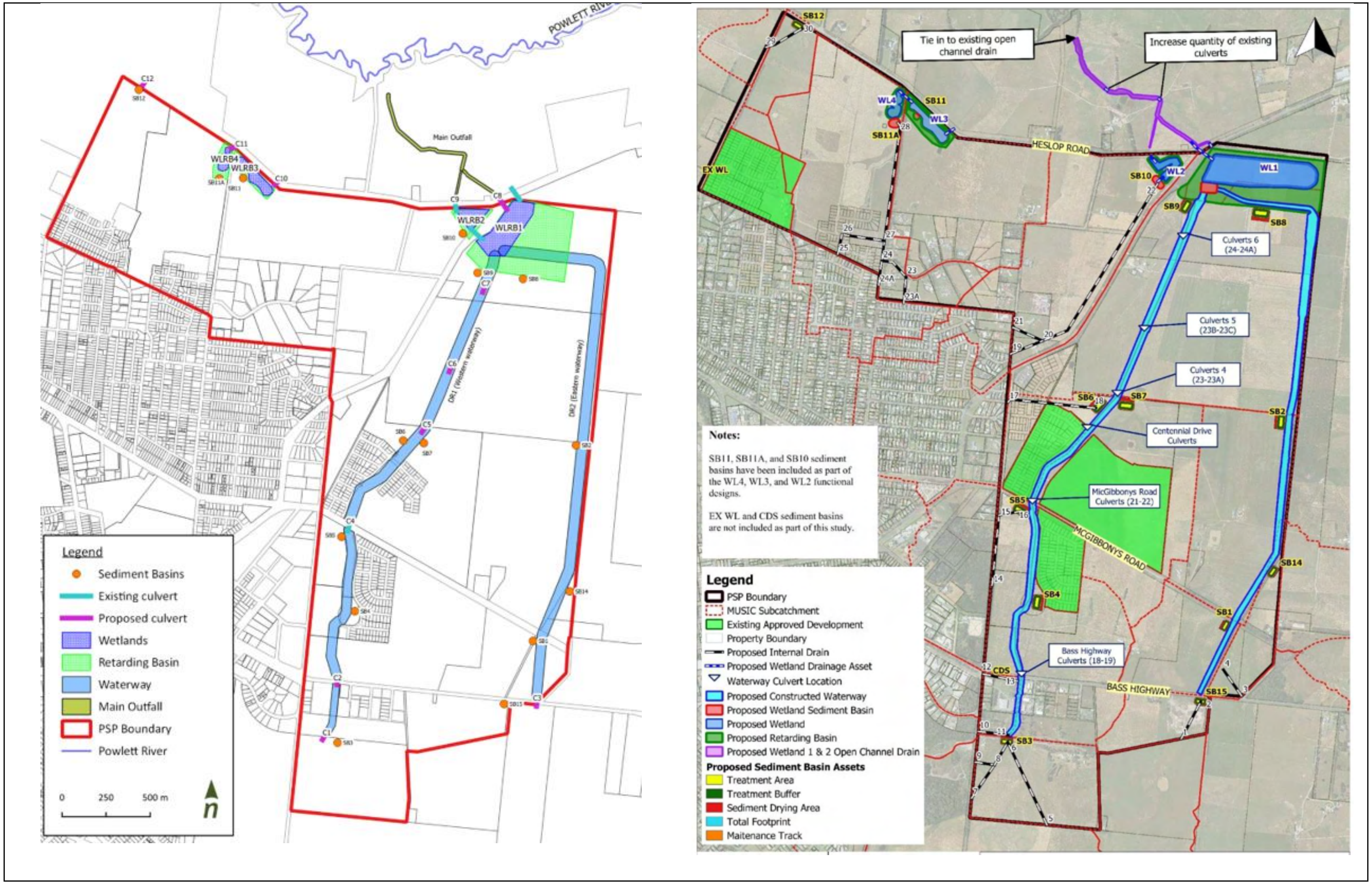


Figure 2. *Showing comparative changes in proposed assets between versions of the Draft Strategy. The DCP / Engeny Strategy 2019 proposed layout (left) and Final Strategy September 2021 (right). Note: Powlett River Outfall concept by Engeny is incomplete – outfall to Powlett River not shown.*

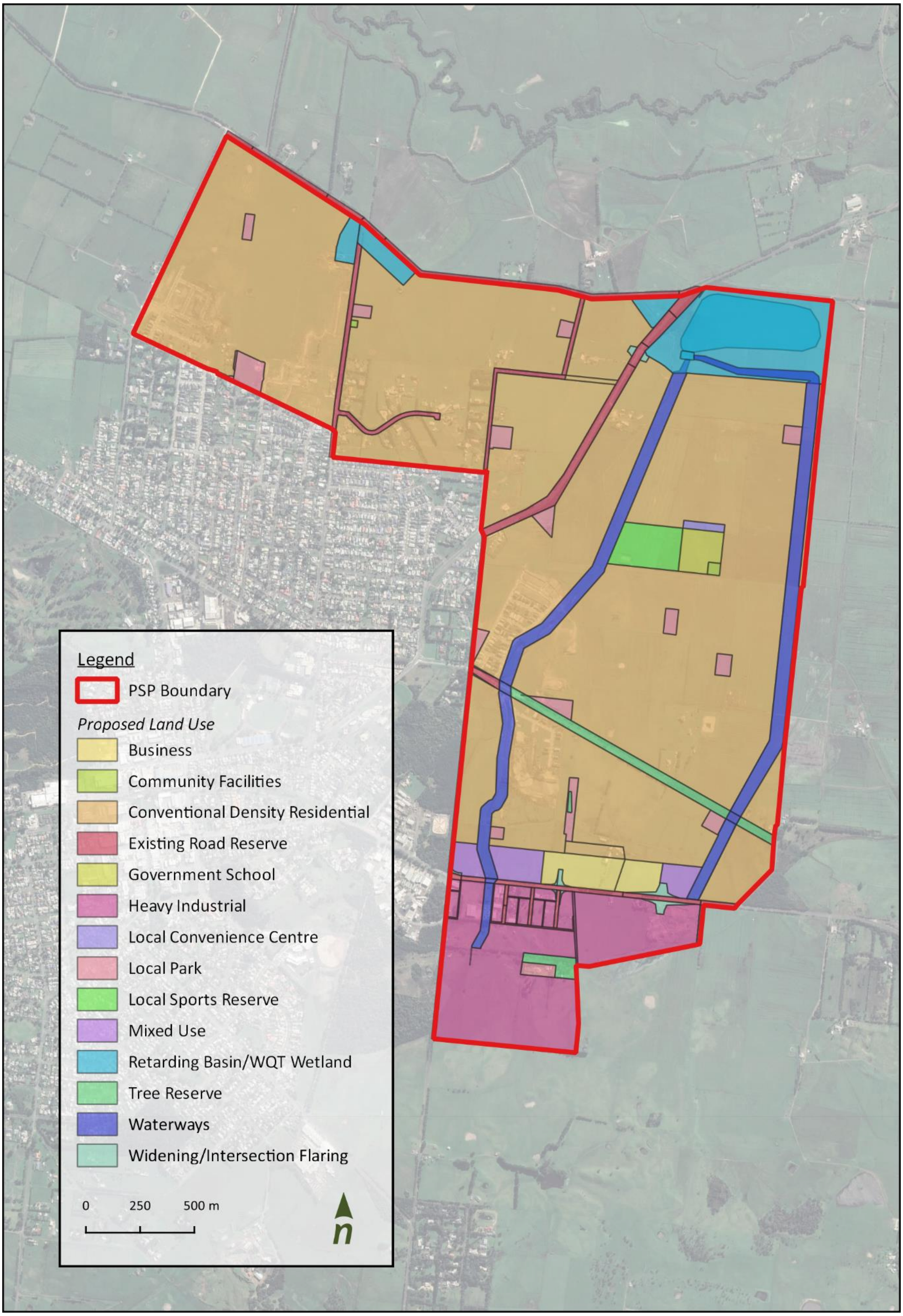


Figure 3. *Site Overview - project PSP area and proposed land use (source: modified from GIS proposed land use data, VPA).*

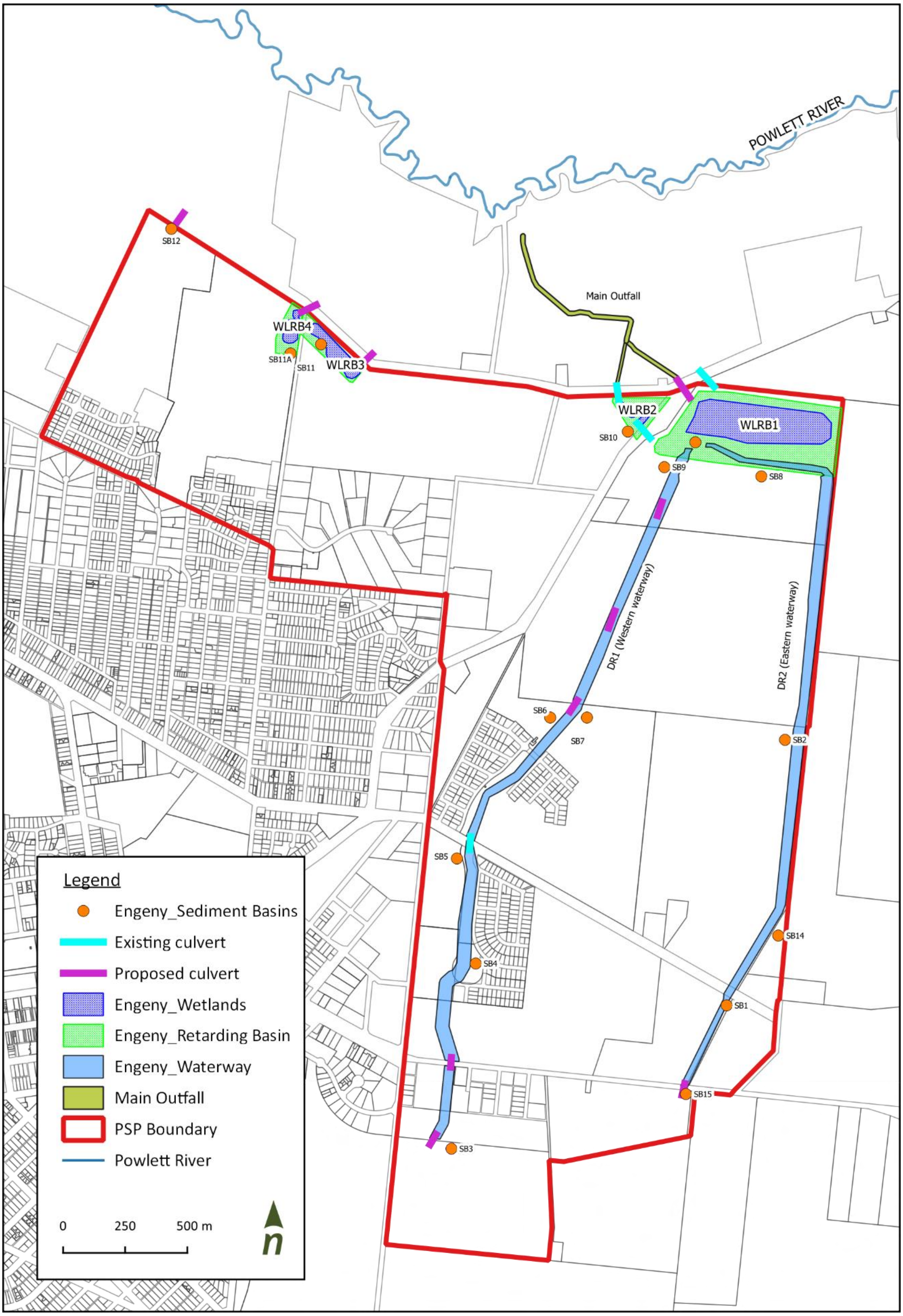


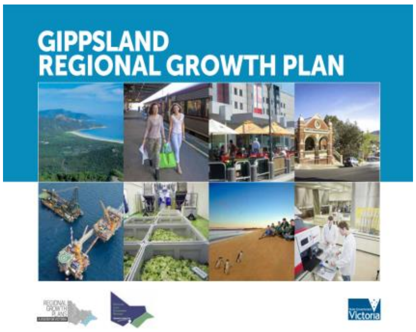
Figure 4. *Engeny Concept Layout Plan fpr PSP with approx. 30 proposed stormwater assets (source: digitised assets identified in final Engeny Strategy Sept 2021).*

2.1 Strategic context

Planning for growth in Wonthaggi has been driven by the VPA's work in regional city growth plans. The sustainable management and use of surface waters (runoff) in the landscape, and the appropriate guidance for urban development adjacent to riverine floodplains, are vital to the continued growth and water resilience of the region.

Similarly, the IWM Forum vision for the West Gippsland Strategic Directions Statement has a focus on *Working together through sustainable water management to enhance urban landscapes and maximise amenity, environment, and economic outcomes for our communities.* In our experience with other IWM plans, stormwater drainage strategies, PSPs and DCPs, a clear and shared vision is critical in setting the focus and achieving intended outcomes.

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

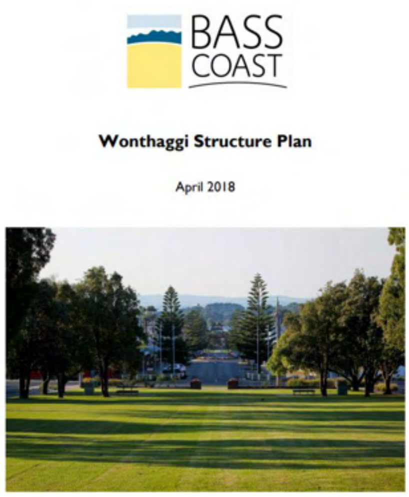


Gippsland Regional Growth Plan (VPA, 2014)

This plan addresses a wide range of challenges by recognising Gippsland's assets of regional significance and putting an integrated planning framework in place to direct and manage sustainable growth across the region.

It establishes regional policy to guide the use and preservation of these assets and provides a higher level of certainty and direction for investors, infrastructure and service providers, the community and decision makers.

Gippsland is forecast to become a fast-growing part of Victoria as more people relocate to the region from Melbourne. This plan considers the implications of growing the region to a population of 386,000 by 2041, an increase of 116,000 people.



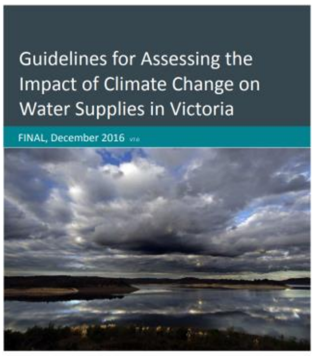
Wonthaggi Structure Plan (BCSC, 2018)

The Plan recognises and responds to the significant growth and change in the Wonthaggi area which is emerging as a major centre in the West Gippsland region. Emerging issues to be addressed by the plan include:
- potential economic and social impacts on local townships
- population growth
- role of Wonthaggi as a regional centre
- opportunities for the preservation of remnant vegetation and environmental areas.

The 2018 Wonthaggi Structure Plan has incorporated key recommendations identified by the Future Wonthaggi Focus Group. The group produced a report (Future Wonthaggi Focus Group Workshop – Community Representative Report, 2016) which identified six key themes to enhance liveability in Wonthaggi:
- A safe town to walk and move around
- Create an interest and understanding of the community
- Focus on our infrastructure
- Deliver strong tourism services
- Wonthaggi a model town
- Stimulate job growth.

IWM Forum – Gippsland Strategic Directions Statement (DELWP, 2018)
The Strategic Directions Statement (SDS) has a region-specific vision, outcomes, objectives, and priority actions. Collaboration between Traditional Owners, Councils, Water Corps, CMAs, and DEWLP, with representatives from a cross section of these institutions has led to shared ideas, buy-in, and momentum.

Opportunities identified through this project will demonstrably align with the following outcomes and their associated objectives:
1. Safe secure and affordable supplies
2. Effective and affordable wastewater systems
3. Reduced flood risks
4. Healthy and valued waterways, and Gippsland Lakes
5. Healthy and valued urban landscapes
6. Community values are reflected in place-based planning
7. Jobs, economic benefits and innovation.



Guidelines for Assessing the Impact of Climate Change on Water Supplies in Victoria (DEWLP, 2016)
This document provides a guideline for planning for climate variability and climate change, translating Global Climate Models into projections for Victorian river basins.

The document can inform the Wonthaggi North East PSP through assessment of future system reliability, urban water strategy planning and drought preparedness. The combined decrease in rainfall and increase in temperatures will result in a larger impact on runoff of 15.6%. Aquifer recharge will also be impacted.

This modelling and DELWPs recommendations will guide our understanding of issues, particularly for systems that are at risk with a reduction to rainfall and runoff, and our considerations of the effectiveness of climate dependant alternative water sources (such as rainwater and stormwater harvesting).

3 Existing conditions

3.1 Site visit

A site visit was conducted on the 14th July 2021 by the Alluvium project team with representatives from Bass Coast Shire Council and the Victorian Planning Authority in attendance. The site visit commenced at McGibbonys Road, near the developing Powlett Ridge subdivision to the south and Parkview residential estate (north of McGibbonys Road), and progressed around the precinct, identifying key sites that will inform and affect the functional design package (see Figure 5). Proposed locations for key stormwater assets as identified in the Engeny stormwater strategy were included to better understand the landscape, surrounding features and connections, challenges, issues and constraints, as well as opportunities. Sites included Powlett Ridge Estate, Parkview Estate and the proposed industrial area on Carneys Road.

It is noted that the land area south of McGibbonys Road and west of Connection Road / Powlett Ridge estate (currently under construction) has recently been sold to the Department of Education and Training Victoria.

A summary of our key findings from the site visit is shown below.

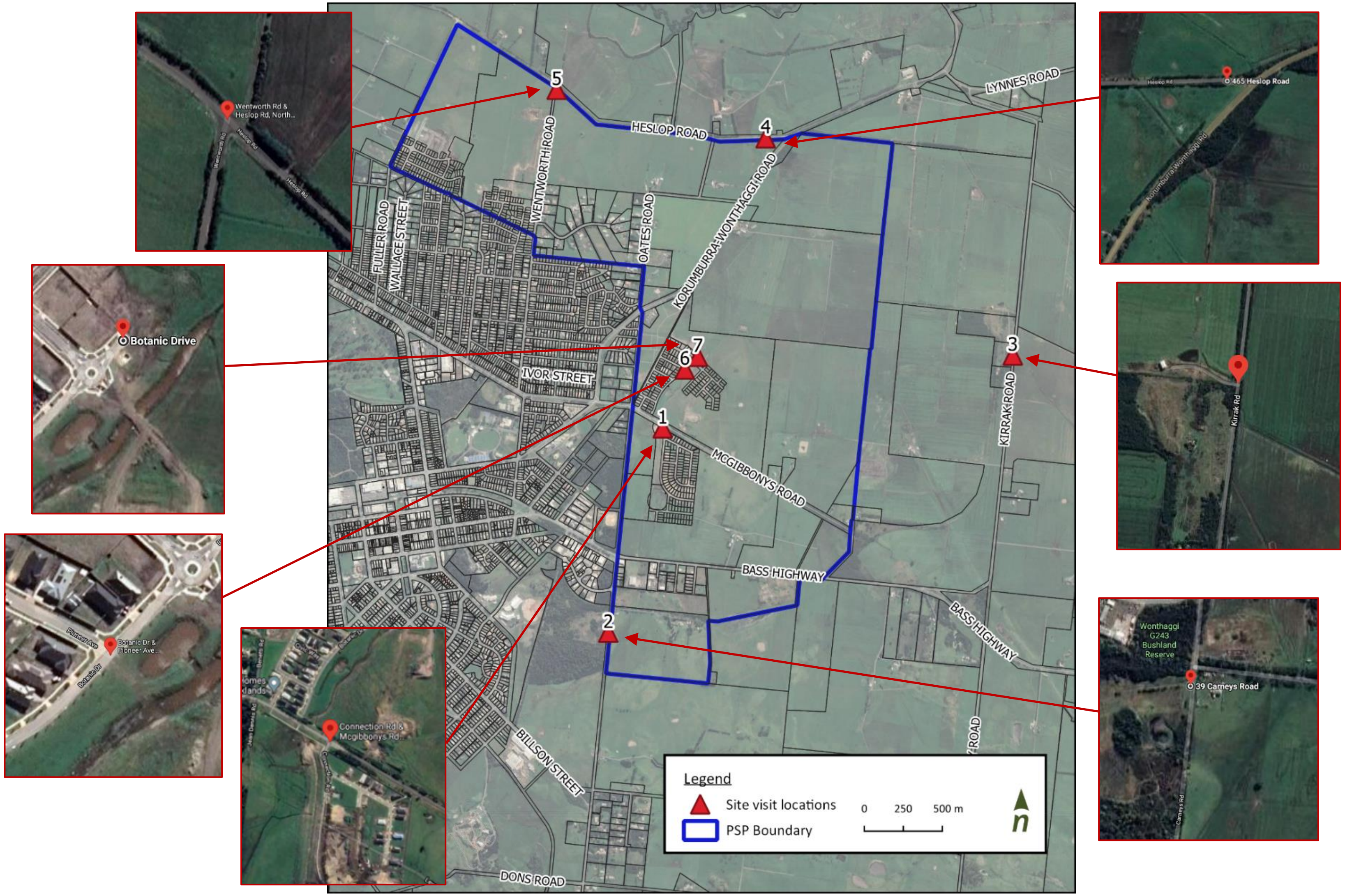


***Figure 5**. Site visit locations with georeferenced site photos (July 2021)*

Site 1 – McGibbonys Road and Connection Road – Powlett Ridge Estate

The Powlett Ridge estate is located south of McGibbonys Road and is currently under development, with several houses and internal roads already constructed. The estate is adjacent and east of the proposed constructed waterway 'west' alignment. West of the constructed waterway corridor (and south of McGibbonys Road) land has been purchased by the Department of Education and Training Victoria (DETV) for a proposed local school.

DETV has undertaken some site drainage works with pipe outfalls into the newly constructed western waterway. It was noted on site, that these pipe outfalls have been poorly constructed, placed and finished and is already resulting in significant headward gully erosion, with no end wall treatments, or rock armouring to dissipate erosive impacts of stormwater discharges. It was evident that the combined sediment loading to the newly constructed waterway (from both the DETV land and Powlett Ridge subdivision under construction) will require removal of this build up and re-shaping/reinstatement of the waterway floor/banks.

While this situation is outside the scope of this study and the issues relate to approved development activity, we offer this as advice in support of Council's planning compliance, who should act and ensure rectification to protect this new asset from potential rework. These matters will not form part of the functional design and costings of this study and are offered only as guidance here, for council-community benefit and to ensure issues are addressed sooner than later, so as to protect the assets being designed as part of this study.

The section of waterway adjacent to the Powlett Ridge Estate is generally in poor condition. Vegetation along the waterway bed (floor) has not established, and only a sparse non-indigenous grassed layer exists along the banks, resulting in erosional scour of banks where stormwater outfalls are resulting in sediment deposition to the waterway floor. This low flow channel (western waterway) lacks natural sinuosity along its length, and lack of rock armouring at critical locations (pipe outfalls to waterway) and ongoing impacts are highly likely.

Powlett Ridge Estate temporary sediment basin, looking upstream of constructed waterway 'west' alignment.

Existing headward and gully erosion along the newly constructed waterway banks from DETV land

Existing outfall drain from Powlett Ridge estate into constructed waterway 'west' alignment.

Constructed waterway 'west' alignment, looking upstream

Figure 6. *Site investigation photos of constructed waterway 'west' alignment (as proposed)*

Site 2 - Proposed Industrial Area (Carneys Road)

The proposed industrial area (Figure 7) is located at the southern boundary of the Wonthaggi North East precinct (WNEP). An undeveloped greenfield, external catchment falls through the industrial area from the south. The external catchment sheet flows across this relatively flat landscape. To the west of this industrial zone is the Wonthaggi Bushland Reserve and Wetlands (ID - G244).

It is noted that the existing industrial buildings / warehouses at this location, currently do not have any stormwater treatment infrastructure installed, prior to the area out-falling into one of the two proposed 'internal' constructed waterways (the west alignment in this instance), therefore exposing these assets to potentially hazardous pollutants. Ideally, Council should negotiate some form of proprietary intervention to protect the future waterway and downstream retarding basin/wetlands. While this study is not to resolve this issue or design and cost a solution to this area of the PSP, it is provided as guidance to council to ensure this is not an ongoing issue or risk to proposed water assets. The urban pollutant load of this area will need to be a consideration in the MUSIC model (urban node selection) for the functional designs.

Permit conditions for the industrial area did make allowance for a 40m wide waterway reserve (proposed western waterway) which is critical in the ability to design and construct this waterway with reasonable space allowed and urban buffering.

Note: Any investment into the two constructed waterways for the precinct should be made with confidence that the ecology and stream integrity will be protected, sustainable, and over time, naturally enhanced to become centralised features of the developed landscape and future community neighbourhood. It is highly recommended that Council consider / negotiate an appropriate treatment asset (e.g. Triple interceptor or similar) to manage the quality of stormwater discharges from the industrial area, before they enter the proposed constructed waterways and downstream wetlands to ensure investment and effort is not undermined at the outset.

Upstream of the proposed industrial area of Wonthaggi NE PSP, looking south at the future extension of Carneys Road.

Kirrak coal mine site (ruins) has been derelict for 100+ years and likely to be heritage protected. The land is owned by the State (Council).

Undulations and 'hills' are representative of coal mine spoil piles, otherwise the area is relatively flat.

West side of Carneys Rd (looking west) across the Wonthaggi Bushland Reserve and Wetlands (ID - G244). The site is outside the PSP area and opposite the proposed industrial zone (within the precinct/PSP area).

Figure 7. *Carneys Road proposed industrial precinct at southern extent of WNEP (PSP area) and surrounding landscape features.*

Site 3 – Kirrak Road

Kirrak Road runs north-south on the eastern side of the PSP area, that is, it is just outside the WNEP. The landscape is relatively flat and surface runoff falls gently easterly from Kirrak Road which is proposed to be a future 40m wide bypass road (BCSC). Therefore, flows from this external catchment are not entering the precinct / study area but falls away from it.

Site 4 – Wetlands 1 & 2

Wetland-Retarding Basin 1 (WLRB 1)

The Engeny stormwater strategy proposes an integrated wetland and retarding basin (WLRB1) at the downstream extent of the precinct, off the Korumburra-Wonthaggi Road. The site was inaccessible at the time of the site visit due to constrained timelines, where access to private property was not able to be arranged with enough forewarning. As a result, the analysis of the WLRB1 will completed based on a desktop analysis using NearMap and Google maps.

WLRB1 is proposed to be located within the natural depression of the property close to the Korumburra-Wonthaggi Road property boundary. The location selected is based on existing flood overlays and the Engeny flood modelling undertaken to date, indicating that this location is subject to flooding.

Looking east from Heslop Road towards proposed site for WLRB1 (behind tree line).

Figure 8. *Proposed site for WLRB 1 (beyond tree line) on Korumburra-Wonthaggi Road*

Wetland 2 (WL2)

WL2 is proposed as a treatment-only wetland and located at the corner of Korumburra-Wonthaggi Road and Heslop Road. The site has a natural depression near the downstream corner of the site with an open cut drainage channel through the proposed WL2 location, which then outfalls through existing culverts under Heslop Road (image left) and flows northwards across a private farm (referred to as the 'subject property' hereon, image right) to its ultimate outfall to the Powlett River.

Negotiations with the property owner of the subject property is underway with BCSC to address drainage issues and provide an ultimate outfall alignment from the WNEP to the Powlett River. This outfall will now form part of the functional design set (additional asset #30) to be undertaken by Alluvium.

Existing outfall from proposed WL2 site to culvert on Heslop Road (looking west).

Existing open channel outfall to Powlett River (looking north from Heslop Road) across subject property (private farm). The outfall design from the precinct to the River will be functional design #30.

Figure 9. *Site investigation photos of the proposed Wetland 2 landscape. and ultimate outfall to Powlett River (tree line in the north of image right).*

Site 5 – Wetlands 3 & 4

Wetland 3 (WL 3)

WL3 is also proposed to be located at the northern extent of the precinct south of Heslop Road and on the east side of Wentworth Road, at their intersection. Based on Council advice, under the proposed development, Wentworth Road alignment is to be discontinued as part of the future PSP.

The landscape at this location generally falls to the east, towards the location of the proposed WL3 area. Based on the Engeny flood modelling and flood overlays, there is existing inundation that occurs within the location of the proposed WL3 asset, therefore the proposed asset will have some functionality as a retarding basin integrated into its water quality treatment functionality.

Wetland 4 (WL 4)

WL4 is located at the north-western extent of the precinct, just south of Heslop Road and on the west side of the 'discontinued' Wentworth Road alignment and is 'perched' within the landscape (sits significantly higher than WL3). WL4 is the smallest of all 4 wetlands proposed for the precinct. During the site visit, discussion was had around merging WL3 and WL4 as one consolidated asset (should levels allow). However, as advised by Council, WL4 has been approved as part of a Development Plan (2011) and planning permit process to allow for the construction of the residential subdivision east of Fuller Road and to the west side of the Wentworth Road alignment. These approvals were completed prior to investigations into the Wonthaggi North East PSP process, the actual future development of which could be at least another 10yrs away.

As discussed with Council, there is the possibility to merge WL3 and WL4 assets as part of a future asset renewal program if value-adding (some 30-50yrs away, or sooner if significant issues arise with the systems) to improve on overall function and landscape amenity and potential reduction in assets to maintain and land take associated with independent maintenance access hard stand and sediment drying areas. Therefore, for the purposes of the PSP progression and development of the functional design set, WL3 and WL4 assets are being considered as separate structures.

WLRB 3 site, looking east along Heslop Road

Intersection of Wentworth Road alignment and Heslop Road, looking west across the sites proposed for WL3 and WL4

Figure 10. *Site investigation photos for WL3 and WL4 proposed locations.*

Site 6 – Pipe Track at Pioneer Ave & Botanic Dve

An existing pipe track at this location offers an ideal opportunity to connect its alignment in both directions to better connect the PSP and future community with existing blue-green corridors and existing community. Trail links could extend northwards from this point through to the functional water assets along the northern extent of the PSP. This northern extent provides a potential blue-green passive recreation corridor asset for the future development. This trail link could then be further extended to the Powlett River along the ultimate precinct outfall through the current private farm north of the PSP (this is subject to landowner/council negotiations and creation of a drainage reserve).

The existing pipe track could be further enhanced by extending it south along the Carneys Road section of the PSP and/or through existing walks and trail links to the south of the precinct, thereby connecting current and future trails and communities along/to/from the PSP via a series of “living links”.

As can be seen in Figure 11 below, Wonthaggi township is well serviced with extensive walkable routes and key sites of ecological, historical and social recreational value. There is an unusually high number of ‘destinations’ and trail links that could successfully be connected to the WNE PSP and further enhance these community, landscape and passive recreation opportunities.

Living Links- Potential community connections via existing walking trails (insets) with proposed trails from PSP (blue lines)

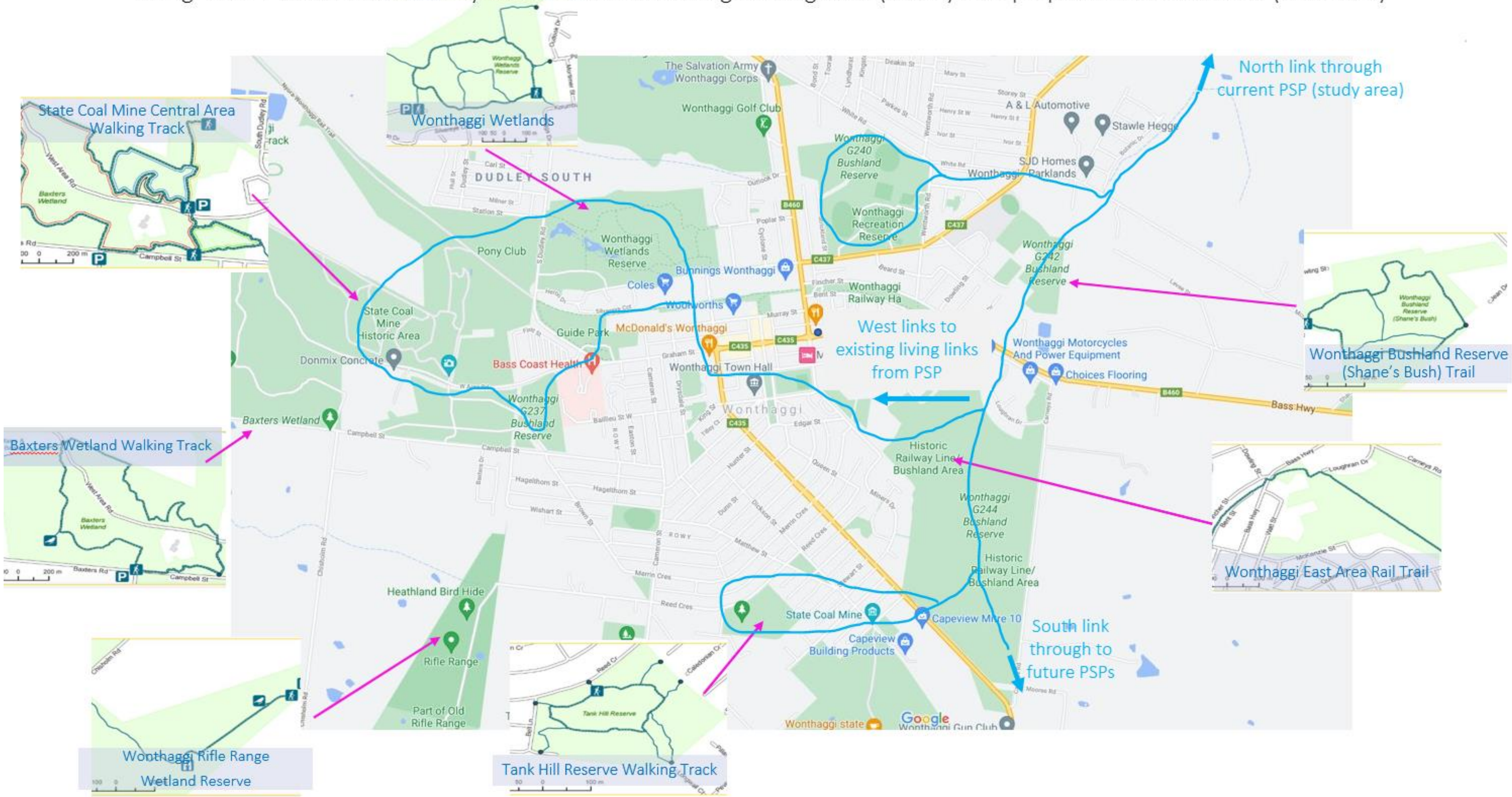


Figure 11. *Map of proposed trails from the Wonthaggi North East PSP to existing mapped trails as potential community connections along 'living links'.*

Site 7 - Parkview Estate Constructed Waterway (west alignment)

The Parkview estate is located north of McGibbonys Road and has been developed with all necessary stormwater drainage infrastructure completed. Adjacent to the estate is a section of the constructed waterway corridor (west waterway alignment, W-WW). This section of the waterway connects to the upstream section recently constructed as part of the Powlett Ridge Estate (refer Site 1 details above).

The Parkview estate outfalls into two interim / temporary sediment basins located adjacent to the waterway. The waterway is generally in good condition with meanders present in the upstream section of the corridor and has healthy aquatic vegetation established. The waterway appears to back up just upstream of the culvert / road crossing likely due to a restricted outlet at the downstream section of the estate. This appears to have been retained in place as a form of interim stormwater *quantity* control so as not to impact downstream landowners during these temporary / interim drainage conditions that are in place.

Existing interim / temporary sediment basin

Existing waterway profile, looking upstream with good vegetation establishment

Existing temporary waterway outfall control for flood/drainage protection of downstream properties

Existing waterway profile, looking downstream

Figure 12. *Site investigation photos of the constructed waterway 'west' alignment (W-WW) through Parkview Estate, north of McGibbonys Road and east of Carneys/Korumburra-Wonthaggi roads.*

3.2 Topography

The precinct has a mostly flat topography ranging from 13m AHD on the northern Heslop Rd boundary to 32m AHD at a central highpoint. The catchment falls steadily from the central highpoint in the precinct area and is divided into three distinct catchments (North West Catchment, South West Catchment and East Catchment). The average slope of the precinct area is towards the north, directing most of the flow to the Powlett River.

An overview of the topography is presented in Figure 13.

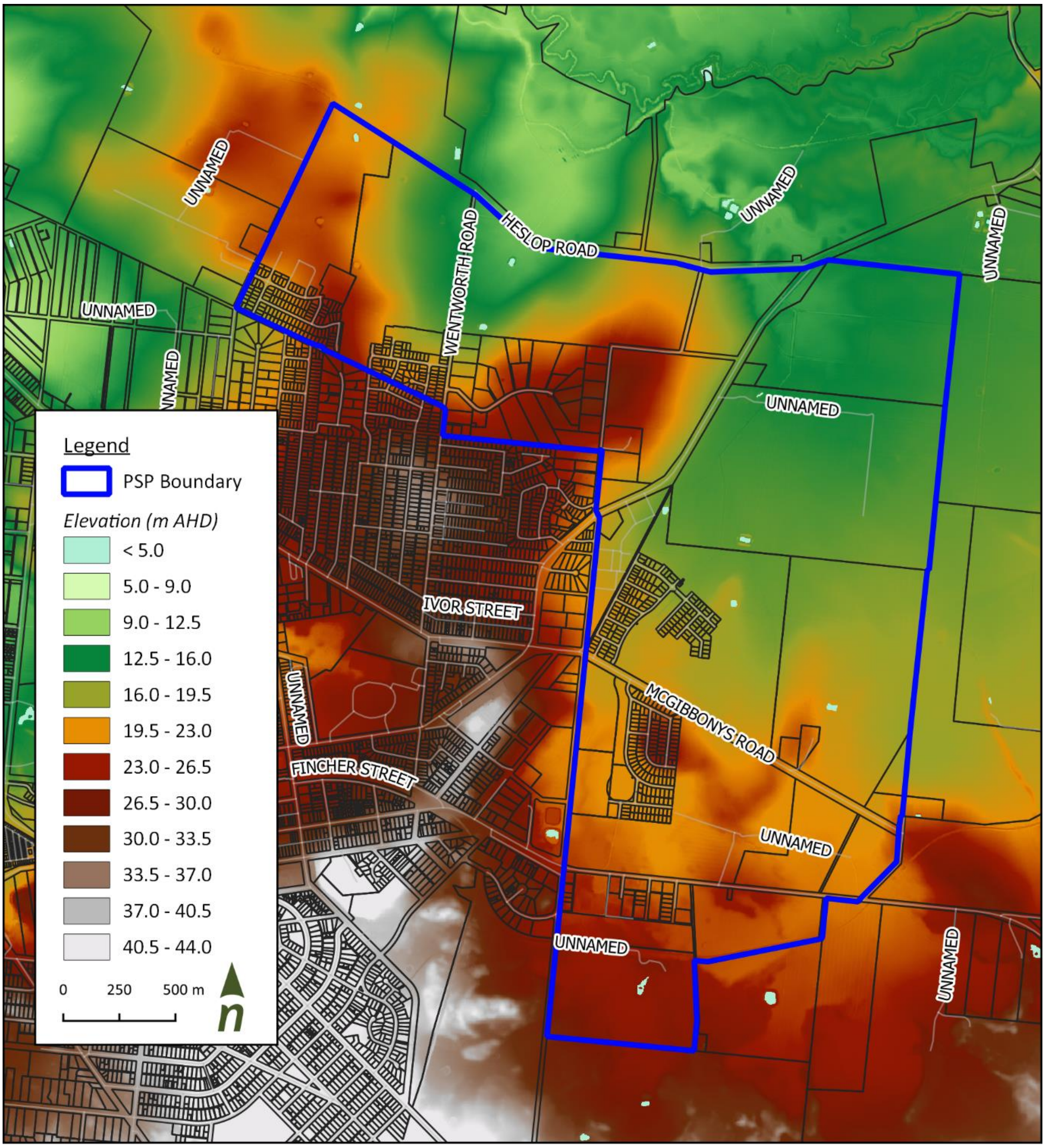


Figure 13. *Topography of PSP and surrounding area*

3.3 Existing services and infrastructure

The PSP area is intersected by major roads including the Korumburra-Wonthaggi Rd which runs north-east from Wonthaggi CBD, and the Bass Highway which runs east of the CBD. There are four existing culverts on the site (see Figure 14). Three of these culverts are used to convey the partially constructed west waterway (W-WW) flows from McGibbonys Rd, under Korumburra-Wonthaggi Rd and out falling to the proposed wetland systems along Heslop Road at the northern extent of the PSP. The fourth culvert conveys eastern flows under the Korumburra-Wonthaggi Rd.

Another major infrastructure in the area around the PSP is the pipeline from the Victorian Desalination Plant. The pipeline runs from the plant west of Wonthaggi and borders the north east edge of the PSP boundary, then runs parallel along Heslop Road and northwards towards the Powlett River. The pipeline is of particular significance in planning the outfall from the PSP, as the outfall is proposed to pass over the desal pipeline.

Engeny's more recent Dial Before You Dig assessment has identified water supply mains and a gas main. These alignments have been added to the map below using digitised information provided.

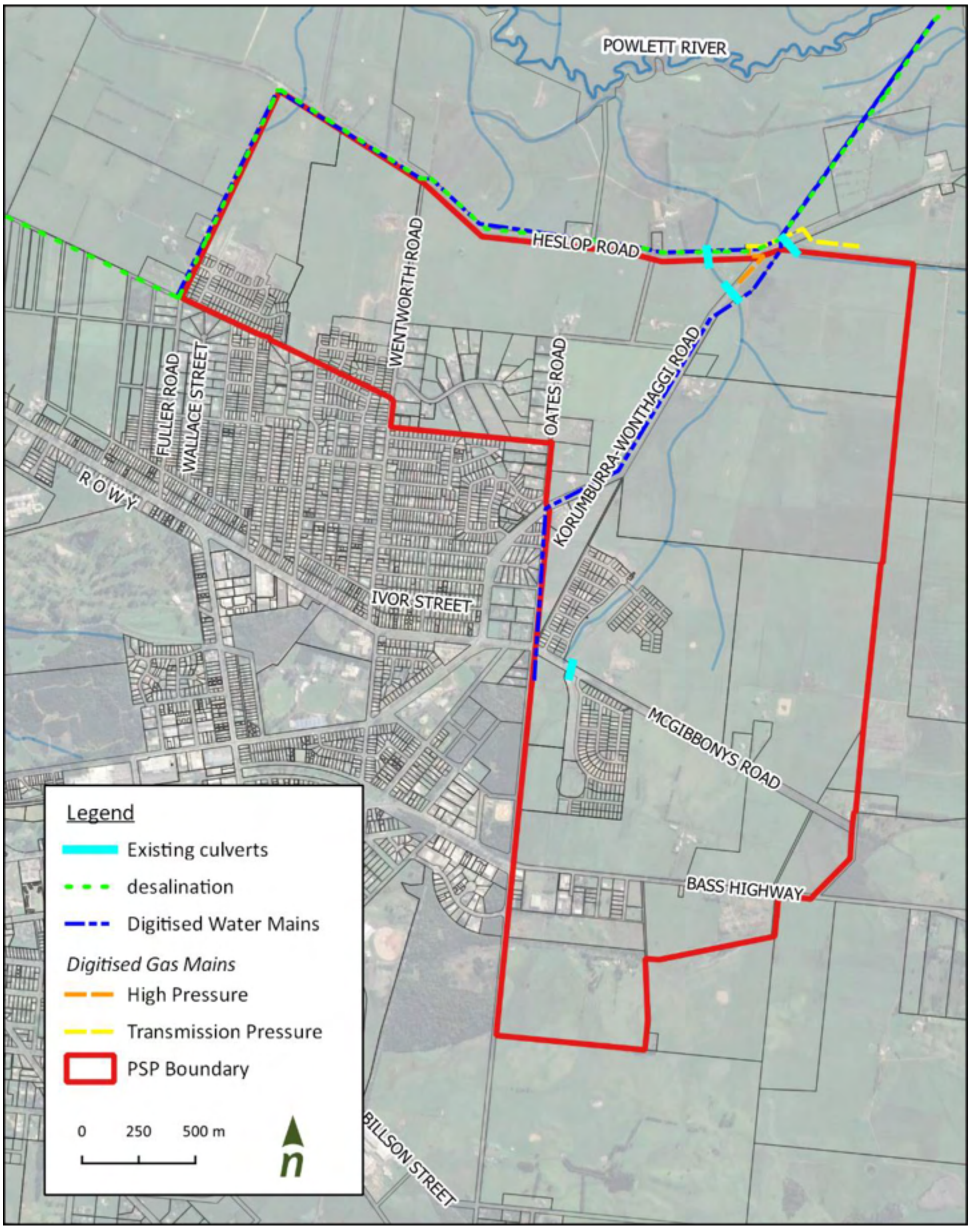


Figure 14. *Existing services and infrastructure in PSP area. Water mains digitised based on images by South Gippsland Water, gas mains digitised based on images by Multinet Gas - based on data provided 27/08/2021)*

3.4 Catchments & Sub-Catchments

There are three distinct catchments that cross the PSP study area (Figure 15) all of which stem from the local highpoint in the south-west extent of the precinct. The north-west catchment (green) is approx. 300 ha, and the eastern catchment (yellow) is approx. 1540 ha – together they cover the majority of the PSP area. These two catchments fall predominantly towards the north and ultimately outfall to the Powlett River. The eastern catchment extends south past the PSP area and further east until it intersects with Kirrak Rd. This large section of the eastern catchment (external to the PSP) will need to be accounted for in the functional design solutions. A grassy swale which runs along Kirrak Road captures and conveys flows from further east and drains away from the PSP - the area falls gently easterly from Kirrak Road (Council, at site visit).

The south-west catchment (blue) falls south-westerly away from the PSP area and the Powlett River. Due to the current development activity in the south-west catchment, it is assumed that a drainage strategy for this area has already been established as part of the approved Development Plan (Council communication at site visit).

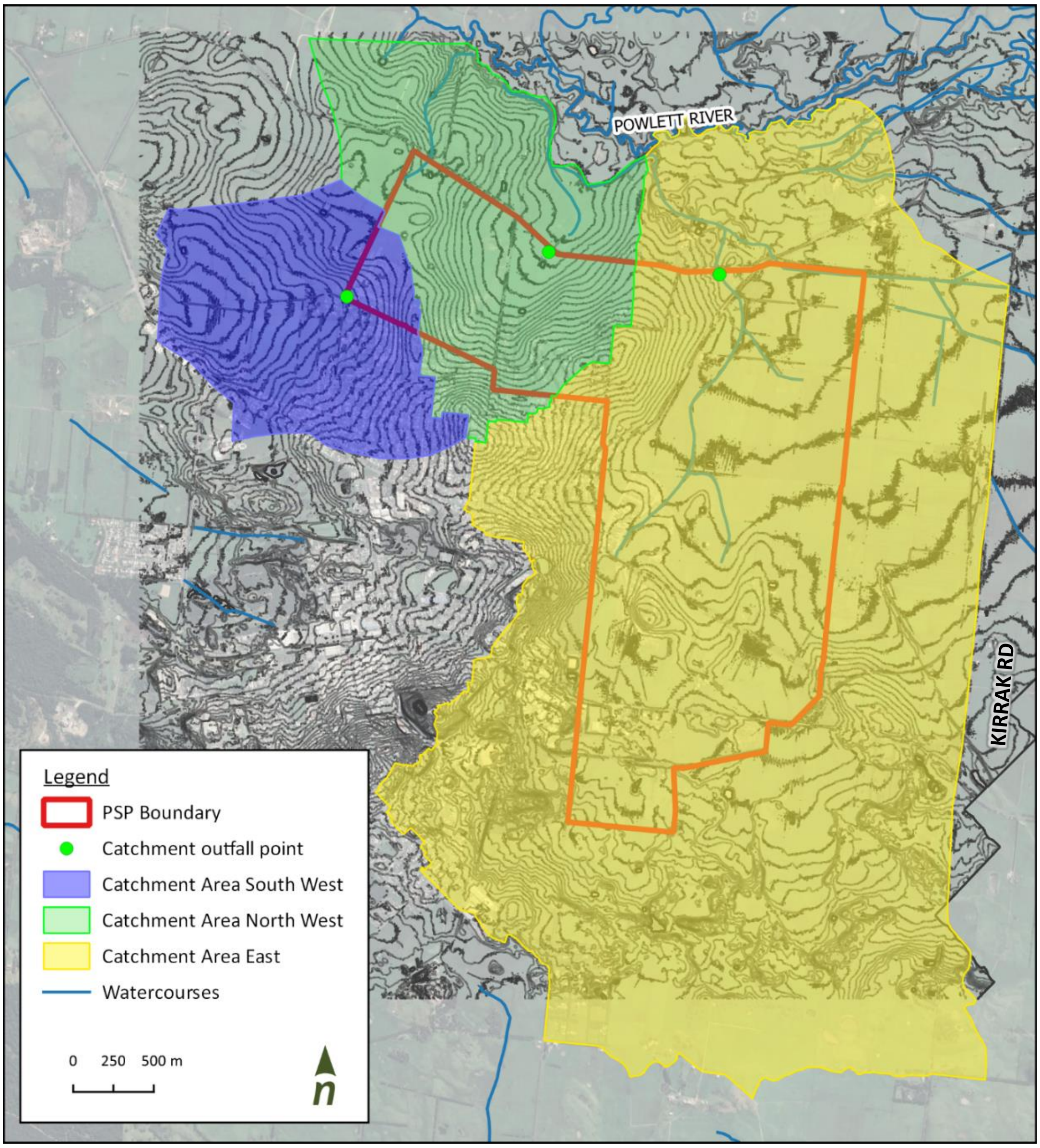


Figure 15. *Catchments across the PSP and broader area*

The proof of concept approach undertaken by Alluvium sought to better understand the impacts of these catchment areas (outside the PSP boundary) on the proposed constructed waterways and WLRBs. Figure 16 below highlights key locations across the sub-catchments that would be ideal locations for future stormwater management infrastructure (retardation and/or treatment) to meet best practice, and ensure assets proposed for the PSP are able to function as intended and for duration of asset life (approx. industry standard for wetlands is 30-50yrs subject to design, catchment condition and maintenance regimes).

Recommendations:

- White – proposed assets for the Wonthaggi North East PSP identified and being resolved in this study
- Green – existing subdivisional treatment wetland
- Red – untreated existing subdivisional areas – Council opportunities to retrofit the catchment and protect PSP WLRBs and waterways. This would form part of Council's long term capital works delivery to protect the Powlett River given development has been completed/subdivisions already approved.
- Orange – untreated agricultural landscape – VPA future opportunity to flag treatment systems for future PSPs / growth area planning.

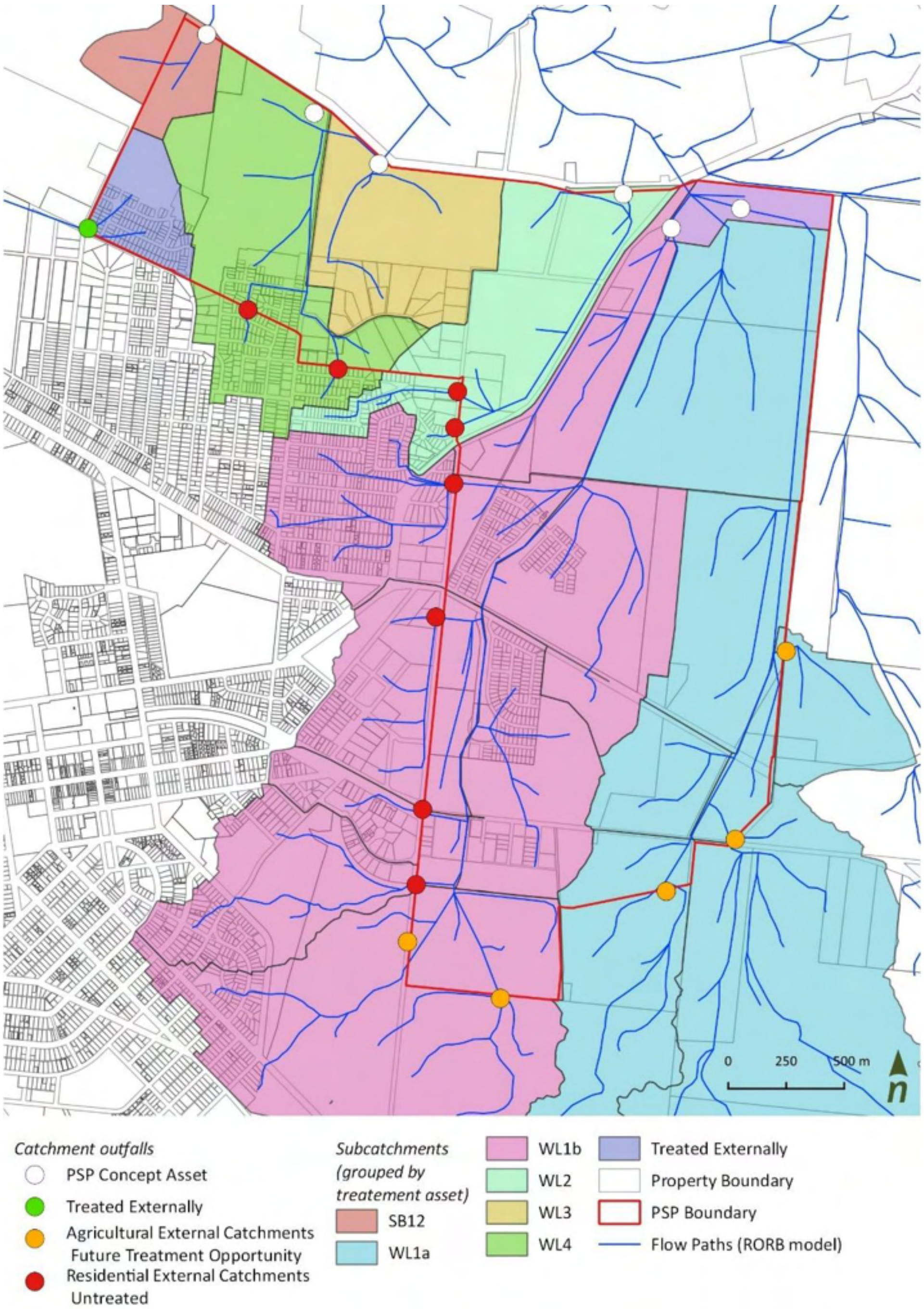


Figure 16. *Map of drainage catchments and respective outfalls indicating ideal treatment asset locations within/beyond PSP.*

The three catchments that cross the PSP may be further broken down into smaller stormwater drainage sub-catchments (Figure 17). There are 3 large sub-catchments south of the WNE PSP that is currently agricultural land use which drains through the precinct and will need to be accounted for in the functional designs. These areas have been factored into the WLRB-1A and 1B concept design footprints.

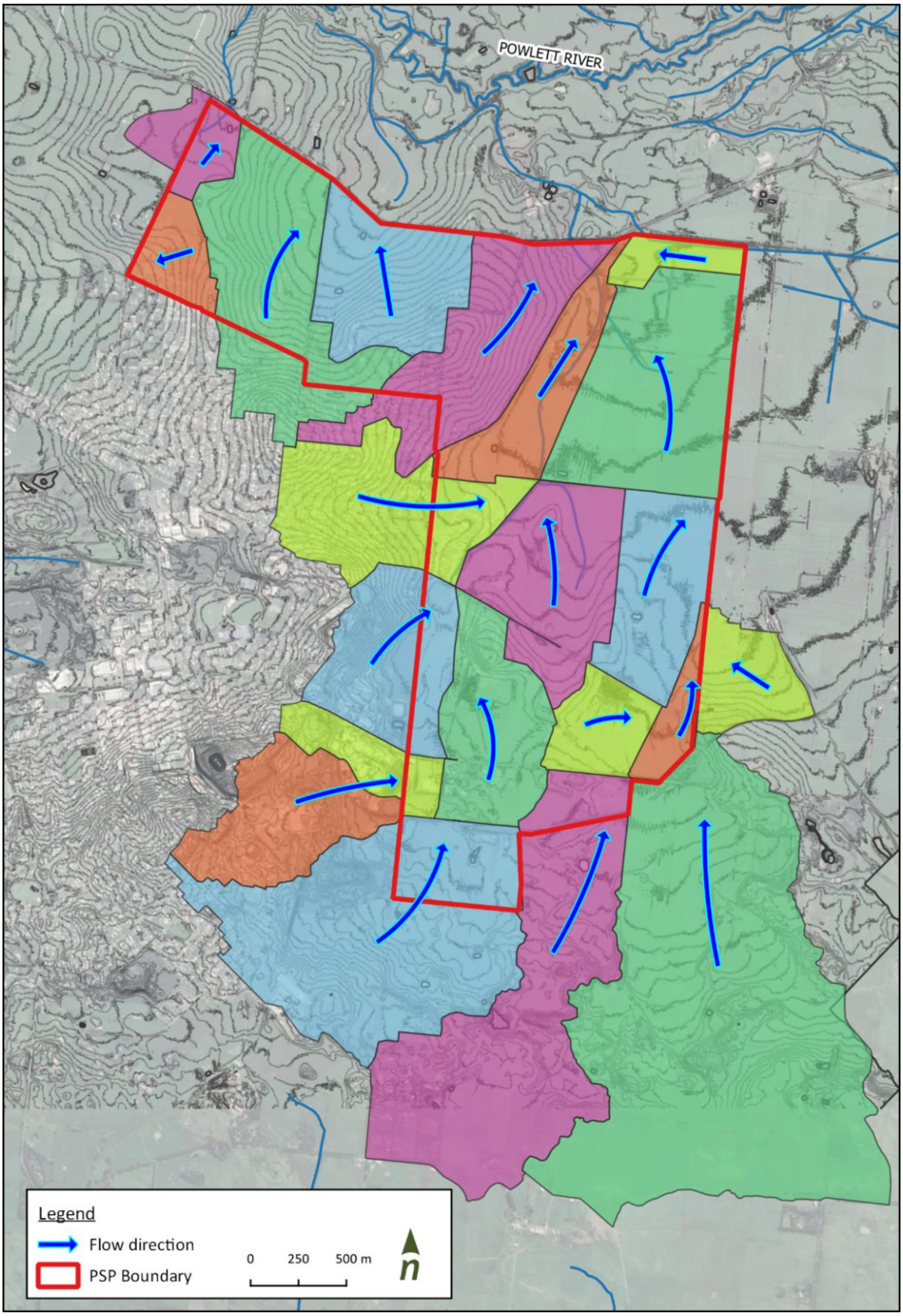


Figure 17. *Stormwater drainage sub-catchments across the PSP area (Engeny delineations, 2021)*

3.5 Flora and fauna values

As part of the precinct planning process, Nature Advisory were engaged by Council in 2020 to conduct a biodiversity assessment of the PSP area. The investigation provided information on the extent and conditions of native vegetation in the area according to *Victoria's Guidelines for the removal, destruction or lopping of native vegetation* to be used as input into the Native Vegetation Precinct Plan for the area. The study was conducted by a review of existing information on the region and two independent site visits.

- The site primarily comprised of agricultural lots which supported introduced pastures and/or used for cattle grazing
- The predominant native vegetation recorded throughout the PSP area includes:
  - Swamp Scrub (EVC 53), mainly around roadsides
  - Damp Sands Herb-rich Woodland (EVC 3)
  - Lowland Forest (EVC 16)
  - Grassy Woodland (EVC 175)
  - Tall Marsh (EVC 821)
  - Swampy Woodland (EVC 937)
- A total of 14 large native trees were recorded across the area. Nature Advisory noted under the DEWLP Native Vegetation Removal report conducted May 2020, any approval for removal of native vegetation would have the offset requirements:
  - 1.744 general habitat units with a minimum strategic biodiversity value score (SBV) of 0.338
  - The protection of the 14 large trees
- A large wetland exists near the intersection of Bass Hwy and Carneys Road, providing an aquatic habitat, and is heavily vegetated with Narrow-leaf Cumbungi (*Typha domingensis*)
- Based on the current development plan, no threatened ecological communities, flora or fauna species are likely to be impacted
- A map of identified native vegetation is provided in Figure 18.

Additional to the general biodiversity assessment, Nature Advisory was also engaged by Council in 2020 to conduct targeted Growling Grass Frog, Swamp Skink and Latham's Snipe Surveys. The surveys consisted of three separate field trips to the PSP area including active searches for the target species and placement of cameras. The surveys concluded that the PSP development posed a low threat to the target species due to:

- the current considerations and PSP retain the main fauna habitat linkages
- a lack of presence of the target species in the PSP area.

Based on the ecological studies undertaken the proposed PSP poses a low risk to the target species. The presence of roadside native flora and pre-existing wetland ecosystems provide opportunity to be incorporated into drainage strategies. Relevant existing flora should be considered when developing naturalised drainage assets such as the wetlands and waterways to improve the desired ecological outcomes.

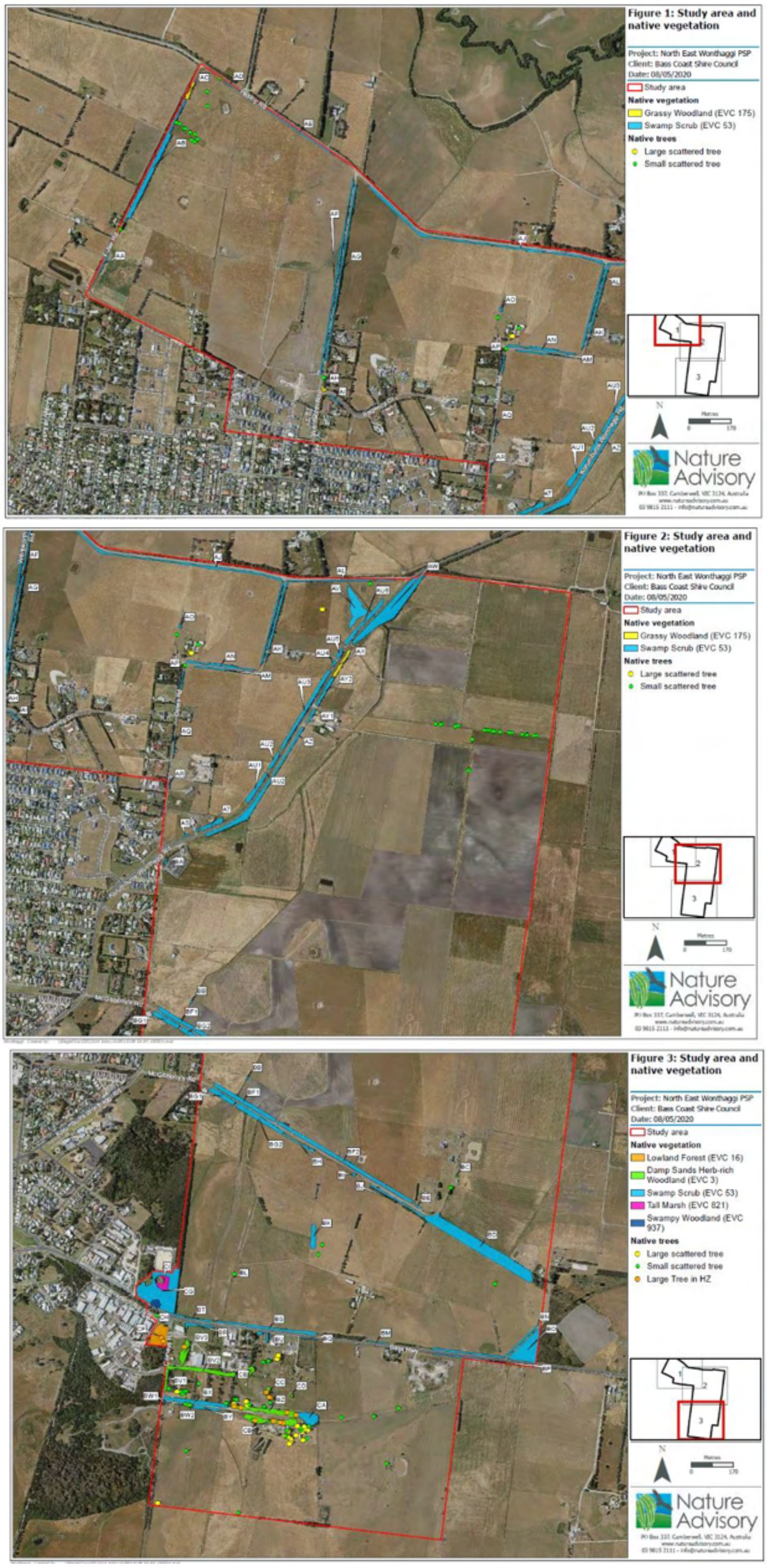


Figure 18. *Native vegetation in PSP area (source: Nature Advisory, May 2020)*

3.6 Cultural heritage

The Yallock Bulluk clan (one of the largest clans of the Bunurong People) are the traditional owners of the region. The traditional land of Bunurong People (see Figure 19) extends from the Werribee River in the north-west, down to Wilson's Promontory in the south east which includes the Powlett River catchment. The Bunurong people have a continuing connection to country, including the lands and water for which the precinct falls within.

Like many other Indigenous Peoples, the Yallock Bulluk People changed with the seasons. Their culture and lifestyle explored all elements of the diverse land around them - from hunting in the ocean for seals and mutton bird, to trading with other Bunurong clans or Koolin People in the Dandenong, Bass Valley and Upper Powlett River. The Boon Wurrung Foundation and Bunurong Land Council Aboriginal Corporation (BLCAC) are the current Traditional Owner Groups for the PSP area, with BLCAC being appointed as a registered Aboriginal Party in 2017. Their feedback and input to this project is critical.

Figure 19. *Bunurong Land Council Aboriginal Corporation (BLCAC) registered Aboriginal party (source: BLCAC website)*

An Aboriginal Cultural Heritage Survey has been prepared by Triskel Heritage Consultants in 2017 as part of the Wonthaggi North East Growth Area (WNEGA) Precinct Structure Plan. The study involved a desktop-based assessment of the PSP conducted in 2016 by Andrew Orr (Triskel) and a fieldwork component conducted in March 2017. The following provides a summary of the Aboriginal Cultural Heritage Survey:

- The survey comprised of visual (surface level only) inspection over most of the WNEGA
- Identified no new artifacts or archaeological features
- There are six approved Cultural Heritage Management Plans (CHMPs) within the current WNEGA boundaries
- Assessment of the CHMPs identified seven Aboriginal places all assessed as having low to moderate significance - no areas of high significance were found
- Dan Turnbull (Manager, Bunurong) emphasized the traditional cultural value of elevated land, while also expressing the importance of the whole area, especially considering the Yowengerra Clan (a relevant clan to the area) potentially having no living descendants.

While waterways (rivers and creeks) were typically travelling routes for Aboriginal peoples, there were often numerous landforms other than waterways, and elevated land areas that can pose a high potential to yield Aboriginal material culture. Any high impact activity (such as the proposed land development for the PSP) within defined areas of Aboriginal cultural sensitivity, requires a mandatory Cultural Heritage Management Plan (CHMP). Key recommendations from the Triskel Heritage study were to produce voluntary CHMPs, especially in the high potential locations as shown in Figure 20, and continue to consult and engage relevant Traditional Owners through the current PSP process, in this instance, the BLCAC. It is noted that to date, no CHMPs have been commissioned for areas within the PSP that indicated areas of *high potential sensitivity*.

The map below shows the predicted likelihood of Aboriginal cultural heritage occurring within the PSP area based on topographical conditions. Of note, is that the proposed locations for the functional stormwater assets to the north of the precinct do not conflict with areas of *High Potential* for Aboriginal cultural value. However, the proposed alignment of the eastern waterway (E-WW) does conflict around the McGibbonys Road intersect and should be considered in the functional design stage, to avoid and protect this 'high potential' location. Under the current regulations, this level of potential sensitivity should trigger a CHMP. In the first instance, Alluvium will seek to adjust the alignment of the E-WW to avoid and protect this location. Cultural Heritage requirements are to be confirmed as part of the functional design, and any adjustments necessary will be incorporated.

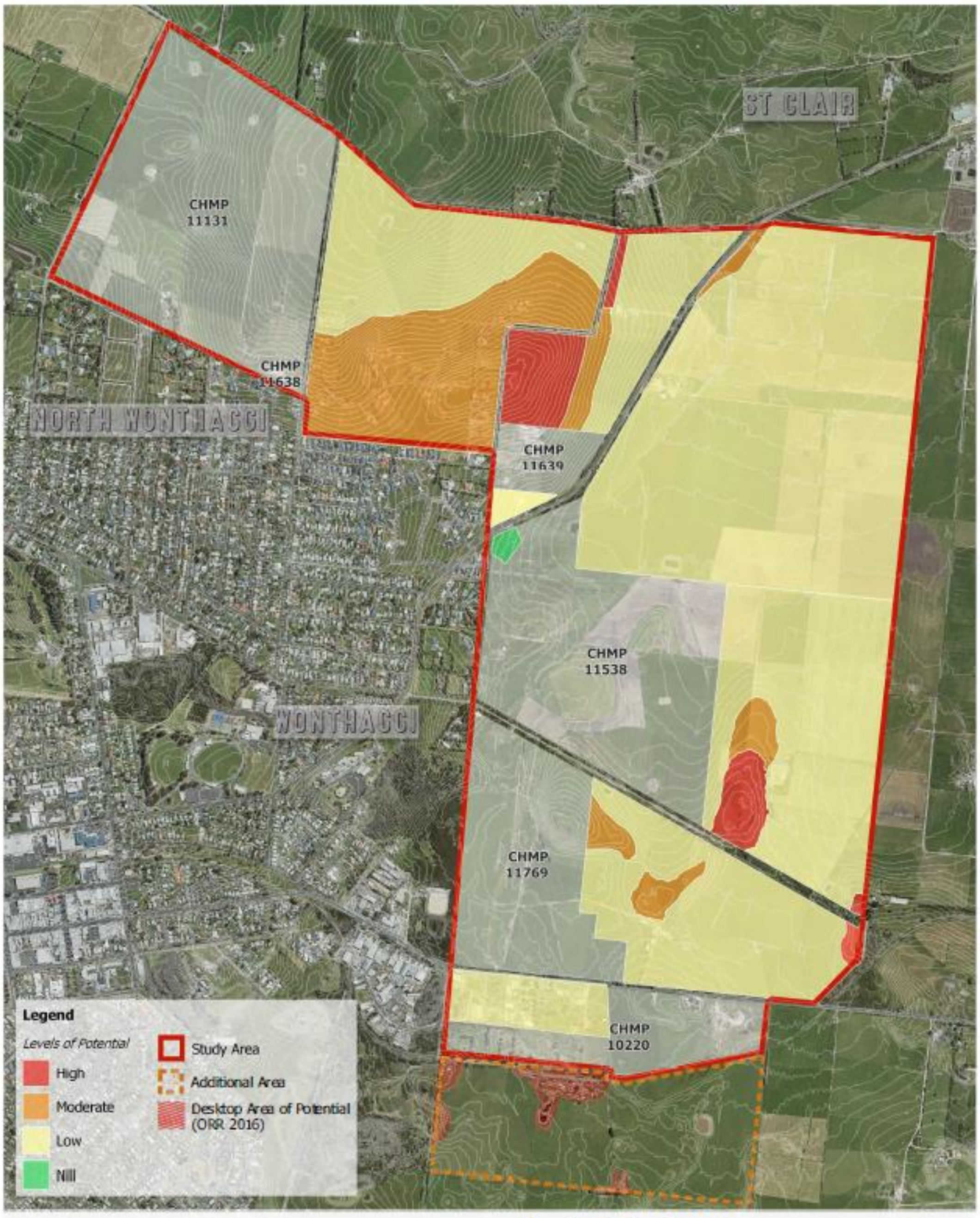


Figure 20. *Areas of Aboriginal cultural heritage potential (source: Triskel, May 2017)*

Key definitions of note for the protection of Aboriginal cultural values

High Impact Activity	Examples include the subdivision of land into three or more parcels/lots. (*Victorian Aboriginal Heritage Act 2006*, Regulation 46)
Areas of Cultural Sensitivity	Are determined using a number of spatial parameters intended to reflect where Aboriginal cultural heritage places are most commonly found; and land within 50m of these (R.25) and land within 200m of a waterway (R.26)
High Sensitivity (Most Likely potential)	As much as possible, these areas should be retained in their current form and, where applicable, be rehabilitated to further stabilise them (e.g. from erosion). This should be in the form of passive open space or other non-developable reserved land. Where lower impact works are proposed in these areas, such as pedestrian and/or bike paths, these works should be designed to minimise impacts and be placed largely on top of the surface, to avoid impacting below the ground surface where material culture is most likely.
Significant ground disturbance	Under the Aboriginal Heritage Regulations these areas are no longer areas of cultural heritage sensitivity as disturbance of the topsoil layer by machine excavation or grading (excluding ploughing) is defined as significant disturbance (R.5)
Registered Aboriginal Parties (RAP)	In this case, Bunurong Land Council Aboriginal Corporation (BLCAC) are given the responsibility for most Aboriginal heritage matters within their registered area, including being responsible for the evaluation of CHMPs (as per *Aboriginal Heritage Act 2006*).

3.7 Geology

A desktop survey was conducted to understand the geological conditions present in the PSP area. Based on publicly available State data, the predominant geological types in the PSP boundary are gravel/sand-silt layers and lithic volcanic sandstone.

It is assumed that further geotechnical investigations will be undertaken prior to the development of the Precinct, and implementation of the proposed drainage assets.

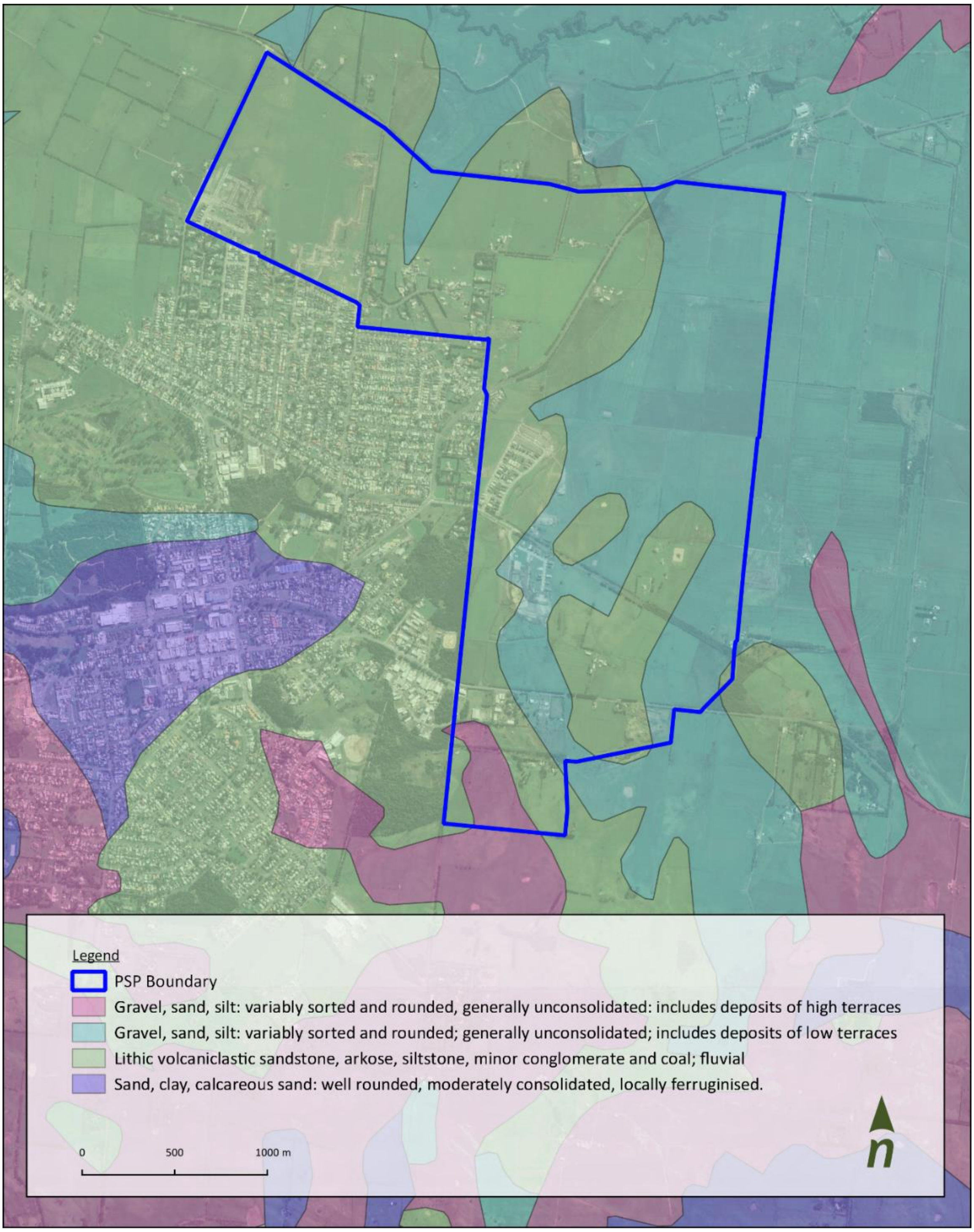


Figure 21. *Geological features of PSP and surrounding areas*

3.8 Climate change

Victoria's climate is changing and will continue to change into the future. With continued increases in greenhouse gas concentrations, the majority of climate models predict Victoria's climate will become hotter and drier. The latest research from the Victorian Climate Initiative (DELWP, 2016) has identified clear reductions in cool season (April to October) rainfall over recent decades. Compared to current conditions, median climate projections for 2065, expect that Victoria will experience a temperature increase of between 1.9 - 2.6°C and an increased rate of potential evapotranspiration of 6% - 8%. The greatest impacts from climate change are projected to occur in western Victoria.

Changes to Wonthaggi's water cycle, due to climate change, have been drawn from DELWP (2016). These guidelines provide projected climate data for Victoria's River Basins to 2065. Figures from the South Gippsland Basin median climate projection are summarised in below.

While the overall annual rainfall and runoff will decrease, the intensity of storms is expected to increase, which is discussed in Section 6.4.

Table 2. Estimated changes in climate, relative to current climate baseline in South Gippsland Basin (DELWP, 2016)

Criteria	Baseline (1975-2019 Average)	Change relative to baseline	
		2040	2065
Temperature			
Median temperature change (°C)		1.1	2.1
Potential evapotranspiration	1100		
Median potential evapotranspiration		4%	7%
Rainfall (mm)	872		
10th percentile (low)		2.6%	2.2%
50th percentile (medium)		-4.5%	-4.4%
90th percentile (high)		-11.7%	-15.9%
Average annual runoff (mm)	170		
10th percentile (low)		8.8%	1.6%
50th percentile (medium)		-11.9%	-16.9%
90th percentile (high)		-33.7%	-44.8%

** Please note: the figures in above table represent the whole South Gippsland Basin and not specifically Wonthaggi.*

Wonthaggi's climate

Wonthaggi has a mild temperate climate zone with warmer, drier summers and cooler, wet winters with an average annual rainfall of 970 mm (SILO gauge 86217, 1975-2019 average). Figure 22 shows the monthly average temperatures and rainfall across the year, and Figure 23 shows the total annual rainfall from 1975-2019.

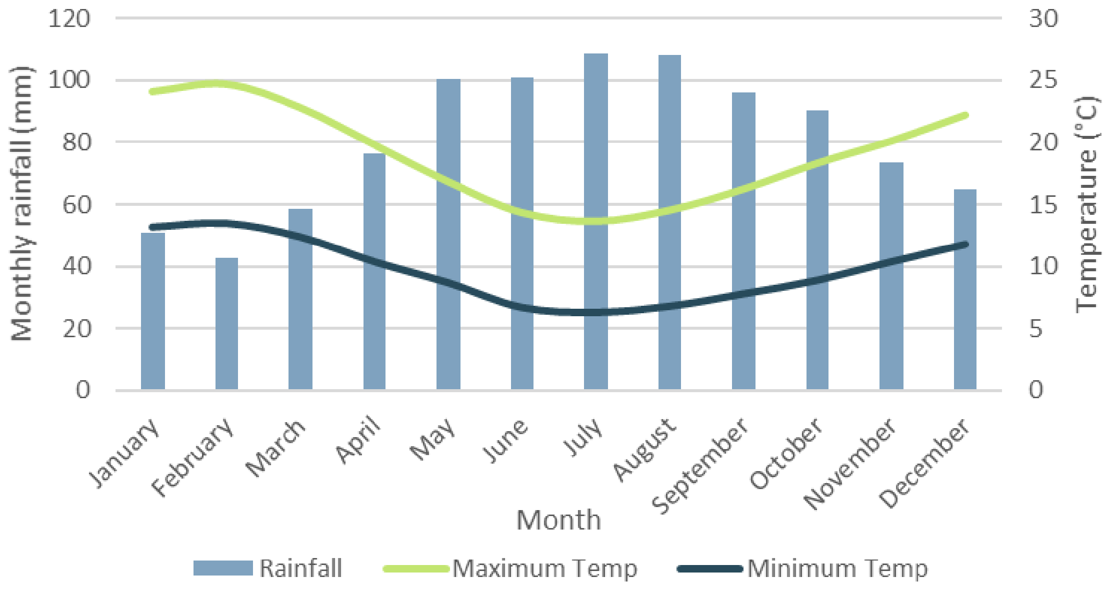


Figure 22. *Wonthaggi's average monthly rainfall (mm), average maximum temperature (°C) and average minimum temperature (°C) based on climate data from 1975 to 2019 (BOM, SILO gauge 86217)*

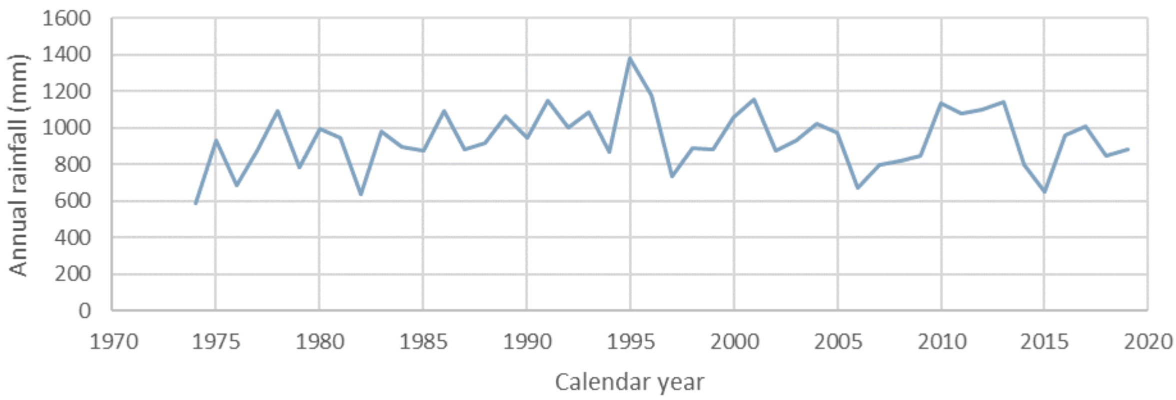


Figure 23. *Wonthaggi's annual rainfall (mm) from 1975 to 2019 (SILO gauge 86127)*

4 Review of Existing Drainage and Flood Studies

Flood Management Strategy for 465 Heslop Road (Engeny, March 2021)

In response to concerns raised in the C152 amendment of the PSP, Engeny was engaged by council to produce an Impact and Proposed Mitigation Works report to reduce flooding conditions to the property at 465 Heslop Road (directly north, and downstream, of the PSP boundary, hereafter referred to as the subject property). The concerns raised by the landowners was that increased runoff from the developed area would exacerbate flood conditions already existing on the property resulting in an inability to run the dairy farm.

Engeny produced an impact assessment using a more complex and detailed software (TUFLOW), allowing for considerations to be made for the inflows (riverine flooding) from the Powlett River. Their findings were that within the subject property:

- An increase in flooding in the 50% AEP event of up to 60 mm (up to 100mm at some locations)
- An increase in flooding in the 20% AEP event of generally less than 40 mm
- An increase in flooding in the 1% AEP event of less than 30 mm with the PSP flows only. When the Powlett River flows are included, there is no increase in the peak flooding experienced on the subject property.

The interpretation of these results was that although there is an increase in flows from the precinct to the subject property in the 1% AEP event, inundation within the subject property was dominated by inflows from rural catchments to the east of the property, flooding into the Powlett River. There is also a significant increase in flooding depth in the 50% AEP.

To reduce the impacts of flooding, Engeny proposed increasing the capacity of existing channels on the subject property (see Figure 24), targeting the conveyance of flow from the proposed PSP's Wetland 1 and Wetland 2 outfalls, and discharging these to a vegetated area adjacent to the Powlett River. The channels were sized to convey a 50% AEP flow. Engeny estimated the mitigation works costing a total of $511,800 which would likely be funded by the PSP and undertaken by Council or a contractor working on their behalf.

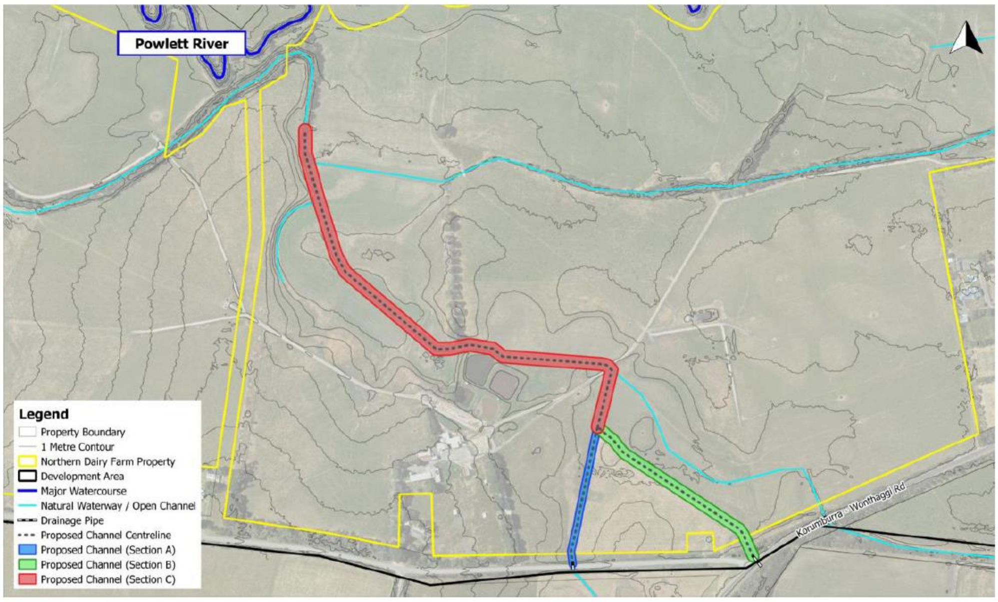


Figure 24. *Planned mitigation works to reduce flooding on the subject property – 465 Heslop Road (source: Engeny, March 2021)*

Alluvium assessment
The challenges identified in the proposed precinct outfall concept (above) is in the ability to evenly distribute discharges (outfall flows) over a suitable vegetated area (as suggested) without causing erosion or vegetation damage/losses. The channelisation of these flows from distributed assets in the precinct through the outfall to the river will naturally increase velocities as flows are concentrated within a defined channel, to a given point in the riparian zone of the river, which potentially can cause - in the short term site erosion, medium term loss of riparian vegetation and bank erosion/collapse, and potentially in the longer term, headward erosion back up the outfall channel through the private land. It should also be noted the presence of levees along the Powlett River and how the channel outfall interacts and does not compromise these flood protection levees.

NOTE: Alluvium understands that Engeny have now submitted all deliverables as part of their previous engagement. This leaves Alluvium/VPA to reconcile the incomplete outfall model and concepts, in order to proceed to the functional design stage. Subject to VPA approval, Alluvium understands that the conceptual model for the ultimate (main) outfall solution for the PSP needs to be undertaken prior to functionals. Of note is for Alluvium to address the missing section of the Engeny outfall design (which currently ends / stops short of the river and discharges to the riparian / vegetation zone). Reconciliation of the river bank levees will also need to be considered here.

Wonthaggi PSP Wetland Functional Layout Plan [WL3 & WL4] (Engeny, February 2020)
Engeny prepared a functional layout plan for the Wetland 3 & Wetland 4 assets for the PSP. The two wetland treatment assets are located at the north-west corner of the PSP at the intersection of the 'proposed' Wentworth Road extension and Heslop Road. The wetland designs include:

- Inlet pond / sediment basin for each wetland
- Maintenance access ramps to the base of each sediment basin
- Sediment dry-out areas provided for each sediment basin
- Balance pipes between open water zones within the macrophyte zone
- Wetland vegetation zones provided in a banded manner
- Sediment basin transfer pits / pipes to outfall from the sediment basin to the macrophyte zone of wetlands
- Outlet from the wetlands through the downstream adjacent property to the north.

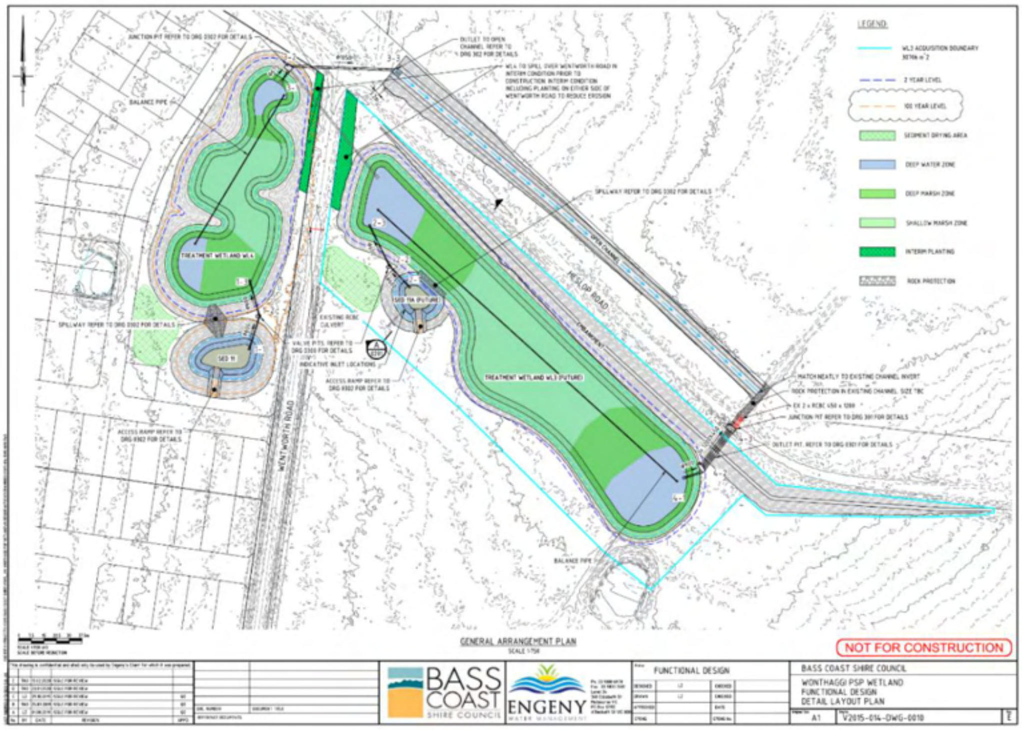


Figure 25. *Functional layout plans for proposed wetlands WL3 & WL4 at Wentworth/Heslop roads (Engeny, 2020)*

Alluvium assessment

An initial assessment of the wetland functional layout plans has been completed as part of Alluvium's background review (July 2021).

Constructed wetlands are man-made surface water management systems that aim to mimic natural wetland systems by filtering surface water flows through:

- Physical processes – a combination of wetland form and aquatic plant selection and placement
- Biological / chemical processes – nutrient cycling, chemical uptake and contaminant removal (including heavy metals)
- Transformation processes – stabilising and 'fixing' contaminants like phosphorus and metals; converting pollutants such as ammonium and nitrogen into inert (non-reactive) gases (denitrification) released safely to the atmosphere; and providing some disinfection through ultraviolet (UV) exposure across open water areas.

Wetlands are a tertiary treatment component typically part of a 'treatment train' with an upstream primary treatment component such as a sediment basin or gross pollutant trap (GPT). Wetlands are shallow waterbodies with extensive vegetation coverage and long flow paths to reduce flow velocities and allow treatment action.

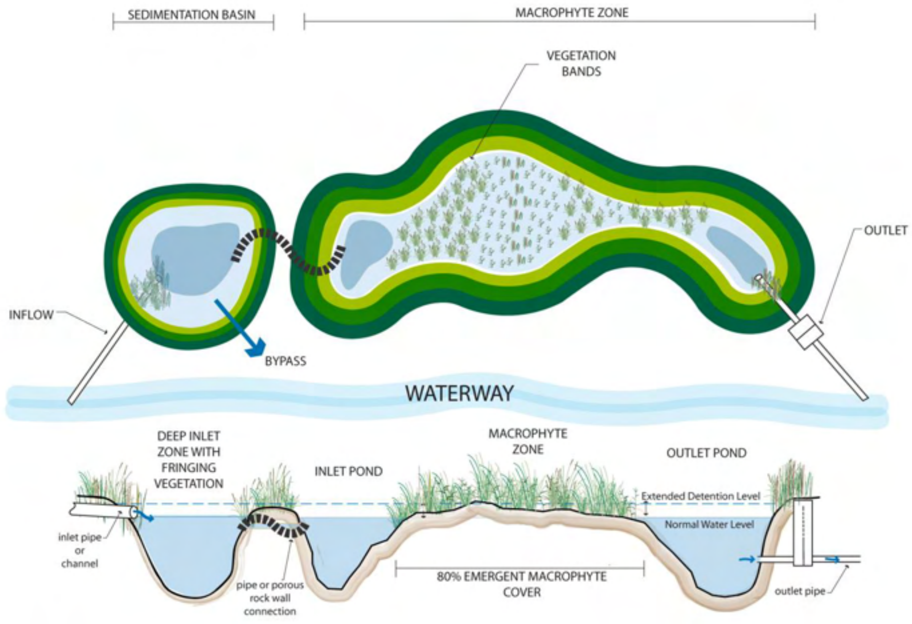


Figure 26. *Typical concept layout of a treatment wetland (source: Melbourne Water)*

Constructed wetlands are comprised of three (3) main parts:

- Inlet zone – a sediment forebay or sediment basin that allows coarse sediment (> 125 micron) deposition (and litter) to protect the main body (integrity and lifespan) of the wetland. The sediment basin performs the primary treatment function in the treatment train and passes pre-treated flows into the inlet zone (first deep pool) of the wetland.

- Macrophyte zone (bounded by with inlet and outlet pools) – Pre-treated flows then move from the inlet zone (first wetland deep pool) and pass slowly over a 48-72hr period through a combination of shallow marsh and deep marsh zones (macrophyte zone) before entering the final deep pool (or outlet zone). A controlled outlet helps detain flows within the wetland for the treatment duration. The macrophyte zones are densely planted with specifically selected aquatic vegetation that filter flows and remove the pollutants from the water column.

    - Fine sediments and heavy metals which adhere to fines (e.g. clays) are trapped by the vegetation and 'locked' to the wetland floor (preventing their re-suspension).
    - Nutrient cycling of dissolved organics in the water column (e.g. phosphorus and nitrogen) is undertaken by the aquatic plants (for their growth and survival).
    - Micro-organisms (biofilms) growing on the surface of aquatic plants absorb pollutants and trap fine suspended particles through adhesion.
    - Stabilisation and 'fixing' of contaminants (e.g. phosphorus and metals) in the wetland soils through regular wetting and drying cycles of the designed wetland.
    - UV treatment in open water sections of the wetland provides a level of disinfection.

- High-flow bypass channel – allows excess flows to pass around (and not through) the wetland to protect wetland stability and plant survival (from bank, floor and vegetation scouring); and ensures further flows are bypassed when maximum extended detention depth (EDD) is reached within the wetland, allowing the system to effectively treat flows and achieve pollutant reduction targets as generated from the source catchment.

  Note: pollutant reduction targets are not about reducing by target percentages from the volume of water that enters the wetland, but a reduction in pollutants generated from the land area. Excess volume within the wetland reduces its design intent function in pollutant reductions.

Summary of Alluvium's assessment

- No indicative inlet location is provided for sediment basin - SB11.
- Connection between the sediment basin (SB11) and the macrophyte zone of WL4 (WLRB4) should be made into the open water zone, not the macrophyte zone. Currently, the concept designs show these flows out-falling from the sediment basin into the deep marsh vegetated zone and will likely result in higher sheer stresses (as flows from SB11 are concentrated and piped, increasing velocities) and stripping vegetation. This also results in a 'short circuit' of the wetland where flows are bypassing the first deep pool or wetland inlet zone where velocities are mitigated, and first line of the treatment process begins.
- The width at NWL along the wetland macrophyte zone of WL4 (WLRB4) is very constricted near the outlet pool, but within the deep marsh zone. Constricting the width at NWL too much at this point will likely result in increased velocities through this vegetated section of the wetland, and likely strip vegetation.
- The wide meanders along WL4 (WLRB4) will likely result in areas of stagnation at the widest points or ineffective flow areas and reduces the overall treatment efficiency of the wetland.
- Sediment basins and wetland macrophyte zones have been set at the same NWL. For maintenance purposes it is more ideal to have the sediment basin NWL set at least 100mm above the wetland macrophyte zone NWL, to allow for draining of the sediment basin for sediment clean outs.
- To protect the integrity of the wetland and vegetation drowning out from an increased inundation duration, it is recommended that a high flow bypass of the wetland asset be incorporated, for events greater than the 20% AEP. Further, if these high flows are not diverted around the wetland, the pollutant reduction performance of the wetland will drop significantly as it is unable to manage these high volumes and reduced pollutant concentrations (dilution is not an acceptable pollutant reduction approach to waterway protection).

  The 1% AEP gap flows (i.e. 1% AEP minus the 20% AEP flow) can be managed via overland flow paths along road reserves.

Powlett Ridge Estate – Endorsed layout plan (June 2019), Revised Stage 1 detailed plan (Feb 2020), Revised Stage 4 detailed plan (Sept 2021)

Powlett Ridge Estate is one of two main developments proposed for the Wonthaggi North East PSP. Brosnan Engineering Solutions produced a 'Proposed plan of subdivision' endorsed by Council (June 2019). Subsequently, Brosnan produced revised detailed layouts for stages 1 and 4 of the proposed Powlett Ridge Estate (dated February 2020 and September 2021 respectively). Alluvium received all three documents on September 9th 2021 and have addressed these as part of this revised PoC.

Summary of Alluvium Assessment of key components of approved plans:

- Land take for proposed W-WW accounted for as 'future reserve space'
- Detailed plans (2020 and 2021) allow for roughly 45m wide future reserve space
- Reserve area broadens at upstream section of precinct
  - Note: This location aligns with proposed SB4
  - Note: Detailed designs do not specify the construction of an SB - Council could negotiate to have this asset (SB4) included in the development plans to manage gross pollutants from the developed area.
- Stage 1 of the development plan included the subdivision of land, where the north-western lot at McGibbonys Rd was purchased by the Department of Education and Training Victoria (DETV)

- **Note:** Currently plans for a sediment basin (SB5) on this location may be difficult to see to fruition – it is recommended that this SB5 be made redundant. The downstream WLRBs have been considered on the basis SB5 will not exist in future.

- Changes in waterway alignment from the endorsed plan (2019) to the detailed layout (2021) has resulted in a widening and straightening of the upstream section of the waterway (W-WW) feeding into the future reserve area
  - **Note:** this relates to the headwaters section of W-WW, south of McGibbonys Road (existing constructed section) and does not directly impact this PoC or functional design set.
- Whalebone Boulevard is currently planned to pass over the waterway entrance to the future reserve, subsequent culverts should be sized appropriately to convey 1% AEP flows.
  - **Note:** this relates to the headwaters section of W-WW, south of McGibbonys Road (existing constructed section) and does not directly impact this PoC or functional design set.
  - **Note:** Other detailed designs regarding stormwater conveyance appear appropriate and require no change.

The subdivisional layout plan has provided a drainage reserve area in line with the proposed PSP land budget for SB4 (based on Engeny's strategy). Revision to straighten the upstream waterway section (under Whalebone Blvd) will allow for a more direct passage of water through the reserve. **Advice to council:** Culverts should be sized appropriately to convey 1% AEP flows; and consideration of flow velocities and potential erosion due to channel change should be considered if undertaken in future.

The recently endorsed / detailed plans provided for Powlett Ridge Estate have been considered for this study and are found to be in line with Alluvium's prior understanding of the site based on background information, discussions with Council/VPA, site assessment and previous strategy documents.

As such no changes are required in our modelling approach in relation to this area.

5 Engeny Drainage Strategy (September 2021)

Engeny were engaged by Bass Coast Shire Council to investigate the stormwater quantity and stormwater quality treatment requirements of the proposed Wonthaggi North East Development Precinct. This section relates to the review of the revised drainage strategy (September 2021) predominately, and review of the original strategy (October 2019) with respect to costings and the initial PSP/DCP layout. A review of the subsequent Engeny reports and outputs (February 2020, March 2021) received to date, has been included in this section.

It is noted, the initial cost estimates used to inform the initial PSP/DCP were based on the original Engeny Strategy (2019), no cost estimates were included as part of the Engeny revised strategy (September 2021), costs are likely to vary between the revised strategy and the original due to a redesign of proposed assets. Alluvium's review and analysis of the proposed approach for the PSP for surface water management is offered in light of an understanding of existing values and constraints, background investigations, stakeholder input, and the PSP objectives.

The revised Engeny drainage strategy was undertaken in parallel with the Wonthaggi North East PSP functional designs (Alluvium study). As a result, the final Engeny Strategy of September 2021 has now informed this PoC Report, and changes have been captured to ensure steps going forward are consistent with the final revised strategy (Sept 2021).

The proposed concept layout plan for the Engeny 'drainage strategy' that informed the DCP and received up to 13th August 2021 has been included in Figure 2 (above) alongside the latest concept layout plan received September 2021 (final strategy). Table 1 (in Section 1) attempts to draw correlations and conflicts / changes between these two key concept layouts to aide in reader tracking. **Note:** This table has been updated to reflect the new 'final strategy'.

5.1 Summary of previous work

The following is based on all information provided up to and including the submission of the Engeny 'final strategy' (and past strategy versions, reports, DCP and data received to date). A review has been completed to inform a base understanding of the PSP area and provides Alluvium with an understanding of the strategy intent and the proposed drainage interventions (assets). The strategy has assumed the following:

- Development density of 11 houses / or lots per hectare
- Fraction impervious of the residential development area of 0.65
- The development precinct is required to meet best practice treatment of stormwater prior to outfall into the Powlett River, which includes:
    - 70% removal of the total Gross Pollutant load
    - 80% removal of the total Suspended Solids (TSS)
    - 45% removal of the total Phosphorus (TP)
    - 45% removal of the total Nitrogen (TN).
- All drains out falling into an existing or constructed waterway will receive primary sediment removal treatment through sediment basins
- Confirmed with the WGCMA there is no requirement to control peak flows to predevelopment peak flow rates for major storm events (i.e. 1% AEP), understanding the significant cost burden likely:
    - Increased runoff due to development in more frequent storm events means downstream land owners are subject to more frequent inundation, as a result more frequent events are to be controlled back to predevelopment peak flow rates.

5.2 High level cost estimates (Engeny 2019)

The Engeny estimated landscape and civil costs for the Wonthaggi North East Development Precinct, based on the original 2019 strategy and DCP are as follows:

- $25,284,000 for conveyance related drainage infrastructure:
    - $16,389,000 is estimated for constructed waterways
    - $4,438,000 is estimated for culvert structures
    - $4,457,000 is estimated for drainage pipelines.

- $10,070,000 for stormwater treatment infrastructure:
    - $3,439,000 is estimated for WLRB1
    - $1,017,000 is estimated for WL2
    - $1,935,000 Is estimated for WL3
    - $1,400,000 is estimated for WL4
    - $2,279,000 is estimated for stand-alone sediment basins.

- $4,328,000 for the retarding basin infrastructure at WLRB1.

The total cost of the Engeny strategy is equal to $39,682,000. This total infrastructure excludes the costs associated with land acquisition and inclusion of litter traps or high flow bypasses of the sediment basins. A 35% contingency was applied to the overall costs.

5.3 Review of final strategy (September 2021)

A high-level review of the Engeny Final Strategy has been undertaken, based on an understanding of known values and constraints, and feedback from stakeholders.

Sediment Basins

- Includes 14 sediment basins, 8 of which outfall directly into the proposed waterway corridors. In order to reduce costs of excavation / land take, consolidation of some sediment basins provides an opportunity to reduce the overall Development Contributions Plan (DCP) rates.

- Each sediment basin will require safe batters, hardstand areas for maintenance access and dedicated area for sediment drying prior to disposal – all of which will impact overall asset footprints / land take / asset costs. These will be addressed as part of the future concept / functional designs and ensure stormwater quality treatment to best practice reduction targets are achieved.

- The proposed sediment basins are to be sized using the Fair and Geyer equation, where sediment basins must meet the following criteria:

    - Capture 95% of coarse particles ≥ 125 µm diameter for the peak 4EY event.

    - It should be noted that several of the sediment basins have been significantly undersized and are currently not meeting the capture efficiency target highlighted above. This is likely to result in a high amount of sediment transferring from the sediment basins into the proposed waterway corridors, and subsequently, the proposed wetland assets.

    - Sediment basins have been designed to include a clean out frequency of 3 years. A 5 year cleanout frequency may be more desirable (and is standard industry practice and recommendation) to reduce ongoing maintenance costs.

    - Sediment basin design calculations / performance (based on Engeny revised strategy) are provided in Appendix A.

Wetlands

- WLRB1 has been designed as online to the constructed waterways, as it is expected to receive flows from the external rural catchment.
- Wetlands that are located online to a waterway generally experience increased durations of inundation and high velocities through the system, as a large volume of flow generated from the catchment is required to pass through an online wetland. This is likely to result in stripping of vegetation due to higher velocities and vegetation 'drowning' due to increased periods and depths of inundation.
- Due to a large contributing catchment to WLRB1, a large regular flow is expected to enter the system via the waterways. Currently, the proposed wetland designs do not meet velocity threshold limits of 0.05 m/s in the 4EY event, and 0.5 m/s in the 20% AEP event, whilst maintaining an appropriate length to width ratio of 4:1. Wetland velocity calculations / performance have now been updated (based on Engeny's Final Strategy, Sept 2021) and provided in Appendix A.
- It is noted WLRB1 is also carrying 319mm of excess volume, above NWL and needs to be addressed through increasing the wetland size and macrophyte zone to safely distribute this volume and ensure wetland function. WLRB's 2, 3 & 4 also have increased water level exceedance, and are to be addressed as part of the functional designs.
- Based on the proposed strategy, it is assumed any future development that occurs upstream of the PSP area is controlled back to predevelopment conditions, and stormwater treated to BPEM guidelines prior to out falling into the PSP area.
- Following the analysis of the RORB and MUSIC modelling undertaken by Engeny, the total contributing wetland catchments are summarised below and in Figure 27.
  - WLRB1 contributing catchment: 1126.42 ha
  - WLRB2 contributing catchment: 73.03 ha
  - WLRB3 contributing catchment: 153.61 ha
  - WLRB4 contributing catchment: 101.34 ha.

Waterway Corridors

- The overall waterway corridor widths provided within the strategy appear adequate (40-60m). However, the lack of sinuosity (meandering) of the waterway layout is likely to lead to higher velocities, erosive capabilities, and in time compromise bed, bank and associated vegetation.
- The proposed industrial area at the southern extent of the precinct on Carneys Road should require installation of a triple interceptor or similarly suitable product to manage quality of flows from this area discharging into the waterway.
- The E-WW (located along the eastern boundary of the PSP) includes a '90 degree' bend prior to outfall into the proposed WLRB1 asset. This is likely to result in localised high velocities / shear stresses, which will result in erosion along the banks and incision of the waterway over time, and potential short circuiting of the system. If a 90 degree bend along the waterway is to remain, substantial rock armouring / beaching will be required to ensure the waterway can be retained in this form (without short circuit/bank collapse). It is recommended the alignment of the waterway is adjusted to remove the bend.
- While the E-WW is proposed to remain within the PSP boundary (as per Council direction to Engeny, Revised Strategy) it is recommended this be reconsidered. Sinuosity of the waterway will improve its overall performance, stabilisation and establishment as a waterway (over time) and not a drain. Currently the proposed footprint form lends itself to being more an open channel or drain with little opportunity for flora and fauna to establish and sustain. Improving waterway meanders will provide increased management of velocities, system stability and reduce maintenance demands.
- Combined with areas of deeper pools and rock riffle zones with meanders, will not only better stabilise and protect the system, but will encourage a biodiverse 'creek' environment allowing

macroinvertebrates to move in and breed, providing a reliable food supply for higher order species (birds, frogs, etc).

- Further, the landscape amenity, community enjoyment and appreciation of these constructed waterways will be further improved, increasing their value to the community and therefore their passive surveillance (through use / visitation) and protection.

Culverts

- Multiple outfall culverts from the PSP are proposed across Heslop Road, more specifically, two are proposed at the WLRB1/WLRB2 locations, and two are proposed at the WLRB3/WLRB4 locations. It may be more desirable to consolidate these culvert assets, designed appropriately and reduce number of assets for long term maintenance / asset renewal costs, and initial capital investment.

- Engeny model has included 10 x 338mm dia. Polypropylene circular pipes under Korumburra-Wonthaggi Road. This is a large number of pipe assets proposed as an outfall system (from WLRB1), alternative outfall arrangements will be investigated as part of the functional design.

Retarding Basins

- Due to the tailwater effects of the Powlett River floodplain, retarding basins have been sized using TUFLOW. As such storage sizes of each retarding basin, and their respective outlets have been sized to reduce flows, and the downstream afflux flood depth (developed conditions flood depth minus the existing conditions flood depth).

- Each retarding basin has been designed to include a wetland located within the base of the system, which provides stormwater quality treatment for the Precinct.

- The TUFLOW model is required to be updated to include any changes to the retarding basin/wetland systems, as well as any changes to the constructed waterway systems.

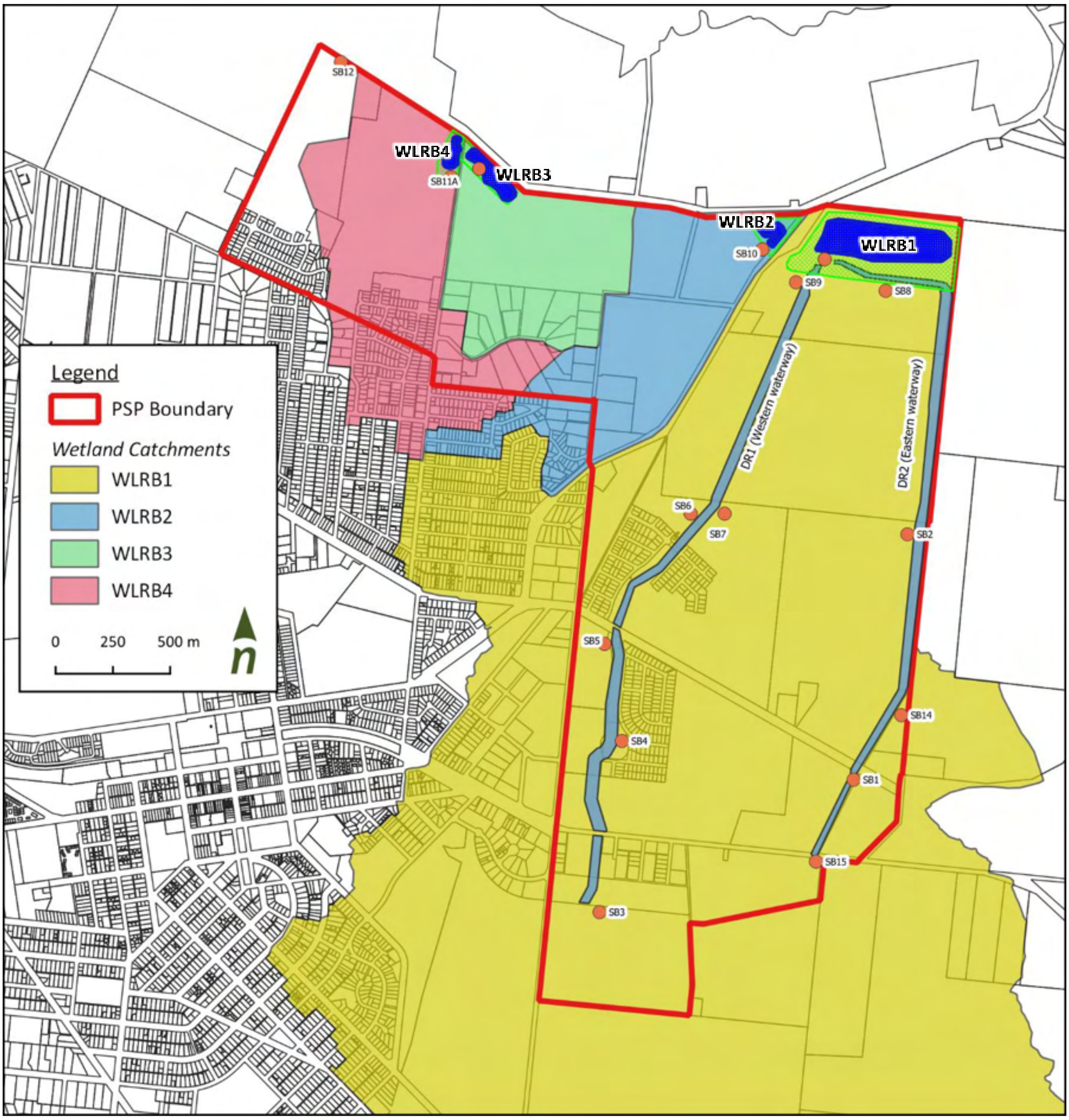
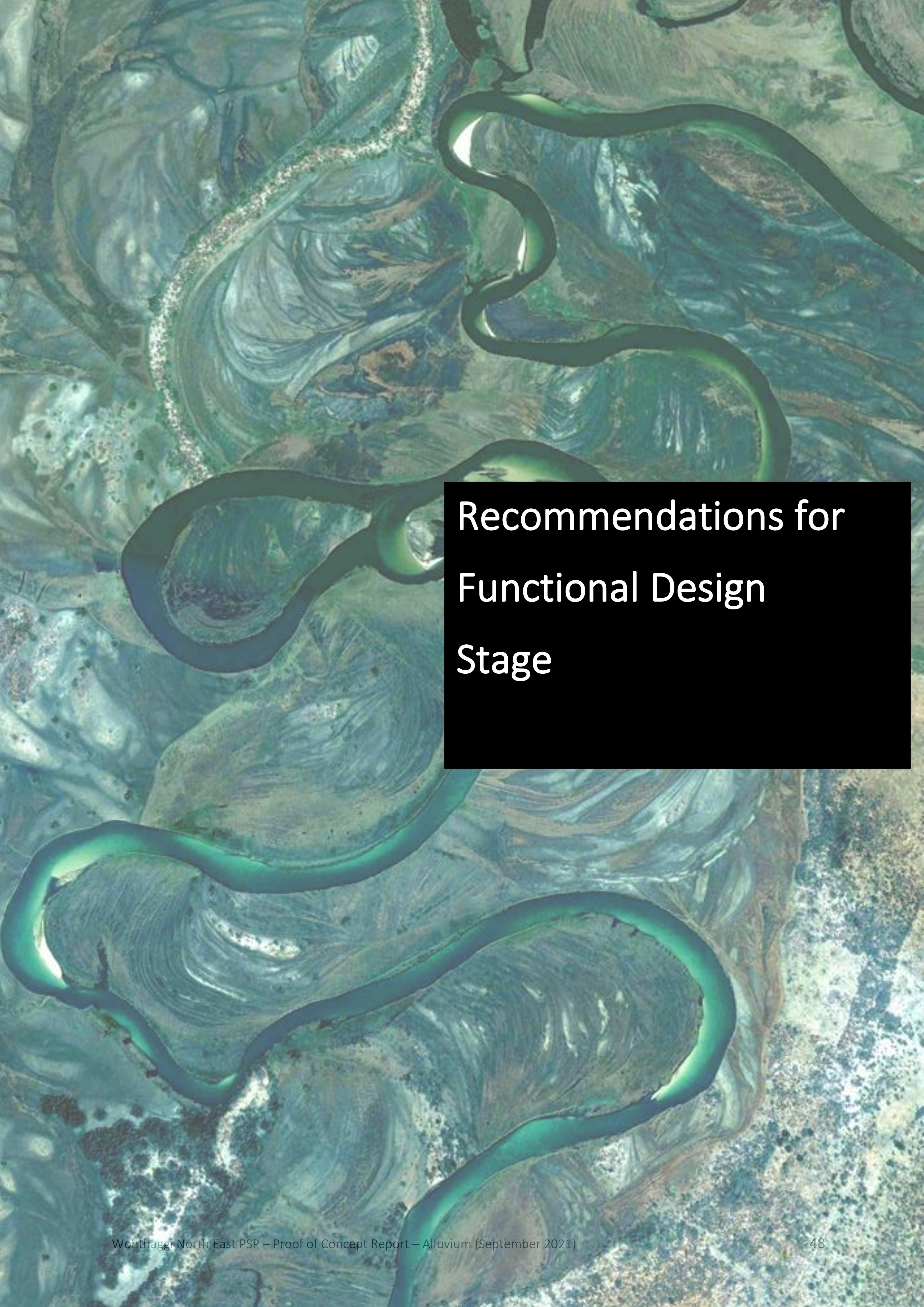


Figure 27. *Contributing catchments for each WLRB (map based on digitized Engeny Sept 2021 proposed layout; and revised RORB models, received July 2021)*



Recommendations for Functional Design Stage

6 Recommendations for Functional Design Stage

6.1 Asset confirmations

The following observations are made of the proposed stormwater assets as they relate to the final strategy work undertaken by Engeny. This section attempts to address all strategies from 2019 to 2021 and account for the changes in assets for the PSP and the likely list of functional designs to be undertaken by Alluvium.

- **Four retarding basins** with a stormwater quality treatment wetland located within each.
  - The 1% AEP gap flow (i.e. the 1% minus the 20% AEP flow) outfalls into the proposed retarding basins via overland flow paths along proposed road reserves, or via the two proposed waterway corridors (W-WW and E-WW).
- **Four stormwater quality treatments wetlands** are located along the northern boundary of the precinct:
  - It is noted that all four wetlands are performing flow retardation function (not just WLRB1), therefore all 4 wetlands are now integrated WLRB assets in their own right.
  - WLRBs 2, 3 and 4 were advised (13 August meeting with Engeny/VPA) to be carrying approx. 100mm extra above NWL, while WLRB1 is carrying approx. 200mm above NWL – these will have an impact on aquatic species selection / plant survival due to inundation depths but could be managed with right selection.
  - However, more recent advice (to Sept 2021) indicates WLRB1 is carrying 319mm above NWL, WLRB2 170mm, WLRB3 144mm and WLRB4 166mm above NWL – these will now require further analysis of the MUSIC models to determine asset performance and plant function/survival which may be achievable for WLRBs 2-4, however, unlikely with WLRB1, which will likely require expansion to distribute this high excess and reduce inundation depth / duration above NWL.

*Therefore, we can confirm that there are **4 integrated WLRBs** that require functional designs for the northern precinct boundary.*

- **Two constructed waterways** are proposed, both of which run through the eastern catchment of the PSP, with up to a 60m wide corridor widths provided (as required by WGCMA):
  - The western waterway (W-WW) runs along the western boundary of the precinct before out falling into the proposed Wetland-Retarding Basin 1 (WLRB1). The waterway consists of a 45m waterway corridor width at the upstream extent of the asset (south of McGibbonys Rd), then transitions to a 60m corridor width at the downstream extent (north of McGibbonys Rd).
  - The eastern waterway (E-WW) traverses the eastern boundary of the precinct, initially starting near the Bass Highway and also out falling into the proposed WLRB1. The waterway consists of a 55m waterway corridor (south of Bass Hwy) before transitioning to a 60m wide waterway corridor at the downstream extent (north of Bass Hwy).
  - It is noted both waterways proposed have very channelised (straightened) footprints which herald potential for bed and bank scour due to high velocities and sheer stress. A further look at the modelling indicates a poor hydraulic width to length ratio – cross section base/top widths are narrow for the required flow conveyance, resulting in a higher flood depth and constrained channel width which will likely lead to erosive conditions. An example of this can already be seen in the constructed section of W-WW along the Powlett Ridge subdivision / DETV land, south of McGibbonys Rd.
  - Alluvium is recommending a more sinuous (meandering) waterway footprint to reduce velocities, flood depths, and maintain integrity of these constructed waterways into the longer term – this is well demonstrated in the section of the waterway adjacent to Park View Estate (refer Section 3.1, site 7 observations).

- It should be noted that during Alluvium's background research of intrinsic site values, we note the Triskel Heritage study which identified areas of potential Aboriginal cultural heritage. Of note is the *high potential* location where McGibbonys Rd intersects with the start of E-WW. While the alignment being proposed by Engeny and Alluvium does not look to excavate in this *high potential* location, its proximity to the proposed works may indeed trigger a CHMP.

*Therefore, we can confirm **2 constructed waterways** (west and east) require functional designs.*

- **17 sediment basins** proposed across all strategies and distributed throughout the precinct (SB1-11, 11A, 12-15, +1 unnamed):
    - 16 initially proposed +1 additional unnamed (as of September Revised Strategy) for WLRB1 inlet zone. SB 13 is missing from the recent strategy – *it is presumed this asset is no longer required and does not require functional design. This is consistent with Alluvium's approach.*

Of the 16 SBs remaining…

- 3 sediment basins (SB 10, SB11, SB11A) have now been integrated as the primary treatment component at the inlet zone of the WLRBs 2, 3 and 4 respectively. This is now consistent with BPEM requirements where primary treatment is required for all tertiary treatment assets (i.e. wetlands) and consistent with the Melbourne Water Constructed Wetlands Design Manual. This is also consistent with Alluvium's alternate Concept Layout Plan being proposed (in this report).

As these SBs are a design requirement for all wetland systems Alluvium recommends that these are NOT separate asset IDs / independent functional designs, but now incorporated as part of best practice wetland design and fall under asset IDs for the WLRBs. Therefore, SB10, SB11 and SB11A will not be referenced separately going forward to functional designs.

Of the now 13 SBs remaining….

- 3 sediment basins are located around the WLRB1 location – 2 SBs were previously identified as SB8 and SB9 (and are still being proposed), and a 3rd SB (unnamed) recently proposed (25 August) and still existing in Final Strategy layout.

Alluvium's Concept Layout Plan proposes SB8 and SB9 are obsolete assets and should be removed from functional designs. Further, as we have re-designed WLRB1 following a review of the recent modelling received, consideration of the size of catchment areas draining to this asset via the two constructed waterways - WLRB1 is now split into 1A (east) and 1B (west). The new 'unnamed' SB is therefore not required in its current Engeny concept.

As is standard wetland design practice, sediment basins have been incorporated (critical primary treatment component) for WLRB-1A and WLRB-1B. As integrated SBs to a wetland, these 2 SBs will not be independently designed or given an asset ID. We have modelled and sized these systems to accommodate catchment inflows and TSS loading, therefore removing the need for SB8 and SB9; and the new 'unnamed' SB.

Of the now 10 SBs remaining….

- 1 sediment basin (SB12) is located in the NW corner of the precinct and currently remains in place.
- 9 sediment basins are proposed to be located along the constructed waterways – 4 on the eastern waterway (SB1, SB2, SB14, **SB15**) and 5 on the western waterway (**SB3** to SB7) – all directly outfall into the waterway corridors. SBs are primary treatment systems designed to capture litter, debris, coarse gravels etc (i.e. gross pollutants):
    - SB3 is critical to the headwaters of W-WW and its downstream protection from TSS.
    - SB15 is critical to the headwaters of E-WW and its downstream protection from TSS.
    - SB1 services a small catchment currently proposed for residential use. Though runoff generated from this catchment will likely contain gross pollutants, the size of the catchment may not justify the construction and land take costs of a sediment basin. Instead, a small GPT is recommended in its place for predominantly litter management

(if desired). A GPT would perform equally well as a SB for the subject catchment but at a cheaper cost/land take. As GPTs are 'off the shelf' products, they would not require a functional design, though would require some MUSIC modelling to ensure downstream assets are properly sized.

- SB5 (on W-WW) is proposed for the DETV land and has been considered redundant / missing from Alluvium's concept as it is deemed "unlikely to be implemented" therefore, we have compensated for its likely absence in our concept design modelling.
- SB14 services a small catchment of predominantly grassed agricultural land where surface runoff from this landscape is likely to be high in organic loads (in a dissolved form) and untreatable by a sediment basin. Further, the grassed landscape provides the primary treatment required to filter gross pollutants/TSS from the runoff (grassed buffer to waterways). We would recommend this SB14 be made redundant.
- SB4 (on W-WW) requires remodelling at functional design stage as the Final Strategy now proposes to move this SB further upstream from its current location. This is likely to alter its ability to service the original catchment area, and likely to be a reduced area. We will need to remodel the catchment and consider in the next stage – we will advise as soon as possible if this asset is needed for the PSP / is somewhat redundant / is critical or negligible in its contribution.

*Therefore, we can confirm **7 independent sediment basins** require functional designs with 1 (SB1) recommended to be replaced with a small GP; and **1 (SB4)** subject to further review / consideration / remodel to determine value to PSP.*

- **12 culverts** were proposed to be located throughout the development precinct:
  - 2 culverts on waterway corridors (CU1 at start of W-WW and CU3 at start of E-WW) – missing from revised strategy layout plan but critical to service future developed areas and protect constructed waterways.
  - 3 culverts are located as the outlet structures from the 4 WLRBs (CU8, CU10 & CU11 – missing from revised strategy layout plan – but critical to the WLRBs) and CU9 is pre-existing on Heslop Rd.
  - 2 culverts have now been determined as pre-existing (final strategy) – CU2 now existing culverts at Bass Highway and CU4 now McGibbonys Rd existing culvert.
  - 3 culverts are located as the outlet structures from the 4 WLRBs (CU8 to CU11 – missing from revised strategy layout plan – but critical to the WLRBs) and 1 culvert is located as the outlet structure from SB12 – missing from revised strategy but critical to SB12
  - 3 culverts (CU 5, 6, 7) are located along the proposed W-WW and require functional designs.

*Alluvium anticipates this is a total of **9 culverts** to move to functional design (3 pre-existing).*

- **1 main outfall** is proposed to be located north of Heslop Road through the subject property to the Powlett River:
  - The current outfall concept poses some challenges relating to the discharge and distribution of channelised flows to the Powlett River vegetation (riparian) zone and likelihood of erosion
  - Possible loss of riparian vegetation
  - Possible headward erosion back up the outfall channel
  - possible impacts on existing levees along the Powlett River.

*Alluvium understands there is an additional design - **1 main outfall** to Powlett River (MOP). Concepts and model outputs received to date do not demonstrate how precinct flows will discharge safely to the Powlett River.*

This brings the total number of functional designs to 23 independent assets designs.

6.2 Strategic objectives – Integrated Water Management (IWM)

The Victorian IWM Framework 2017 is designed to help local governments and water sector partners to meet water management objectives of the state water plan, *Water for Victoria* and ensure that our communities are resilient and liveable, now and into the future. The key premise of an IWM approach is the overall acceptance that managing urban liveability and resilience is a shared responsibility and that water is a key enabler to achieving these shared outcomes. This is captured in the various IWM Forum Strategic Directions Statements across Victorian regions.

> *Integrated water management is a collaborative approach to planning that brings together organisations that influence all elements of the water cycle, including waterways and bays, wastewater management, alternative and potable water supply, stormwater management and water treatment. It considers environment, social and economic benefits (IWM Framework 2017).*

Communities are central to the management of the water cycle. They are provided with water, protected from floods, interact with healthy waterways and benefit from cooler, greener cities and healthier environments. Community participation and contribution (locally and at the lot scale) can make a significant contribution to achieving these values and outcomes, building more resilient landscapes, cities and towns.

The Victorian Planning Authority in its Precinct Structure Plan Guidelines defines IWM as an approach that "*seeks opportunities beyond 'business as usual' to foster innovation and to provide better environmental, health, economic and liveability outcomes in all aspects of water management, supply and disposal*".

The EPAV have published an *Urban Stormwater Management Guidance* (2021) which identifies the need to manage stormwater volumes. Stormwater volume reduction requirements are driven by an ecological and physical form response. Recent updates to EPA guidance sets out flow volume reductions for different areas based on the annual rainfall. These reductions are designed to reduce the impact of increased impermeable surfaces (and decreased vegetation) on the receiving environment by setting out a percentage of impervious runoff to be:

- either infiltrated or filtered to replace the water that would have permeated to the water table to support waterway baseflows, and
- harvested or evapotranspired to make up for water that would have been used by vegetation or evaporated from soils. The EPA runoff reduction targets are applicable to growth areas, and requires infiltrating 5% of the impervious runoff, and harvesting 77% of impervious runoff.

Collectively, these strategic and community influences contribute to Alluvium's approach to best managing stormwater for the Wonthaggi North East PSP as outlined below. The efficient management of water in the urban landscape is now not just about capturing and draining it away, but more about retaining water in the landscape it falls and blending its benefits to the urban form, fundamentally achieving the key outcomes of IWM and community resilience.

1. The social values of stormwater and liveability

IWM allows the management of built and natural forms to collectively achieve multiple benefits of public health, community connectedness and wellbeing, environmental protection and enhancement, landscape amenity and reducing impacts of urban heat through integrated-function assets that are cost-effective, reliable, respond to the impacts of a changing climate, population growth and urban development demands.

Building resilience across our cities to the impacts of climate change such as increasing overall temperatures, hotter summers, more frequent and intense storm events and extreme heat waves, can be achieved through the integration of blue-green infrastructure into the urban landscape. Commonly referred to as water sensitive urban design (WSUD) these blue-green infrastructure approaches can work effectively to keep water safely within the landscape it falls and provide cooling systems to effectively improve heat thresholds through micro-climate benefits at the local scale.

The societal value of open spaces in urban development is also increasing as these provide refuge for community and wildlife; while urban waterways provide welcoming spaces to encourage recreation, safe interaction and community engagement and gatherings – connecting people to places where water meets.

6.3 Design objectives

For any stormwater drainage assessment the aim is to define the flood mitigation and stormwater quality management requirements for the post development conditions (the future land use of the site). In doing so, the work will define the stormwater quantity and stormwater quality assets required to control the impact of development on downstream receiving environments. The design and layout of the proposed surface water management assets are provided here, at a conceptual level.

There are three main objectives as part of this recommended strategy for the functional design stage:

2. **Stormwater quantity management**

Fully developed 50% AEP stormwater runoff rates are to be retarded back to the equivalent 50% AEP pre-development peak flow rates before discharging downstream. Based on Engeny drainage strategy, WGCMA require stormwater quantity control for regular flow events up to and including the 50% AEP (2 year ARI) event. This is typically achieved through the implementation of retention (or detention) systems within the catchment.

This assessment focuses on this aspect of stormwater drainage assessment requirements.

3. **Stormwater conveyance**

Stormwater conveyance is typically designed to a major and minor flow regime where:

- Minor flows i.e. up to and including the 20% AEP storm event (approximately the 1-in-5 year ARI event), are conveyed via the sub-surface stormwater network.
- Major flows i.e. between the 20% AEP and 1% AEP event are conveyed on the surface via roadways, overland flow paths and waterways.

The entire pipe and road network has not been assessed as part of this this assessment, however proposed constructed waterway corridors have been investigated to convey the 1% AEP. In addition to this, the flood modelling completed by Engeny establishes the flood extent, depth and safety risk along roads.

4. **Stormwater quality treatment**

Stormwater treatment concepts are required to meet the State Environment Protection Policy (SEPP) for Waters, the Urban Stormwater Best Practice Environmental Management (BPEM) Guidelines (CSIRO, 1999), and the State pollution reduction targets as per the Victorian Planning Provisions (Clause 56.07-4) before being discharged into stormwater drainage networks and subsequently into receiving waters. These targets are defined as:

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

The recommended approach for the functional design stage of this study is based on a thorough understanding of existing conditions (values and constraints), background investigations to date, stakeholder input and regulatory / State requirements. Below is a summary of the proposed approach and the rationale, which builds off existing investigations and strategic influences.

6.4 Stormwater Quantity Management (Retarding Basins)

The hydrologic analysis of the Wonthaggi North East PSP was undertaken to determine the pre and post-development peak runoff flow rates (m^3/s) for various flood events throughout the catchment. The hydrologic analysis is used to determine the storage capacities of proposed retarding basins required to retard the fully developed peak stormwater runoff rates back to pre-developed conditions, and to determine the flows entering the stormwater quality treatment wetlands proposed. The hydrology results are also used as inputs for the flood modelling.

The aim of the RORB modelling is to establish critical peak flows and the storage requirements within the PSP. As identified by the WGCMA, development conditions peak runoff from the proposed PSP area is to be controlled back to the equivalent 50% AEP predeveloped conditions peak flow. The supplied Engeny RORB and TUFLOW models were reviewed at a concept design level, further refinement of the RORB and TUFLOW models will occur as part of the functional design process.

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

A RORB model is created to determine:

- Existing peak flows
- The impact of development on peak flows
- The reduction in peak flows that is possible using retarding basin storage etc.
- The impact of climate change on peak flows.

The RORB model was built by delineating the major catchments into sub-areas based on topography and potential road alignments. A layout of the RORB model is provided in Figure 28.

Given no gauge data was available for the RORB model validation, Engeny have calibrated the RORB model based initial loss and continuing loss values provided from the ARR datahub and modelled multiple kc scenarios based on the Pearse equation for Victorian Catchments ($k_c = 1.25 \times d_{av}$). The resulting model input parameters were compared against the DNRE flood regression analysis and the RFFE model.

The Engeny model has considered multiple kc, initial loss and continuing loss values to calibrate the model to the equivalent RFFE and DNRE results. However, the RFFE outputs cannot be considered an exact point of truth, and calibration of kc values should not be directly adjusted to meet the RFFE results. This creates uncertainty in model validation as there is a reduced correlation with specified regional equations.

Whilst the selection of kc values is not important when determining rainfall excess hydrographs as input for hydraulic modelling, it is important when determining design flows of storage systems. Although the retarding basin systems have been designed within TUFLOW, the flow input to the model is based on location specific peak flow data, and not sub catchment rainfall excess hydrographs.

Although not required as part of ARR guidelines, it is recommended the kc value is further sanity checked against the rational method to provide further validity of the adjustment. As a result, an update of peak flows into the model is to be determined using updated kc and loss parameters. This will now be undertaken by Alluvium to inform the functional designs.

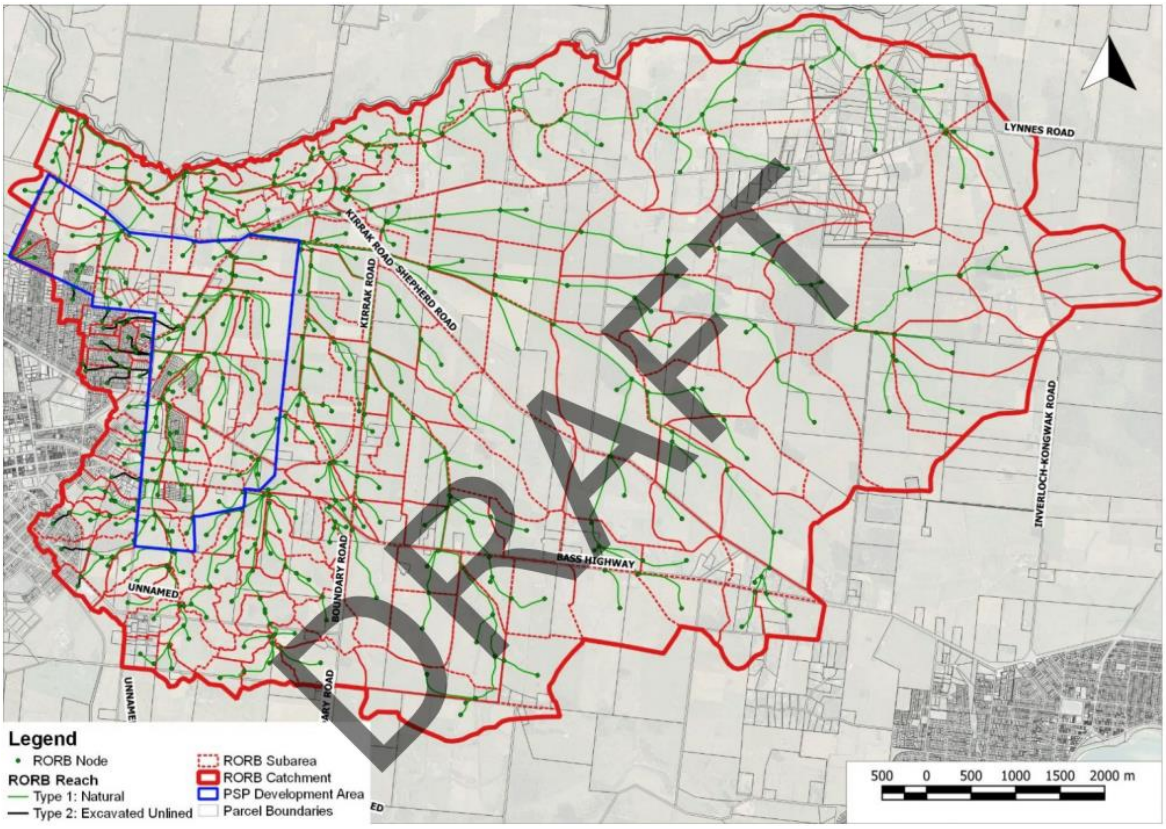


Figure 28. *RORB model layout for the Wonthaggi North East PSP (source: Engeny, Aug 2021)*

A summary of the Engeny RORB outputs, RFFE results, DNRE and Rational Method calculations are provided below.

Table 3. Predevelopment conditions RORB modelling results for the Wonthaggi North East PSP

Calibration	Total catchment Flow (1% AEP)	Total catchment Flow (50% AEP)
RFFE	108.0 m^3/s	21.3 m^3/s
RFFE 5% Limit	47.0 m^3/s	10.8 m^3/s
RFFE 95% Limit	248.0 m^3/s	42.1 m^3/s
DNRE	116.0 m^3/s	-
kc 10.48 (Pearse), IL 21mm, CL 4.6mm/hr	104.6 m^3/s	7.7 m^3/s
kc 10.48 IL 20mm, CL 3.8mm/hr	115.9 m^3/s	13.1 m^3/s
kc 13, IL 10mm, CL 3.8mm/hr	116.1 m^3/s	21.0 m^3/s
Rational Method	55.5 m^3/s	13.7 m^3/s

As shown above, adopting the Pearse kc value (10.48), whilst reducing the Initial Loss/Continuing Loss value results in flows that closely align with the RFFE and DNRE estimation tools, and correlate with rational method results whilst remaining within the RFFE 5% limit. It appears logical to lower the Initial Loss/Continuing Loss marginally, given typical values for Initial Losses and Continuing Losses modelled within Victorian catchments generally vary from 10-25mm and 1-3 mm/hr respectively.

The calibration method still holds true to the specified regional equation for Victorian catchments (Pearse) while determining peak flows generally in accordance with multiple estimation methods.

Based on the supplied RORB model and input parameters, the RORB model was computed for the 1%, 10%, 20% and 50% AEP events for both pre and post developed scenarios, the results are summarised below.

Table 4. RORB modelling results for the Wonthaggi North East catchment

	WLRB1	WLRB2	WLRB3	WLRB4
Catchment area (ha)	1126.42	73.03	52.27	101.34
1% AEP Pre-developed critical flow rate (m^3/s)	15.54	15.84*	6.96^	6.96^
1% Developed critical flow rate (m^3/s)	32.66	6.62	7.62	10.11
10% AEP Pre-developed critical flow rate (m^3/s)	7.49	7.57*	4.12^	4.12^
10% Developed critical flow rate (m^3/s)	20.96	4.28	4.90	6.09
20% AEP Pre-developed critical flow rate (m^3/s)	5.40	5.46*	2.93^	2.93^
20% Developed critical flow rate (m^3/s)	15.56	3.59	3.80	5.08
50% AEP Pre-developed critical flow rate (m^3/s)	2.47	2.49*	1.25^	1.25^
50% Developed critical flow rate (m^3/s)	9.54	2.27	2.53	3.32

* Under existing conditions, runoff generated from the WLRB1 catchment outfalls through the proposed location of WLRB2, as proposed in the developed conditions, flow is to be diverted north under Korumburra-Wonthaggi Road.
^ Under existing conditions, the WLRB3 & WLRB4 catchments naturally fall to the same location, as part of the proposed developed conditions model, the catchments are controlled separately.

The retarding basins for this catchment have been modelled and sized to control the 50% AEP flow. The total required area for the assets has been calculated assuming a 1(V):6(H) batter to existing surface, and an allowance of 600mm of freeboard on top of the peak 1% AEP flood depth. The system is designed to 'not be in fill', however as per the future development of the PSP, all lots must be filled to 600mm above the peak 1% AEP flood level.

Tables 5-8 below show the required capacity of the retarding basins (WLRBs), based on the RORB and TUFLOW modelling completed by Engeny. This is to be further refined as part of the functional design process.

Table 5. WLRB1 retarding basin requirements

Parameter	Retarding Basin WLRB1
Peak RB storage required (m^3)	444,500 m^3 (1% AEP), 229,600 m^3 (50% AEP)
Outlet pipe size (mm)	10 x 338mm dia Polypropylene pipes 3 x 1200mm (B) x 900mm (H) box culverts
Surface Area (ha)	10.10

Table 6. WLRB2 retarding basin requirements

Parameter	Retarding Basin WLRB2
Peak RB storage (m^3)	30,000 m^3 (1% AEP), 7,300 m^3 (50% AEP)
Outlet pipe size (mm)	1 x 1200mm dia. outfall pipe
Surface Area (ha)	1.76

Table 7. WLRB3 retarding basin requirements

Parameter	Retarding Basin WLRB3
Peak RB storage (m^3)	9,300 m^3 (1% AEP), 3,900 m^3 (50% AEP)
Outlet pipe size (mm)	3 x 1200mm (B) x 450mm (H) box culverts
Surface Area (ha)	3.07

Table 8. WLRB4 retarding basin requirements

Parameter	Retarding Basin WLRB4
Peak RB storage (m^3)	21,400 m^3 (1% AEP), 14,300 m^3 (50% AEP)
Outlet pipe size (mm)	1 x 1050mm dia. outlet pipe
Surface Area (ha)	1.30

Climate change

Climate change scenarios have been adopted within the hydrologic models built. The purpose of adopting climate change scenarios is not to design assets to these increased peaks, but to perform a sensitivity check on how increased peak flows will move through the systems designed. For example, how an increased peak 1% AEP will sit within the provided freeboard in a proposed retarding basin.

Climate change scenarios have been modelled in line with guidance from ARR2019 (Book 1, Section 6.2), which suggests the use of Representative Concentration Pathways (RCP's) for low and high concentrations of RCP 4.5 and RCP 8.5. The approach adopted for establishing these scenarios has been:

- The use of Bureau of Meteorology (BoM) IFD curves derived for the site.
- That the IFD curves are adjusted to reflect increased intensity arising from climate change.
- ARR2019 recommends the adoption of a 5% increase in rainfall intensity per degree of global warming (Book 1, Chapter 6) for events up to the 1% AEP.
- RCP 4.5 and RCP 8.5 were adopted for climate change. The catchment is located within the Southern Slopes cluster, which estimates the temperature increase in the RCP 4.5 scenario of 0.5 to 3 degrees during the year 2100 (midpoint of 1.75 degrees selected), and a temperature increase in the RCP 8.5 scenario of 3.6 degrees in the year 2100.
- This approach results in a 9% increase in rainfall intensity for the RCP 4.5 scenario for events up to the 1% AEP, and an increase of 19% in rainfall intensity for the RCP 8.5 scenario.

The Engeny strategy has considered a rainfall intensity increase of 18.4% for the year 2100 climate change scenario only. This increase is slightly higher than the Engeny strategy in the RCP8.5 scenario, the RCP4.5 scenario was not considered.

The Climate Change Scenario modelling was not run with respect to stormwater quantity storage within the Engeny strategy. This will be completed as part of the functional design phase.

Additional modelling will be required to confirm the storage requirements of retarding basins within the 1% AEP and 50% AEP events, as well as Climate Change scenarios. This will be completed as part of the functional design.

6.5 Stormwater Conveyance (Waterways)

The main considerations for waterways adjacent to and within a development precinct are the waterway corridors, constructed waterway designs (including waterway crossings), and flood levels. Proposed waterway corridors must demonstrate they are sufficient in terms of flow conveyance and providing river health and amenity opportunities in a future urbanised landscape.

A waterway corridor is defined as the waterway channel and its associated riparian zones. The riparian zones consist of two parts:

- The vegetated buffer
- The core riparian zone.

A typical waterway corridor section is shown below.

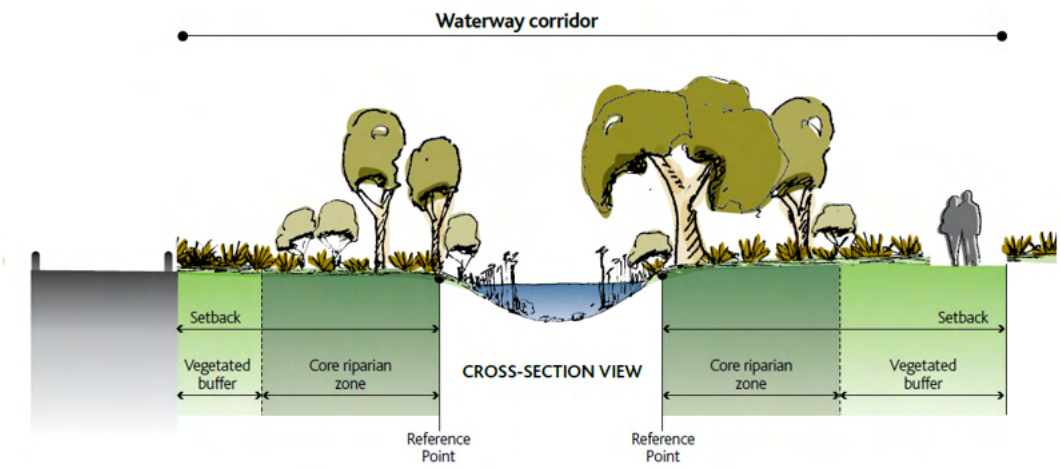


Figure 29. *Waterway corridor (source: Waterway Corridor Guidelines, Melbourne Water)*

Assigning a waterway corridor preserves areas of the riparian zone that protect or enhance native vegetation, instream health and biodiversity, and provides space for recreational infrastructure and activities (e.g. shared paths and (in some cases) stormwater treatment systems).

A fundamental principle is to provide continuity along the core riparian zone. Therefore, the strong preference is to locate shared paths and other infrastructure outside this zone. However, in some instances, stormwater treatment systems such as constructed wetlands and bio-retention systems may be located within the core riparian zone but should form a relatively small proportion of the area so as not to degrade its ecological function.

Therefore, the two proposed constructed waterways should be designed to carry developed flows through the waterway corridor, provide habitat, and improve channel stability and visual amenity.

The constructed waterways in the Engeny strategy (DR1 & DR2) are referenced in this report (and ongoing) as W-WW (western waterway) and E-WW (eastern waterway) and were assessed with respect to concept design standards. HEC-RAS has been used to design the waterway and model the major flows through the waterways to determine flood levels.

There are four primary variables in HECRAS modelling:

- Channel geometry (constructed waterway design cross sections)
- Downstream boundary condition (normal depth from gauge or slope / known flood level)
- Hydraulic roughness (Manning's n) and
- Flow (derived during hydrologic analysis).

The derived flows and downstream boundary conditions have been informed from Engeny's hydrologic and hydraulic modelling, as part of the strategy. The hydraulic roughness (Manning's n) for the model is provided below.

Table 9. Hydraulic parameters adopted for the HEC-RAS model

Hydraulic parameters	Description	Value
Manning's n	High flow channel –	0.055
	Low flow channel -	0.055

The HECRAS model is used to determine the average shear stress along the proposed constructed waterway. Shear stresses should be maintained below specific thresholds for short native grasses (45 N/m2), typically planted along the left and right banks of the high flow section of the waterway; and long native grasses (80 N/m2), typically planted within the low flow meander channel of the waterway.

These thresholds define the maximum allowable shear stress within a waterway to ensure stripping and erosion of the waterway does not occur in a 1% AEP event. A +10% allowance for shear stress thresholds is provided to account for the increased flood depths to minimise shear stress impacts on the banks of the waterway.

There remain some isolated locations with higher shear stresses along the two waterway alignments, typically noticed along open pools and transitions to culvert structures. The design surface supplied by Engeny is to inform the reach scale functional design and therefore does not include fine scale detail of the pool morphology and structures. It is expected that refined geometric design of the pools in a feature scale functional design will address the localised shear stress issues through crest drown-out and rockwork. A summary of shear stresses along the W-WW & E-WW corridors is provided in Figures 30 & 31.

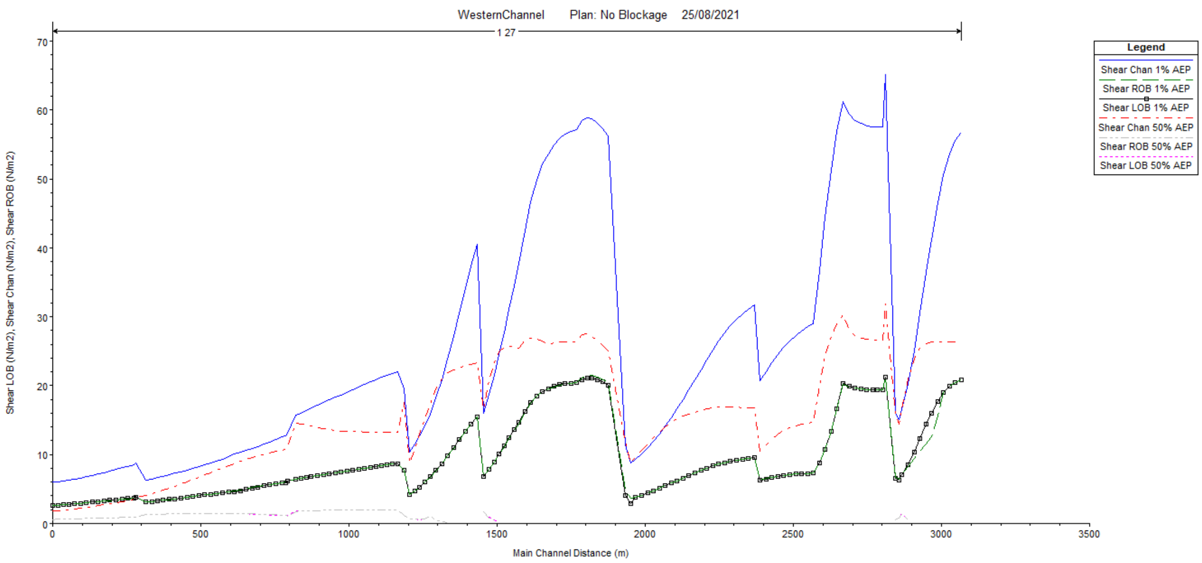


Figure 30. *Average local shears stresses within the western waterway corridor (DR1) for the 1% and 50% AEP events*

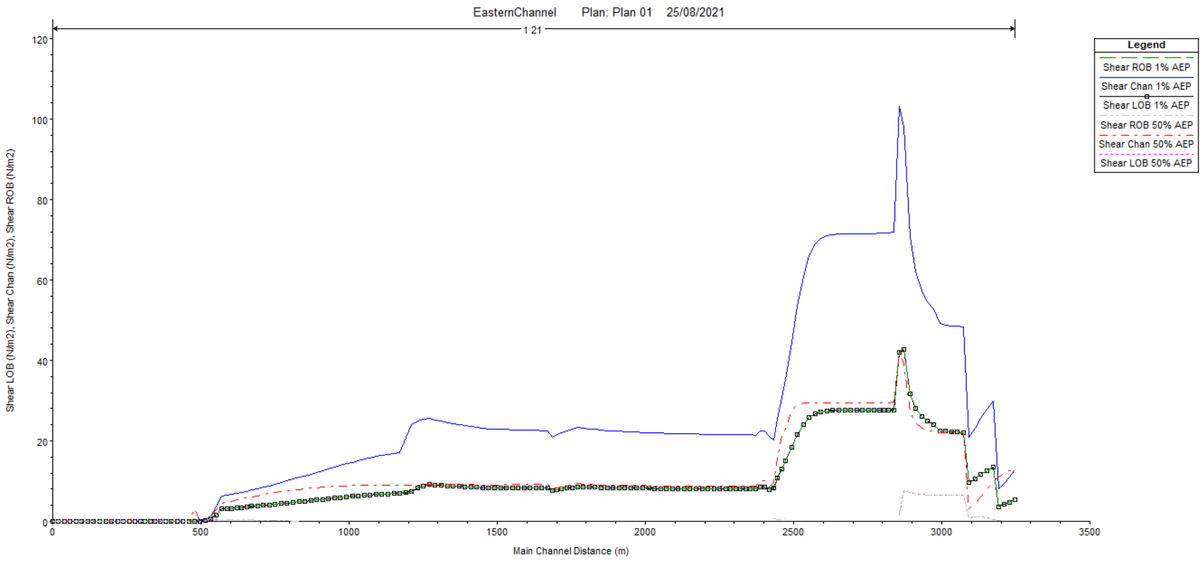


Figure 31. *Average local shears stresses within the eastern waterway corridor (DR2) for the 1% and 50% AEP events*

Waterway / drainage reserve footprints

Based on Engeny's proposed concept layout, Alluvium suggests the introduction of meandering waterway corridors through the PSP, which will help to reduce velocities and average sheer stresses through the proposed constructed waterways, whilst improving the waterway corridors, channel stability, and providing an increased visual amenity and connections for community engagement and use. Alluvium's proposed concept waterway alignments are provided in Figure 33 below.

Of note is Alluvium's proposed alignment of E-WW which has shifted further east, removing isolated pockets of potentially developable land areas as intended, and meanders along the current PSP boundary (Figure 32Figure 32). Some sections intersect / clip the official boundary. While we recommend the waterway proper remains within the PSP, including any associated infrastructure such as maintenance tracks or shared trails, the ultimate drainage reserve width (vegetated zone) does cross the defined boundary – no infrastructure is proposed within these areas.

While we acknowledge this is subject to the consideration of the VPA and Council, given the planning mechanisms and allowances in place, it is shown here to demonstrate opportunity to smoothly connect the current PSP with the future eastern PSP, or more importantly, the future community(ies), by way of this blue-green corridor – public open space asset within the drainage reserve allocation. Further, given the agricultural landscape currently has no treatment, WLRB1A (and 1B) have been modelled to account for external catchment areas (>1000 ha) entering the PSP assets to account for pollutant loading (largely TP and TN) from this surface runoff prior to entering Powlett River. While this is not a requirement, it is a necessary consideration to ensure the WLRBs perform effectively and treat to required best practice.

Table 10 demonstrates the potential land take outside the PSP corresponding to the three curved sections of the E-WW currently proposed to extend outside the PSP boundary (labelled 1 – 3 from upstream to downstream).

Table 10. Land-take associated with E-WW blue-green corridor outside of PSP

E-WW curve outside PSP	Estimated land-take outside of PSP area (ha)
1	0.251
2	0.740
3	0.494

Allowance for the drainage reserve width, and its potential intersection of the PSP boundaries, could be applied by the VPA/Council in their forward growth area planning and highlighted as a landscape and community connectivity benefit. Following its construction for this PSP, the corridor may be well-established by the time future PSPs come on line to the east, adding significant landscape and market improved value to abutting land developments.

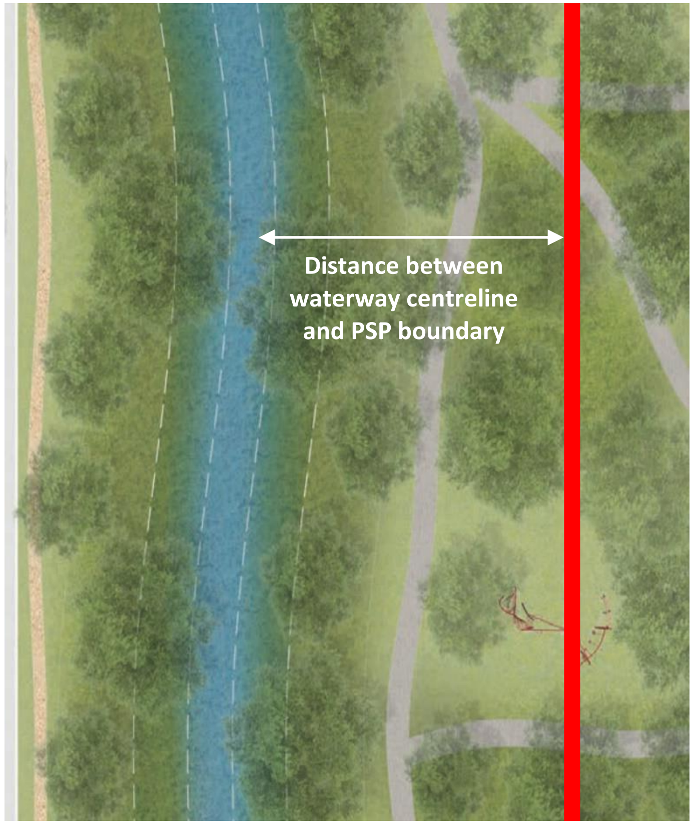


Figure 32. *Conceptual visualisation of blue-green corridor provided by E-WW.*
Note: although waterway corridor (drainage reserve) extends past PSP boundary (red line), watercourse is still within the subject PSP while the created natural corridor becomes a valuable community asset for both the current PSP and future PSP (to the east).

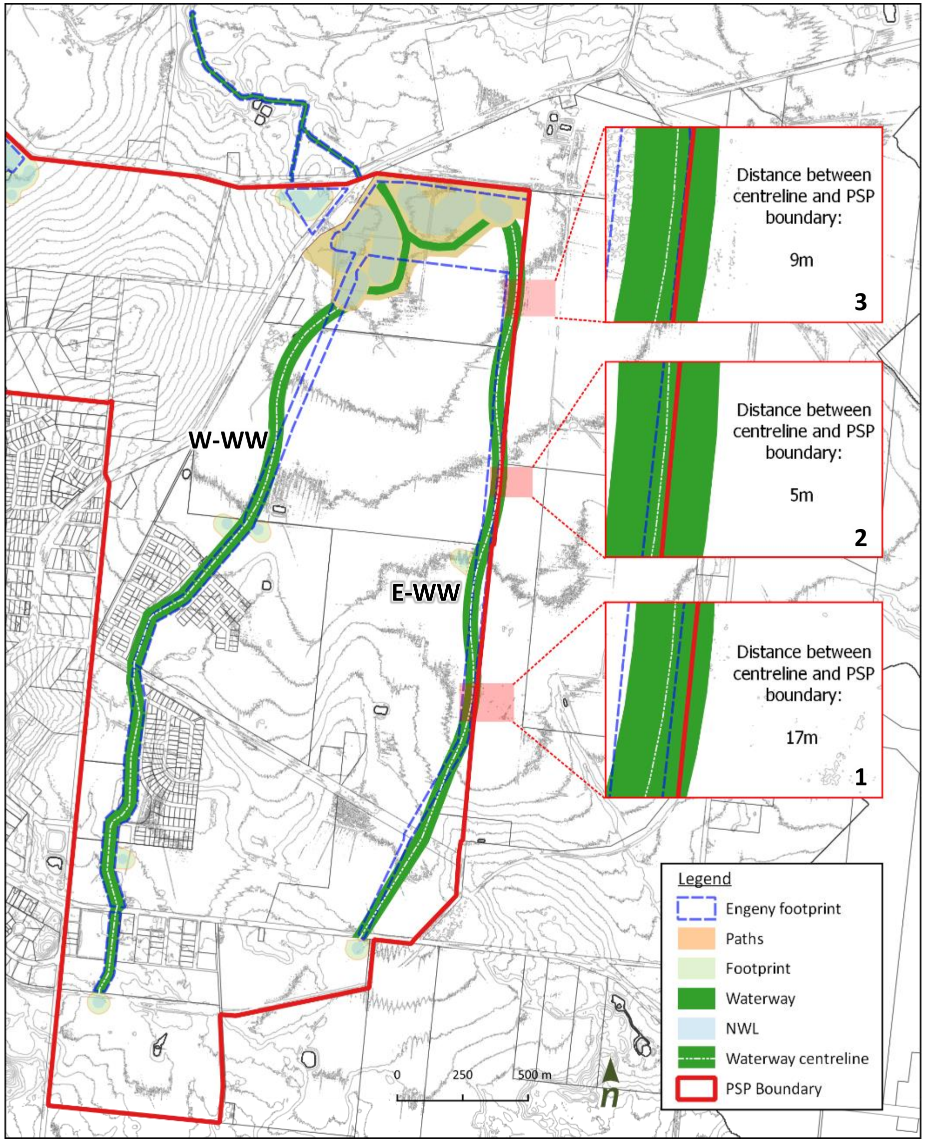


Figure 33 *Proposed waterway alignments for the internal constructed waterways (W-WW & E-WW)*

6.5 Culvert Crossings

As part of the Engeny's final strategy, there are 9 culverts proposed, and 3 existing culverts that need to be included as part of the analysis. Table 11 provides a summary of the assets where culverts are included. A concept level assessment of the provided modelling has been completed, which will be further refined as part of the functional design stage of the retarding basin / constructed waterway design process.

Table 11. Summary of culverts within the Precinct

Asset	Existing culverts	Proposed culverts
W-WW (DR1)	Bass Highway Culverts (4 x 1500mm dia.) McGibbonys Road Culverts (4 x 1650mm dia.) Centennial Drive Culverts (2 X 3.6m (B) x 1.5m (H))	Culvert 4 (4 x 3.6m (B) x 1.5m (H)) Culvert 5 (4 x 3.6m (B) x 1.5m (H)) Culvert 6 (4 x 3.6m (B) x 1.5m (H))
E-WW (DR2)	-	Culvert 3 (3 x 1500mm dia. pipe culverts)
WLRB1	-	10 x 338mm dia Polypropylene pipes* 3 x 1.2m (B) x 0.9m (H) box culverts
WLRB2	-	1 x 1200mm dia. outfall pipe**
WLRB3	-	3 x 1.2m (B) x 0.45m (H) box culverts
WLRB4	-	1 x 1050mm dia. outlet pipe
SB12		4 x 750mm dia. pipe culverts

*Low flow outlet structure from WLRB1, not considered as a culvert structure but required as part of WLRB1 design
**Existing outfall structure from WLRB2, to be further refined as part of the functional design

As part of the Engeny strategy, a blockage factor of 0.25 was applied to each of the culverts located along the Western waterway corridor (W-WW). It is recommended a blockage factor of 0.50 be applied to culverts during the functional design. This is likely to results in a minor upsizing of culvert cell sizes.

Outlet culverts from proposed retarding basin assets are to be further refined as part of the functional design phase.

6.6 Main outfall design

The main outfall from the PSP area is to be designed to carry the 50% AEP flow from the WLRB1 and WLRB2 outflow location. The main outfall alignment is likely to remain similar to the proposed design within the Engeny revised strategy. This is due to the designed constraints associated within crossing existing infrastructure along Korumburra-Wonthaggi Road (Gas main, Desal water supply main, Wonthaggi water supply main). A summary of the proposed alignment, and the existing infrastructure is shown in Figure 34 below.

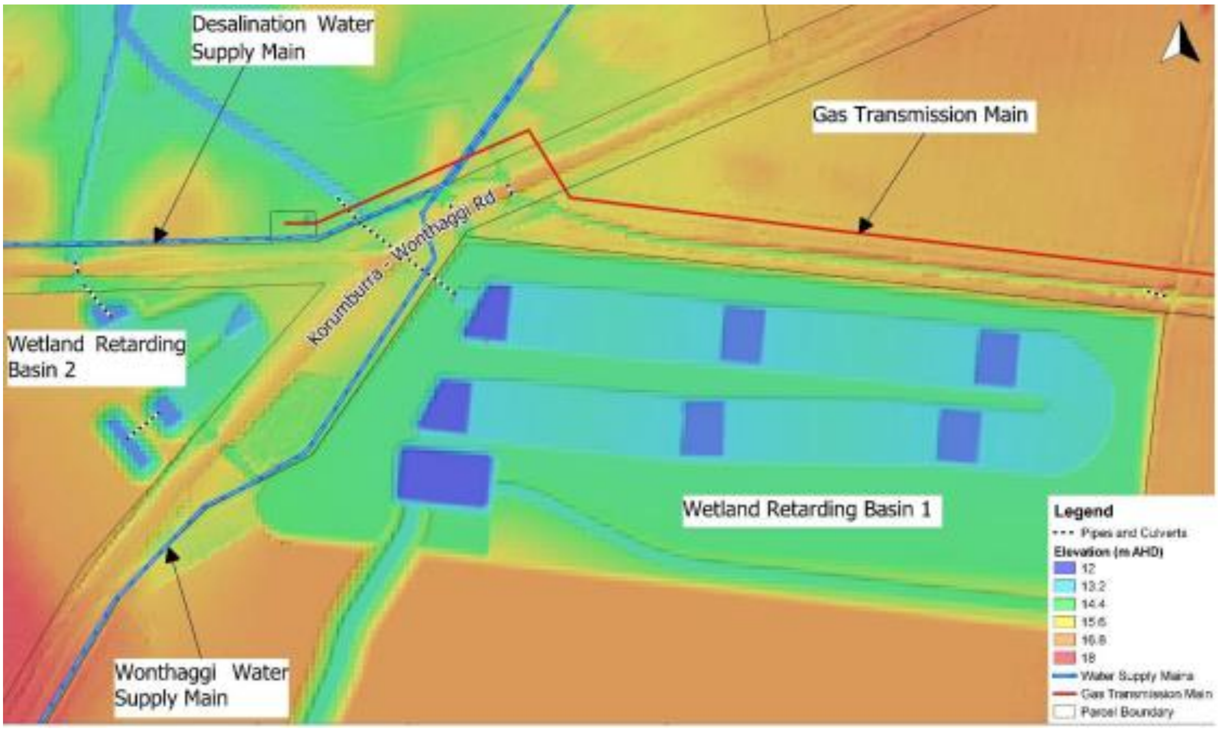


Figure 34. *Existing gas and water services (Engeny, August 2021)*

The Engeny strategy proposes low flow pipes to cross the gas main with a clearance of 500mm, a high flow outfall channel is proposed to cross the gas main with vertical separation of 70mm between the top of the gas main and the invert of the channel. A 200mm thick concrete slab is proposed to protect the pipe from erosion. As part of the functional design process, alternatives to the proposed concrete slab will be investigated (i.e. rock armouring). A summary of the proposed Engeny channel section is provided below.

Based on the provided Engeny Strategy, the main outfall channel design has not considered ultimate connection to the Powlett River. As per Engeny's Strategy, the main outfall channel connects into the local cut drains through the downstream private property. The outfall design has not been mentioned in detail within the Engeny Strategy and is likely to require further analysis to ensure the concept design is appropriate. Connection to Powlett River must consider the impact on the flood levels within the floodplain, existing values (flora and fauna), and existing levee banks along the river near at the proposed outfall location for the PSP.

Further analysis and design calculations of the main outfall alignment are to be considered as part of the functional design. This includes:

- Velocity and sheer stress analysis for erosion impact along the outfall,
- Capacity check of the channel to effectively convey the 50% AEP event,
- Appropriate connection to the downstream Powlett River, to ensure no impact on the existing flood extents.

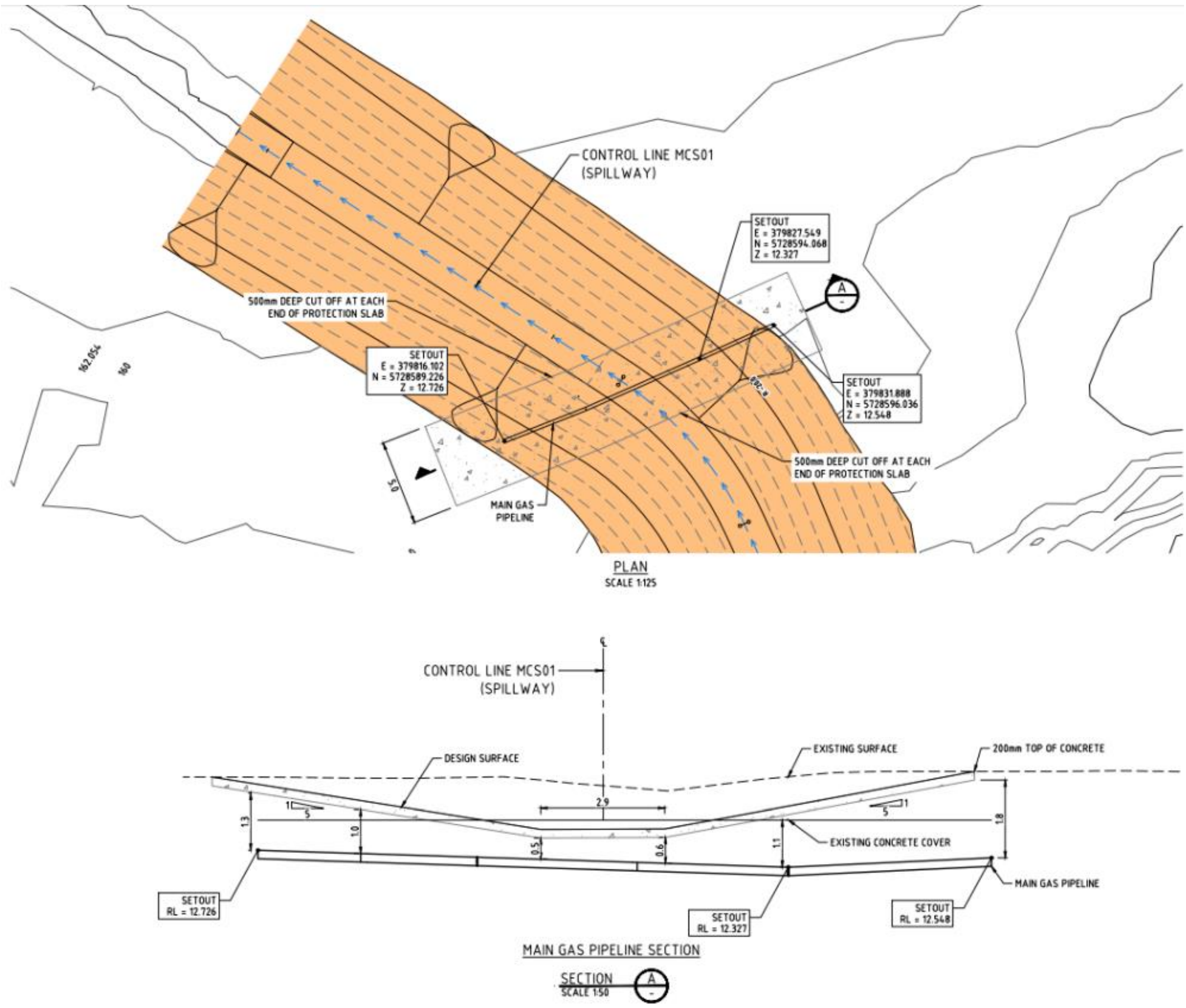


Figure 35. *Proposed channel crossing of the gas main (Engeny, Aug 2021)*

6.7 Stormwater Quality Treatment (Wetlands, Sediment Basins)

A key principle for the development of the Wonthaggi North East PSP is that all stormwater is to be treated to BPEM Guidelines before being discharged from the precinct to the receiving waterway environment (Powlett River). The following BPEM targets have been adopted:

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

Table 12 shows the multiple sub-catchments (as identified in Figure 17 above) that fall within, and external, to the PSP, indicating contributing catchment areas (hectares) discharging to the proposed treatment assets for the WNE PSP.

Table 12. Contributing catchments (sources) and receiving treatment asset

Asset	Area type	Area (ha)	Asset Size - NWL (m²)	
			Inlet pond	Macrophyte Zone
WLRB 1A	External Agricultural	442	9,000	35,000
	PSP	199		
	Total	**640**		
WLRB 1B	External Agricultural	137	11,800	47,500
	External Urban	146		
	PSP	225		
	Total	**507**		
WLRB2	External Urban	14	900	10,000
	PSP	59		
	Total	**73**		
WLRB3	PSP	52	1,250	6,100
	Total	**52**		
WLRB4	External Urban	23	2,800	20,000
	PSP	78		
	Total	**101**		
SB7	PSP	11	500	
	Total	**11**		
Total catchment area		**1386**		

A MUSIC (Model for Urban Stormwater Improvement Conceptualisation) model was developed by Engeny to estimate the pollutant loads generated from the developed conditions scenario. This is used to define the target pollutant load reduction, and therefore test the sizing and treatment capacity of assets required to meet the pollutant reduction targets. The modelling and asset sizing does not seek to treat existing residential areas upstream to best practice, only future residential areas proposed within the Precinct.

The catchment nodes used in the east catchment model have been calculated based on the areas, land uses, and associated fraction impervious values used in the RORB modelling. The MUSIC model layout is shown in Figure 36 below.

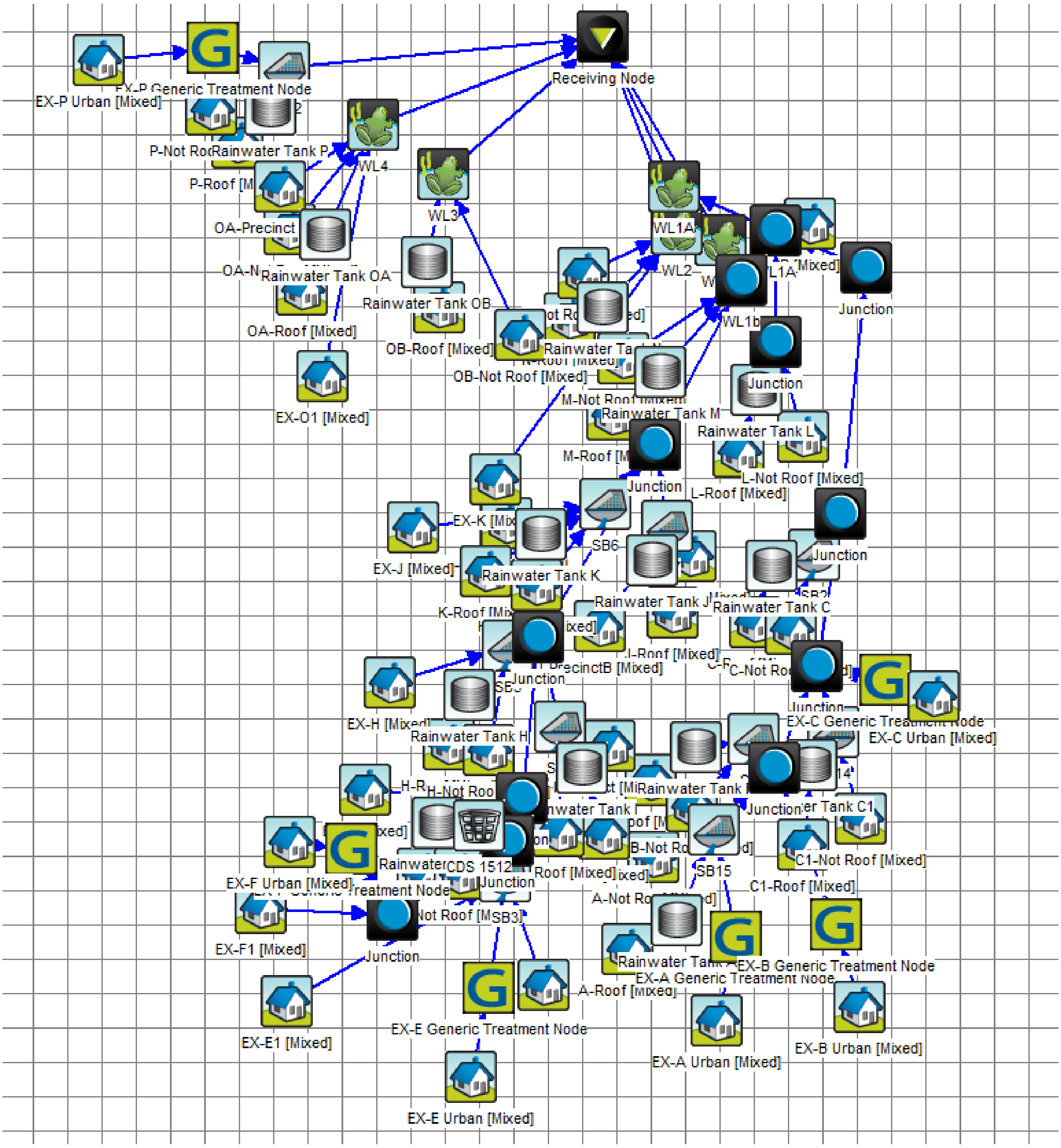


Figure 36. *MUSIC model for the Wonthaggi North East PSP (Alluvium, Aug 2021)*

Whilst the overall treatment system is designed in MUSIC to meet BPEM, sediment basins and wetlands need to be designed to function appropriately based on duration of inundation and velocity threshold limits. If stormwater quality infrastructure does not consider these as part of the overall design, then it is likely the system will fail.

Sediment basins should be sized to meet a required capture efficiency greater than 95% for the 4EY peak flow and provide adequate sediment storage, while wetlands designed to meet minimum width requirements with respect to velocity threshold limits. These are discussed further below.

Sediment Basin Sizing

The sediment basin has been sized to ensure a capture efficiency greater than 95% for the 4EY peak flow and provide adequate sediment storage. The procedure outlined in the *WSUD Engineering Procedures (2005)* has been followed and are based on the typical sediment loading rate of 1.6 m^3/ha/yr for a developed catchment, plus an additional 0.4 m^3/ha/yr for systems without a GPT immediately upstream (assumed). Provision for sediment dewatering has also been made. These areas assume a depth of 500mm and a sediment cleanout frequency of 5 years. The sediment basins were assumed to have an average depth of 0.8m, and the volume was used in the MUSIC modelling. The details of these calculations / system performance are provided in Appendix B.

Velocities – WLRB1

The maximum width of each of the wetlands was determined using the length to width ratio of at least 4:1. Due to predicted large inflows through WLRB1, from a >1000 ha contributing catchment (within and external to the PSP boundary) the WLRB1 asset is proposed to be split into two separate assets, referred to as WLRB-1A (east) and WLRB-1B (west).

WLRB1A is designed to treat the approx. 600 ha catchment out falling through the E-WW (DR2), and WLRB1B is designed to treat the 500 ha catchment out falling through the W-WW (DR1).

The area of the WLRB1A macrophyte zone is proposed at 35,000 m^2 and 9,000 m^2 at the inlet pond, as established in the MUSIC modelling. Therefore a width of 93m is the maximum average width possible in the macrophyte zone to ensure an adequate width to length ratio.

The velocity through each treatment asset is considered here. A flow depth of 0.35m, which is the extended detention depth, has been assumed for 4EY and 20% AEP events.

For WLRB1A, the minimum design width is 90m in the macrophyte zone and 49m in the inlet pond to meet velocity threshold requirements. Table 13 provides details on the minimum widths and velocities determined.

Table 13. System velocity calculations and design checks – WLRB1A

	Parameter	4EY	20% AEP
Flow Conditions	Design flow (m^3/s)	1.61	8.92
	Flow depth (m)	0.35	0.35
Inlet pond	Width at NWL (m)	49	49
	Width at EDD (m)	53.2	53.2
	Average Width (m)	51.1	51.1
	Flow area (m^2)	17.9	17.9
	Flow velocity (m/s)	0.09	0.50
	Check	<0.5 OK	<0.5 OK
Macrophyte zone	Width at NWL (m)	90	90
	Width at EDD (m)	94.2	94.2
	Average Width (m)	92.1	92.1
	Flow area (m^2)	32	32
	Flow velocity (m/s)	0.05	0.28
	Check	<0.05 OK	<0.5 OK

The area of the WLRB1B macrophyte zone is proposed as 47,500 m^2 and 11,800 m^2 at the inlet pond, as established in the MUSIC modelling. Therefore, a width of 158m is the maximum average width possible in the macrophyte zone to ensure an adequate width to length ratio.

During the 4EY and 20% AEP events, flows are 'split' along dual branches of the macrophyte zone, this ensures a length to width ratio is maintained, whilst allowing the wetland to meet the velocity requirements.

The velocity through each treatment asset is considered here. A flow depth of 0.35m, which is the extended detention depth, has been assumed for 4EY and 20% AEP events.

For WLRB1B, the minimum design width is 77 m in the macrophyte zone and 86 m in the inlet pond to meet velocity threshold requirements. Table 14 provides details on the minimum widths and velocities determined.

Table 14. System velocity calculations and design checks – WLRB1B

	Parameter	4EY	20% AEP
Flow Conditions	Design flow (m^3/s)	2.76	15.34
	Flow depth (m)	0.35	0.35
Inlet pond	Width at NWL (m)	86	86
	Width at EDD (m)	90.2	90.2
	Average Width (m)	88.1	88.1
	Flow area (m^2)	30.8	30.8
	Flow velocity (m/s)	0.09	0.50
	Check	<0.5 OK	<0.5 OK
Flow Conditions (split)	Design flow (m^3/s)	1.38	7.67
	Flow depth (m)	0.35	0.35
Macrophyte zone	Width at NWL (m)	77	77
	Width at EDD (m)	81.2	81.2
	Average Width (m)	79.1	79.1
	Flow area (m^2)	28.0	28.0
	Flow velocity (m/s)	0.05	0.28
	Check	<0.05 OK	<0.5 OK

Velocities – WLRB2

The area of the WLRB2 macrophyte zone is proposed at 10,000 m^2 and 1,250 m^2 at the inlet pond, as established in the MUSIC modelling. Therefore, a width of 50 m is the maximum average width possible in the macrophyte zone to ensure an adequate width to length ratio.

The velocity through each treatment asset is considered here. A flow depth of 0.35m, which is the extended detention depth, has been assumed for 4EY and 20% AEP events.

For WLRB2, the minimum design width is 50 m in the macrophyte zone and 27 m in the inlet pond to meet velocity threshold requirements. Table 15 provides details on the minimum widths and velocities determined.

Table 15. System velocity calculations and design checks – WLRB2

	Parameter	4EY	20% AEP
Flow Conditions	Design flow (m^3/s)	0.91	5.05
	Flow depth (m)	0.35	0.35
Inlet pond	Width at NWL (m)	27	27
	Width at EDD (m)	31.2	31.2
	Average Width (m)	29.1	29.1
	Flow area (m^2)	10.2	10.2

	Flow velocity (m/s)	0.09	0.50
	Check	<0.5 OK	<0.5 OK
Macrophyte zone	Width at NWL (m)	50	50
	Width at EDD (m)	54.2	54.2
	Average Width (m)	52.1	52.1
	Flow area (m^2)	18.0	18.0
	Flow velocity (m/s)	0.05	0.28
	Check	<0.05 OK	<0.5 OK

Velocities – WLRB3

The area of the WLRB3 macrophyte zone is proposed at 6,100 m^2 and 1,250 m^2 at the inlet pond, as established in the MUSIC modelling. Therefore, a width of 39 m is the maximum average width possible in the macrophyte zone to ensure an adequate width to length ratio.

The velocity through each treatment asset is considered here. A flow depth of 0.35m, which is the extended detention depth, has been assumed for 4EY and 20% AEP events.

For WLRB3, the minimum design width is 37 m in the macrophyte zone and 20 m in the inlet pond to meet velocity threshold requirements. Table 16 provides details on the minimum widths and velocities determined.

Table 16. System velocity calculations and design checks – WLRB3

	Parameter	4EY	20% AEP
Flow Conditions	Design flow (m^3/s)	0.68	3.76
	Flow depth (m)	0.35	0.35
Inlet pond	Width at NWL (m)	20	20
	Width at EDD (m)	24.2	24.2
	Average Width (m)	22.1	22.1
	Flow area (m^2)	7.7	7.7
	Flow velocity (m/s)	0.09	0.49
	Check	<0.5 OK	<0.5 OK
Macrophyte zone	Width at NWL (m)	37	37
	Width at EDD (m)	41.2	41.2
	Average Width (m)	39.1	39.1
	Flow area (m^2)	14.0	14.0
	Flow velocity (m/s)	0.05	0.27
	Check	<0.05 OK	<0.5 OK

Velocities – WLRB4

The area of the WLRB4 macrophyte zone is proposed at 22,000 m^2 and 2,800 m^2 at the inlet pond, as established in the MUSIC modelling. Therefore, a width of 74 m is the maximum average width possible in the macrophyte zone to ensure an adequate width to length ratio.

The velocity through each treatment asset is considered here. A flow depth of 0.35m, which is the extended detention depth, has been assumed for 4EY and 20% AEP events.

For WLRB4, the minimum design width is 73 m in the macrophyte zone and 40 m in the inlet pond to meet velocity threshold requirements. Table 17 provides details on the minimum widths and velocities determined.

Table 17. System velocity calculations and design checks – WLRB4

	Parameter	4EY	20% AEP
Flow Conditions	Design flow (m^3/s)	1.31	7.25
	Flow depth (m)	0.35	0.35
Inlet pond	Width at NWL (m)	40	40
	Width at EDD (m)	44.2	44.2
	Average Width (m)	42.1	42.1
	Flow area (m^2)	14.7	14.7
	Flow velocity (m/s)	0.09	0.49
	Check	<0.5 OK	<0.5 OK
Macrophyte zone	Width at NWL (m)	73	73
	Width at EDD (m)	77.2	77.2
	Average Width (m)	75.1	75.1
	Flow area (m^2)	26.0	26.0
	Flow velocity (m/s)	0.05	0.28
	Check	<0.05 OK	<0.5 OK

Duration of inundation MUSIC analysis

Plant suitability is based on consideration of the plant height and whether the water depth in the wetland will exceed 50% of the plant height for more than 20% of the time. If this is exceeded, it is considered that the plant will be inundated to excessive depths too frequently and is unlikely to establish and grow successfully in these conditions.

The water depth is determined using cumulative frequency analysis to determine the depth above normal water level (NWL) that will be exceeded 20% of the time, then the planting depth is added. The resulting depth is compared with 50% of the plant height to determine whether water depth will exceed this. If not, the plant is considered suitable (see schematic below).

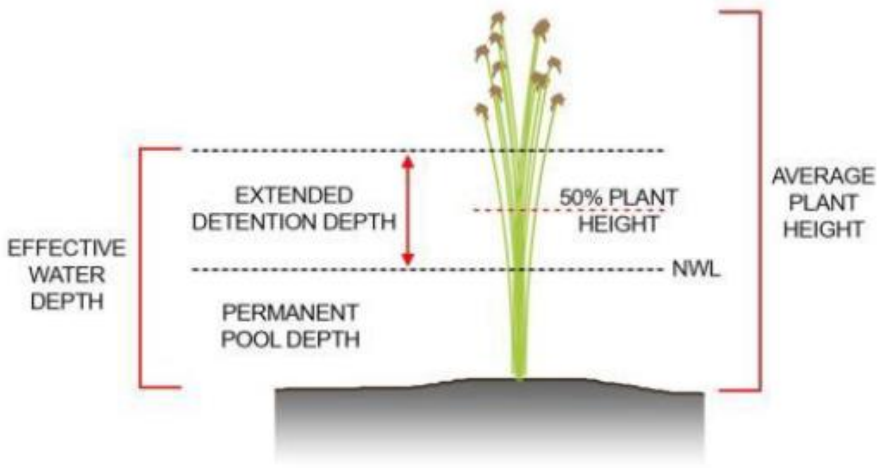


Figure 37. *Effective plant heights relative to inundation depths.*

Although plant height can survive if the inundation level does not exceed 50% of the plant height for 20% of time, plants are likely to ‘drown out’ if the water level exceeds 50mm for 50% of the time, effectively raising the normal water level of the wetland system. Based on Engeny’s revised strategy, the following effective normal water levels were documented. It should be noted that WLRB1 (WL1 in Engeny Table 5-5) is predicted to be carrying 319mm above NWL.

Table 5-5: Wetland Outlet Design Parameters

Wetland ID	Penstock Opening (mm)	Residence Time	Water Level Exceeded 50% of the time (m)	Design NWL (m AHD)	Resultant eNWL (m AHD)
WL1	250.0	3 days	0.319	13.6	13.869
WL2	47.0	3 days	0.17	14.05	14.17
WL3	130.4	3 days	0.144	13	13.094
WL4	52.4	3 days	0.166	13.3	13.416

Figure 38. *Water level inundation analysis (Engeny, 2021)*

As shown above, inundation exceeds half of the average plant height for 50% of the time by up to 300mm, which is a significant increase of the effective Normal Water Level (NWL) which is likely to result in drowning of the wetland vegetation. This issue can be resolved by some key adjustments to the wetland system:

- Reduce residence time within wetland (lowers treatment efficiency, falls short of BPEM/State targets)
- Reduce extended detention depth (EDD) of the wetland (lowers treatment efficiency)
- Increase treatment macrophyte area (required as part of velocity check)
- Raise bathymetry of the wetland system.

As part of the functional design process, Alluvium will further address the issue of inundation frequency, and ensure plant life within the wetland macrophyte area will be unlikely to drown out for excess periods under the future proposed developed conditions. Based on Engeny's current design, this treatment system is likely to fail.

MUSIC modelling treatment asset summary

The MUSIC modelling determined the sizing required for the four wetland assets located at each of the catchment low points, and the sediment basins located throughout the PSP area. The details of the required wetland treatment systems and sediment basins are provided in Table 18 and 19 below.

Given the increased wetland size required to meet velocity threshold limits, the retarding basin / wetland assets have been redesigned within the land subject to inundation extent, to maximise the area for stormwater quantity and quality drainage works. The proposed drainage reserve as part of the Alluvium drainage design is provided in Figure 39 below.

The land within the inundation extent falls within the LSIO. For development to occur within this area, land is required to be filled 600mm above the 1% AEP flood level. This is likely to result in a large cost to the developer due to large volumes of fill material required within the inundated land. As a result, it is best practice to maximise the use of this land for drainage purposes, to ensure the upstream potential developable area is 'freed up' and maximised. A summary of the proposed treatment assets is provided in Figure 39 below.

Table 18. Wetland treatment asset parameters for the Wonthaggi North East PSP

	WLRB1A	WLRB1B	WLRB2	WLRB3	WLRB4
NWL area, m^2	35,000	47,500	10,000	6,100	22,000
Inlet pond area, m^2	9,000	11,800	1,100	1,250	2,800
Inlet pond volume m^3	7,200	9,440	880	1,000	2,240
Ave. depth wetland, m	0.40	0.40	0.40	0.40	0.40
Extended detention, m	0.35	0.35	0.35	0.35	0.35
Extended detention time, hr	72.0	72.0	72.0	72.0	72.0

Table 19. Sediment basin treatment asset parameters for the Wonthaggi North East PSP

	SB2	*SB3*	*SB4*	*SB6*	*SB7*	*SB12*	*SB15*
NWL area, m^2	1,000	1,500	1,300	1,400	1,400	500	1,500
Average depth, m	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Extended detention, m	0.35	0.35	0.35	0.35	0.35	0.35	0.35

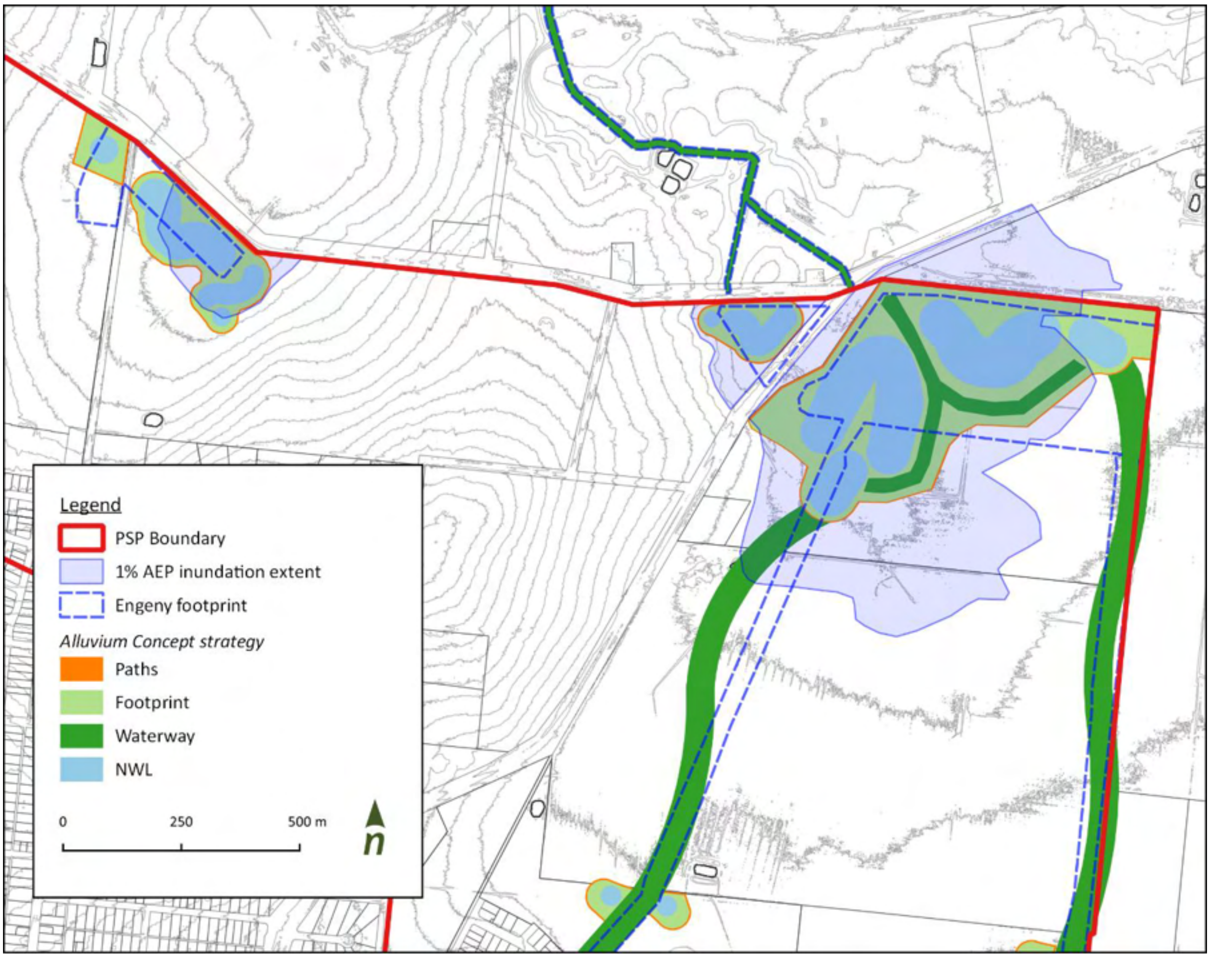


Figure 39. *Drainage reserve within the inundation extents (Alluvium concept, Sept 2021)*

Based on the above wetland and sediment basin treatment asset parameters, the MUSIC model was computed for three scenarios:

- Scenario 1: Meeting BPEM for the Precinct, assuming the external agricultural land to the south will remain as such for the foreseeable future, including the sediment basins out falling into the proposed constructed waterways.
- Scenario 2: Meeting BPEM within the wetland treatment systems, assuming the external agricultural land to the south will remain as such for the foreseeable future, whilst *removing* the requirement for upstream sediment basins out falling directly into the constructed waterways.
- Scenario 3: Future design scenario where the upstream external agricultural land to the south of the PSP will be part of a future development precinct and will be treated to BPEM prior to out falling into the Wonthaggi North East PSP area (as is currently the case based on existing topography).

Overall treatment performance – Scenario 1

As previously mentioned, the scenario 1 modelling undertaken assumed all upstream sediment basins directly discharging into the proposed internal waterways (W-WW & E-WW) are required. The modelling has assumed the upstream external catchment to the south remains as agricultural land, which has no prior treatment or control before directly out falling through the Wonthaggi North East PSP area.

The proposed wetlands have been redesigned / upsized in comparison to the Engeny strategy in order to meet velocity threshold requirements. The sediment basins have been upsized using the Fair and Geyer equation, where sediment basins are required to meet a 95% sediment capture efficiency of coarse particles ≥ 125 µm diameter for the peak 4EY (4 Exceedances per Year) event. Overall treatment performance has only considered meeting BPEM for the PSP area only. As a result, source loads generated from external catchments are not considered in the overall reduction results.

The results of the MUSIC modelling analysis demonstrates that BPEM targets <u>are met</u> with the performance of the wetland and sediment basin assets, as shown in Table 22.

Table 20. Total model inflow, PSP and external load, removal target, Scenario 1 and 2

	Removal target	Total model load	External load	PSP load	Removal target
TSS (kg/yr)	80%	694,080	197,000	694,080	555,260
TP (kg/yr)	45%	1,470	810	1,470	660
TN (kg/yr)	45%	10,740	10,400	10,740	4,830
GP (kg/yr)	75%	141,500	0	141,500	106,120

Table 21. Overall MUSIC modelling results – Scenario 1 treatment system

	Total model load	PSP load	Residual load	% Reduction Total model	Kg/yr removed	% Reduction PSP load only
TSS (kg/yr)	902,020	694,080	197,000	78.1	705,000	101.6%
TP (kg/yr)	2,070	1,470	810	60.8	1,260	85.5%
TN (kg/yr)	15,560	10,740	10,400	33.3	5,100	47.5%
GP (kg/yr)	175,970	141,500	0	100	176,000	124.4%

Overall treatment performance – Scenario 2

The scenario 2 modelling assumed the upstream sediment basins directly discharging into the proposed internal constructed waterways (W-WW & E-WW) are not required within the treatment system, considering sediment control is managed as part of the downstream online wetlands WLRB1A and WLRB1B. The WGCMA requires sediment control prior to outfall into natural waterway systems, so considering the internal constructed waterways are designed as a method of stormwater conveyance only, sediment control can be managed downstream prior to outfall into the proposed wetlands.

The modelling has assumed the upstream external catchment to the south remains as agricultural land, which has no prior treatment or control before directly out falling through the Wonthaggi North East PSP area. Overall treatment performance has only considered meeting BPEM for the PSP area only. As a result, source loads generated from external catchments are not considered in the overall reduction results.

The results of the MUSIC modelling analysis demonstrates that BPEM targets <u>are met</u> with the performance of the wetland and sediment basin assets, as shown in Table 24.

Table 22. Overall MUSIC modelling results – Scenario 2 treatment system

	Total model load	PSP load	Residual load	% Reduction Total model	Kg/yr removed	% Reduction PSP load only
TSS (kg/yr)	902,020	694,080	239,000	73.5	662,000	95.4
TP (kg/yr)	2,070	1,470	880	57.3	1,190	80.6
TN (kg/yr)	15,560	10,740	10,700	30.9	4,900	45.6
GP (kg/yr)	175,970	141,500	0	100	176,000	124.4

Overall treatment performance – Scenario 3

The provided Engeny modelling has assumed the external catchment to the south is agricultural land, and as such an agricultural source node has been used in the modelling. Agricultural source nodes generate high volumes of organic pollutants compared to urban land use types. As the external catchment to the south ultimately outfalls through the PSP area, the volumetric load reduction contributes to the overall treatment performance of the stormwater quality management strategy with regards to meeting BPEM for the site.

Considering the land south of the PSP area may be subject to future development, a scenario has been modelled to identify the risks associated with the change in land use type.

Scenario 3a

If the external catchment to the south is adjusted to an urban source load, and treated to BPEM prior to out falling into the Wonthaggi North East PSP, then the stormwater quality management strategy for the Wonthaggi North East PSP will not meet BPEM for TN. A summary of the results are provided below. As these flows are already treated by external (to the WNE PSP) wetlands, they dilute the water entering the WNE PSP wetland (WLRB1), meaning the water in the system has a lower concentration of pollutants making reduction targets more difficult to attain with the residence times as standard design.

The external and total model loads increase in this scenario and are included in Table 23.

Table 23. Total model inflow, PSP and external load, removal target, scenario 3a and 3b

	Removal target	Total model load	External load	PSP load	Removal target
TSS (kg/yr)	80%	1,510,000	815,920	694,080	555,260
TP (kg/yr)	45%	3,220	1,750	1,470	660
TN (kg/yr)	45%	23,500	12,760	10,740	4,830
GP (kg/yr)	75%	311,000	169,510	141,500	106,120

Table 24. Overall MUSIC modelling results – Scenario 3a treatment system – external catchment treated to BPEM

	Total model load	PSP load	Residual load	% Reduction Total model	Kg/yr removed in external catchment	Kg/yr removed in PSP	% Reduction PSP load only
TSS (kg/yr)	1,510,000	694,080	353,000	76.5	535,580	621,420	89.5
TP (kg/yr)	3,220	1,470	1,360	57.7	640	1,220	82.9
TN (kg/yr)	23,500	10,740	14,400	38.6	4,620	4,480	41.7
GP (kg/yr)	311,000	141,500	0	100	96,190	214,810	151.8

This poses a risk to the Powlett River and further downstream natural systems, due to a volumetric shortfall in pollutant removal as part of the Wonthaggi North East PSP. As this results in the PSP not meeting BPEM due to future development of the Wonthaggi township (external to the precinct), this scenario suggests development to the south will occur, which may not be likely within the current lifespan of the treatment wetland assets proposed for the WNE PSP. That is, areas south/south-east and external to the PSP boundary may be developed in 30yrs (or more) which aligns with asset renewals of the PSP treatment wetlands (assuming imminent delivery). As a result, two options are proposed:

- Increase the overall footprint of each wetland within the Wonthaggi North East PSP to account for the future shortfall of the BPEM targets.
- Diverting the external catchment (future PSPs) around the Wonthaggi North East PSP area, out falling to Powlett River, post treatment.

Both options pose opportunities to meet the overall target of BPEM in a future development conditions scenario, however costs associated with each should be considered within the development of the Wonthaggi North East DCP.

Scenario 3b

There is an opportunity to provide some form of open space / future drainage reserve located along the upstream boundary of the WLRB1A & WLRB1B, for future rectification / upsizing of these systems if development was to occur as part of a future PSP (upstream reaches of the catchment, external to WNE PSP) to the south of the Wonthaggi North East PSP area. It is important to note that the assets would not need to be built to this size until such a development occurs, but 2ha of extra space would need to be retained for future expansion to account for this development change.

Table 25. Changes in macrophyte zones for scenario 3b

Asset	Area at normal water level (m^2)			
	Inlet pond	Macrophyte zone scenario 2	Macrophyte zone scenario 3b	Increase
WL1a	9,000	35,000	45,000	10,000
WL1b	11,800	47,500	55,000	7,500
WL2	900	10,000	10,000	0
WL3	1,250	6,100	6,100	0
WL4	2,800	20,000	20,000	0
SB12		500 (SB area)	500 (SB area)	0
			Total increase	17,500

Table 26. Overall MUSIC modelling results – Scenario 3b treatment system – additional macrophyte zones

	Total model load	PSP load	Residual load	% Reduction Total model	Kg/yr removed in external catchment	Kg/yr removed in PSP	% Reduction PSP load only
TSS (kg/yr)	1,510,000	694,080	353,000	77.8	535,580	646,420	93.1
TP (kg/yr)	3,220	1,470	1,360	59.4	640	1,289	87.5
TN (kg/yr)	23,500	10,740	14,400	39.9	4,620	4,882	45.5
GP (kg/yr)	311,000	141,500	0	100	96,190	214,810	151.8

	Infrastructure	Area m²	Rate $/m²	Cost $	Total	+ 35% contingency
3b – If land is encumbered /LSIO	Wetland	17,500	67	1,172,500	$M 1.17	$M 1.58
	Land Acquisition	20,000	10	200,000		
3b – if land is residential /developable	Wetland	17,500	67	1,172,500	$M 2.37	$M 3.20
	Land Acquisition	20,000	60	1,200,000		

N.B. The cost of this option is heavily dependent on the price of available land to extend the treatment asset.

Scenario 3c

If the external catchment to the south of the Wonthaggi North East PSP is developed and treated to best practice outside of the PSP area, and then diverted around the assets of the WNE PSP (i.e. discharging directly to Powlett River) then the PSP will still meet BPEM (the results are provided below). This changes the total model inflow from scenario 3a and 3b (included in Table 27). Treatment areas, as used in Scenario 2.

In this option the system meets BPEM. A pipe would be required for low flows, which could be installed through the drainage reserves in the waterway corridors (encumbered land). This could be outlet into the high flow bypass of the wetlands or to Powlett River.

Table 27. Total model inflow, PSP and external load, removal target, scenario 3c

	Removal target	Total model load	External load	PSP load	Removal target
TSS (kg/yr)	80%	836,000	141,920	694,080	555,260
TP (kg/yr)	45%	1,800	330	1,470	660
TN (kg/yr)	45%	13,300	2,560	10,740	4,830
GP (kg/yr)	75%	173,000	31,510	141,500	106,120

Table 28. Overall MUSIC modelling results – Scenario 3c treatment system – external catchment diverted from PSP

	Total model load	PSP load	Residual load	% Reduction Total model	Kg/yr removed	% Reduction PSP load only
TSS (kg/yr)	836,000	694,080	190,000	77.2	646,000	93.1%
TP (kg/yr)	1,800	1,470	661	63.2	1,139	77.4%
TN (kg/yr)	13,300	10,740	8,130	38.7	5,170	48.1%
GP (kg/yr)	173,000	141,500	0	100	173,000	122.3%

	Asset	Length m	Rate $/m	Cost $	Total	+ 35% contingency
3c – pipe in each waterway corridor to WL bypass	450mm Rubber Ring Jointed pipe	7,000	206	1,442,000	$M 1.44	$M 1.95
3c - single pipe through the eastern waterway, to WL bypass (may be technically difficult with flat landscape)	450mm Rubber Ring Jointed pipe	4,000	206	824,000	$M 0.82	$M 1.11

N.B. The cost of this option is heavily dependent on whether or not the pipes can be consolidated into one pipe asset to convey the water. Land acquisition costs have not been included because it is assumed there is enough space in the waterway corridor to accommodate.

Cost comparison

The DCP costing has a total cost for WLRB1 of $2,547,333 with a NWL area of 38,000m^2. This is an approximate unit rate of $67/ m^2, which has been assumed as a representative rate for the additional macrophyte zone that would be required in scenario 3b.

The DCP costing has a total cost for pipe reference 43-45; a 210m long, 450mm diameter pipe. This is an approximate unit rate of $206/m, which has been assumed as a representative rate for a pipe to convey treated low flows through the drainage reserves as required in scenario 3c.

	Scenario 3b	Scenario 3c
Asset	17,500m^2 Macrophyte zone extension	2 x 3.5km rubber ring jointed pipes
Unit	m^2	m
Unit cost	$67/m^2	$206/m
Total cost	$1,172,500	$1,442,000
+35% contingency (as per DCP)	$1,582,875	$1,946,700
Other comments	Land acquisition cost has not been included, for 2ha. Cost will depend on where area is LSIO.	

Scenario 4

One further scenario was explored – increasing the size of the assets to treat the upstream flows from the existing residential areas. The removal targets are updated as outlined in Table 29, with adopted sizes outlined in Table 30 and model results in Table 31.

This would require an extra 52,000m^2 of macrophyte zone, as well as areas for accompanying infrastructure. Council could contribute to purchasing extra land in these areas which would likely be less expensive than retrofitting distributed treatments within the catchment.

Table 29. Total model inflow, PSP and external load, removal target, scenario 4

	Removal target	Total model load	External Load (agricultural)	External Load (existing urban)	PSP load	Removal target
TSS (kg/yr)	80%	902,020	63,640	144,300	694,080	670,700
TP (kg/yr)	45%	2,070	270	330	1,470	810
TN (kg/yr)	45%	15,560	2,300	2,520	10,740	5,970
GP (kg/yr)	75%	175,970	2,660	31,820	141,500	129,990

Table 30. Changes in macrophyte zones for scenario 4

Asset	Area at normal water level (m^2)			
	Inlet pond	Macrophyte zone scenario 2	Macrophyte zone scenario 4	Increase
WL1a	9,000	35,000	80,000	32,500
WL1b	11,800	47,500	22,000	12,000
WL2	900	10,000	6,100	0
WL3	1,250	6,100	27,500	7,500
WL4	2,800	20,000	80,000	32,500
SB12		500 (SB area)	500 (SB area)	0
			Total increase	**52,000m^2**

Table 31. Overall MUSIC modelling results – Scenario 4 treatment system – Existing urban areas treated in PSP

	Total model load	External Load (existing urban)	PSP load	Residual load	% Reduction Total model	Kg/yr removed	% Reduction PSP load only
TSS (kg/yr)	902,020	144,300	694,080	178,000	80.2%	722,000	86%
TP (kg/yr)	2,070	330	1,470	740	64.2%	1,330	74%
TN (kg/yr)	15,560	2,520	10,740	9,560	38.5%	5,940	45%
GP (kg/yr)	175,970	31,820	141,500	0	100%	176,000	102%

6.8 Recommended Concept Layout Plan - Alluvium

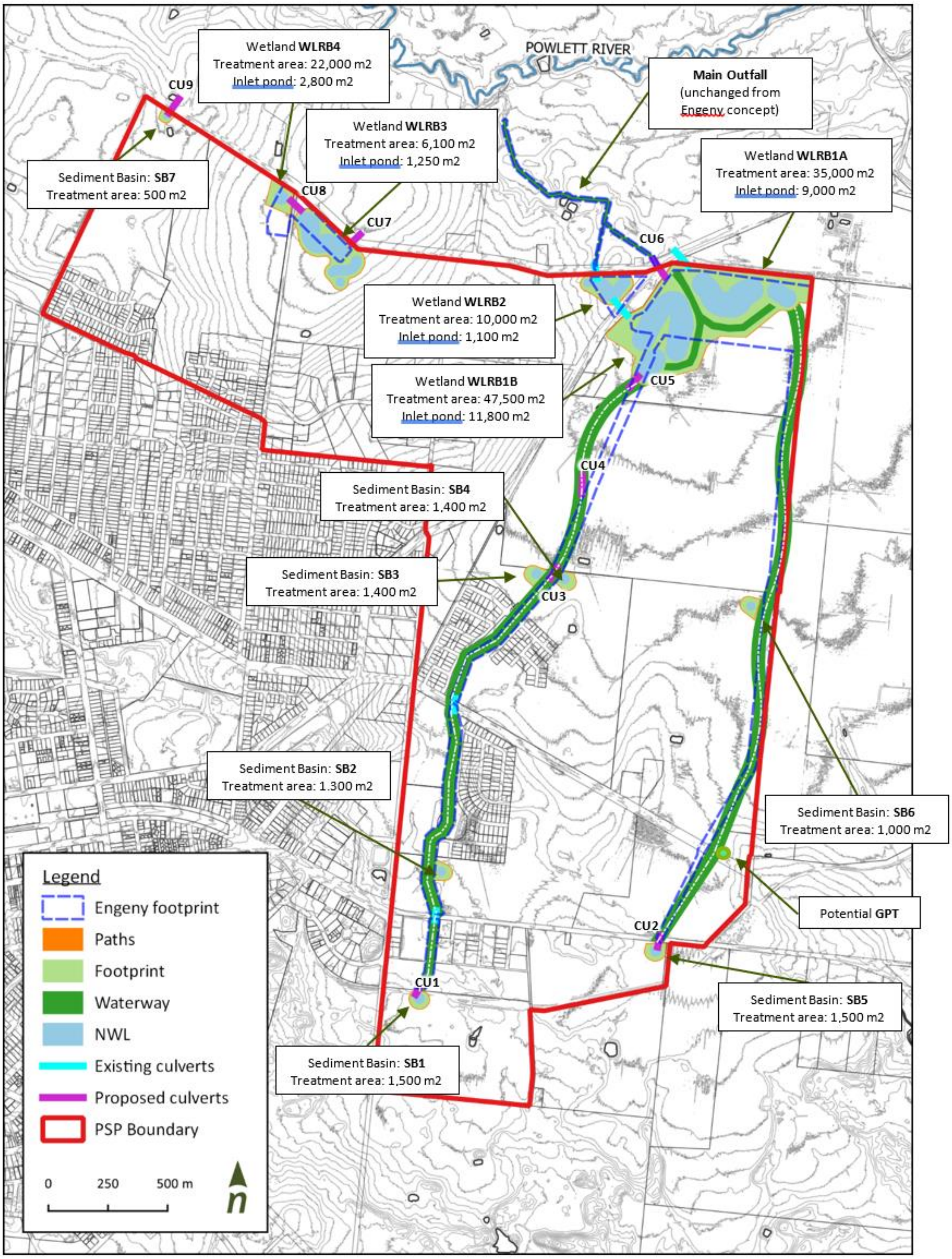


Figure 40. Alluvium stormwater treatment assets proposed layout (Alluvium concept, Sept 2021)

7 Conclusion

Alluvium Consulting has been engaged by the VPA in partnership with Bass Coast Shire Council to undertake the stormwater drainage functional designs and associated cost estimates for the Wonthaggi North East PSP.

This 'Proof of Concept' Report is the first stage of the project, documenting the site context for the growth corridor, previous stormwater drainage investigations, background reviews and analyses, and stakeholder feedback / input to best service the future WNE PSP.

Alluvium completed a review of previous strategic work, studies for the area, modelling and concept designs undertaken by others. We have built on this wealth of work and a thorough review of the PSP landscape, future plans, current conditions and intended outcomes, and have developed a revised stormwater management concept for the PSP, focusing on creating a more cost-effective outcome, minimises land take and promotes sustainable lot yield, improves upon water attenuation and treatment capacity, and provides a more viable developer contribution cost for the precinct.

Underlying this objective is the requirement for multi-outcome/multi-functional assets which not only treat stormwater and manage flows, but provide for broader community benefits such as amenity, recreation, cooling, connectivity and health wellbeing outcomes, biodiversity / cultural heritage preservation and/or enhancement, and IWM opportunities. Well-designed assets, which also integrate with the surrounding urban landscape, can meet all these objectives, as recommended in this PoC report.

Through the review process, Alluvium found that Engeny's strategic concepts had both pros and cons as they relate to the overall project objectives, optimised asset function, and broader community benefits. Therefore, this PoC highlights Alluvium's recommended stormwater management approach for the PSP.

We recommend the way forward in the functional design phase, approach these asset designs with the following in mind:

- all wetlands have a retarding function, subsequently adopting the naming convention WLRB from hereon.
- considering flow volumes modelled to pass through WLRB1, we propose to 'split' this system into two parts (WLRB1A and WLRB1B) with corresponding inlet zones. This will improve overall treatment performance and asset integrity (given the contributing catchments in play), while ensuring overall land take (footprint) is confined to existing areas prone to inundation.
- increase sinuosity of W-WW and E-WW to reduce flow velocities and protect integrity of WLRB1A and WLRB1B and promote long term stability and ecological health of these constructed waterways and their associated riparian zones (vegetation buffer for bank protection).
- reduce the number of independent sediment basins by integrating them into WLRB assets or removing unnecessary assets - a major cost saving element in this proposed approach.

We are mindful of the multiple factors that go into PSP planning and believe the recommended strategy provides the best outcome for VPA, Council, developers, and the future community.

Acknowledging the challenge of this study running in parallel with the development of the drainage strategy for the PSP being done by others (Engeny), there has been some confusion throughout the process as naming conventions and asset counts changed as the drainage strategy was refined and revised.

To clear confusion, Table 1 (Section 1) provided a consolidated summary of past and current asset naming and numbering across all documentation.

Going forward, Alluvium recommends that all assets are re-numbered and renamed as proposed in Table 32 (below) for ease and clarity during the future functional design stage, drawing numbering, and ease in future implementation process. The aim of this is reduce confusion in future documentation and provide simple tracking through the PSP's development (and easier for Council and developers alike).

The next stages of the design process are:

- Receive feedback / acceptance of Alluvium's proposed stormwater management approach (VPA/stakeholders)
- Alluvium to progress the preferred approach through to 23 functional designs including:
  - Treatment modelling of all assets to confirm treatment areas and inundation frequencies
  - Undertake hydrologic modelling to size storage requirements
  - Model the assets in a 3D earthworks modelling program (12d), identifying all key design levels, pipe inverts, key infrastructure
  - Prepare a functional design drawing set for proposed assets
  - Prepare cost estimates for the proposed works.

Table 32. Proposed asset naming convention for future Alluvium functional design

#	PROPOSED ALLUVIUM ASSET ID FOR FUNCTIONAL DESIGN	FORMER ENGENY FINAL STRATEGY ASSET ID
1	W-WW	W-WW
2	E-WW	E-WW
3	WLRB1A (east) & WLRB1B (west)	WLRB1
4	WLRB2	WLRB2
5	WLRB3	WLRB3
6	WLRB4	WLRB4
7	SB1	SB3
8	SB2	SB4
9	SB3	SB6
10	SB4	SB7
11	SB5	SB15
12	SB6	SB2
13	SB7	SB12
14	CU1	CU1
15	CU2	CU3 (missing from Final Strategy but critical)
16	CU3	CU5
17	CU4	CU6
18	CU5	CU7
19	CU6	CU8
20	CU7	CU10
21	CU8	CU11
22	CU9	CU12
23	MOP	Main Outfall
TOTAL	**23 designs to progress to functional design stage**	

8 References

BCSC & VPA, 2020. Wonthaggi North East Development Contributions Plan

BCSC & VPA, 2020. Wonthaggi North East Precinct Structure Plan

Bunurong Land Council Aboriginal Corporation website: https://www.bunuronglc.org/

Engeny & BCSC, 2019. Drainage Strategy for Wonthaggi North East PSP (October 2019)

Engeny, 2021. 465 Heslop Road Wonthaggi NE PSP Impact and Proposed Mitigation Works (March 2021)

Engeny, 2021. Revised HECRAS and MUSIC Modelling for Wetlands 1 and 2 (13th August 2021)

Engeny, 2021. Revised 12D Design for Wetland-Retarding Basins 1 & 2 (20th August 2021)

Engeny, 2021. Revised Drainage Strategy for Wonthaggi North East PSP (25th August 2021)

Engeny, 2021. (Final) Drainage Strategy for Wonthaggi North East PSP (September 2021)

Nature Advisory & BCSC, 2020. Wonthaggi North East Precinct Structure Plan Flora and Fauna Assessment

Triskel Heritage Consulting, 2017. Wonthaggi North East Growth Area: Aboriginal Cultural Heritage Survey

Attachment A
Engeny Strategy Design Calculations

Sediment basin sizing for SB1

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	23.13
	Area of Basin (m^2)	520
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.30
	Permanent Pool Depth, dp (m)	0.5
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.1
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.5
	Design Discharge (m^3/s) [Q3-month]	0.438
	Capture Efficiency	96.3%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2
	Desired clean-out frequency, Fr	5
	Storage volume required, St	223
	Available sediment storage volume	260
	Check (Available storage > required storage)	OK
Sediment dewatering	Depth for dewatering area (m)	0.5
	Area required for dewatering (m^2)	446

Sediment basin sizing for SB2

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	48.36
	Area of Basin (m^2)	810
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.30
	Permanent Pool Depth, dp (m)	0.5
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.1
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.5
	Design Discharge (m^3/s) [Q3-month]	0.727
	Capture Efficiency	96.0%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2
	Desired clean-out frequency, Fr	5
	Storage volume required, St	464
	Available sediment storage volume	405
	Check (Available storage > required storage)	Not OK
Sediment dewatering	Depth for dewatering area (m)	0.5
	Area required for dewatering (m^2)	929

Sediment basin sizing for SB3

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	147.33
	Area of Basin (m^2)	700
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.30
	Permanent Pool Depth, dp (m)	0.5
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.1
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.5
	Design Discharge (m^3/s) [Q3-month]	1.024
	Capture Efficiency	92.7%
	Check (>95%)	Not OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2
	Desired clean-out frequency, Fr	5
	Storage volume required, St	1366
	Available sediment storage volume	350
	Check (Available storage > required storage)	Not OK
Sediment dewatering	Depth for dewatering area (m)	0.5
	Area required for dewatering (m^2)	2732

Sediment basin sizing for SB4

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	52.58
	Area of Basin (m^2)	850
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.30
	Permanent Pool Depth, dp (m)	0.5
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.1
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.5
	Design Discharge (m^3/s) [Q3-month]	0.918
	Capture Efficiency	94.9%
	Check (>95%)	Not OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2
	Desired clean-out frequency, Fr	5
	Storage volume required, St	499
	Available sediment storage volume	425
	Check (Available storage > required storage)	Not OK
Sediment dewatering	Depth for dewatering area (m)	0.5
	Area required for dewatering (m^2)	999

Sediment basin sizing for SB5

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	54.63
	Area of Basin (m^2)	880
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.30
	Permanent Pool Depth, dp (m)	0.5
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.1
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.5
	Design Discharge (m^3/s) [Q3-month]	0.688
	Capture Efficiency	96.7%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2
	Desired clean-out frequency, Fr	5
	Storage volume required, St	528
	Available sediment storage volume	440
	Check (Available storage > required storage)	Not OK
Sediment dewatering	Depth for dewatering area (m)	0.5
	Area required for dewatering (m^2)	1056

Sediment basin sizing for SB6

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	68.27
	Area of Basin (m^2)	1030
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.30
	Permanent Pool Depth, dp (m)	0.5
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.1
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.5
	Design Discharge (m^3/s) [Q3-month]	0.991
	Capture Efficiency	95.7%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2
	Desired clean-out frequency, Fr	5
	Storage volume required, St	653
	Available sediment storage volume	515
	Check (Available storage > required storage)	Not OK
Sediment dewatering	Depth for dewatering area (m)	0.5
	Area required for dewatering (m^2)	1306

Sediment basin sizing for SB7

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	63.90
	Area of Basin (m^2)	980
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.30
	Permanent Pool Depth, dp (m)	0.5
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.1
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.5
	Design Discharge (m^3/s) [Q3-month]	0.968
	Capture Efficiency	95.5%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2
	Desired clean-out frequency, Fr	5
	Storage volume required, St	610
	Available sediment storage volume	490
	Check (Available storage > required storage)	Not OK
Sediment dewatering	Depth for dewatering area (m)	0.5
	Area required for dewatering (m^2)	1221

Sediment basin sizing for SB8

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	87.90
	Area of Basin (m^2)	1230
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.30
	Permanent Pool Depth, dp (m)	0.5
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.1
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.5
	Design Discharge (m^3/s) [Q3-month]	1.263
	Capture Efficiency	95.3%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2
	Desired clean-out frequency, Fr	5
	Storage volume required, St	838
	Available sediment storage volume	615
	Check (Available storage > required storage)	Not OK
Sediment dewatering	Depth for dewatering area (m)	0.5
	Area required for dewatering (m^2)	1675

Sediment basin sizing for SB9

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	38.037
	Area of Basin (m^2)	700
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.30
	Permanent Pool Depth, dp (m)	0.5
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.1
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.5
	Design Discharge (m^3/s) [Q3-month]	0.493
	Capture Efficiency	97.1%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2
	Desired clean-out frequency, Fr	5
	Storage volume required, St	369
	Available sediment storage volume	350
	Check (Available storage > required storage)	Not OK
Sediment dewatering	Depth for dewatering area (m)	0.5
	Area required for dewatering (m^2)	739

Sediment basin sizing for SB11

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	52.27
	Area of Basin (m^2)	920
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.30
	Permanent Pool Depth, dp (m)	0.5
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.1
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.5
	Design Discharge (m^3/s) [Q3-month]	1.187
	Capture Efficiency	93.8%
	Check (>95%)	Not OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2
	Desired clean-out frequency, Fr	5
	Storage volume required, St	490
	Available sediment storage volume	460
	Check (Available storage > required storage)	Not OK
Sediment dewatering	Depth for dewatering area (m)	0.5
	Area required for dewatering (m^2)	980

Sediment basin sizing for SB12

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	20.25
	Area of Basin (m^2)	500
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 μm]	11
	Hydraulic Efficiency (λ)	0.30
	Permanent Pool Depth, dp (m)	0.5
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.1
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.5
	Design Discharge (m^3/s) [Q3-month]	0.247
	Capture Efficiency	98.2%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2
	Desired clean-out frequency, Fr	5
	Storage volume required, St	199
	Available sediment storage volume	250
	Check (Available storage > required storage)	OK
Sediment dewatering	Depth for dewatering area (m)	0.5
	Area required for dewatering (m^2)	398

Sediment basin sizing for SB14

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	13.62
	Area of Basin (m^2)	500
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 μm]	11
	Hydraulic Efficiency (λ)	0.30
	Permanent Pool Depth, dp (m)	0.5
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.1
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.5
	Design Discharge (m^3/s) [Q3-month]	0.264
	Capture Efficiency	98.0%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2
	Desired clean-out frequency, Fr	5
	Storage volume required, St	133
	Available sediment storage volume	250
	Check (Available storage > required storage)	OK
Sediment dewatering	Depth for dewatering area (m)	0.5
	Area required for dewatering (m^2)	267

Sediment basin sizing for SB15

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	147.50
	Area of Basin (m^2)	500
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.30
	Permanent Pool Depth, dp (m)	0.5
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.1
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.5
	Design Discharge (m^3/s) [Q3-month]	0.566
	Capture Efficiency	94.7%
	Check (>95%)	Not OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2
	Desired clean-out frequency, Fr	5
	Storage volume required, St	1397
	Available sediment storage volume	250
	Check (Available storage > required storage)	Not OK
Sediment dewatering	Depth for dewatering area (m)	0.5
	Area required for dewatering (m^2)	2793

Velocity Calculations for WL1

	Parameter	4EY	20% AEP
Flow Conditions	Design flow (m^3/s)	4.25	23.63
	Flow depth (m)	0.35	0.35
Sediment Basin	Width at NWL (m)	50	50
	Width at EDD (m)	54.2	54.2
	Average Width (m)	52.1	52.1
	Flow area (m^2)	18.2	18.2
	Flow velocity (m/s)	0.23	1.30
Macrophyte zone	Width at NWL (m)	120	120
	Width at EDD (m)	124.2	124.2
	Average Width (m)	122.1	122.1
	Flow area (m^2)	43	43
	Flow velocity (m/s)	0.10	0.55

Velocity Calculations for WL2

	Parameter	4EY	20% AEP
Flow Conditions	Design flow (m^3/s)	0.91	5.05
	Flow depth (m)	0.35	0.35
Sediment Basin	Width at NWL (m)	27	27
	Width at EDD (m)	31.2	31.2
	Average Width (m)	29.1	29.1
	Flow area (m^2)	10.2	10.2
	Flow velocity (m/s)	0.09	0.50
Macrophyte zone	Width at NWL (m)	44	44
	Width at EDD (m)	48.2	48.2
	Average Width (m)	46.1	46.1
	Flow area (m^2)	16	16
	Flow velocity (m/s)	0.06	0.31

Velocity Calculations for WL3

	Parameter	4EY	20% AEP
Flow Conditions	Design flow (m^3/s)	1.98	11.01
	Flow depth (m)	0.35	0.35
Sediment Basin	Width at NWL (m)	25	25
	Width at EDD (m)	29.2	29.2
	Average Width (m)	27.1	27.1
	Flow area (m^2)	9.5	9.5
	Flow velocity (m/s)	0.21	1.16
Macrophyte zone	Width at NWL (m)	57	57
	Width at EDD (m)	61.2	61.2
	Average Width (m)	59.1	59.1
	Flow area (m^2)	9.5	9.5
	Flow velocity (m/s)	0.10	0.53

Velocity Calculations for WL4

	Parameter	4EY	20% AEP
Flow Conditions	Design flow (m^3/s)	1.31	7.25
	Flow depth (m)	0.35	0.35
Sediment Basin	Width at NWL (m)	25	25
	Width at EDD (m)	29.2	29.2
	Average Width (m)	27.1	27.1
	Flow area (m^2)	9.5	9.5
	Flow velocity (m/s)	0.14	0.76
Macrophyte zone	Width at NWL (m)	38	38
	Width at EDD (m)	42.2	42.2
	Average Width (m)	40.1	40.1
	Flow area (m^2)	14	14
	Flow velocity (m/s)	0.09	0.52

Attachment B
Sediment Basin Design Calculations

Sediment basin sizing for SB2

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	48.36
	Area of Basin (m^2)	1,000
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.11
	Permanent Pool Depth, dp (m)	0.50
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.12
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.50
	Design Discharge (m^3/s) [Q3-month]	0.73
	Capture Efficiency	95.0%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2.0
	Desired clean-out frequency, Fr	5
	Storage volume required, St	459
	Available sediment storage volume	620
	Check (Available storage > required storage)	OK
Sediment dewatering	Depth for dewatering area (m)	0.50
	Area required for dewatering (m^2)	918

Sediment basin sizing for SB3

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	100
	Area of Basin (m^2)	1,500
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.11
	Permanent Pool Depth, dp (m)	0.50
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.12
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.50
	Design Discharge (m^3/s) [Q3-month]	1.02
	Capture Efficiency	95.4%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2.0
	Desired clean-out frequency, Fr	5
	Storage volume required, St	954
	Available sediment storage volume	1,143
	Check (Available storage > required storage)	OK
Sediment dewatering	Depth for dewatering area (m)	0.50
	Area required for dewatering (m^2)	1,908

Sediment basin sizing for SB4

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	52.58
	Area of Basin (m^2)	1,300
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.11
	Permanent Pool Depth, dp (m)	0.50
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.12
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.50
	Design Discharge (m^3/s) [Q3-month]	0.92
	Capture Efficiency	95.2%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2.0
	Desired clean-out frequency, Fr	5
	Storage volume required, St	500
	Available sediment storage volume	991
	Check (Available storage > required storage)	OK
Sediment dewatering	Depth for dewatering area (m)	0.50
	Area required for dewatering (m^2)	1,000

Sediment basin sizing for SB6

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	68.27
	Area of Basin (m^2)	1,400
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.11
	Permanent Pool Depth, dp (m)	0.50
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.12
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.50
	Design Discharge (m^3/s) [Q3-month]	0.99
	Capture Efficiency	95.2%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2.0
	Desired clean-out frequency, Fr	5
	Storage volume required, St	650
	Available sediment storage volume	956
	Check (Available storage > required storage)	OK
Sediment dewatering	Depth for dewatering area (m)	0.50
	Area required for dewatering (m^2)	1,298

Sediment basin sizing for SB7

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	63.9
	Area of Basin (m^2)	1,400
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.11
	Permanent Pool Depth, dp (m)	0.50
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.12
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.50
	Design Discharge (m^3/s) [Q3-month]	0.97
	Capture Efficiency	95.3%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2.0
	Desired clean-out frequency, Fr	5
	Storage volume required, St	609
	Available sediment storage volume	956
	Check (Available storage > required storage)	OK
Sediment dewatering	Depth for dewatering area (m)	0.50
	Area required for dewatering (m^2)	1,218

Sediment basin sizing for SB12

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	20.25
	Area of Basin (m^2)	500
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.11
	Permanent Pool Depth, dp (m)	0.50
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.12
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.50
	Design Discharge (m^3/s) [Q3-month]	0.25
	Capture Efficiency	96.7%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2.0
	Desired clean-out frequency, Fr	5
	Storage volume required, St	196
	Available sediment storage volume	341
	Check (Available storage > required storage)	OK
Sediment dewatering	Depth for dewatering area (m)	0.50
	Area required for dewatering (m^2)	392

Sediment basin sizing for SB15

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	100
	Area of Basin (m^2)	1,500
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.11
	Permanent Pool Depth, dp (m)	0.50
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.12
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.50
	Design Discharge (m^3/s) [Q3-month]	0.57
	Capture Efficiency	97.5%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2.0
	Desired clean-out frequency, Fr	5
	Storage volume required, St	975
	Available sediment storage volume	1025
	Check (Available storage > required storage)	OK
Sediment dewatering	Depth for dewatering area (m)	0.50
	Area required for dewatering (m^2)	1,950

Sediment basin sizing for WLRB1A

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	552
	Area of Basin (m^2)	9,000
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.11
	Permanent Pool Depth, dp (m)	0.50
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.12
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.50
	Design Discharge (m^3/s) [Q3-month]	1.61
	Capture Efficiency	98.9%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2.0
	Desired clean-out frequency, Fr	5
	Storage volume required, St	5,460
	Available sediment storage volume	7,170
	Check (Available storage > required storage)	OK
Sediment dewatering	Depth for dewatering area (m)	0.50
	Area required for dewatering (m^2)	10,920

Sediment basin sizing for WLRB1B

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	498
	Area of Basin (m^2)	11,800
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.11
	Permanent Pool Depth, dp (m)	0.50
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.12
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.50
	Design Discharge (m^3/s) [Q3-month]	2.76
	Capture Efficiency	98.5%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2.0
	Desired clean-out frequency, Fr	5
	Storage volume required, St	4,907
	Available sediment storage volume	9,400
	Check (Available storage > required storage)	OK
Sediment dewatering	Depth for dewatering area (m)	0.50
	Area required for dewatering (m^2)	9,814

Sediment basin sizing for WLRB2

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	73
	Area of Basin (m^2)	1,250
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.11
	Permanent Pool Depth, dp (m)	0.50
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.12
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.50
	Design Discharge (m^3/s) [Q3-month]	0.91
	Capture Efficiency	95.0%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2.0
	Desired clean-out frequency, Fr	5
	Storage volume required, St	694
	Available sediment storage volume	854
	Check (Available storage > required storage)	OK
Sediment dewatering	Depth for dewatering area (m)	0.50
	Area required for dewatering (m^2)	1,388

Sediment basin sizing for WLRB3

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	52
	Area of Basin (m^2)	1,250
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.11
	Permanent Pool Depth, dp (m)	0.50
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.12
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.50
	Design Discharge (m^3/s) [Q3-month]	0.68
	Capture Efficiency	96.3%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2.0
	Desired clean-out frequency, Fr	5
	Storage volume required, St	501
	Available sediment storage volume	854
	Check (Available storage > required storage)	OK
Sediment dewatering	Depth for dewatering area (m)	0.50
	Area required for dewatering (m^2)	1,002

Sediment basin sizing for WLRB4

	Parameter	Proposed design
Conditions	Contributing Catchment (ha)	101
	Area of Basin (m^2)	2,800
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11
	Hydraulic Efficiency (λ)	0.11
	Permanent Pool Depth, dp (m)	0.50
	Extended detention depth, de	0.35
	Number of CTSR's, n	1.12
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.50
	Design Discharge (m^3/s) [Q3-month]	1.31
	Capture Efficiency	96.9%
	Check (>95%)	OK
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr)	2.0
	Desired clean-out frequency, Fr	5
	Storage volume required, St	979
	Available sediment storage volume	2,081
	Check (Available storage > required storage)	OK
Sediment dewatering	Depth for dewatering area (m)	0.50
	Area required for dewatering (m^2)	1,958