INTEGRATED WATER MANAGEMENT GUIDELINES

NEIGHBOURHOOD DESIGN MANUAL

Version 1.1
February 2024

City of Whittlesea

Contents

These Guidelines were developed in partnership with Melbourne Water and E2DesignLab

Melbourne Water
Enhancing Life and Liveability

E2DESIGNLAB

Peter Hopper Lake in Redleap Reserve, Mill Park

1. Introduction

The City of Whittlesea's Integrated Water Management (IWM) Guidelines were developed for the purpose of effectively managing water resources and promoting sustainable development practices. The Guidelines serve to align water management approaches with local context and specific goals, fostering uniformity and clarity for the development industry. This document shall provide essential support for urban planning and design processes, offering practical guidance and recommendations for integrating Water Sensitive Urban Design (WSUD) and Integrated Water Management (IWM) practices into new developments or retrofitting existing infrastructure. The comprehensive approach shall facilitate informed decision-making, ultimately leading to the creation of more resilient and water-sensitive urban environments.

About the Guidelines

The Neighbourhood Design Manual's Integrated Water Management Guidelines (the Guidelines) provide details on Council's preferred water management outcomes and guidance on design and documentation to plan for and deliver attractive, safe, inclusive, functional and sustainable developments in the City of Whittlesea.

Relevant policies and standards

The Guidelines have been prepared to support policies and strategies from the Victorian Government and the City of Whittlesea, including but not limited to:

- *Sustainable Environment Strategy 2022-2032* (City of Whittlesea)
- *Yarra Catchment Integrated Water Management Plan 2022* (Yarra IWM Forum)
- *Greening Whittlesea City Forest Strategy 2020-2040* (City of Whittlesea)
- *Urban Stormwater Management Guidelines 2021* (EPA Victoria)
- *Whittlesea Water for All 2020-2030* (City of Whittlesea)
- *Designing for a Cool City 2020* (CRC for Water Sensitive Cities)
- *Healthy Waterways Strategy 2018-2028* (Melbourne Water)

How to use the Guidelines

This document is designed to guide the integration of IWM into all types of developments. The Guidelines aim to set out the City of Whittlesea's expectations for IWM projects within the municipality to inform developers, consultants, Council project managers and design engineers. The document provides information on the approvals process, design and modelling considerations, suitability of IWM technology types in different conditions and requirements for construction, protection, maintenance and handover of IWM assets.

The IWM Guidelines do not seek to recreate the technical guidance provided in other published documents, but rather to tie these documents together and act as a first reference point for IWM projects.

What the Guidelines cover:

- The City of Whittlesea's IWM aspirations for new urban environments.
- The City of Whittlesea's requirements on IWM contribution reporting.
- IWM asset design and modelling advice.
- IWM design submission and asset handover requirements.

The Guidelines do not cover:

- Engineering requirements for stormwater drainage.
- Flood management and mitigation infrastructure.
- General landscaping requirements.
- Design and operational requirements on the City of Whittlesea's irrigation assets.
- Potable, recycled and wastewater management.

1.1 Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) aims to minimise the impact of urban development on water resources and ecosystems. It emphasises the design of physical infrastructure and features that promote sustainable water management, such as blue-green infrastructure, stormwater harvesting, and decentralised water treatment systems. WSUD assumes a critical role in safeguarding the ecological integrity of urban waterways and ecosystems.
By employing WSUD principles, urban areas can effectively manage stormwater runoff, reduce flooding risks, and protect water bodies from pollution. Well designed and maintained WSUD can provide many co-benefits, including enhancing local amenity, reducing the urban heat island effect, increasing local access to nature and supporting biodiversity.

1.2 Integrated Water Management

Integrated Water Management (IWM) encompasses the holistic approach to managing water resources at a regional or catchment scale. It considers the entire water cycle, including the supply, treatment, use and disposal of water. IWM seeks to optimise the overall management of water resources and ensure their long-term sustainability and benefit to the community. The City of Whittlesea's role in IWM as the local drainage authority concentrates on optimal stormwater management across its municipality, to ensure stormwater is adequately utilised as a resource for healthy urban climates. Prioritising stormwater as a local resource, IWM nurtures the intricate web of life within urban environments, promoting resilience and sustainability.

The City of Whittlesea follows three basic principles in stormwater management which apply to all developments within the municipality, from infill development, large residential estate establishment to the City of Whittlesea's own infrastructure projects.

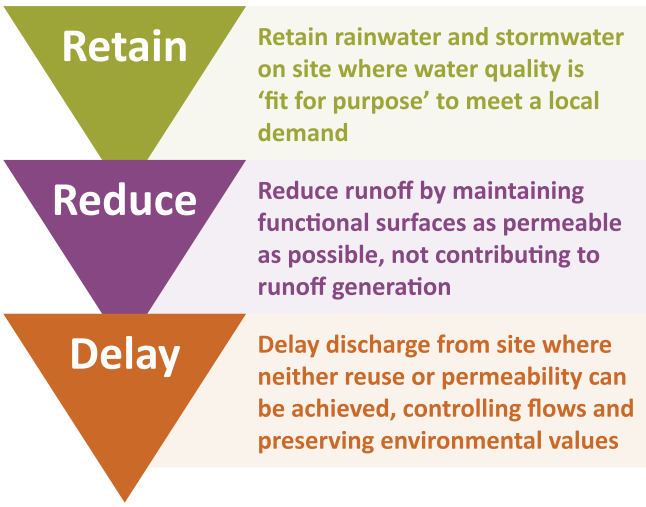

Figure 1 Stormwater management preferences

Preference (in order)	Retain	Reduce	Delay
	Retain rainwater and stormwater on site where water quality is 'fit for purpose' to meet a local demand	Reduce runoff by maintaining functional surfaces as permeable as possible, not contributing to runoff generation	Delay discharge from site where neither reuse or permeability can be achieved, controlling flows and preserving environmental values
Buildings	Maximise rainwater capture to satisfy facility/dwelling demands such as toilet flushing or any other site operation where potable water quality is not required. Tanks come in multiple forms and shapes to suit available real estate and amenity objectives. Tanks can be proactively or passively used for landscape irrigation around the building, such as via drip irrigation systems.	Buildings can feature green roofs which reduce rainwater runoff, contribute to micro-climate cooling, provide ecological habitat and improve building insulation.	Where no on-site demand exists for the surplus of rainwater, the volume may still be stored in tanks to allow for slow flow release in order to mimic pre-development site runoff.
Car parks	Pavements and hardstand areas can act as water catchments for passively irrigatable landscapes when surface finishes are sloped towards garden beds and trees.	Block pavers and paver grids can hold stormwater on-site and therefore achieve a great reduction in runoff. The moisture held in pore spaces evaporates back into the atmosphere. While filtrating water through pavement profiles, it also causes a delay in overall surface runoff relieving stress on the downstream drainage network.	
Streetscapes	Pavements and hardstand areas can act as a water catchment for passively irrigatable street trees to promote accelerated growth in the initial years of tree establishment.	As above.	
Public spaces	Hardstand areas can slope towards urban trees for passive irrigation. Furthermore, runoff (if sufficiently pre-treated) can be a source for ornamental waterbodies in the urban landscape. These provide habitat for a variety of biodiversity and act as a cool sink in urban environments to combat urban heat.	Paved surfaces can remain permeable where traffic loads are light and infrequent. Water may be allowed to infiltrate into underlying soils where no impact on nearby structures can be expected or excluded by design.	

Table 1 Preferred IWM responses in the City of Whittlesea

1.3 Threats of climate change

Climate change has significant impacts on the water cycle, altering the balance and availability of water resources. Rising temperatures intensify evaporation, leading to increased water loss from lakes, rivers and soils. This, coupled with changing precipitation patterns, results in more frequent and severe droughts in some regions, while others experience intensified rainfall and flooding events. These changes disrupt the natural flow of water, posing challenges for agriculture, ecosystems and human communities that rely on consistent water accessibility.

Climate change exacerbates extended periods of water scarcity, alters hydrological patterns, and necessitates adaptive measures in managing and preserving water resources. Integrated Water Management (IWM) optimises the use of finite water resources and reduces the reliance on traditional supply mechanisms. Following the three principles of optimal stormwater management (retain, reduce, delay) greatly supports a community to be adaptive and resilient to changing climates.

During Melbourne's 2000s Millennium Drought, rainfall in the City of Whittlesea had dropped as low as 450mm per annum. The Millennium Drought put pressure on Melbourne's water supplies. On the contrary, the highest rainfall event recorded in the City of Whittlesea was on 3 February 2005, with more than 130mm rain recorded in a single day.

Incorporation of IWM infrastructure in urban developments seeks to mitigate the urban heat island effect, improve air quality and provide shade, thus reducing the impacts of heatwaves and enhancing urban liveability in changing climates. Different surface materials in residential developments exhibit vastly contrasting heat signatures. While all impervious and dark surfaces absorb solar energy and radiate it back to the surrounding environment, green infrastructure such as trees and grassed reserves allow for shade-cooling and cooling through evapotranspiration effects. Bare and dry soils radiate much higher temperatures back into the environment, with air pockets in the void space conducting heat much more efficiently than water does. Stormwater can play a pivotal role in optimising a catchment's soil moisture retention to promote growth and maintain the health of green infrastructure.

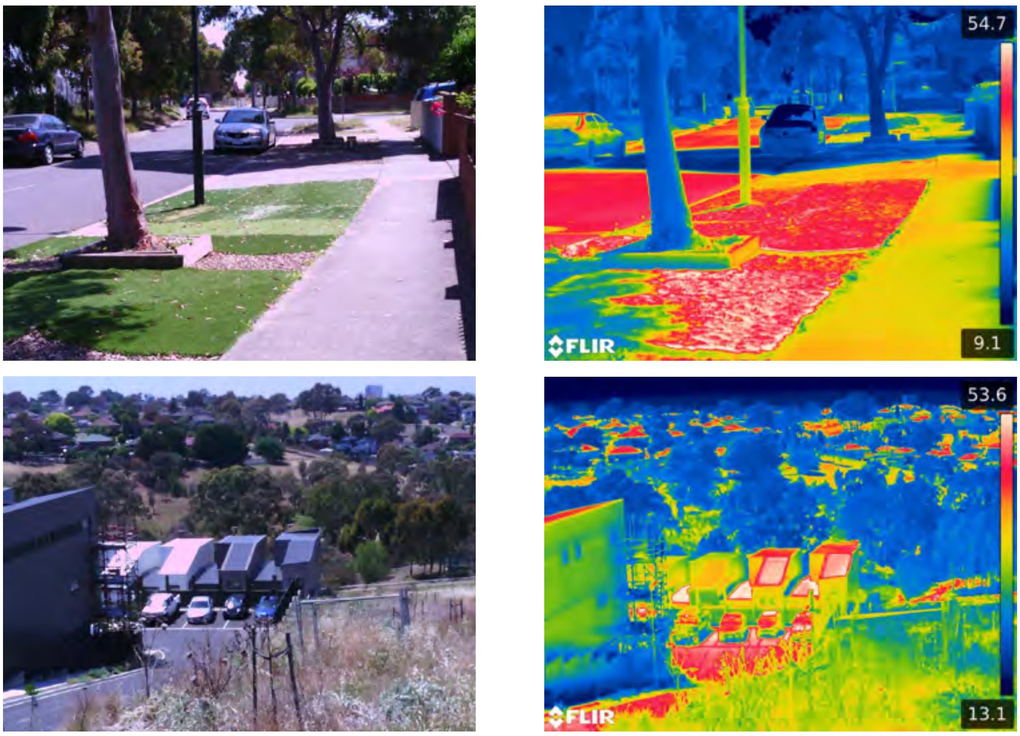

Figure 2 Thermal radiation of roads, synthetic turf and dark roofs compared to tree-shaded roads, natural grasses and light coloured roofs. Infrared imagery courtesy of Dr Scott Rayburg, Swinburne University of Technology

1.4 Regulations

The Victoria Planning Provisions (VPP) contain many clauses that require the delivery of Water Sensitive Urban Design (WSUD) and Integrated Water Management (IWM). These include the State Planning Policies clauses 14.02 and 19.03, which pertain to all types of development within the state. The City of Whittlesea is responsible for administering planning policies, and these clauses provide a solid basis in the Planning Scheme for councils to apply WSUD and IWM requirements to all developments, including residential, industrial and commercial uses.

Particular clauses relate to Integrated Water Management in residential subdivisions, commercial and industrial development as well as public space development, and mandate best practice targets for pollutant load reductions and flow discharges to be met. The City of Whittlesea also has introduced the local environmentally sustainable design policy 15.01-2L which includes strategies relating to Integrated Water Management.

The table below presents an overview of currently applicable clauses per development type and water management objective.

Water management objective	Development type			
	Townhouse/ units	**Apartment buildings**	**Subdivisions residential, commercial, industrial**	**Commercial/industrial development >50m², public land**
Waterway protection objective (Healthy Waterways Strategy)	12.03-1S	12.03-1S	12.03-1S	12.03-1S
Integrated Water Management strategies	15.01-2L (from 2 dwellings)	15.01-2L (from 100m² gross floor area)	15.01-3S	15.01-2L (from 300m² gross floor area)
Stormwater runoff minimisation through Water Sensitive Urban Design	19.03-3L	19.03-3L	19.03-3L	19.03-3L
Treatment of stormwater to BPEM objectives, pollutant reductions of: 80% total suspended solids 45% total phosphorus 45% total nitrogen 70% gross pollutants	55.03-4 B9	55.07-5 B39 (up to 4 storeys) 58.03-8 D13 (5+ storeys)	56.07-4 C25 (residential) 53.18-4 W1 (commercial/industrial)	53.18-5 W2
Contribute to urban cooling, habitat and amenity	55.03-4 B9	-	56.07-4 C25 (residential) 53.18-4 W1 (commercial/industrial)	53.18-5 W2

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Water management objective	Development type			
	Townhouse/ units	Apartment buildings	Subdivisions residential, commercial, industrial	Commercial/industrial development >50m², public land
Rainwater tanks (laundry/toilet)	-	55.07-5 B39 (up to 4 storeys) 58.03-8 D13 (5+ storeys)	-	-
Connect to dual pipe recycled water supply	-	55.07-5 B39 (up to 4 storeys) 58.03-8 D13 (5+ storeys)	56.07-2 C23 (residential)	-
Prevent chemicals/ toxicants from entering the stormwater system	-	-	-	53.18-5 W2
Site management during construction	65.01 (Decision Guidelines)	65.01 (Decision Guidelines)	56.08-1 C26 (residential) 53.18-6 W3 (commercial/industrial)	53.18-6 W3
Maximise infiltration of stormwater into tree pits and permeable areas	-	55.07-5 B39 (up to 4 storeys) 58.03-8 D13 (5+ storeys)	-	-

Note: The Whittlesea Planning Scheme clauses must be reviewed at the time of application and may be subject to change.

Table 2 Development types and applicable clauses

1.5 Context

1.5.1 Precinct Structure Plans

A Precinct Structure Plan (PSP), Structure Plan or Strategy is a comprehensive planning document that outlines the future development and land use within a specific area or precinct in the City of Whittlesea. It typically provides a framework for the use and development of land over a specified period.

A PSP is an essential tool used by local or regional planning authorities to guide and manage the development of urban or suburban areas. It includes details such as the intended land use, density of development, infrastructure requirements, transportation networks, open space provisions, environmental considerations and other relevant aspects necessary for the sustainable and orderly development of the precinct.

PSPs serve as crucial reference points for developers, landowners and stakeholders involved in the planning and execution of land development within the designated precinct, ensuring that development aligns with the broader goals and objectives of the region.

Integrated Water Management forms one of the infrastructure provision pillars within PSPs, outlining requirements as well as guidance to the implementation. It is recommended that the developer refers to available Precinct Structure Plans as well as their supporting background studies in IWM, drainage and water topics.

All PSPs relevant to the City of Whittlesea can be accessed through the VPA's Greenfield Planning Map.

1.5.2 Development Plans

A Development Plan (DP) is a more detailed document that follows the guidelines and objectives set out in the relevant Structure Plan or Strategy. It focuses on the specific details and requirements for individual development projects or smaller areas within the broader precinct. Development Plans provide comprehensive and specific guidelines for land subdivision, building designs, setbacks, landscaping and infrastructure provision.

Development Plans are triggered by the City of Whittlesea's Planning Overlay (Clause 43.04) and, depending on the schedule, require Stormwater Management Strategies to be submitted to inform the layout of the Development Plan.

The plans (or their strategies) often reference Melbourne Water's Development Services Schemes if established for the site.

1.5.3 Development Services Schemes

Melbourne Water manages numerous Development Services Schemes (DSS) which provide for the implementation of strategically located stormwater infrastructure to allow for urban growth. These conceptualised assets are often referenced in PSPs and form part of the delivery objectives of a gazetted plan. Ownership of assets can sit with Melbourne Water or the City of Whittlesea and is regularly delineated by the contributing catchment size to the asset. The confirmed delineation sits at 60ha.

Developers have the option to discharge their statutory requirements on stormwater quality management through financial contributions to a DSS.

The applicant can investigate the referenced map whether the developable land qualifies for DSS contributions. Further information on how the cost-recovery model works and details on the contribution and reimbursement policies can be obtained on Melbourne Water's website.

Under this offering, a developer has the choice to:

a. Pay a complete contribution to a scheme in lieu of providing on-site infrastructure.
b. Deliver conceptualised infrastructure as outlined in the DSS if the asset is located on the subject land.
c. Provide for a range of Integrated Water Management (IWM) measures on the development-scale to contribute to (or meet) statutory requirements.
d. Pay partial contributions to a scheme where proposed infrastructure provisions fail to meet statutory requirements.

Proposals for IWM measures on a development-scale that have the potential to impact hydrology and demand for conceptualised DSS assets need to be consulted with Melbourne Water and the City of Whittlesea at a pre-application meeting and prior to the formulation of a Stormwater Management Strategy for the subject land.

1.5.4 Stormwater quality offsets

The City of Whittlesea's Planning Scheme comprises of applicable clauses for all relevant types of developments to allow for appropriate layout design and accommodation of stormwater management infrastructure. All developments are expected to meet 100% of the Best-Practice Environmental Management objectives.

It is the developer's responsibility to demonstrate best practice achievement and that all practical measures corresponding to a development have been exhausted. Payment of an offset for the balance of unmet water quality conditions is subject to individual assessment and acceptance by the City of Whittlesea.

In the absence of a Council-operated voluntary offset scheme, the City of Whittlesea does not accept offset payments and refers to Melbourne Water's stormwater quality offset contribution program. It is at the City of Whittlesea's discretion to permit a dispensation to the delivery of site-specific infrastructure and allow an applicant access to Melbourne Water's program.

1.5.5 Healthy Waterways Strategy

Melbourne Water's *Healthy Waterways Strategy* captures the regional vision on preserving and improving the vitality and value of all natural freshwater systems in the Melbourne metropolitan zone. The City of Whittlesea is partner to the *Co-Designed Catchment Program for the Yarra Catchment* and committed to delivering on the performance objectives as outlined in the program for each sub-catchment.

There are three sub-catchments enveloped by the City of Whittlesea's municipal boundaries:

- Reaches of the upper and lower Merri Creek.
- Most reaches of the Darebin Creek.
- The source, the upper and reaches of the lower Plenty River.

Each sub-catchment has a unique set of values, current waterway conditions, actions and performance objectives.

The objectives of predominant interest in context of this guideline are the stormwater conditions aspired to protect our creeks and their ecological systems from harmful runoff volumes and frequencies. Volumetric targets for stormwater harvesting and stormwater infiltration are set to maintain directly connected imperviousness below thresholds required to preserve healthy waterway hydrology.

Applicants intending to develop land within priority stormwater areas are expected to emphasise runoff volume reduction through a wide palette of accepted IWM measures. Developers and their consultants shall refer to the practitioner's note in *Healthy Waterways Strategy Stormwater Targets* to further explore reduction targets based on development locality.

1.5.6 Catchment-scale Integrated Water Management plans

The State of Victoria's Integrated Water Management Framework was established in 2017 and resulted in the launch of individual forums delineated by Melbourne's major metropolitan river catchments. The City of Whittlesea is partner and contributor to the Yarra Catchment Forum and endorsee of the 2022 completed *Yarra Catchment Integrated Water Management Plan*.

This project holds significant importance for Greater Melbourne as it enables industries to gauge their advancement in IWM across the five metropolitan catchment areas. It establishes specific benchmarks associated with strategic outcomes for 2030 and 2050 to drive initiatives and offers a structured approach for evaluating prospective projects and determining priority zones spatially. The initiative generates data at both the sub-catchment and local government area levels, facilitating comparative analysis and the development of tailored, location-specific strategies.

The City of Whittlesea's contribution to the long-term delivery commitment manifests proactively through Council-driven and delivered initiatives, and passively through facilitation of land development. The responsibility for achieving desired outcomes significantly falls within the domain of the land development sector, owing to its pivotal role in creating new urban spaces. The sector offers a crucial avenue for integrating innovation and enhancing resilience in the face of uncertain climate futures.

Details on how contributions to the plan can be measured and reported through land development processes are outlined in the section for Stormwater Management Strategies.

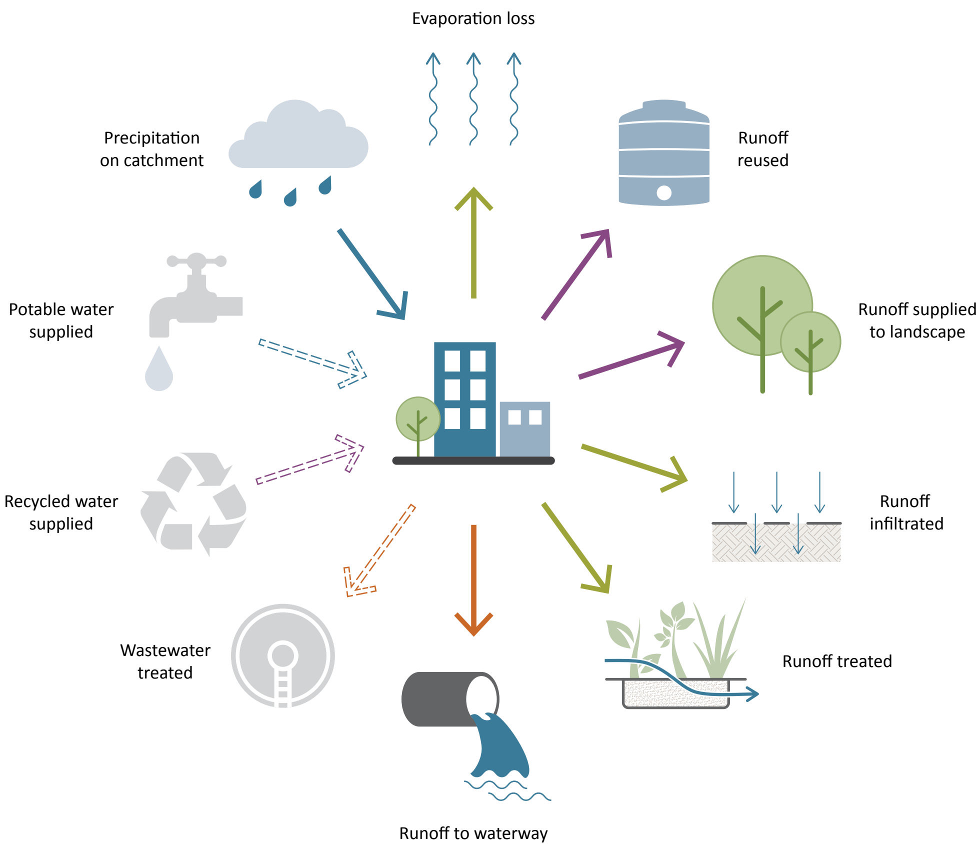


Figure 3 Urban water balance

2. Stormwater Management Strategies

Developers and their consultants are required to prepare and submit a Stormwater Management Strategy (SWMS) for review by the City of Whittlesea and Melbourne Water.

A Stormwater Management Strategy demonstrates that the proposed development site will meet the appropriate drainage requirements, including flood protection, waterway and water quality protection standards, as well as practical Integrated Water Management measures, to comply with statutory requirements. SWMS must be submitted with development applications, to inform the decision on the issuing of a permit and to allow for the condition of stormwater management details.

This section outlines the City of Whittlesea's requirements on SWMS submissions, to streamline reporting and demonstration that any proposed stormwater control measures are able to satisfy the City of Whittlesea's core asset design requirements and standards. If the strategy is incomplete or not submitted to the City of Whittlesea's satisfaction, the application may not be assessed until all relevant information is provided.

Where development sites are covered by a Melbourne Water Development Services Scheme (DSS), the strategy must also be reviewed by Melbourne Water.

2.1 Information sources

The developer (or their consultant) will need to draw on many relevant information sources to complete a SWMS to the City of Whittlesea's satisfaction. The below list is not exhaustive, but will serve the applicant as a guide:

- Precinct Structure Plans (PSPs), Structure Plans, Strategies and Development Plans (DPs).
- Details on existing drainage schemes and options of financial contributions.
- Records of site inspections and photos taken.
- Latest aerial imagery and any historically relevant maps.
- Previous Stormwater Management Strategies.
- Discussions with the City of Whittlesea.
- Discussions and information as provided by Melbourne Water.
- Referenced guidelines applicable to the development.
- Applicable Environmental Planning instruments and Planning Frameworks.
- Plans and site surveys.
- Past hydrological models.
- Description of existing infrastructure information.
- Historic flood and water quality studies.
- Topographic information, including commercially sourced LiDAR data.
- Existing flood mapping.
- Underlying geomorphology, hydrology and soil information.

2.2 Report structure

While the refined content of a strategy may vary and be dependent on the development type, the below outline should be followed for a standardised structure, with minimum requirements highlighted that apply to all development (including infill situations):

1. **List of background information, designs and reports, including PSPs, PSP IWM strategies, DSS plans.**
2. **Site locality description and latest aerial imagery used.**
3. **Topography and land use description.**
4. **Summary of the geology, soils and groundwater conditions at the site.**
5. A soil and land capability analysis may be required as part of planning permit application to determine the presence or absence of sodic and dispersive soils. If these soils are found to be present, a sodic soils management strategy shall be submitted as part of the SWMS addressing interim and ultimate drainage designs, as applicable. A strategy must include, to the satisfaction of the City of Whittlesea:
    a. Details of the location, classification and distribution of sodic or dispersive soils across the project area.
    b. A vulnerability assessment for all construction phases and stages and the ultimate post-development scenario.
    c. An assessment of management actions (if required) for all phases of the development and all ultimate asset characteristics.

6. **Description of planning zone, response to planning policy and allowable densities (in accordance with approved strategic documents).**
7. **Description of proposed development layout.**
8. Proposed conservation areas created.
9. Description of external catchments, their planning zoning, development status and impact on the subject site.
10. **Description of the subject site's stormwater quantity management.**
    a. This includes demonstration of downstream drainage capacities and stormwater retardation requirements for the relevant storm event to pre-development rates at the outlet of the land, addressing flood storage and flood protection measures.
    b. This section may also include acceptance letters for any proposed temporary outfall arrangements from the City of Whittlesea and affected downstream landowners.
    c. Refer further information under Hydrological modelling.
11. **Description of the subject site's stormwater conveyance system (interim and ultimate scenarios) for the minor (20% annual exceedance probability (AEP)) and major (1% AEP) storm events.**
    a. Addressing the proposed alignment for any 20%/10% AEP drainage infrastructure and any associated overland flow path directions for the 1% AEP flood event.
    b. This section may also need to consider safe conveyance of existing (pre-developed) overland flows and external catchment peak discharges required to pass through the subject site.
    c. Temporary outfall conditions and treatment must be addressed.
    d. Refer further information under Hydraulic modelling.
12. **Description of the subject site's stormwater treatment requirements.**

    Where applicable to the development Best Practice Environmental Management (BPEM) water quality achievements must be demonstrated. Refer to Water quality models for further information and requirements on submissions.
13. **Description of proposed drainage infrastructure to detail as outlined under** Stormwater asset details.
14. **An Integrated Water Management response.**

    Describing the development's efforts to retain water at source for fit-for-purpose reuse and within local landscapes for an improved urban microclimate. Refer to section Integrated Water Management response for further reporting requirements.
15. Description of development phases and proposed timing, including details on proposed staging of the development and how this aligns with the construction of temporary or ultimate drainage assets; addressing interim development and ensuring compliance with the General Environmental Duty (GED) at all stages of development.
16. Discussion of a development or water treatment staging plan. The applicant may be required to determine the progressive treatment effort for each development stage, and demonstrate how ongoing changes in hydrology will affect the proposed asset(s) as the development advances. In such cases, applicants are required to demonstrate that the delivery of stormwater quality infrastructure in earlier works stages will not be compromised through the following successive development impacts:

a. An initially small contributing catchment which may not allow for mature development hydrology to nourish the asset and risks critical vegetation survival. Developers may propose the staging of certain components of the asset to align with development progress and catchment size.

b. Lack of erosion and sediment control in built-out phase, risking silt-up of sensitive asset components and shortening of asset lifespans. Developers may propose new assets to feature appropriate protection measures for silt capture such as temporary or sacrificial sedimentation basins, silt curtains, geofabric membranes or flocculation dosing mechanisms, or consider quick reset functions as part of the asset design.

17. **A construction site management response.**

Response on how best practice stormwater management will be maintained throughout construction and development stages, addressing erosion and sediment runoff control. Stormwater runoff from the subdivision must achieve State Environment Protection Policy (Waters of Victoria) objectives for environmental management of stormwater.

The response must further include demonstration of adequately sized temporary sediment basins (if adopted) complying with Appendix B Book 2 of the Best Practice Erosion & Sediment Control Guidelines (2008).

18. Significant tree protection and conservation areas response.

Where significant trees such as River Red-gums or flow-dependant ecosystems such as natural wetlands are required to be protected, the pre-development hydrology is required to be defined, in both flood and drought conditions and compared to post-development conditions. The applicant must demonstrate and describe the proposal of appropriate techniques to mimic natural hydrology.

2.3 Hydrological modelling

The City of Whittlesea has the following content requirements for the hydrological modelling discussion in the SWMS report:

- Statement on the runoff-routing modelling package used, and version thereof.
- ARR2019 data set used, as well as the date the data hub was accessed.
- Statement on LiDAR version used.
- Model description and screenshot of the model.
- Pre-development model schematic shown with legend.
- Post-development model schematic shown with legend.
- Catchment tables pre- and post-development included.
- Stage-storage-discharge relationships adopted.
- Adopted model parameters for external and internal catchments in tables.
- Modelling results discussed.
- Model submissions supplied as ZIP file.
- Catchment polygons separately filed as shape files.

2.4 Hydraulic modelling

The City of Whittlesea has the following content requirements for the hydraulic modelling discussion in the SWMS report:

- Statement on the 1- or 2-dimensional hydraulic model used, and version thereof.
- Minor system concept design in layout and longitudinal section(s).
- Model description with relevant screenshot for the underground-contained minor storm system.
- Major system overland flow path compliance in layout and critical cross sections.
- Model description with relevant screenshot for the overland flow major storm system.
- Adopted model parameters in tables, including stage-storage relationships, if applicable.
- Modelling results discussed.
- Model output supplied as ZIP file.

2.5 Water quality models

The City of Whittlesea has the following content requirements for the water quality modelling discussion in the SWMS report:

- Version of MUSIC software used.
- Meteorological data used.
- Map outlining catchment areas and direction of flows.
- Total catchment area must match with those adopted in hydrological and hydraulic models, noting delineations can vary and be more granulated.
- Model description and screenshot of model provided.
- Any routing used and justification thereof.
- Treatment node parameters adopted for each major asset and for each decentralised asset type (in case of multiple identical configurations).
- Any modelling parameters highlighted that are not in accordance with these or Melbourne Water's latest guidelines.
- Model results discussed.
- Statement on flow frequency (in days/year), comparing pre-developed conditions, post-developed untreated conditions and post-developed treated conditions.
- MUSIC Auditor report generated and attached.
- Model submitted as SQZ file for MUSIC Version 6.3 compatibility.

2.6 Stormwater asset details

- All asset sizing calculations must be demonstrated and reference the relevant guidelines used.
- Asset design checklist (for sediment ponds and wetlands) covering all **conceptual** Deemed to Comply Design Criteria.
- An asset staging plan must be submitted, if applicable (refer Point 15).
- An asset protection methodology must be formulated, with practical instructions for a proactive maintenance program to guard the completed infrastructure from ongoing sediment loads from lot-scale construction activities.
- Concept design plans and MUSIC model for the asset(s) demonstrating that the designated surface area can accommodate the required asset(s) in accordance with relevant guidelines.
- A plan of each proposed asset showing the indicative footprint (allowing for minimum offsets, batter slopes, high-flow bypass, maintenance access routes and location of any pipe connections. The plan must show these items overlaid on site survey or a recent aerial photograph.
- If applicable, a summary of the site's Flora and Fauna survey, including a risk assessment as to whether species or vegetation community listed under the *Flora and Fauna Guarantee Act 1988* and *Environmental Protection and Biodiversity Conservation Act 1999* or protected by the *Planning and Environment Act 1987* will be impacted by the proposed WSUD asset.
- If applicable, a summary of the Cultural Heritage Management Plan (CHMP) which clearly identifies areas of cultural heritage importance that may be impacted by the proposed WSUD asset footprint.
- For proposed infiltration systems a soil report must be carried out by a qualified geotechnical practitioner. The soil test report must provide details of soil type, saturated hydraulic conductivity (in mm/hr), groundwater table of the site, and sodicity levels.
- All proposed stormwater quality management assets for the City of Whittlesea's ownership and operation to have life-cycle costing documented.

2.7 Conceptual plans

Plan sets that accompany a Stormwater Management Strategy need to be submitted in a format with the following content included and details shown:

- A site overview plan.
- A catchment plan with sub-catchment delineations.
- The trunk minor system concept layout.
- The trunk major system concept layout and all overland flow paths shown with flow directions.
- Enlarged asset layouts (for permanent and temporary assets).

Layout plans must show, as a minimum:

- The boundary of the reserve within which the asset will be located.
- Existing waterways and pipe networks within or adjacent to the reserve.
- Levels (m AHD) of land surrounding the asset.
- The location of the inlet, high-flow bypass and outlet.
- Locations of existing or proposed services determined from a desktop study (such as sewer, gas, mains water underground electrical cables and overhead power lines).
- Locations of existing vegetation to be retained.
- Locations of cultural or historical features to be retained.
- Locations of existing or proposed community facilities adjacent to the asset location (such as playgrounds, buildings and walking paths).
- The boundary of any planning overlays.
- Details on which assets the developer is proposing will be transferred to the City of Whittlesea.
- Extent of normal water level (NWL).
- Outline of top of extended detention (TED).
- Legend.

Any asset system section must show, as a minimum:

- Existing surface level.
- NWL or filter bed surface (m AHD).
- TED.
- Base of permanent pool or filter bed.
- Invert of inlet pipe or channel(s).
- Invert of outlet pipe and how this relates to the receiving waterway or drain.
- Weir crest levels (if applicable).
- Batter slopes (if applicable).
- Legend.

2.8 Integrated Water Management response

The City of Whittlesea is an endorsee and active contributor to the *Yarra Catchment Integrated Water Management (IWM) Plan*, sharing a unified vision for secure water supplies and flood resilience, vitality of open spaces, and the overall health of our waterways. Acknowledging the significant role that land development plays in shaping our community and the vast majority of the City's built environment, the City of Whittlesea holds the expectation that new developments not only meet the statutory requirements but also align with the broader catchment vision.

To facilitate a streamlined approach for quantifying and reporting contributions to the plan, applicants are mandated to incorporate a dedicated IWM response within the framework of the Stormwater Management Strategy. The response shall include, as a minimum:

- A description of the development's water balance, quantifying all projected water demands and supplies for various uses within the subject land.
- The completion of the designated IWM contributions form (below) to summarise the performances of the proposed infrastructure.

Item	Measure	Input variable	Unit
1.2b	Quantity of all alternative water sources that substitute potable mains water supply	Recycled water use Rainwater use Stormwater use	ML/yr
1.2a	Percentage of total projected potable demand substituted by alternative water sources	Recycled water use Rainwater use Stormwater use	%
2.1	Projection of recycled water deliverable to end users	Recycle water use	ML/yr
3.3	Cross-consideration of IWM and flood mitigation opportunities as part of the development design	n/a	Y/N
4.1	Annual runoff volume reduction	Rainwater harvested Stormwater harvested Stormwater infiltrated	ML/yr
4.2a	Annual total suspended solids prevented from discharging to receiving waters	Rainwater harvested Stormwater harvested Stormwater treated	tonnes/yr (=’000 kg/yr)
4.2b	Mean annual total nitrogen prevented from discharging to receiving waters	Rainwater harvested Stormwater harvested Stormwater treated	tonnes/yr (=’000 kg/yr)
5.1	Percentage of trees that are supported with permanent irrigation from an alternative water supply, relative to all trees planted on public land	n/a	%
5.2a	Percentage of active public open space (sports fields and organised recreation) supported by an alternative water source	n/a	%
5.2b	Percentage of passive public open space (parkland and gardens) supported by an alternative water source	n/a	%
5.3	Total area of green infrastructure supplied with an alternative water source	Active open space Passive open space Tree canopy Understorey landscaped areas	ha (=0’000 m^2)
6.2	Percentage of developable area enhanced through IWM as a result of blue-green infrastructure creation	Vegetated stormwater treatment assets POS supported with alternative water Trees supported with alternative water Re-naturalised drainage channels Daylighted drains in lieu of pipes Surfaces with retained permeability	%

Table 3 Development contributions to IWM

Public realm		Lot-scale	
Asset description	Value	Asset description	Value

Approval process for planning permit applications

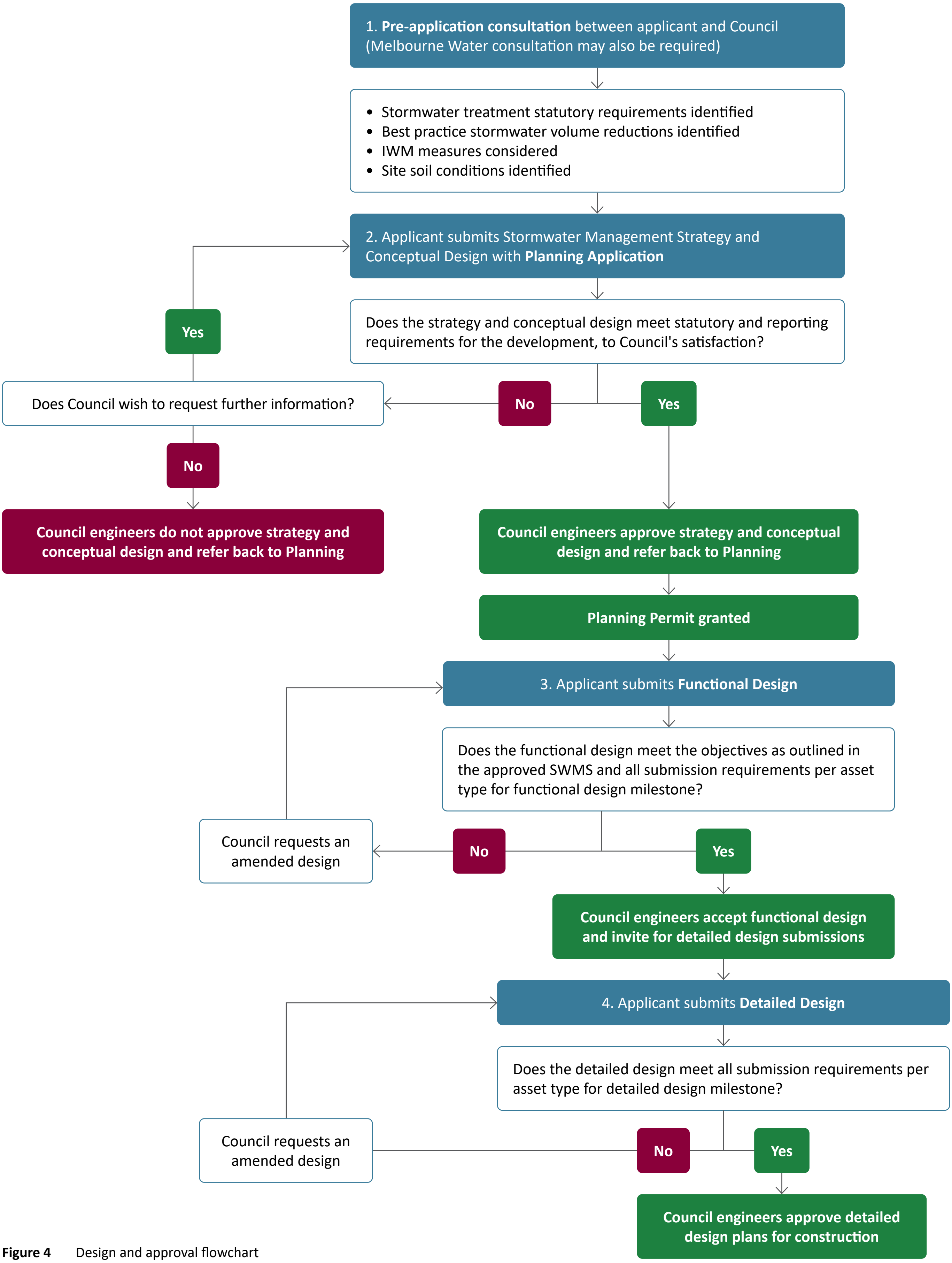


Figure 4 Design and approval flowchart

3. Modelling Standards

The City of Whittlesea's water quality modelling standards align with Melbourne Water's most recent guidance. Any deviations from these guidelines for the modelling of specific treatment types are explicitly discussed in asset-specific subsections.

3.1 Modelling tools

The City of Whittlesea only accepts submissions from two recognised water quality modelling tools – eWater's MUSIC (Model for Urban Stormwater Improvement Conceptualisation) Version 6.3 or X, and Melbourne Water's STORM (Stormwater Treatment Objective-Relative Measure) Calculator.

Table 4 below illustrates the City of Whittlesea's accepted output formats based on development type and size, and the desired asset type to be modelled.

The City of Whittlesea may require submissions (file outputs) from various other software packages which are not directly related to water quality modelling. These requirements are discussed in the specific treatment type sections.

General	STORM	MUSIC
Treatment trains	✗	✓
Development types		
Subdivisions (residential, commercial, industrial)	✗	✓
Townhouses/units	✓	✓
Apartment buildings	✓	✓
Commercial/industrial (infill)	(✓)	✓
Asset types		
Rainwater tanks for toilet and laundry reuse only	✓	✓
Rainwater tanks for irrigation reuse and leak functions	(✓)	✓
Permeable pavements (flexible bound porous pavements)	(✓)	✓
Permeable pavements (unbound interlocking pavers, grid pavers)	(✓)	✓
Green roofs/walls	✗	✓
Passively irrigated street trees	(✓)	✓
Buffer strips	✓	✓
Soil moisture banking and wicking beds	✗	✓
Sediment ponds	✗	✓
Wetlands	✗	✓
Bioretention systems (simplified and matching STORM calibrations of 100 and 300mm EDD, media fully drained)	✓	✓
Bioretention systems (with added complexity, varying EDD, part of treatment trains, submerged zones)	✗	✓
Swales	✗	✓

(✓) denotes that tool can be used with support of figures contained in this guide

Table 4 The City of Whittlesea's modelling package requirements

3.2 Model setup

3.2.1 STORM model calibration

Inputs into the STORM tool include:

- Municipality and rain station – to be set to Whittlesea LGA.
- Total site area – equivalent to the total area of the development site (note, this value does not affect the overall modelling results as only listed impervious areas will be computed).
- Impervious area – all proposed impervious areas within the development site must be included regardless of whether they drain to a treatment or not.
- Treatment measures as explained below.

The following must be considered when entering treatment measures into STORM:

- The size and type of treatment measure shall be as per design plans.
- Lost impervious area catchments entered as 'none' treatment line.

For further information about STORM, the inputs and the various other treatment types please refer to the STORM online help guide.

Emerging IWM technologies such as passively irrigated tree pits and permeable pavements can be modelled in STORM. The methodologies are described in the individual asset sections.

STORM reports must be submitted to the City of Whittlesea as part of the development application and achieve or exceed a rating of 100%. Where a development proposal fails to achieve 100% treatment while having demonstrated all reasonably practical and Council-accepted solutions, the developer may be eligible for payment of an offset for the balance to meeting best practice.

3.2.2 MUSIC model calibration

Input to the MUSIC application shall conform with Melbourne Water's latest MUSIC modelling guidelines.

Models must be set up to include:

- A minimum of 10-year rainfall data using one of the standard rainfall templates applicable to Whittlesea LGA. The City of Whittlesea and its urban growth area sit within the 650-750mm Melbourne City (1952-1961) and the 500-650mm Melbourne Airport (1971-1980) rainfall banding.
- A six-minute time step application.
- Current and future external catchments must be modelled, where applicable, to account for realistic inundation frequencies and volumes. Refer detailed procedure under External catchments.

The following input parameters must be considered when creating and modifying catchment source nodes in MUSIC:

- For vacant lot subdivisions the default pollutant concentration data shall be applied, together with Melbourne Water's guide on the impervious land fraction.
- If the roof and road areas within a development can be defined, the source nodes in MUSIC must be split into roof and road catchment areas, using Melbourne Water's pollutant concentration data.

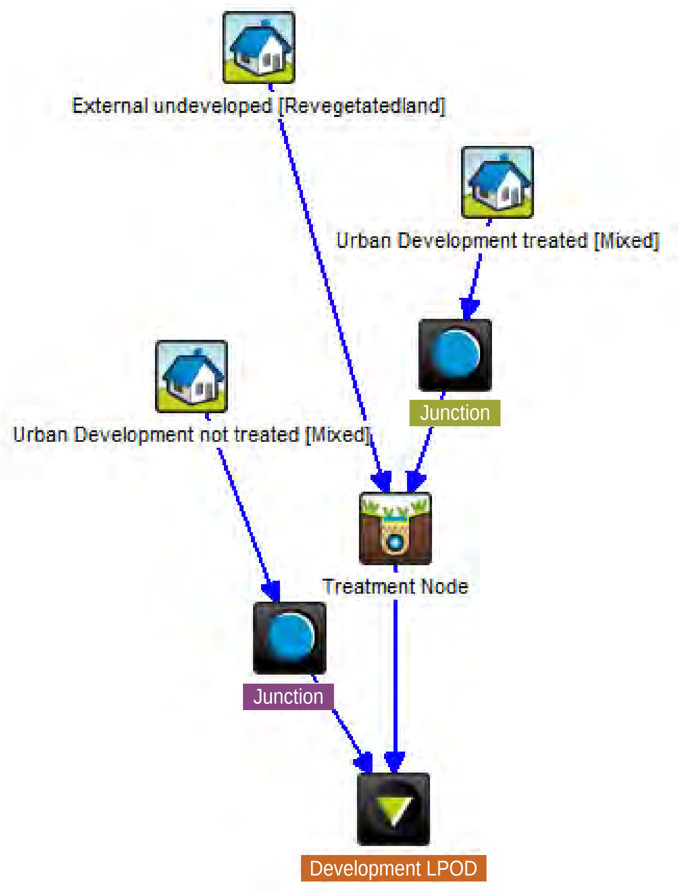
MUSIC model outputs must be submitted to the City of Whittlesea in SQZ file format as part of the development application and accompanying Stormwater Management Strategy. Where a development proposal fails to achieve all best-practice-defined pollutant reductions while having demonstrated all reasonably practical and Council-accepted solutions, the developer may be eligible for payment of an offset for the balance to meeting best practice for the total nitrogen (TN) reduction deficit.

3.3 General rules

1. Model submissions must be accompanied by appropriate catchment plans identifying all development-internal (treatable) sub-catchments, and all relevant external catchments (non-treatable) draining through the subject site.
2. Model node labelling must correspond to the catchment plan.
3. The model must include all catchments as identified on plans.
4. MUSIC model outputs must report on annual stormwater volume reductions and compare to *Environment Protection Authority (EPA) guidance* on reduction targets.
5. Low-flow and high-flow bypasses must be modelled to realistically reflect flows through and around treatment nodes.
6. MUSIC model submissions must be accompanied by a MUSIC Auditor report. Any flagged model discrepancies must be addressed or otherwise justified through the report output or within the Stormwater Management Strategy, where applicable.

3.4 External catchments

Where external catchments to a developable site contribute flows to a proposed WSUD asset, such catchments must be included in the model to account for realistic inundation frequencies and volumes, even though these don't have to be treated. External catchments can be existing as well as future developments on vacant land that will ultimately drain through the subject development. External catchment source nodes are to be modelled using Melbourne Water's defined impervious fractions and the default pollutant concentration data as per catchment type (residential, commercial, industrial and others).



1. To determine the treatable pollution load, all internal catchments shall be interrogated upstream of the treatment node using junctions.
2. The source quantities from these junctions shall then be used to apply best practice removal rates for the respective pollutant → this sets the target pollution reduction for the development.
3. The reduction load of the complete model at the receiving node (including external catchments) can then be compared to the target loads → Actual load reduced / Σ of treatable source loads.

	Source	Residual load	% reduction	% target reduction	Target load	Load reduced	% actual reduction
Flow	4.7	4.7	0				
TSS	910	910	0				
TP	1.89	1.89	0				
TN	13.3	13.3	0				
GP	177	177	0				
Flow	1.17	1.17	0				
TSS	230	230	0				
TP	0.471	0.471	0				
TN	3.35	3.35	0				
GP	44.2	44.2	0				
Σ Flow	5.87	5.87	0	36	2.1		
Σ TSS	1140	1140	0	80	912.0		
Σ TP	2.361	2.361	0	45	1.1		
Σ TN	16.65	16.65	0	45	7.5		
Σ GP	221.2	221.2	0	70	154.8		
Flow	14.7	14.6	0.5			0.10	**2%**
TSS	1600	719	54.9			881.00	**77%**
TP	3.56	2.7	24.1			0.86	**36%**
TN	28.9	21.3	26.1			7.60	**46%**
GP	342	44.2	87.1			297.80	**135%**

Figure 5 External catchment modelling schematic

4. IWM Infrastructure Options

This section of the IWM Guidelines discusses the wide-ranging portfolio of stormwater management assets that can be deployed to meet best practice stormwater treatment objectives and achieve Integrated Water Management outcomes. Each asset type references the City of Whittlesea's preference on:

- Adoption opportunities and constraints.
- Industry design guidance and Council-specific design requirements.
- A modelling approach to demonstrating asset performances.
- Council's submission and asset documentation requirements.
- Council's construction hold-points, documentation requirements and handover criteria
- Asset maintenance considerations.

The City of Whittlesea distinguishes between various asset families according to their primary water management function.

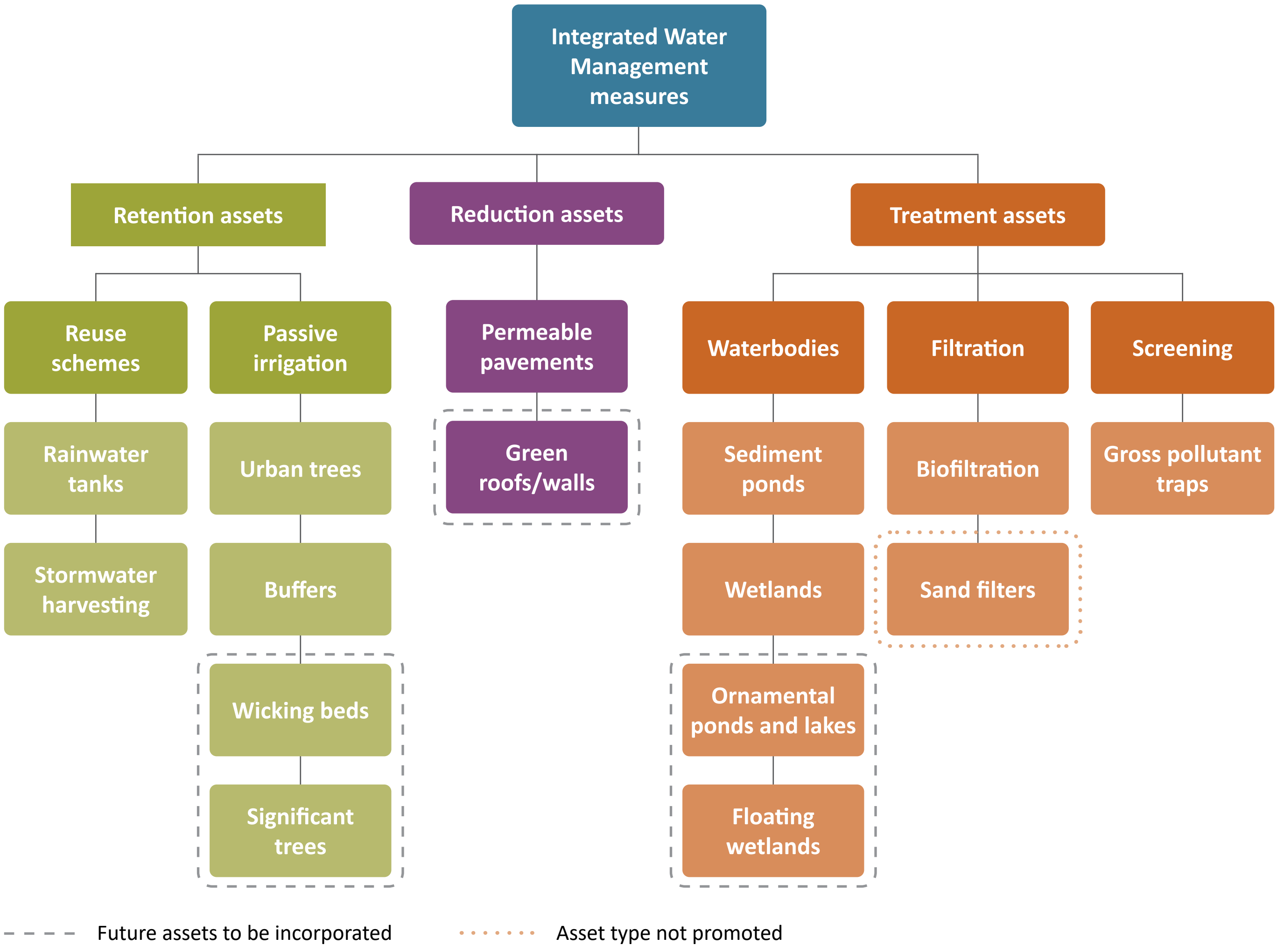


Figure 6 Asset groups and subtypes

4.1 Rainwater tanks

4.1.1 Function

Rainwater tanks in Victoria play a significant role in sustainable water management. Tanks effectively mitigate stormwater-related challenges by reducing flow volumes while reducing the reliance on potable water for non-potable demands in many urban settings. This includes residential, commercial and industrial zones as well as the public realm. Retaining rainwater on site through tanks greatly assists in preserving the health of receiving waters and their ecosystems impacted by frequent hydraulic fluctuations. Moreover, they contribute significantly to flood mitigation by reducing stormwater runoff into the public drainage system, lessening the risk of urban flooding during heavy rainfall. Rainwater tanks can be designed with active and passive irrigation systems in addition to common uses in buildings. By gradually releasing retained water to landscaped areas, they promote urban greening while reinstating storage capacity during storms. Tanks can be considered a valuable asset to any property during prolonged periods of droughts and uncertain water supplies, as well as benefit the community at large by collectively contributing to flood storage.

Figure 7 Rainwater tank at Houston Street Depot, Epping

4.1.2 Adoption and constraints

Preferred use	Non-preferred use
✓ On residential lot-scale for reuse ✓ Council facilities and community buildings ✓ Commercial sites for reuse ✓ Industrial sites for attenuation ✓ Larger-scale tanks can be used for irrigation of both passive and active open space ✓ Greenfield, redevelopment and retrofit ✓ In combination with recycled water backup	✗ On sites where runoff may be highly contaminated (for example, retrofit of older or heritage buildings with lead-based roof paints ✗ Underground tanks due to their higher installation and maintenance costs

4.1.3 Design criteria

Some important resources which provide guidance on rainwater tanks include:

- *WSUD Engineering Procedures: Stormwater* (Melbourne Water, 2005), Chapter 12.
- *Rainwater use in urban communities; Guidelines for non-drinking applications in multi-residential, commercial and community facilities* (Department of Health, 2013).

For rainwater tanks to function effectively and to maximise benefits, the following design components should be considered:

Roof catchment and connections

- The roof area draining to the tank shall be maximised to optimise reuse yield.
- Consider connecting multiple downpipes and using charged pipe configurations.
- Charged lines should not be under buildings or structures.
- If charged downpipes are used, they must:
  - not be laid under buildings
  - have a maintenance flush provision.
- The proportion of the roof area which can be captured by the tank must be sufficient to provide an acceptable supply reliability of 80% for the reuse demand specified.

Inflow treatment

- Appropriate screening and water treatment measures must be fitted to the connection to the tank.
- The choice of screening and treatment should consider anticipated uses and any identified risks (overhead trees, for example).
- Screening and water treatment measures may include leaf guards, leaf screening rain heads and choosing vortex filters over traditional first flush diverters.

Tank size

- All forms of water reuse should be explored on a lot-scale which can include landscape watering, food production and any other residential or commercial operations.
- Minimum tank volume is 2,000L for any installation.
- Tanks should be maximised to economise on potable water consumption.
- The tank size must be sufficient to provide an acceptable supply reliability of 80% for the reuse demand specified.
- A simplified tank selection guide for **residential subdivisions** is presented in the table below, based on an average 400m^2 residential lot, 20% land permeability and an 80% reuse reliability for various end-use combinations. The respective flow reduction achieved equates to 80% of the below stated demands and can be accounted towards annual volume reductions.

Reuse purpose	Demand	Roof catchment size [m^2]			
	[kL/yr]	200	150	100	50
Toilet flushing only	**21.9**	2	2	2	2
Garden watering only	**40**	3	4	6	-
Toilet flushing + laundry	**51.1**	2	2	3	-
Food production only	**60**	7	9	-	-
Toilet flushing + garden watering	**61.9**	4	6	9	-
Toilet flushing + food production	**81.9**	9	-	-	-
Toilet flushing + laundry + garden watering	**91.1**	6	10	-	-

Table 5 Minimum residential tank sizes (kL) based on reuse type and contributing catchment

- For **industrial** developments with no significant on-site reuse demands, the City of Whittlesea accepts the attenuation of rainwater runoff to the pre-development baseflow rate as meeting best practice for the roof area effectively captured. This is conditional on flows being directed to the site's landscaped area of adequate size for passive irrigation.
- A **20L** volume is required **for every m² of roof area** attenuated. The controlled tank leak rate is calculated to the local soil's absorption capacity and daily evaporation rate, equating to **12L per day per m² landscape area**. Refer to the Modelling approach section for nomination of adequate landscaping areas.
- Tanks can be considered for adjacent public land use on a case-by-case basis (sport field irrigation, for example).
- Controlled passive leaks must be designed to protect the low-flow passage from clogging and from undesired tampering or modification.

Figure 8 Low-flow control through ball valve and inline filter (source: University of Melbourne)

Tank positioning

- There should be a sufficiently-sized stable, level surface which can withstand the loading generated by a full tank (2,000L ~ 2t).
- Tanks should have a low centre of gravity and be secured against leaning.
- The tank must be in a location where safe maintenance access can be provided.
- The tank should be located in proximity to a power source for the pump.
- The tank should not be placed over other utility connections that may require access.
- Tanks should not be placed where tree overhang may risk direct leaf litter and animal access influencing the water quality.
- Tanks must be appropriately signed with a description of where the water is utilised.

Reuse demands

- Accepted residential indoor supplies with rainwater include toilet flushing and laundry connections, active backyard irrigation and a controlled leak to a suitably sized landscape or garden bed.
- In-building demands based on occupation and visitation shall be in accordance with the *WSUD Engineering Procedures: Stormwater* for rainwater tank sizing (Chapter 12).
- Active landscape irrigation demands shall be based on plant species requirements.

Figure 9 Bubbler irrigation system at the Houston Street Depot Nursery using rainwater

Overflows and outlets

- Overflow outlet size must be equal to or exceed the inflow capacity (consider inflows under head, if applicable).
- Overflow pipes must connect to the underground drainage network to AS/NZS 3500. This can be via direct pipe to pipe connections or with a grated pit intercepted to make overflows visible.
- The overflow should have appropriate screening to prevent insects, animals or debris from entering the tank.
- The tank scour outlet must be oriented in such way that sludges during tank maintenance can easily be captured.
- Appropriate mosquito meshing (fine type) at inlet and outlets of tanks should be installed to avoid risk of in-tank mosquito breeding.

Pumped systems

- The pump should be an AS2040 compliant pump with suction filter and dry-run prevention.
- Pumps (in-line or sump pumps) should feature adequate sound isolation and weather protection.
- Outlets to dwellings should be placed at a minimum 100mm height above tank floor to prevent uptake of sludge upon water extraction.
- The pump rated power should be adequate for the on-site usage (for example, consider head required for a small landscaping micro-spray irrigation setup).

Mains switch

- Water diverters or mains switches have the objective to select mains water (recycled or potable) on demand when the water level within the tank reaches a critical low level. The trigger is normally governed by the vertical position of a mechanical float switch inside the tank.
- Electronic mains diverters must have built-in backflow protection in compliance with AS/NZS 3500-1-2003, be WaterMark certified and installed by a licenced plumber.
- Mains diverters must be adequately chosen depending on float type (top entry, side entry, submersible).
- Where design elevations allow, consider floatless mains switch devices with flooded suction application.
- The minimum tank top-up through air gaps (where adopted) may be based on the daily average demand depending on the reuse type (one full cycle for irrigation, for example).

Passive irrigation features

- Passive irrigation can be achieved through direction of hoses towards landscaped areas and distribution channels (simplified), or via more sophisticated drip irrigation setups.
- The grass, lawn or garden bed area where flows from a rainwater tank can passively drain to should be of sufficient size to absorb water all year round without becoming excessively wet or boggy. This is a risk where the roof catchment area is substantially larger than the landscaping area.
- The soil storage capacity in the Melbourne metropolitan region is 120mm. The soil absorption can be improved over time by adding organic material and applying mulch layers.
- Provision for relief underdrainage to mitigate risk of saturation and waterlogging should be considered.
- The surface absorption and filtration rate (with underdrains) should be higher than the controlled drainage rate (the leak).
- Provision of controlled overland flows may be considered where excess moisture can drain to the formal stormwater drainage system (such as surfacing low points with grated pits, use of egress pathways).
- A valve may be provided to allow the owner to divert flows to stormwater during winter – if so, this should be accounted by assuming only 50% of the potential annual estimated benefits will be realised or provide alternate calculations.
- Plans must clearly show the landscape area and note rainwater reduction purpose.
- Where private land is proposed to adopt rainwater tanks and passively or actively irrigated landscapes, the infrastructure must be documented through appropriate restrictions on title, noting that these assets must be retained on site and maintained appropriately by the landowner or owner's corporation.

Tank level monitoring

The City of Whittlesea recommends monitoring the performance of the tank via remote level sensing, using:

- 24VDC level transducers.
- Battery or solar-powered data loggers.
- 4G external modem or SIM compatible, Wi-Fi or Bluetooth.
- Recording level readings at hourly intervals.

Sites requiring high performance and reuse efficiencies (such as commercial centres and industrial operations) may benefit from the use of ready-made proprietary systems which come with online dashboard subscriptions and mobile phone apps with automated level notifications.

Miscellaneous

- Some tanks require corrosion protection such as sacrificial anodes. These should be easily re-identified at regular replacement intervals.
- Acidity levels in rainwater can be controlled by adding permeable bags of gypsum.
- For tanks larger than 5,000L sub-metering is recommended where potable or recycled water top-up to the tank is required.

4.1.4 Greywater systems and recycling

Reuse of greywater is accepted for gardening purposes only and shall be guided by the City of Whittlesea's *Sustainable Gardening* booklet.

4.1.5 Modelling approach

Rainwater tanks will be sized and modelled using a suitable stormwater model such as MUSIC or STORM Calculator.

The Melbourne Water *MUSIC Guidelines* (as revised) provide useful resources for tank modelling.

It is recommended that reuse for outdoor purposes should be modelled as annual demand incorporating rainfall and potential evapotranspiration (PET-rain). A monthly distribution of demands may alternately be used where data or suitable assumptions and calculations are available to support this approach.

Design parameter	Value
Inlet properties	
Low-flow bypass (m^3/s)	0 typical.
High-flow bypass (m^3/s)	Usually left at default as insignificant for most modelling purposes. Use limiting capacity of gutters and inflow pipes if these are considered likely to affect results.
Tank properties	
Volume below overflow pipe (kL)	Variable and to be determined using an iterative process to achieve an 80% reliability on reuse supplied (in the *Node Water Balance* results).
Depth above overflow (m)	0.2 typical, unless detention function built into the tank volume.
Surface area (m^2)	As per tank product or a probable footprint to achieve a realistic tank height range of 2-3m.
Initial volume (m^3)	Half of the total tank volume is typical.
Outlet properties	
Overflow pipe diameter (mm)	As per hydraulic design requirements (overflow capacity > inflow capacity).
Reuse	
Seasonal annual demand (kL/year) Constant daily demand (kL/day)	Demands may be estimated based on: • Number of occupants or daily visitors (typically taken to be approximately equal to number of bedrooms for residential developments or employees in a commercial setting). • Typical water use demands as provided by water retailer. • Appliance efficiency (such as WELS rating). • Appliance usage rates. • Garden irrigation requirements (based on size and vegetation type). Where specific data is not available, indicative demands for Melbourne as follows may be used: • Toilet flushing: 20L/person/day. • Clothes washer: 40L/person/day (up to max 80L/household/day). • Irrigation: 0.5kL/m^2/year. • Food production: 0.75kL/m^2/year.

Table 6 Tank modelling parameters

Passive irrigation tanks ('leaky' tanks)

Rainwater tanks can be adapted for passive irrigation by incorporating a garden hose or drip irrigation system, gradually releasing water to nearby landscaped areas. This controlled release promotes infiltration and evapotranspiration, and therefore contributes to the overall reduction of runoff volumes. Designing appropriate flow rates and volumes ensures effective water uptake, considering vegetation type, soil, and water balance. The precise drawdown optimises storage for increased rainfall capture, thereby replenishing flood storage continuously. It is imperative that modelling of the irrigated area alongside the tank is essential to account for soil moisture uptake restrictions and excess water to feed back into the site discharge. This is best represented as a vegetated sponge asset (as detailed in Biofiltration) or an infiltration node.

There are at least two ways the passive irrigation rainwater tank can be represented in MUSIC with the choice of the outlet being a controlled orifice plate with a constant outflow rate or a simple outlet pipe:

- **Option 1 – Controlled orifice plate with constant outflow rate:** represented as a second 'slow release' rainwater tank (downstream of the first standard rainwater tank representing only the passive irrigation portion of storage) with a controlled release fixed at a flow rate (using the constant daily demand reuse rate in MUSIC) that can be accommodated by the downstream landscaped area or WSUD asset.
- **Option 2 – Simple outlet pipe:** represented as a storage volume defined by 'depth above overflow', 'surface area' and 'overflow pipe diameter' sized to ensure outflow rates from the pipe can generally be accommodated by the downstream vegetated sponge or WSUD asset (and will be much smaller than a standard overflow pipe diameter).

Either a secondary link for reuse flows (option 1) or a secondary link with the primary flow functions of outflows and overflows (option 2) may be used to direct flows from the passive irrigation tank to the landscaped area.

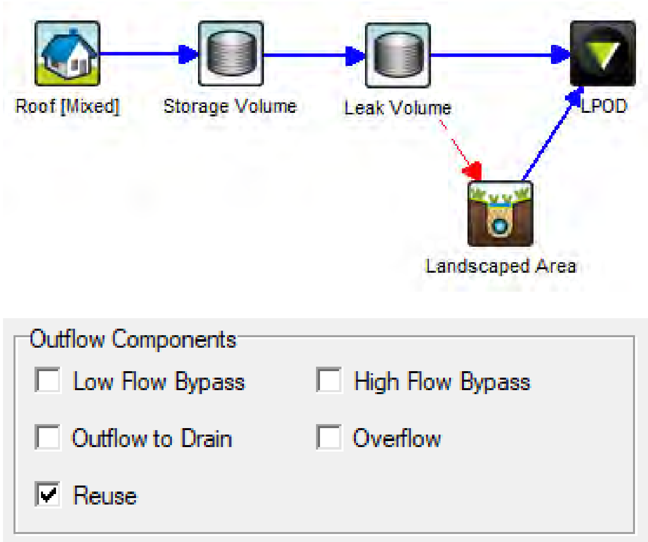


Figure 10 Option 1: Representation of the passive irrigation storage component of a rainwater tank as a second tank within the model (the constructed tank may be either a single unit or two tanks in series)

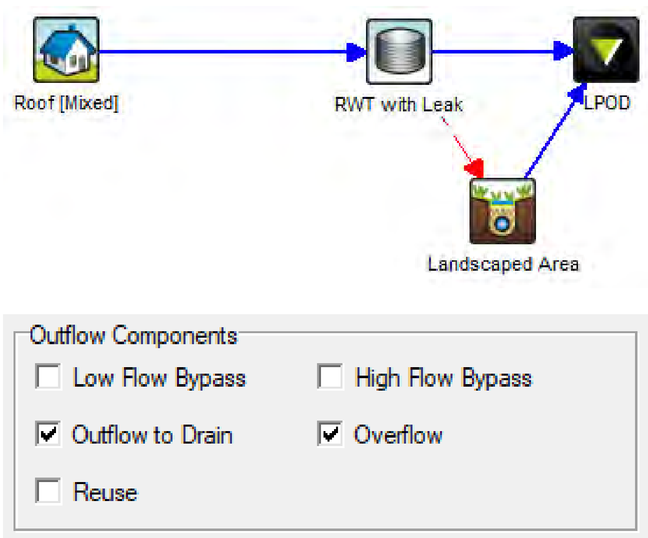


Figure 11 Option 2: Representation of the passive irrigation storage component of a rainwater tank using the depth above overflow and a constrained overflow pipe diameter to limit discharge flow rates

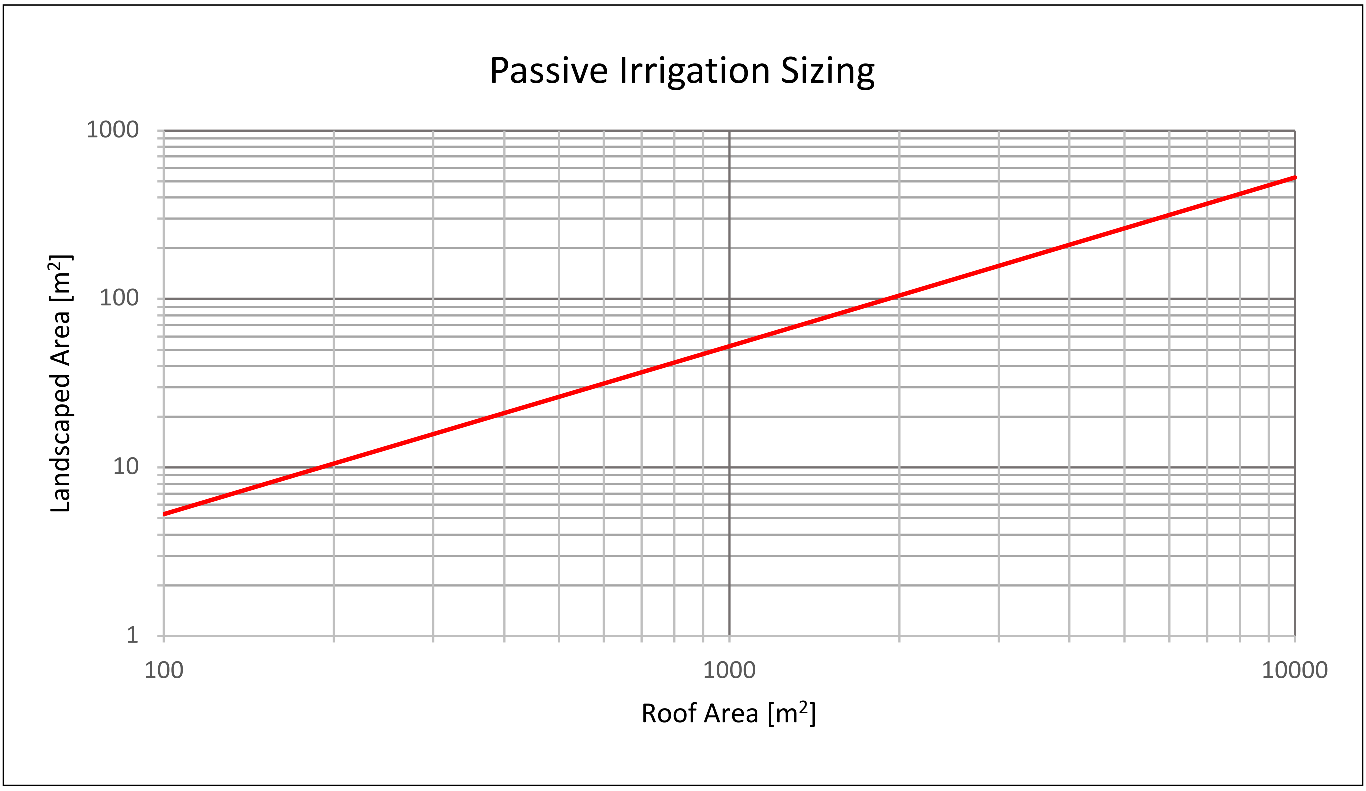


Figure 12 Passive irrigation landscape sizing per roof catchment

As an approximation, the tank leak rate may be set equal to the contributing catchment's baseflow rate. This rate is in turn translated to a minimum landscape area for the controlled flows to be received, infiltrated and lost to evaporation. The above chart demonstrates a correlation based on characteristic soils and minimum evapotranspiration effects in the City of Whittlesea.

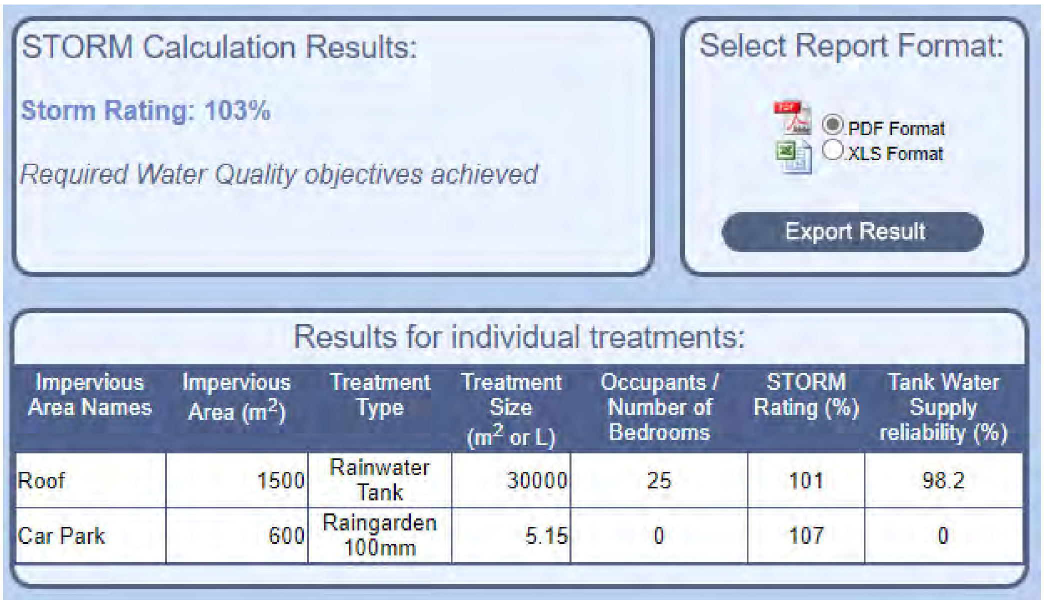
Example 1

A typical residential roof of 200m² drains to a 4,000L rainwater tank with the sole purpose of passive irrigation. The required lawn or garden bed size to accommodate attenuated flows is ~10m² and would be controlled at a 120L/day controlled leak rate. This treatment approach achieves a 45% TN reduction (100% STORM score) and a 36% flow reduction which meets 100% of the EPA recommended volume reductions through harvesting and infiltration in the City of Whittlesea's climatic zone.

Example 2

An industrial development with a 1,500m² warehouse roof requires a 75m² landscaped area and a 30kL tank which discharges rainwater to the landscaped area at a 900L/day flow rate.

The selection of the tank size and corresponding landscape area results in a 45% TN reduction which equates to a 100% STORM rating for the relevant roof area treated. In the STORM Calculator the applicable roof area and tank size is entered, with calibration of the number of occupants to achieve the 100% score for the roof.



Impervious Area Names	Impervious Area (m^2)	Treatment Type	Treatment Size (m^2 or L)	Occupants / Number of Bedrooms	STORM Rating (%)	Tank Water Supply reliability (%)
Roof	1500	Rainwater Tank	30000	25	101	98.2
Car Park	600	Raingarden 100mm	5.15	0	107	0

Figure 13 STORM calculation results

4.1.6 Submission requirements

The functional design package for the City of Whittlesea's assessment must include the following documentation:

- Functional design drawings, including layout plans, sections and typical details, noting all proposed tank functionalities.
- Supporting water quality model – MUSIC model or STORM report.
- Computations and assumptions for tank sizing, reuse demands (and passive irrigation modelling parameters, if applicable).

The detailed design package for the City of Whittlesea's assessment must include the following documentation:

- Detailed design drawings, including layout plans, sections and specific details, noting all tank functionalities and showing all connections in and around buildings (and landscaping areas, if applicable).
- Supporting water quality model – MUSIC model or STORM report.
- Full tank specifications and detailed description of volume reservation, outflow/leak/overflow rates where controllable.
- Orifice sizes and relevant protection measures documented.
- Pumps and all other system components such as strainers, filters, disinfection units and irrigation systems fully specified on plans or separate document, ready for product order and installation.

4.1.7 Construction and establishment

There are general considerations which apply to all tank installations:

- A qualified plumber should perform the installation adhering to the National Plumbing and Drainage Code (AS/NZS 3500), including the plumbing connection back into household appliances.
- Consider the foundation pad to include workable space around the tank for access.
- Base preparation in concrete, sand or crusher dust shall be as per manufacturer's specifications.
- Some tank installations require crane lifting depending on size, weight, modularity and position of the tank.
- Some tanks require initial water fill as per manufacturer's advice to resist wind blow.
- For delivery purposes consider truck dimensions entering and existing on site (if applicable).

Construction hold points

Individual lot-scale installations are commonly inspected and approved by a registered building surveyor. Tanks designed and installed for the City of Whittlesea's end-use require the following critical construction steps to be witnessed by Council's project manager or Construction Surveillance Officer:

- **Bulk earthworks:** set out of base, locate existing services and prepare base for tank.
- **Tank placement:** check for levelness and tank security against displacement.
- **Plumbed connections:** the necessary connections have been installed and are in accordance with the National Plumbing and Drainage Code (AS/NZS3500) and the National Construction Code (NCC). This includes meeting requirements for fixture efficiencies, discharge pressure, water velocity, flow rates, access and isolation, and safeguard against uncontrolled discharge.

- **Health and safety:** necessary water quality measures such as corrosion protection, leaf screening rain heads, vortex filters and mosquito or vermin screens have been installed.
- **Finished levels and hard landscape features:** levels as per design and flush with adjacent areas.
- **Overflow:** all necessary pipework (including connection into the downstream drainage network if required) has been completed in accordance with the City of Whittlesea's standards and ensures safe conveyance of excess stormwater.
- **Controlled leak (if applicable):** the required flow rate is demonstrated and pipework laid to receiving landscape areas.
- **Electrical elements:** installation according to Australian Standards. Pumps and mains switches have been tested for cut-in/cut-out as per design intent.
- **Building survey certification** that tank has been installed, tested and is functioning to comply with national and state codes.

This is consistent with the checklists for construction by the VBA Audit 99: Rainwater Tank Installation (Victorian Building Authority, March 2023).

Council handover (Council assets only)

The City of Whittlesea requires digital (not hand-sketched) as-constructed plans, and all photo and video documentation of the construction, to be submitted to the Construction Surveillance Officer at Practical Completion stage.

A precise functional description of the tank purpose is to be documented on as-constructed plans for Facilities and Asset Management records. The description must entail all tank components, including make, model, size, material and control logic description.

Where tanks form part of a larger municipal harvesting system, refer to the Construction and establishment section of Stormwater harvesting.

4.1.8 Asset operation and maintenance

Once installed tanks and passive irrigation tanks are relatively low maintenance and will sustain their functionality for substantial periods without active operation. The most common failure modes for tanks are the mains switch and pump controls, which require professional inspection and repair, if compromised. Regular maintenance of rainwater tanks is summarised in the table below.

Figure 14 Commercial-scale reclaimed rainwater treatment, Houston Street Depot, Epping

Frequency	Component	Maintenance required
Every 3 months	Roof	Consider trimming tree branches overhanging the roof to reduce debris from being collected.
	Gutter	Remove leaves and debris acumulated. Stuck debris can rot and pose flow obstructions towards the tank.
	Leaf-shedding rainheads	Only choose removable screens – monitor and clean (if required) on a monthly basis or after rain events following prolonged dry periods – stainless steel products are recommended.
	First flush devices	Remove end cap and internal filter cartridge and hose until clean.
	Tank inlet strainer	Brush and hose clean and ensure mosquito mesh is intact; replace if damaged.
	Mosquito screens on tank overflow outlet	Repair or replace if necessary.
	Pumps	Periodic acoustic test should be undertaken to see if pump is running. If not, float switch could be stuck on tank wall. Low pressure can be an indicator that pump needs to be re-primed. Submersible in-tank pumps have no priming issues, however, extraction for troubleshooting or maintenance is more complicated. Submersibles may be positioned underneath inlet strainers.
Every 6 months	Flashings	Check for defects and repair/replace, if required.
	Roof	Consider trimming tree branches overhanging the roof to reduce debris from being collected.
	Water quality	Inspect colour and smell. Identify cause for quality changes, if observed.
Once a year	Structural integrity	Check tank body and foundations.
	Filters	Pleated filters can be water-hosed for backwashing. Drinking water filters should be replaced annually.
Every 2-3 years	Sediment level in tank	The idea is to avoid the pump taking sludge in and compromising inline filters or desired end-use water quality (if used for laundry, for example). De-sludging can be achieved through syphoning when no scour valve comes with the tank product. It is best to have a ball valve at tank base to facilitate de-sludging.
	Leaf guards	Hose or brush down every 2 years.
As per manufacturer's recommendations	All electrical equipment, pumps, filters, disinfection units	As per product maintenance specifications.
	Tank product	Some tank products require OEM service for warranty extensions.

Table 7 Rainwater tank maintenance routine

4.2 Stormwater harvesting

4.2.1 Function

Stormwater harvesting (SWH) systems collect stormwater runoff, typically from stormwater drains, for subsequent reuse. Stormwater harvesting is an increasingly important option of stormwater management with the benefits of both reducing potable water use and reducing the volumes of runoff and pollutants entering the downstream waterways.

Stormwater harvesting systems generally consist of the following components: collection and diversions, storages and buffers, transfer stations, tertiary water treatment and distribution. The storage type for these schemes can vary, however they are commonly designed as storage tanks (either above or below ground) or open water ponds or dams.

Stormwater harvesting and reuse is applicable to various uses, including industrial or commercial uses, residential uses, and for irrigation of public parks or recreation reserves. They are typically a centralised system, and may require a relatively large area, particularly if using above-ground storage.

The adoption of stormwater harvesting schemes can find attraction in new developments where PSPs allow for future sportsground delivery by Council. An applicant may propose a partnership with the City of Whittlesea (and Melbourne Water, where applicable) to co-deliver a stormwater harvesting scheme, in full or in parts, to meet statutory requirements in stormwater management. Such proposals should be submitted at the pre-application stage and will be subject to the City of Whittlesea's discretion for acceptance.

A general overview of systems components and characteristics is available on Melbourne Water's stormwater harvesting webpage. The below guidance can be considered as a precursor to a more comprehensive guideline scheduled for 2024 completion.

Figure 15 Underground storage of the Mosaic stormwater harvesting scheme in Lalor

4.2.2 Design criteria

Feasibility and planning phase

For the feasibility of a stormwater harvesting scheme, a consultant must consider demonstration and documentation of the following criteria:

Water source

- If the supply catchment can provide 200% of the annual water demand during the summer rainfall period, then further water balance studies are warranted. If it cannot, then it is highly unlikely that a system reliability of at least 75% can be achieved.
- Multiple water supply options should be thoroughly investigated (if applicable), including high-level water balance studies and cost estimates, to inform a cost/benefit analysis.
- Where stormwater flowing to a stream from an existing development is to be intercepted, 50% of stormwater can be harvested for consumptive use and 50% must be reserved for the environment. Where a scheme feasibility study proposes to harvest more than 50% of water, a further investigation is required to assess the implications for the environment.
  Where stormwater generated from a new development is to be harvested, all of it is available for consumption with the aim of the development reducing runoff impacts on the receiving waterways.
- A stormwater harvesting licence will be required from Melbourne Water to:
  - connect to any new or modified stormwater drain, watercourse or open channel controlled by Melbourne Water.
  - harvest any quantity of stormwater from a waterway controlled by Melbourne Water or any Melbourne Water asset.

System yield

- A water balance model must demonstrate average 10 dry year yield where water is proposed to be directly harvested from waterbodies, ensuring impact on vegetation is avoided and applying sensitive draw-down levels.
- Annual water demands for subject sites are to be confirmed with the City of Whittlesea's Operations Department. Operational improvements shall be discussed at this stage to inform any irrigation cycle alterations (multi-zone supplies at reduced total cycle times, for example).
  In the absence of any recorded demands, an average 4.5ML/ha/year rate can be applied.
- A MUSIC file is to be submitted upon feasibility stage completion, quantifying the proposed system's overall stormwater flow reductions and water quality improvements to the downstream environment.

Site logistics

- Consultation with all possible site stakeholders, including the City of Whittlesea's Facilities operations, is to be undertaken where harvesting off Council buildings is proposed. Facilities can advise of any leased areas around building complexes which may pose no-go zones for new infrastructure.
- Conduct a site meeting with stakeholders prior to feasibility studies, including reserve managers and contractors, facility managers (if applicable), Operations staff, design consultant and third party authorities (if other infrastructure is affected).
- Masterplans may be available for subject sites and shall be referenced to ensure integrity with future works proposals.
- Geotechnical investigations shall be established to inform soil bearing capacities, soil contamination levels, groundwater levels and further treatment requirements to inform the feasibility of underground tank proposals.
- Mapping of all existing underground services shall be undertaken as part of a site topographical survey.
- Existing electricity supplies shall be located and feasibility of upgrades and extensions established, if required.

Regulations and external controls

- Public health and environmental risks form the foundation of design. The *Australian Guidelines for Water Recycling: Managing health and environmental risks – (Phase 2) Stormwater harvesting and reuse* (NHMRC, 2009) serves as the cornerstone for evaluating a SWH schemes' compliance and is primarily designed to support health and environmental risk management for water harvesting schemes that source water from stormwater systems.
- Planning overlays shall be referenced which may impact the site's project feasibility.
- Proximity of Melbourne Water assets and other utilities, their clearance requirements and any notification, permission or security bond obligations for works near other authorities' assets need to be confirmed.

Design phase

The functional and detailed design phase requires a multitude of considerations. These are outlined below and distinguished by major system components and functions.

General design requirements

- When harvesting from waterbodies, preference is to extract water from overflow structures where no extended detention depth (EDD) and NWL are impacted.
- Electrical supply design must be undertaken by a qualified electrical practitioner with certification to liaise with supply retailers and register new metering (if required). An electrical wiring diagram must be submitted as part of the design plan set.
- All surface-exposed infrastructure must be vandalism-proof through appropriate caging, fencing and bollards.
- Safety in design must consider all risks of hazardous situations, including but not limited to, falling, drowning, tripping, electrocution and bacterial or viral infection with untreated water.
- Earthworks surplus management is preferably onsite. This is to be discussed with the reserve manager.
- Designs must allow for a direct potable to ring main backup (in addition to tank top-up) to bypass the entire harvesting scheme. Reduced pressure zone devices may be required to be registered with Yarra Valley Water.
- All on-site plumbing work is to be done in accordance with the Plumbing and Drainage Standards (AS/NZS 3500 2003).
- The consultant must confirm with suppliers that proposed products and instrumentation have reasonable order and delivery lead times in the Australian market.
- All ancillary structures such as pump rooms and above-ground tanks require adequate drainage connections to the City of Whittlesea's satisfaction.
- Spare conduits must be specified between all sites requiring electrical or communication connections.
- The water balance model must be refined with final adopted design parameters to confirm original system reliability.
- Critical construction hold points or witness points must be documented on plans.
- A risk assessment workshop with all stakeholders at functional design milestone should be considered.
- At completion of detailed design phase, the design should be 'walked' at the subject site to identify any remaining constraints and uncertainties for construction.
- Detailed design packages may be peer-reviewed by suitable qualified consultants or contractors.

The figure on the right illustrates the various components of a stormwater harvesting scheme which may be considered during the design phase.

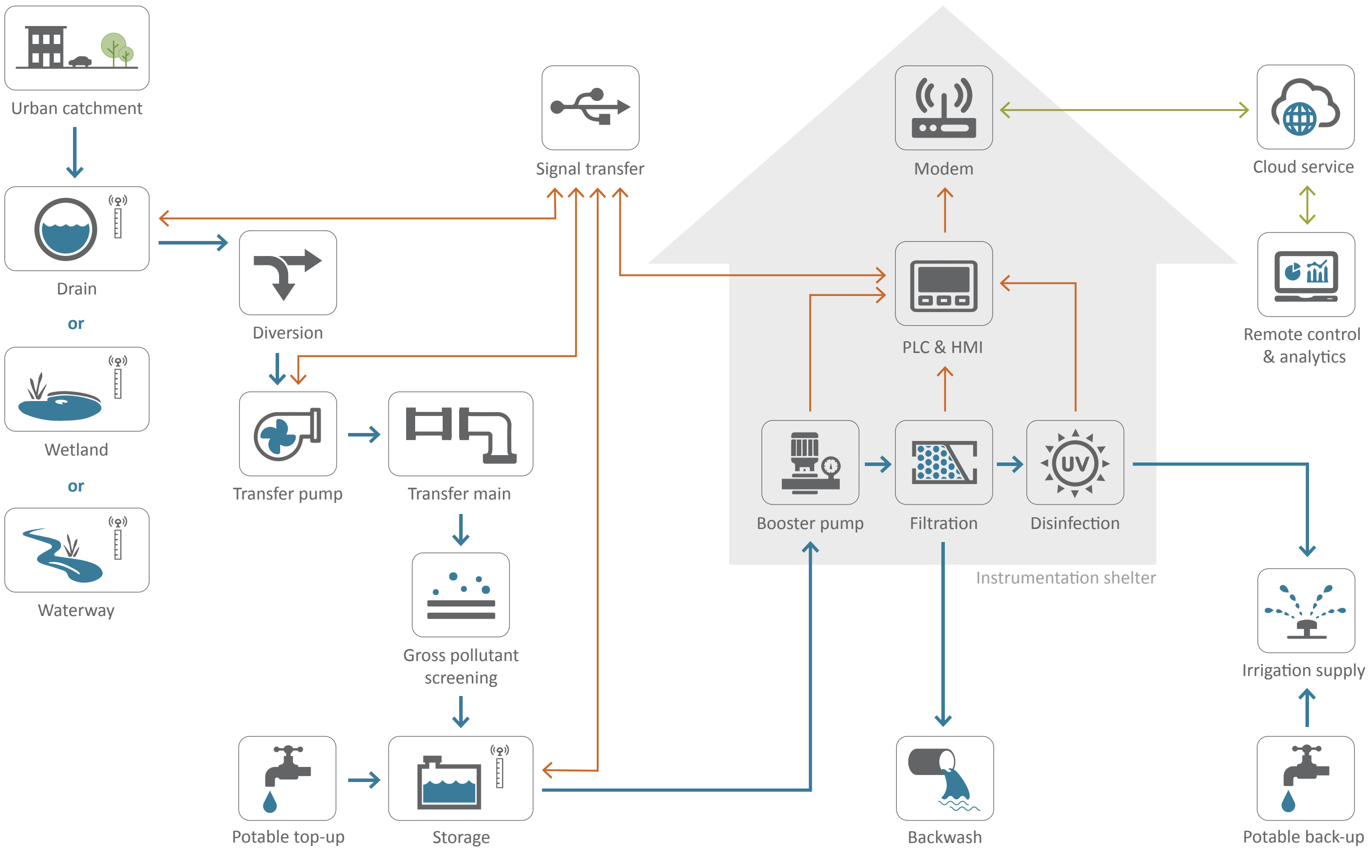


Figure 16 Stormwater harvesting design components

Diversions

- For diversions or extractions from Melbourne Water owned assets, the *Guidelines for Stormwater Harvesting on Melbourne Water Drainage Assets* (Melbourne Water, 2016) apply as relevant, together with the set of standard drawings.
- Diversion structures shall not negatively impact on minor and major storm hydraulic grade lines. This must be demonstrated through a DRAINS model.

Storages and buffers

- Storages and buffers must be isolatable from inflows during maintenance and inspection activities.
- Where storage is compartmentalised (such as tanks in series), overflows must be provided on all individual storages.
- Compartmentalised storages must be manually isolatable.
- Compartmentalised storages must have individual level sensing (and external indicators in the case of above-ground tanks).
- Transfer pump submersion in buffer tanks must be accounted for effective buffer volumes.
- Storages must consider water dumping mechanisms, preferably via gravity.

Transfer mains

- All pipework needs to comply with the *MRWA WSAA Water Supply Code* and backfill specifications.
- Transfer mains shall limit (or avoid, if possible) vertical deflections requiring scour valves in low-points or air valves in high-points. Where this cannot be avoided, these maintenance points must be located in safe operable environments.
- Transfer mains must feature appropriate flushing options.
- All sources, splits, combinations and diversions of pressurised flows shall have separate flow metering.

Pumps and instrumentation shelter

- Design plans must include a detailed pump and water treatment train layout, as well as a continuous elevation along the pipework and treatment train.
- Enclosure-style housing of all instrumentation must achieve access all around the enclosure.
- Pump room-style housing requires all instrumentation to be installed along the room perimeter, leaving clear operational space in the centre of the room.
- Pump rooms must feature appropriate cross-ventilation in accordance with Australian Standards.
- Where prefabricated sheds are proposed as pump rooms, the treatment train elevation profile must show controller cabinet locations (suspended off walls) to allow for wall reinforcement in those locations.
- Pump rooms must feature appropriate floor drainage.
- All electrical installations, cabling and wiring must comply with Australian Standards and the Victorian Electricity Safety Regulations.

Figure 17 Different types of instrumentation housing:
a) Enclosure style at Laurimar Recreation Reserve, Doreen
b) Pump room style at Pinks Reserve, Kilsyth

System controls

- All on-site controls, including PLC, software, HMI, remote-viewing licence and recorded data must be fully owned by the City of Whittlesea and products be specified accordingly. The City of Whittlesea does not accept third party subscriptions post asset handover.
- On-site controls must be capable for API data push and pulls to the City of Whittlesea's requirements.
- Local PLCs must be programmed to display the following infographic on site and (if applicable) remote HMI. This can be through several pages or page scrolls.

    1. **System schematic** showing all critical scheme and asset components as well as their current sensor or meter reading status. This includes, as a minimum:
        a. Storages and their current fill level.
        b. Pumps and their current activation status and pressure.
        c. Ultraviolet disinfection units and their current UV intensity level.
        d. Actuated or solenoid valves and their current open or close position.
        e. Water meters and their current cumulative reading.
    2. **Operational setpoints** showing all transfer and irrigation pump cut-in and cut-out levels with all buffers and storages, as well as potable top-up criteria. The operations setpoints page may also display critical water quality metrics, water dilution or tank content dumping triggers. Setpoints must have appropriate overwrite protection.
    3. **Alarm setpoints** showing buffer or storage high- and low-level thresholds, by exceeding which would indicate a fault in one or more of the instrumentations. This can be signal-based or instrument-based faults.
    4. **Daily data log** showing all instantaneous or cumulative readings as per system schematic for a minimum of 36 months. The displayed data set is required to be pushed into the City of Whittlesea's Azure Data Warehouse for further infographic production in PowerBI.
    5. **Time-series charts.** Data logs are plotted on timescales for visual interrogation. This will be a mix of cumulative and fluctuating graphs (for water meters, level and water quality sensors). The timescales should be specifiable manually to allow for zoom-in.
    6. **System reliability.** Calculations from data logs are required to display year-to-date yield on stormwater versus potable water consumption on any given site, or for any specifiable date range. This may be displayed through pie charts or bar charts.
    7. **Fault log** showing date, time, asset component (or code thereof) and the fault message.

Further documentation

- The system control logic shall be part of the design documentation and shall be in an 'if/then' format, to be further used and refined by the contractor in construction phase.
- System faults must be clearly documented on how each fault is established (such as no flow registered by meter shown as pump fault) to assist operational troubleshooting.
- Design specifications must include reinstatement works of all disturbed surfaces.
- Detailed designs must be accompanied with a site-specific maintenance and operations (O&M) manual, with reference to all adopted product suppliers and their warranty details.
- The works specifications document must include a practical system commissioning protocol for the testing of all critical controls and instrumentation function at Practical Completion milestone.

4.2.3 Modelling approach

Stormwater harvesting performance should be determined using a water balance model. MUSIC can provide a basic water balance model, however in some cases this may not be accurate enough and a more detailed model may need to be used accounting for soil moisture depletion and other irrigation triggers.

For complex on-site demands such as irrigatable sportsgrounds and nurseries, a custom demand is required to be modelled defining water demands for each six-minute time-step for a 10-year data set.

Reuse demands, soil characteristics, crop factors of vegetation (turf) are to be enquired with the City of Whittlesea's Operations department for existing and established sites, and to be enquired with Landscape and Open Space Planning department for future, developable sites.

Water balance models from feasibility studies must be reconfirmed at completion of the detailed design phase when all construction specifications are confirmed. Any changes in catchment sizes, diversion rates and storage provisions will influence system reliability.

4.2.4 Construction and establishment

The City of Whittlesea requires many site management practices, construction hold points and witness points to be adhered to. The following provides a broad, but not exhaustive, list of the City of Whittlesea's construction compliance requirements for stormwater harvesting schemes:

General items

- The contractor must submit a SEMP, mapping site material storages (stockpiles) and tree protection or no-go zones, as well as sediment and runoff erosion controls held in place for the duration of works.
- A site induction meeting prior to commencement of works is to be held to go through all logistics and construction hold points requiring inspection notice.
- Clarify construction access logistics prior to works commencement. This includes garbage truck timing, emergency evacuations in proximity to facilities and assembly areas kept clear. Consider shared access gates be fitted with a padlock chain.
- Clarify necessary power outages (due to new connections) with all impacted stakeholders and reserve users as early as possible to avoid interruptions.
- Ensure site security, especially when children are expected around the site looking for adventures (entering underground tanks that are not yet completed, for example).
- All works must be safely compounded to exclude unauthorised access.
- As-constructed CAD plans are required upon works completion. Consider self-arranged as-built survey through independent surveyor to check on correct levels and positions.
- At Practical Completion, allowances are to be made to have full stakeholder attendance for the commissioning of the system, and training provided to Operations in remote viewing and controlling.
- Prior to the end of the specified defects liability period or on-maintenance period, the contractor must update the printed O&M manual to the satisfaction of the City of Whittlesea's Operations department. A full log of system faults must be documented and submitted to the City of Whittlesea, with troubleshooting descriptions and resolutions noted to each fault that occurred during the initial operations phase.

Works specific items

- All above-ground exposed metering and rising main arrangements must be on concrete slabs and caged.
- Subsidence on heavy infrastructure, such as full tanks inducing extra stress on pipe connections, must be considered. Allow for flexible couplings where there are concerns of differential subsidence.
- Test transfer flow capacities upon completion and recalibrate pump cut-in and cut-out levels accordingly.
- Test that the irrigation pump achieves the desired flow rate and pressure for irrigation purposes. The City of Whittlesea's Operations department shall consider performing a catch cup test for a representative irrigation zone.
- Test transfer mains and potable top-up lines for water hammers. Consider mains pressure testing prior to construction to allow for suitable fittings and pressure reduction measures.
- Consider partial system commissioning with suitable generator hire while waiting on new electrical connections to be established.
- Locations of sacrificial tank anodes need to be consistent across multiple tanks.
- Ask for compaction test reports on tank base, prior to commencing tank installations.
- Ensure valve testing as part of commissioning, simple manual open/close function as well as actuated valves, solenoid valves and others.
- Check level sensors against external indicators to ensure they are consistent.
- Be satisfied with the level of detail shown on the final HMI interface (controls screen):
    - Are all functional instruments shown graphically? Are all water movements (totals and instant, if applicable) shown on the graphic?
    - Are all functional setpoints defined and described and understandable?
    - Are data logs visible and to the required frequency?
    - Is a history of faults visible?
- Ensure all instrumentation manuals (hard copies) are kept in the pump room.
- Ensure pipework and instrumentation are properly secured to pump room walls and floor slab.
- All pipework, conduits and wiring into and out of the pump room must be visibly labelled with tags for ease of future identification.
- All electrical and communication conduits must be appropriately sealed and watertight on either end if exposed to the elements. This includes alignment through underground valve boxes.
- Ensure water spillages in sheds can escape underneath walls or through suitable floor drains.
- Ensure air valves are not facing towards any electrical components within the shed or cabinet.

4.2.5 Asset operation and maintenance

Preventative maintenance is required to ensure a stormwater harvesting scheme operates as per design intent.

All possible asset failure modes shall be listed in the O&M manual and have a regular inspection and servicing routine specified.

SWH schemes benefit from multi-stakeholder access to the basic monitoring system and have asset knowledge sufficiently disseminated in the City of Whittlesea's Operations.

Each instrumentation requires a service plan which is to be documented in the O&M manual.

A SWH system will also require periodic system compliance checks which include the testing of water quality (upstream and downstream of the treatment train) to ensure compliance with the national guidelines for reclaimed water use, for the safety of the public and scheme operators.

4.3 Passively irrigated trees

4.3.1 Function

Passively irrigated trees are trees which receive stormwater from surrounding surfaces into the tree root zone as a regular water source. They are relatively similar to biofilters or raingardens but typically contain one or more trees and may or may not contain other vegetation around the tree.

Passively irrigated trees can provide effective treatment of stormwater through the tree root zone and increase retention of stormwater runoff within the landscape. Stormwater pollutants, such as nutrients that otherwise increase risks of algal blooms in waterways, act as fertilisers and are beneficial for tree growth.

Using stormwater to passively irrigate street trees not only helps keep trees healthy but also delivers on a range of stormwater objectives that would otherwise need to be met using other infrastructure.

Passively irrigated trees contribute to the *City Forest Strategy* to achieve better liveability outcomes in The City of Whiitlesea's growth areas.

A passively irrigated tree pit typically consists of:

- A reservoir that stores water and allows it to infiltrate into the soil (such as surface ponding or aggregate void space volumes, an infiltration trench or leaky pipes within the soil profile surrounding the tree).
- Adequate soil volume and quality (including filter media, engineered soils or other surrounding soils) providing suitable conditions for tree root growth.

Figure 18 New Epping's passively irrigated street trees

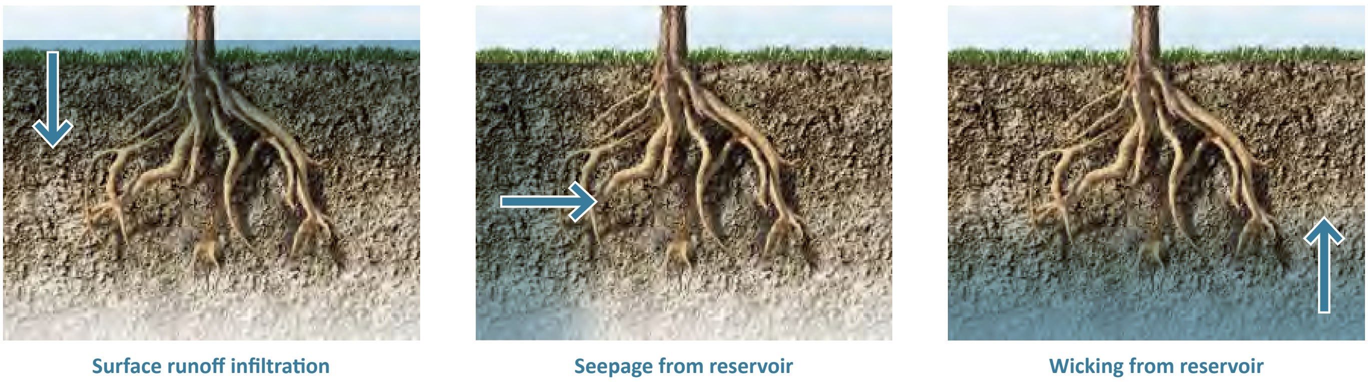


Figure 19 Various water supply mechanisms to tree pits

4.3.2 Adoption and constraints

Preferred use	Non-preferred use
✓ Kerb outstands	✗ In line with utility trenches
✓ Median strips and wide verges	✗ Planting in 'soft' growing media due to concerns about root stability
✓ Parallel parking strips	✗ Street low points – needs to be at-grade
✓ Car parks	✗ Overhead infrastructure (such as powerlines, tram lines, street awnings)
✓ Town centres and urban space	✗ Steep terrain (>8%)
✓ Along active transport routes (walking or cycling tracks)	✗ Shallow groundwater conditions risking waterlogging
✓ In combination with permeable pavements as inflow screens	✗ Sites with highly sodic soils, unless treated under the guidance of a soil scientist
✓ In flat terrain (<8%)	

4.3.3 Design criteria

Passively irrigated street trees provide a range of benefits, including shading, cooling, amenity, ecological habitat and stormwater management. For the purposes of this guideline, the design considerations are focused on the stormwater management component.

There are many design guidelines that provide advice on the planning and design of passively irrigated trees, including:

- *Trees for Cooler and Greener Streetscapes* (Victorian Government, September 2019) providing guidelines for streetscape planning and design.
- *Designing for a cool city – Guidelines for passively irrigated landscapes* (CRC for Water Sensitive Cities, April 2020) containing detailed design considerations.

Figure 20 Examples of tree pit configurations

To ensure passively irrigated tree pits can support healthy trees and provide effective stormwater management, the following interdependent design parameters need to be considered:

1. **Water source:** supply of water to the tree pit is sufficient.
2. **Soil volume and quality:** the media quality and volume can support tree growth and provide adequate stormwater treatment.
3. **Soil moisture:** the soil moisture conditions can support a healthy tree.
4. **Tree type:** a suitable tree species should be selected for the tree pit.
5. **Safety considerations:** the location and design of the tree pit also needs to consider potential impacts on surrounding infrastructure and community.

There are many design considerations addressing the above key parameters which will influence the optimal configuration. These are summarised below with the City of Whittlesea's preferred design response.

Design consideration	City of Whittlesea preferred design response
Water source	
• Inlet designed to allow water to enter the tree pit with a reduced risk of blocking and clogging. • Storage reservoir designed to store the design volume of water and allow it to infiltrate into the tree pit. • Catchment area large enough to generate the volume of water required. • Pragmatic maintainability of the inlet with either passive street sweeping processes or long-term inlet failure. • Trees planted in trenches may experience unequal growth depending on regular inlet intervals. Frequency of water supply can vary along the length of the trench.	**Inlets** ✓ Preferred water supply is through permeable surfaces and pavements. ✓ Kerb openings into tree pits within the road are acceptable, but must avoid inlet erosion. ✗ Inlet configurations such as kerb cut-outs which capture gross pollutants and require manual clearing are not accepted. ✗ Grated inlets may only be accepted if street sweeping processes are guaranteed to not be obstructed (such as by parked cars and tight kerb radii). ✗ Open-ended leaky pipes or standard kerb lintels where debris and silts can enter are not accepted. **Reservoirs** ✓ On surface or beneath (as EDD or within aggregate void space). ✓ Submerged or wicking zone under the condition that growing media capillary effect is demonstrated. ✗ Infiltration trenches adjacent to the tree root ball unless there is adequate space and guaranteed avoidance of interference with service trenches. **Catchments** ✓ **Catchment size minimum 10x mature tree canopy area (m^2).** ✓ Consider low-flow side entry pit bypasses to increase catchments.

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Design consideration	City of Whittlesea preferred design response
Soil volume and quality	
• Soil media specifications should balance the need for permeability, stormwater treatment and moisture holding capacity to support healthy vegetation and stormwater treatment. • Tree pit should be sized to provide stormwater treatment and sufficient soil or filter media volume to allow room for the tree to grow. • Structural solutions to protect soil from compaction should be used where traffic can be expected.	**Soil media specifications** • The tree pit growing media shall comply with AS4419 – 2003 (Soils for Landscaping and Garden Use): ◦ Organic matter content 4-8% (w/w). An organic content higher than 5% is likely to result in leaching of nutrients. ◦ pH 5.5-7.5 before delivery to site, add dolomite as required. ◦ Electrical conductivity (EC) <800 mg/kg. ◦ Orthophosphate content <50 mg/kg. ◦ Total nitrogen content <800 mg/kg. ✓ Soil specifications should be optimised by an experienced arborist or horticulture practitioner. ✓ Hydraulic conductivity should be between 30-50mm/hr for tree soils or alternately 100-200mm/hr for biofilter media. **Tree pit sizing** ✓ Depth should be at least 700mm (if the system is lined). ✓ **Desirable soil volume (m^3) for the root zone is approximately one-third of the mature-size tree canopy (m^2).** ✓ Desirable soil moisture volume (m^3) (volume of water that can be temporarily stored within the tree pit reservoir and growing media) is approximately 1/30th of the catchment size (m^2). **Structural solution** ✓ Structural soils are preferred (ratio of 5:1 of aggregate to soil should be assumed and the effective soil volume should be calculated as 20% of the total volume of structural soil).

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<table>
<tr><th>Design consideration</th><th>City of Whittlesea preferred design response</th></tr>
<tr><td colspan="2">Soil moisture</td></tr>
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Ensuring top 300mm (minimum) and 500mm (preferred) of growing media is free draining under aerobic conditions. A subsoil drain will usually be required with invert at this depth to ensure this is achieved.
Soil moisture modelling in MUSIC may be required if adequate subsoil drainage or access to deep soil moisture (due to lined or contained configurations) is not achievable.

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Outlet or drainage
✗ Kerb overflow – tree pits in kerb outstands cannot be an obstruction to major storm kerb flows.
✓ Overflow pits must connect to the minor drainage system.
Subsoil drainage options
✓ Connection to existing subsoil drains or minor drainage network.
✗ No corrugated AG pipes.
✓ Manually slotted pipes with smooth internal walls. The designer must specify adequate slot size, number of slots and protection from blockages and drawing media out of the pit.
✓ Elevated outlet to create wicking zone.
Hydrology
Where catchment to tree pit size ratios sit outside a recommended 10:1 (min) to 50:1 (max), the designer may be required to demonstrate that the accepted hydrology does not result in harmful impacts to the tree, avoiding roots to either dry out or be drowned for prolonged periods. In such cases, the designer has to prove that the following two criteria are met:
✗ Dry soil spell events greater than 35 days do not occur more than once per year. A dry spell event is defined as a period where soil moisture drops to wilting point, defined as a soil moisture saturation of 0.11 (11%).
✗ Wet soil spells don't exceed more than five days in duration within a 10-year period. A wet spell event is defined as a period where soil moisture is greater than or equal to a soil moisture saturation of 0.8 (80%).

The soil moisture frequency curve can be generated using the 'Flux graphs' feature in MUSIC.
The water retention capacity of the soil can be increased by up to 50% through the addition of a 5% volumetric mixture of biochar.

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<tr><th>Design consideration</th><th>City of Whittlesea preferred design response</th></tr>
<tr><td colspan="2">Tree selection</td></tr>
<tr><td>Tree height and diameter should be suitable for the location.
Tree species should be suitable for the expected soil moisture conditions.</td><td>Tree species
The tree should generally not be greater than 8m in diameter (~50m^2) at full maturity unless it can be shown that there is sufficient soil volume and space above ground to support the tree size.
Species selection shall generally be in agreement with the City of Whittlesea’s A Guide to Growth Area Street Tree Planting. Promoted species are:
Acacia implexa (Lightwood)
Callistemon citrinus (Kings Park Special)
Eucalyptus leucoxylon cv. (Euky Dwarf)
Hymenosporum flavum (Native frangipani)
Koelreuteria paniculata (Golden Rain Tree)
Lagerstroemia indica (Crepe Myrtle)
Lophostemon confertus (Brush Box)
Melia azederach (White Cedar)
Pistacia chinensis cv. (Chinese Pistache)
Platanus x acerifolia (London Plane)
Pyrus calleryana (Red Spire)
Quercus rubra (Northern Red Oak)
Syzygium smithii cv. (Lilly Pilly)
Tristaniopsis laurina (Kanooka)
Tree stock shall conform with AS2303-15 Tree Stock for Landscape Use and must be minimum 45L and a minimum height of 1.5m at the time of planting.</td></tr>
<tr><td colspan="2">Safety considerations</td></tr>
<tr><td>Tree pits need to be designed to mitigate potential impacts to surrounding infrastructure (such as underground services, roads, pathways and buildings) from root intrusion and saturation of soils.
Pedestrian safety also needs to be considered in the placement and design of tree pits to ensure there is adequate space, sightlines and there are no trip or fall hazards.
It is the full responsibility of the designer to ensure that all safety risks have been considered and addressed.</td><td>Structural stability
Review required offsets from buildings and roads.
The tree pit may require to be designed with structural soils at an angle of repose for the zone of influence of a building, road or structure to satisfy structural safety requirements.
Impermeable liners may be required on the side of the tree pit adjacent to the structure to reduce risk of root penetration and excessive moisture ingress.
Community safety
Review traffic and pedestrian management requirements, Disability Discrimination Act (DDA) compliance, footpath and bicycle clearance requirements.
Locate and plant passively irrigated street trees to ensure they have no impact on sightlines, especially near intersections.
Use covered tree pits (grated or permeable paving) or tree pits that use underground storage (such as infiltration trenches) where needed to reduce trip and fall hazards. Where open tree pits are proposed, the City of Whittlesea requires the pit surface to be planted with adequate ground cover species.</td></tr>
</table>

Table 8 Tree pit design parameters and preferences

The City of Whittlesea has further configuration- and material-specific requirements on passively irrigated tree designs:

- Trees planted in permeable resin-bound aggregates require sacrificial steel rings for the expected mature-size tree trunk diameter. Sacrificial surface thickness is to be to manufacturer's specifications.
- Trees planted in mowable swales require mulch to be locally retained by adequate mulch barriers or containment rings.
- Underdrain flushing risers must be flush with finished surfaces while protected from surrounding debris and grass clippings. Use of adequate valve boxes is recommended. Turf choice must be adequate to avoid growing runners over valve boxes.
- Hand-sized rock for use as energy dissipation must be concreted.

Figure 21 Passively irrigated urban trees: a) and b) side entry pit bypass for catchment increase (Fernhill Road, Mt Evelyn), c) interlocking block pavers and mulch combination (Were Street, Montmorency), d) pervious tyre-derived aggregate (TDA) pavement used around existing tree (Were Street, Montmorency), e) planting in permeable resin-bound aggregate with sacrificial steel ring (Hume Civic Centre, Broadmeadows)

4.3.4 Modelling approach

Passively irrigated tree pits will be sized and modelled using a suitable stormwater model such as MUSIC.

Users are referred to the following design guidelines as the best available source of guidance for modelling passively irrigated trees:

- *Designing for a cool city – Guidelines for passively irrigated landscapes* (CRC for Water Sensitive Cities, 2020).
- Current published version of the MUSIC modelling guidelines by Melbourne Water.

While a **bioretention node** is used for the modelling, there are many key differences between bioretention and tree pits which require some refinement of the bioretention node. These differences are explained below.

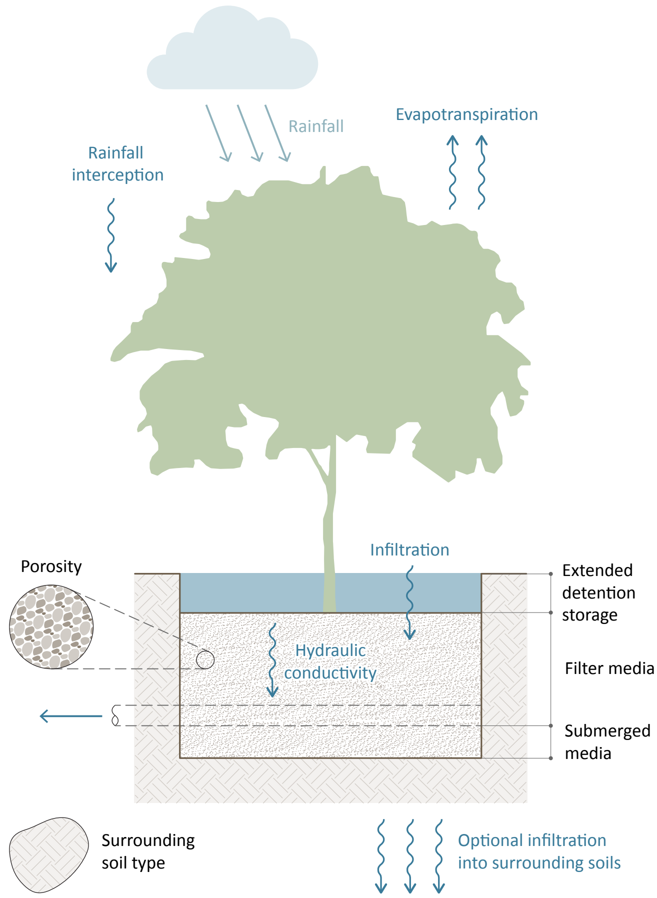


Figure 22 Schematic of a tree pit and associated flow processes

Modelling parameter	Bioretention node assumption	Tree pit design	Modelling response
Surface area/ evapotranspiration	Filter media area and the evapotranspiration area are equal	The surface area over which evapotranspiration can occur is the canopy area of the mature tree which is often larger than the surface area of the tree pit itself.	Refine the use of the potential evapotranspiration (PET) factor to account for tree water use and the larger canopy area.
Surface area/filter media	Surface area is equal to or greater than the filter media area	The area of filter media or dedicated soil may also be larger than the surface area and it may include structural soils that allow for tree roots to expand beyond the tree pit.	Revise the area and depth of the filter media to retain the correct volume while representing the area for infiltration. Modelling depth can vary from design depth.

Table 9 Bioretention to tree pit modelling variances

Recommendations for modelling parameters are outlined in the table below.

Design parameter	Value
Bypass	
Low-flow bypass	This is only required if lower flows will bypass the tree pit. For example, if the kerb cut-out sits higher than the base of the kerb resulting in some water bypassing.
High-flow bypass	Inlet capacity where this is limited, otherwise treatable flow rates are determined by the storage volume. Where inlets can pose flow restrictions, the inlet capacities should be designed to allow at least 90th percentile catchment flow rates.
Storage properties	
Extended detention depth (m)	0.05-0.3m typical range. This should be based on the volume of the storage within ponding water or aggregate void space.
Filter area	This represents the tree pit surface area. Water infiltrates through the filter area into the media. Water also evapo-transpires from the media across the filter area.
Filter media depth (m)	0.5-1.0m. At least 0.7m recommended.
Saturated hydraulic conductivity (mm/hr)	Bioretention filter media: 100mm (design range 100-300). Tree planting media: 30mm (design range 30-50).
Nutrient content (mg/kg)	Total nitrogen (design <800). Orthophosphate content (design <50).
Evapotranspiration rates	
High water use tree	MUSIC PET scaling factor: 1.8 x (canopy area/filter area).
Low water use tree	MUSIC PET scaling factor: 1.5 x (canopy area/filter area).

Table 10 Modelling parameters reflecting the uptake of water from the tree

The figures below and on the next page show the total nitrogen and total flow reductions in percent, based on a standard pit depth of 700mm and high water use tree selection. The variables are the contributing catchment areas relative to the selected tree pit area (indicated as canopy size).

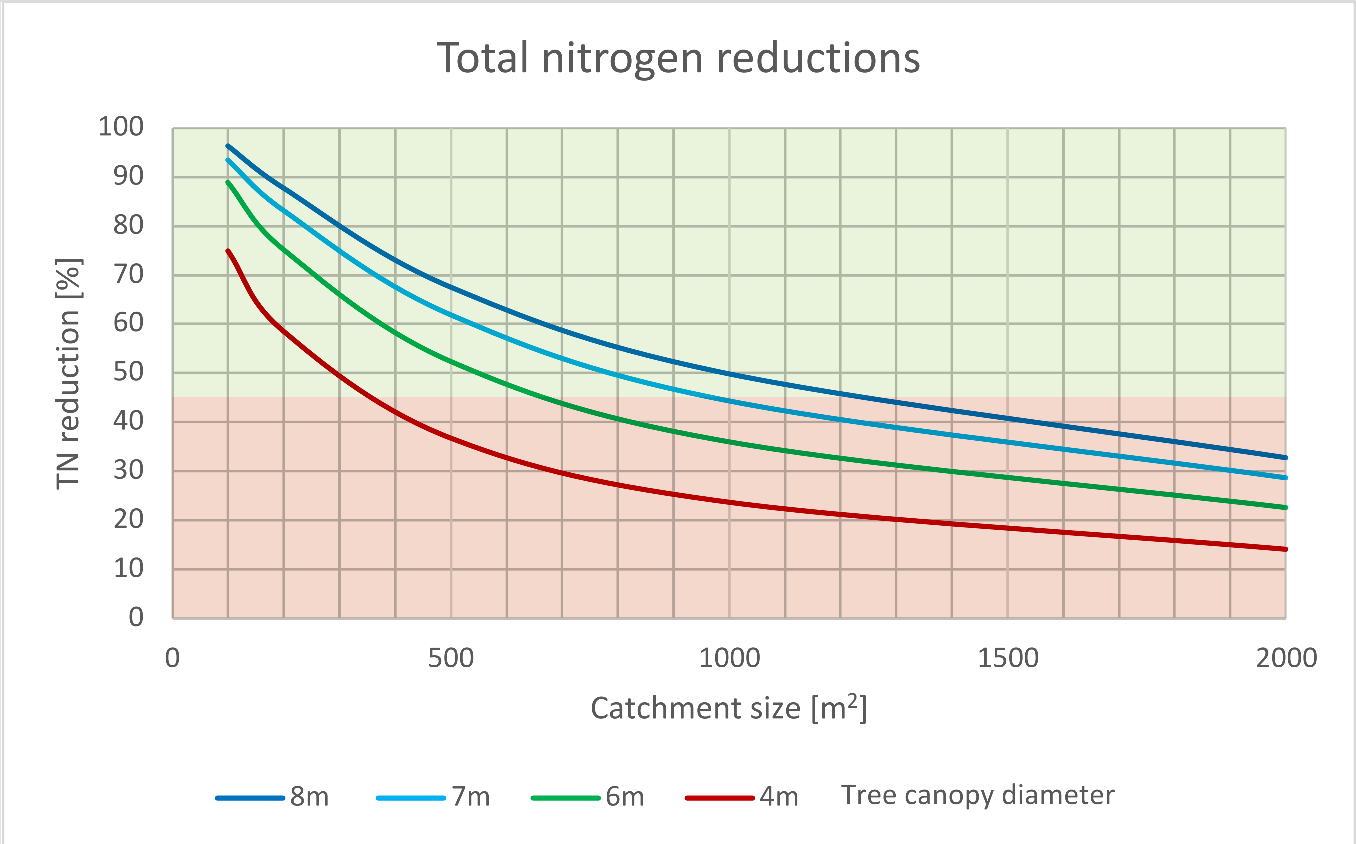


Figure 23 Total nitrogen reduction based on target canopy size

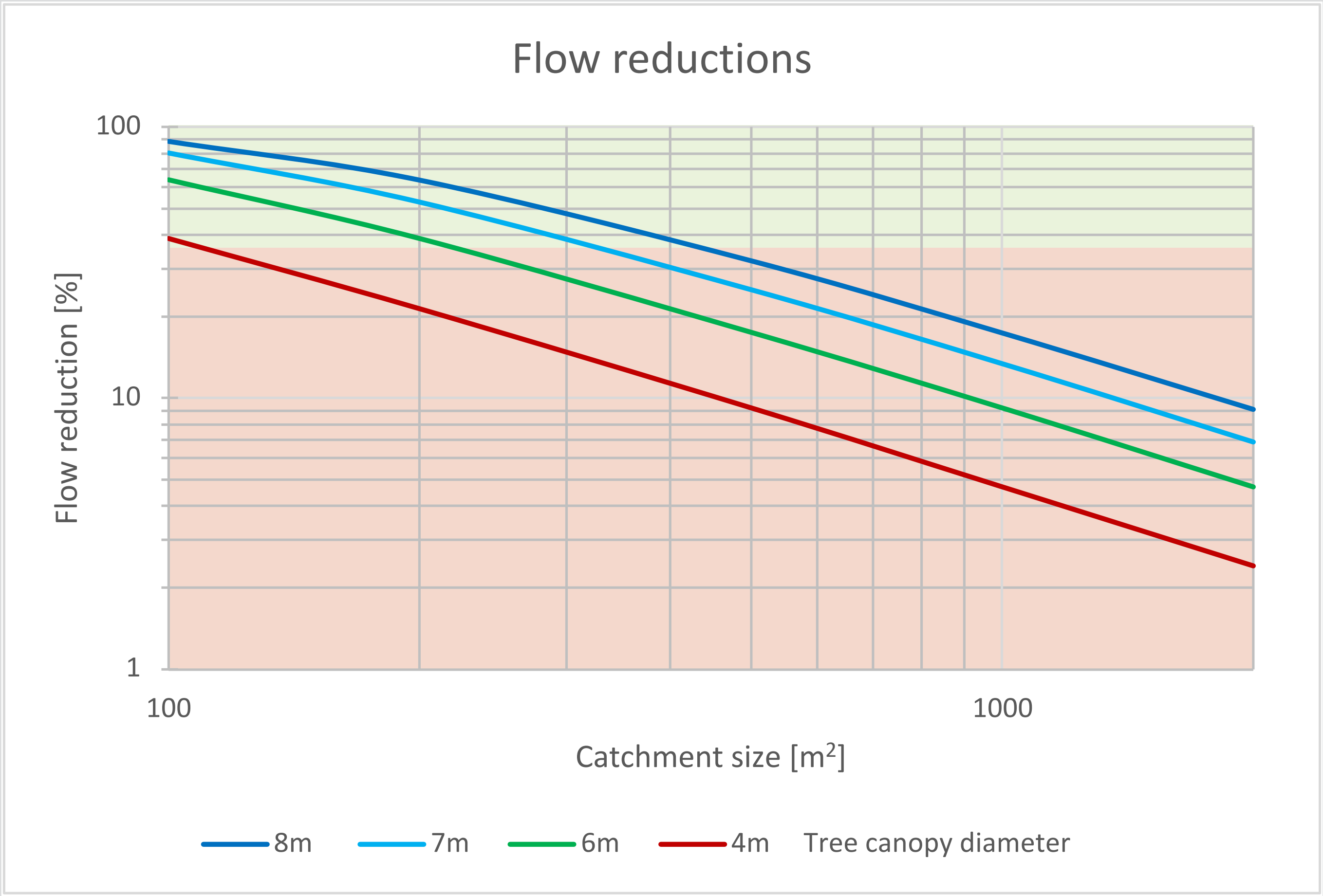


Figure 24 Flow reductions based on target canopy size

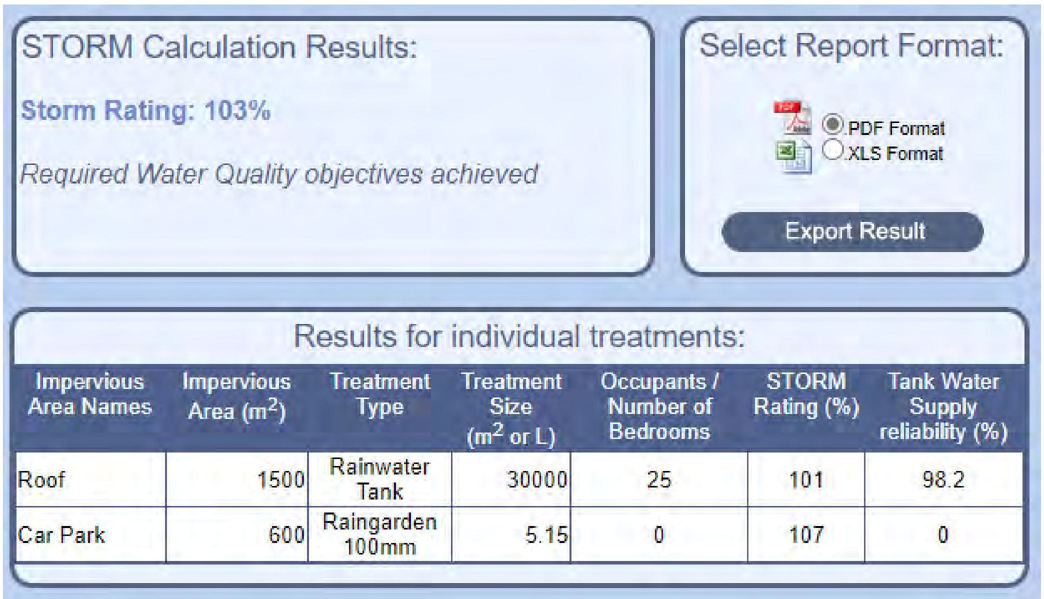
In the STORM Calculator, enter the treatment catchment area and scale the raingarden treatment option to achieve the equivalent reduction in the graph (for example, 45% TN reduction = 100% STORM rating for the relevant catchment).

Example 1

A commercial lot features a 600m² car park with 24 parking bays. One parking bay is sacrificed to install a passively irrigated tree pit with a soil volume that allows a 6m canopy tree to grow. The tree pit can remove 48% TN annually which equates to a STORM score of 107%. In the STORM Calculator, the total 600m² car park is entered and a raingarden treatment node is scaled to achieve the 107% score to contribute to the development's water quality improvements.

Example 2

A 350m long local residential road features an impervious surface of approximately 2,625m². To achieve best practice total nitrogen reduction for the road, four pits for a 6m canopy tree are required at ~650m² catchment to each pit. These four trees achieve a total flow volume reduction of 15%. It would require six 8m canopy trees within the subject street to reduce flows to the minimum EPA recommended 36%.



Impervious Area Names	Impervious Area (m²)	Treatment Type	Treatment Size (m² or L)	Occupants / Number of Bedrooms	STORM Rating (%)	Tank Water Supply reliability (%)
Roof	1500	Rainwater Tank	30000	25	101	98.2
Car Park	600	Raingarden 100mm	5.15	0	107	0

Figure 25 STORM Calculator results

4.3.5 Submission requirements

The functional design package for the City of Whittlesea's assessment must include the following documentation:

- Functional design drawings, including layout plans, sections and typical details.
- Supporting stormwater modelling, for example MUSIC modelling.
- Report and soil moisture modelling (if required).
- Supporting background documents such as a geotechnical report, masterplan and others.
- Written permission from other utility providers on proposed service relocations or deviations from standard offsets and clearances.

The detailed design package for the City of Whittlesea's assessment must include the following documentation:

- Detailed design drawings, including layout plans, sections, specific construction details and full material specifications.
- Landscape detailed design drawings.
- Supporting stormwater modelling, for example MUSIC modelling.
- Report and soil moisture modelling (if required) for asset performance re-verification.
- Construction and establishment approach documented on plans.

4.3.6 Construction and establishment

The successful construction of passively irrigated trees will require coordination between the design team, and civil and landscape contractors.

Construction and establishment should be in accordance with the construction and establishment checklists provided in **Appendix A** of *Designing for a cool city – Guidelines for passively irrigated landscapes* (CRC for Water Sensitive Cities, 2020).

Construction hold points

The City of Whittlesea requires the following critical construction and establishment hold points to be witnessed and documented.

- **Bulk earthworks:** system setout, location of services, subgrade preparation.
- **Impervious liner and subsurface drainage (if adopted):** installation and material to specification.
- **Soil media and structural soils or cells (if adopted):** material delivered to site meets specification, testing of in situ material. The contractor must supply lab-tested media certification and proof of purchase.
- **Tree installation:** stock is healthy and meets specification as captured under Design criteria. A sample installation may be requested prior to progression of the remaining trees.
- **Surface finishes and hard landscape features:** levels as per design and flush with adjacent areas. A sample installation may be requested prior to progression of the remaining pits.
- **Protective measures:** Ensure systems are protected during construction phase prior to landscape installation. Refer to EPA guidance on sediment control.
- **Landscape establishment:** to ensure trees are successfully established after the City of Whittlesea's regular defects liability period of two summers and three months, in accordance with the Neighbourhood Design Manual's Landscape Guidelines.

Council handover

The City of Whittlesea requires digital (not hand-sketched) as-constructed plans, and all photo and video documentation of the construction and establishment, to be submitted to the Construction Surveillance Officer at Practical Completion stage.

Prior to asset handover, the passively irrigated tree will need to be successfully established with new growth visible.

- A qualified Council arborist may be ordered to inspect and verify tree health.
- The water inflow measures are required to be free of blockages and clogged material (silts).
- Where adopted, the subsurface drain may be inspected with CCTV and tested for effective water capture and conveyance out of the tree pit.

4.3.7 Asset operation and maintenance

Vegetated systems, including tree pits, require ongoing monitoring and maintenance to ensure they are operating in accordance with the design intent.

The maintenance regime shall generally follow the City of Whittlesea's *A Guide to Growth Area Street Tree Planting*, with particular focus on the following aspects:

- Periodic removal of organic matter and litter at pit inlets.
- Weed removal in open tree pits.
- Seasonal pruning to the extent of standard City of Whittlesea street trees.
- Regular tree health check as per standard City of Whittlesea street trees.

Maintenance checklist forms are provided in **Appendix B** of *Designing for a cool city – Guidelines for passively irrigated landscapes* (CRC for Water Sensitive Cities, 2020).

4.4 Buffer strips

4.4.1 Function

Buffer strips are zones of vegetation designed to intercept and treat surface stormwater flows. Inflows should be evenly distributed as sheet flow over the buffer. Stormwater treatment occurs as shallow flows pass through the dense vegetation, which slows velocities and causes sediments to deposit. Buffer strips are frequently used as a pre-treatment for other stormwater measures, particularly vegetated swales where flows are distributed along the banks of the swale (Queensland Department of Agriculture, 2013).

Figure 26 Roadside turfed buffer strip at Edmond Crescent, Wandin North

4.4.2 Adoption and constraints

Preferred use	Non-preferred use
✓ Immediately downstream of source catchment areas (at-source)	✗ In locations with steep topography (>4% grade)
✓ Roads adjoining conservation reserves and landscaped areas	✗ Large catchments (>2ha)
	✗ Terrains with risk of downstream flow-channelisation
	✗ Along private property frontages and any proximity to buildings and structures

4.4.3 Design criteria

The following design and modelling guidelines and references for buffer strips should be used in the first instance (in hierarchical order):

- *WSUD Engineering Procedures: Stormwater* (Melbourne Water, 2005b), Chapter 8.
- Buffer strips fact sheet (Queensland Department of Agriculture, Fisheries and Forestry, 2013).

Key design considerations for buffer strips are as follows:

- Typically, buffer strips are applicable for smaller-scale contributing catchments up to 2ha. A mix of native vegetation species should be selected to prevent erosion and reduce risk of weeds.
- Slopes should ideally be 2% or less.
- Velocities must be demonstrated to be:
    - <0.1m/s for frequent flow events (4 exceedances per year (EY) flows).
    - <2m/s for major storm events (1% AEP flows).
- The width and slope of the buffers will influence treatment performance. Wider buffers provide more treatment surfaces while steep slopes increase flow velocities and decrease treatment potential.
- Even distribution of the flows through the buffer is required to ensure there is no channelisation.
- Parking should be discouraged on buffer strips through signage or bollards.
- Buffer strips should be set down by 40-50mm typically to avoid sediment accumulation at the pavement and buffer interface.

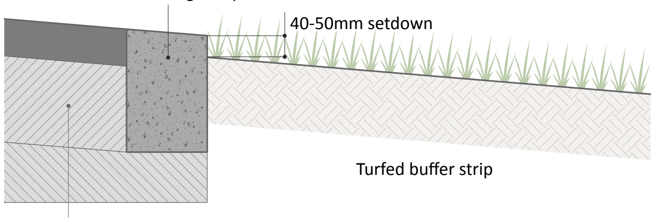


Figure 27 Recommended set-down for buffer strips

4.4.4 Modelling approach

Buffers are a primary treatment and the main focus is the removal of sediment (total suspended solids). It should generally be expected that other secondary treatments will be needed to meet nutrient objectives in most cases.

The buffer node in MUSIC does not represent evapotranspiration although it is recognised that some evapotranspiration from the soil will occur.

A simple way to approximate this is to increase the exfiltration rate (mm/hr) to include a conservative allowance for evapotranspiration. For example, evapotranspiration may typically vary between 2-6mm/day or approximately 0.1-0.25mm/hr. The exfiltration rate could be increased above the assumed level to incorporate this. It is important that any such assumption is clearly documented in the MUSIC treatment notes.

As an alternative modelling approach, a buffer area can be approximated using a shallow bioretention node with no underdrain or submerged zone and a low saturated hydraulic conductivity and PET factor. The filter media depth should represent the layer of topsoil with effective root depth.

In the STORM Calculator, there is no evapotranspiration accounted for the buffer strips and hence unsuitable to quantify volume reductions.

Design parameter	Value	Guidance
Sizing		
Buffer area	User defined	Based on length and width.
Inlet properties		
Inlet types	Buffer should accept distributed overland flows. No high-flow bypasses possible.	Buffers require distributed flows and therefore are not ideally suited to piped inflows unless flows can be spread using flow spreaders before they enter the buffer area.
Buffer properties		
Slope	Less than or equal to 2%	Reduces risk of erosion (lower velocities).
Exfiltration rate	0-100mm/hr	Given requirements for volume reduction by EPA to address the General Environmental Duty, infiltration from buffers may be represented for reducing stormwater flow volumes. Exfiltration rate assumptions should be supported by geotechnical testing results or at a minimum a conservative assumption based on soil type.

Further modelling guidance for buffer strips can be found on the eWater Wiki website.

Table 11 Modelling parameters for buffer strips

4.4.5 Submission requirements

Functional and detailed design package for the City of Whittlesea should include:

- Functional and detailed design drawings, including layout plans, system sections and typical details.
- Supporting calculations and MUSIC model.
- Supporting documentation such as geotechnical investigation results, percolation tests and others.
- Design and assessment checklist as per Chapter 8 of *WSUD Engineering Procedures: Stormwater* (Melbourne Water, 2005).

4.4.6 Construction and establishment

The following should be considered during the construction and establishment phase (Queensland Department of Agriculture, Fisheries and Forestry, 2013):

- Earthworks should be minimised to utilise existing terrain.
- Buffer strips need to be well planted. Suitable species are grasses, sedges and rushes.
- Dry seasons are better for planting to minimise sediment runoff during plant establishment.
- When the catchment hydrology is unchanged, buffer strips should remain with their existing native vegetation. This avoids the requirement for any clearance approvals of vegetation.
- Soil compaction to 95% is required immediately adjacent to roads to avoid kerb break-away or tilting.

Construction hold points

The City of Whittlesea requires the following critical construction hold points to be documented on plans, which allow the contractor to notify the City of Whittlesea's Surveillance Officer to inspect the milestones at a minimum of 48 hours' notice:

- **Slopes and levels** of the buffer strip should be checked for steepness, minimum stepdown and uniform flow distribution. Check for trap points and unintended flow concentrations.
- **Levelness** of flow spreaders, where utilised, for flow introduction to a buffer strip.
- **Landscaping sample:** planting densities and stock health demonstrated prior to full batter vegetation planting.

Council handover

Prior to handover, the City of Whittlesea should check that the buffer strip plants are properly established. Sediment accumulation should also be checked and cleared if required. All weeds should be removed.

4.4.7 Asset operation and maintenance considerations

The primary objective of maintaining buffer strips is to ensure consistent vegetation density and maximum heights of 300mm.

Sediment accumulation, weed ingress, erosion and vegetation loss should be monitored regularly for timely attendance.

4.5 Permeable pavements

4.5.1 Function

Permeable pavements, also referred to as pervious and porous pavements, are load-bearing structures that allow water to permeate. They find use in residential, industrial and commercial settings, including car parks, footpaths, low (and with suitable design, high) traffic streets, shopping areas, residential driveways and bike tracks (Mullaney & Lucke, 2014).

These systems allow water to pass through the permeable surface layer into a sub-surface base course, gradually infiltrating surrounding soils or being stored in reservoir zones. This process replenishes the natural water table and can supply water for other uses. By reducing stormwater flow, they alleviate pressure on drainage systems, mitigating flood risks and limiting waterway pollution. Permeable pavements can also mitigate urban heat island effects through evaporative cooling and support greenery with passive irrigation.

Figure 28 Block paver road in Charelle Court, St Helena

4.5.2 Adoption and constraints

Preferred use	Non-preferred use
✓ Recreation reserves	✗ Environments with coniferous trees
✓ Town centres and pedestrian precincts	✗ Environments with high expected sediment loads
✓ Private and public car parks	✗ In areas prone to frequent flooding
✓ Driveways	✗ Regular storage of dangerous goods (such as petrol and fertilisers)
✓ Parallel parking strips	✗ Locations with expected heavy loads and tight turning circles (such as cul-de-sacs)
✓ Can treat runoff from adjacent surfaces	

Permeable pavements may be adopted in unfavourable soil conditions under the provision of appropriate subsoil drainage (underdrains) or structural isolation from underlying soils via impermeable liners or capping layers.

4.5.3 Permeable pavement types

Porous asphalt

Porous asphalt (PA) is similar to typical hot mix asphalt, however, does not contain as much of the fine portion of the aggregate. This results in a coarser-textured, open-graded mixture which allows for water to pass through an interconnected void space (Bruinsma et al, 2017). In general, PA pavements include one or more layers of porous asphalt overlying a choke stone or treated base layer and aggregate base or subbase reservoir (Bruinsma et al, 2017). Typically, the void space in PA surfaces is between 18% and 25% (as opposed to 5% for conventional hot mix asphalt) (Bruinsma et al, 2017; Kolluru et al, 2014), and can generally replace traditional impervious pavement for applications, including footpaths, driveways, car parks and low-volume roadways (Kolluru et al, 2014).

Permeable or pervious concrete

Pervious concrete (PC) consists of a specially formulated mixture of cement binder (such as generic Portland cement), uniform, open-graded coarse aggregate, and water. Fine aggregates usually present in traditional concrete are omitted from PC production to increase its infiltration capacity (Mullaney & Lucke, 2014). The PC surface layer is typically placed over a choke stone or treated base layer and aggregate base or subbase reservoir (Bruinsma et al, 2017). A typical PC pavement comprises 15-25% void space (the interconnected pore space in the concrete which allows for passage of water) (Kolluru et al, 2014). Typical concrete generally comprises a total air void content of ~6.5%. Due to its high void content, pervious concrete is lightweight (1,600 to 1,900 kg/m^3) although has limited compressive strength (3.4-27MPa). Consequently, PC is generally only suitable for applications such as car parks, driveways, footpaths and other light traffic areas.

Figure 29 Open graded asphalt wearing course on School Road car park, Menzies Creek

Figure 31 Permeable concrete driveway in Ringwood

Figure 30 Permeable tyre-derived aggregate wearing course on Ramsden Street, Clifton Hill

Permeable interlocking concrete pavers

Permeable interlocking concrete pavements (PICP) consist of concrete blocks or pavers (typically impervious), which are specifically shaped to allow water infiltration through small openings between permeable joints. To ensure a level surface for the concrete blocks, a bedding layer of small-sized aggregates is generally present below the PICP surface and on top of the choke stone layer. During rainfall events, stormwater passes down through the joints into a crushed stone aggregate bedding layer and base or sub-base reservoir (Bruinsma et al, 2017). The permeable joint space between pavers (and sometimes openings within grids) can range from 4% to 36% of the total surface area and may be filled with the same 2-5mm aggregate employed for the paving bedding layer (Bruinsma et al, 2017; Hunt & Collins, 2008; Kolluru et al, 2014; Mullaney & Lucke, 2014), which promotes rapid absorption between the pavers.

Grass or gravel structural cells or reinforcing

Structural cells filled with grass or gravel constitute a further permeable pavement type. These consist of either a concrete grid or alternately lightweight, high-strength interlocking plastic cells designed for reinforcing grass or gravel in areas subjected to some loading stress, including vehicle parking areas, footpaths, driveways, golf courses and slopes. The pavers are locked together to evenly distribute load application on the surface and minimise compaction, formation of potholes and ponding.

These are often suitable for driveways and parking sites in the private realm. They generally are not intended to support frequent traffic loadings where the PCIP, PC and PA responses are more suitable. However, with appropriate base course design it is possible for them to be designed to withstand occasional heavy loads. A common application is for fire or maintenance access tracks in parks and reserves.

Figure 32 Permeable interlocking concrete pavers (modified tri-hex) adopted on Were Street, Montmorency

Figure 33 Concrete grid pavement with screenings infill on School Road car park, Menzies Creek

4.5.4 Design criteria

The following provides an overview of the common permeable paving structure. In general, permeable pavement systems comprise up to four layers with distinguishable functions.

Surface layer: the surface layer is a porous material that allows the infiltration of water into the subsurface layers. This can comprise of open graded asphalt, permeable concrete, interlocking block pavers, grid arrangements with voids, resin bound aggregates and aggregates recycled from crumb rubber.

- ✓ Installations must generally be to supplier's specifications.
- ✓ Must have an all-round defined edge constraint.
- ✗ Excess runoff must freely drain from the pavement surface upon saturation of the profile. The City of Whittlesea does not accept prolonged surface ponding to preserve the structural integrity of the pavement profile.
- ✓ Surface colour and texture selection must be in agreement with slip safety, amenity and urban heat reduction objectives.
- ✓ Turf specifications for vegetated concrete grids: any selected turf species must feature the following characteristics:
  - Must be robust and able to withstand regular traffic forces.
  - Must be resilient to dry spells without active irrigation.
  - Must have low to no ongoing fertiliser demand.
  - Cut height to be between 30-40mm.

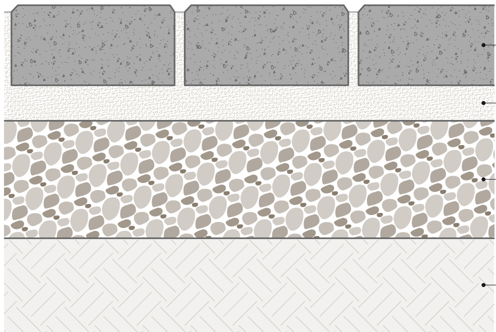


Figure 34 Typical permeable pavement makeup

For permeable interlocking concrete pavers (PICP) the following applies:

- ✓ Products must be compliant with AS/NZS 4455.2.
- ✓ The minimum paver thickness must be 80mm at 6kN break load for all vehicle trafficked surfaces.
- ✓ Pavers need to be concreted in areas with abrupt surface slope changes (such as for channel formation or wombat crossings).
- ✓ The designer may refer to the CMAA Concrete Segmental Pavements Detailing Guide.

Bedding layer: the permeable pavement is directly underlain by a very coarse sand or washed aggregate bedding layer to provide a stable and even base for the surface layer.

- ✓ A 2-5mm clean uniformly graded aggregate is recommended for permeable interlocking concrete pavers (CMAA, 2010) (Shackel, 2006).
- ✓ The bedding layer is to be a minimum of 40mm thick.
- ✗ Medium sands for bedding and joints are not preferred due to their vulnerability to clogging.

  Long-term in situ infiltration performance depends on the grain size of the aggregates used for joint filling.

Base course: most commonly an unbounded, permeable and load-bearing aggregate is used. Typical guidance is available with a single or uniform size aggregate being most commonly used.

- ✓ Storage zones (reservoirs) above the subgrade shall preferably be no-fines aggregate with a void ratio of 40%.
- ✓ Grading recommendations for unbound base course for permeable interlocking concrete pavers can be extracted from the *PA02 Concrete Segmental Pavements Design Guide for Residential Accessways, Roads and Commercial Spaces*.
- ✓ In the absence of full-depth concrete kerbs or impermeable liners, non-woven geotextiles are recommended around the edges to separate the base course from the adjacent soil subgrade if it is used as a reservoir.
- ✓ In application with passively irrigated trees, structural soils may be considered. Structural soils are load-bearing substrates made largely of crushed stone (basalt) and a small amount of filler soil mix (loam to clay loam with nutrient additives) at a ratio of typically 5:1 of volume (assuming void space of 40%). Under compaction, structural soils form a uniform, rigid, stone “lattice” with dispersed spaces (pores or voids) that allows for the controlled passage of oxygen, water and tree roots deep beneath concreted pavements and roads. These voids also provide room for an uncompacted soil mix rich in nutrients and trace elements for plant growth and water retention.
- ✓ Unbound aggregate base layers can benefit from placement of geocells to reinforce the layer against lateral displacement forces.

Subgrade: the subgrade is the natural soil underlying the base course (the native soil underlying the permeable pavement) and should be lightly compacted where possible, or in the context of roads, compacted as per standard road construction.

- ✓ Compaction standards shall comply with AS/NZS 1289.
- ✗ Subgrade profile shall not fall towards buildings and footings or other load-bearing structures.
- ✓ Consider steepening subgrade profiles to maximum 4% (in combination with subsoil drains) where infiltration to underlying soil should be minimised.
- ✓ Consider using a terraced subgrade design in sloped areas, especially when the subgrade slope exceeds 4%.
- ✓ Use of geotextiles or impermeable liners depends on the asset’s design intent to infiltrate flows into underlying soils. Permeable pavements can be designed to support full infiltration, partial infiltration, or no infiltration (Smith et al, 2015).

Infiltration of water into underlying soils is dependent on many factors and should be verified by a qualified geotechnical professional:

- ✗ In locations with known contaminated soils (former landfills and industrial land).
- ✓ In soils with hydraulic conductivity >0.36mm/hr with provision of subsoil drainage.
- ✗ In soils with low bearing capacities unless ✓ appropriate base course depths and subgrade compaction are designed.
- ✗ In highly expansive (swelling and shrinking) clay soils due to risks of ground movement unless ✓ contact with soil can be minimised through steepened cross fall and subsoil drainage.
- ✓ Where 2m clearance to the groundwater table can be maintained.
- ✓ When permeable pavements are situated above fill soils with adequate subsoil drainage.

4.5.5 Performance objectives

The design of permeable pavements needs to address structural and hydraulic performance objectives. These include the following detailed aspects:

Structural

- **Load bearing capacity:** to withstand expected surface traffic (frequency and weight of vehicles).
- The City of Whittlesea accepts the use of *DesignPave* software to demonstrate structural adequacy for PICP subject to traffic loads. Given the limited guidance available for other pavement types, the guidance available for PICP may be used as an indicative reference.
- Capacity to withstand lateral **stresses on the surface**. Through vehicle breaking, accelerating and turning forces surfaces can be deformed based on shear stress applied. It is the designer's responsibility to choose adequate material with resistance to shear stresses and choose logic paving patterns that avoid paver misalignments (such as avoiding continuous joints in direction of travel).
- **Internal filter stability:** similar to filter stabilities required in a bioretention system, the use of different size aggregates in various pavement layers may be required to demonstrate avoidance of particle displacement. The City of Whittlesea suggests using the following criteria:

Percolation Water filtration function	**Erosion** Ingress of smaller particles down into larger particle voids	**Contact erosion** Ingress of larger particles down into displaced smaller particles
$\frac{D_{15}}{d_{15}} \geq 1$	$\frac{D_{15}}{d_{85}} \leq 5$	$\frac{D_{50}}{d_{50}} \leq 25$

D_x = Xth %ile diameter of coarser aggregate, d_x = Xth %ile diameter of finer aggregate

Table 12 Criteria for unbound pavement particle filter stability

Hydraulic

- **Detention:** stormwater quantity management for flood event runoff volume and peak flow reduction for flood mitigation. The flood storage capacity of a permeable pavement can be calculated using the effective joint space and pore space within the underlying bedding and base course. *PermPave*, or hydraulic modelling software, may be used to demonstrate the detention functionality of permeable pavements. However, it is subject to the City of Whittlesea's engineering review and approval of any contributions to OSD as the success of this function is highly dependent on detailed design and regular maintenance of the asset.
- **Retention:** stormwater quantity management of mean annual runoff volume reductions through infiltration and evaporative, even stormwater harvesting mechanisms. eWater's MUSIC tool can demonstrate flow reductions as described in the Modelling approach section below.
- **Water quality:** capacity to reduce stormwater pollutants through screening and denitrification processes within the pavement profile. eWater's MUSIC tool can demonstrate pollutant reductions as described in the Modelling approach section below.

Further reading is recommended on the Water Sensitive South Australia website for a collection of resources, guidance and case studies on permeable pavements.

4.5.6 Modelling approach

The maximum catchment area ratio for a permeable pavement should preferably be no more than three times the actual permeable pavement area. The contributing area may be increased depending on the expected sediment loads in the additional runoff (such as roof runoff), to an absolute limit of five times.

There are two approaches for representing permeable pavers in stormwater models such as MUSIC, recognising that MUSIC does not have a dedicated permeable pavement node, and both of these may be used in parallel to report on appropriate corresponding objectives:

- **Approach 1:** A bioretention node may be used to represent the permeable paving with differing properties depending on the type of pavement used. This approach is most suitable for assessing stormwater volume reductions (since it includes moisture storage and evaporation) and is preferred by the City of Whittlesea for this purpose.
- **Approach 2:** A media filtration node may be used to represent the permeable paving. This approach is most suitable for demonstrating stormwater pollutant load reductions.

Catchment nodes should be modelled as per Melbourne Water's *MUSIC Guidelines* as revised.

For the purposes of modelling stormwater quality in MUSIC or similar, the infiltrated pollutants should be routed back to the model outlet node and accounted for in the outflow pollutants.

Design parameter	Dense pavers	Grids with gravel	Permeable pavers	Permeable asphalt or concrete	Grids with turf	Guidance
Sizing						
Surface area as percentage of total catchment area (%)	33-100% of catchment recommended 20-100% of catchment required					Recommended for sustainable sediment loading rates. Catchment area includes permeable paving area and upstream areas.
Filter area	~4-7%[1]) surface area	~36%[2]) surface area	~25%[2]) surface area	~20%[2]) surface area	~36%[2]) surface area	1) Collective joint area adopted, or 2) Voids area (ratio) adopted as per product
Storage properties						
Extended detention depth (m)	0.01-0.05 or EDD = porosity x paver height		0.01-0.05		0.01-0.05	Usually, zero in practice assuming water overflows freely from the permeable pavement. Set at 0.01 in model or, if needed, slightly higher for numerical stability. For pavers with joints filled with gravel or aggregate: Porosity x paver height (for example, 40% x paver height).
Filter depth (m)	Bedding + base course – depth below underdrain		Paver + bedding + base course – depth below underdrain	Pavement surface + bedding + base course – depth below underdrain	Grid + bedding + base course – depth below underdrain	Include depth of permeable paver and base course layers. Can vary widely depending on design. Should be designed considering bearing strength of underlying soil as well as stormwater objectives. *Exclude depth below underdrain.*
Submerged zone depth (m)	0-0.5					Depth below underdrain: *Exclude depth above underdrain.*
Unlined filter media perimeter	User input					Calculate based on perimeter of paving. Note that exfiltration is assumed to occur through sides based on flow = exfiltration rate x perimeter x filter

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Design parameter	Dense pavers	Grids with gravel	Permeable pavers	Permeable asphalt or concrete	Grids with turf	Guidance
Saturated hydraulic conductivity (mm/hr)	100					Conservative value to allow for some clogging. Recognises infiltration rates decline exponentially and long-term infiltration likely to be far below manufacturer specification for most of effective life. Cleaning recommended if measured infiltration <100 mm/hr.
Filter media TN content (mg/kg)	250[1]				300[2]	Typical average values for 1. Washed sand bedding and crushed rock 2. Topsoil, washed sand and crushed rock
Orthophosphate content (mg/kg)	20[1]				30[2]	Typical average values for 1. Washed sand bedding and crushed rock 2. Topsoil, washed sand and crushed rock
Exfiltration rate (mm/hr)	0 to 100					The exfiltration rate applies to the underlying soil (not the filter media) and must be set using the guidance provided in the Melbourne Water's *MUSIC Guidelines*. Conservative indicative rates for modelling by soil type (sensitivity at measured rate if higher): ◦ Medium clay: 0.36 mm/hr ◦ Sandy clay: 3.6 mm/hr ◦ Sandy loam: 36 mm/hr ◦ Sands: 100 mm/hr
Base lined	Yes/No					Depending on soil suitability for infiltration or other infiltration constraints.
Vegetation properties	Unvegetated				Ineffective vegetation	
Underdrain	Yes					Include relief underdrainage unless not required due to high infiltration rates (such as sandy soils).

Table 13 Modelling guidance – Approach 1 Bioretention node

Design parameter	Dense pavers	Grids with gravel	Permeable pavers	Permeable asphalt or concrete	Grids with turf	Guidance
Sizing						
High-flow bypass	Saturated hydraulic conductivity x collective joint or void area					Converted from mm/hr to cbm/sec. Application of a realistic high-flow bypass according to the intake capacity of the pavement's porous surface allows representative simulation of runoff from the pavement surface. This sensitivity cannot be modelled in the Bioretention node.
Surface area as a percentage of total catchment area (%)	33-100% of catchment recommended 20-100% of catchment required					Recommended for sustainable sediment loading rates. Catchment area includes permeable paving area and upstream areas.
Filter area	~4-7%[1]) surface area	~36%[2]) surface area	~100%[3]) surface area	~100%[3]) surface area	~36%[2]) surface area	1) Collective joint area adopted, or 2) Voids area (ratio) adopted as per product, or 3) Porosity adopted in voids ratio
Storage properties						
Extended detention depth (m)	0.01-0.05 or EDD = porosity x paver height		0.01-0.05		0.01-0.05	Usually, zero in practice assuming water overflows freely from the permeable pavement. Set at 0.01 in model or slightly higher if needed for numerical stability. For pavers with joints filled with gravel or aggregate: EDD = porosity x paver height (for example, 40% x paver height).
Filter depth (m)	Bedding + base course		Paver + bedding + base course	Pavement surface + bedding + base course	Grid + bedding + base course	Represents the depth of the treatment zone. Include depth of permeable paver, bedding and base course layers as appropriate. Should be designed considering bearing strength of underlying soil as well as stormwater objectives. *Total depth above and below underdrain.*

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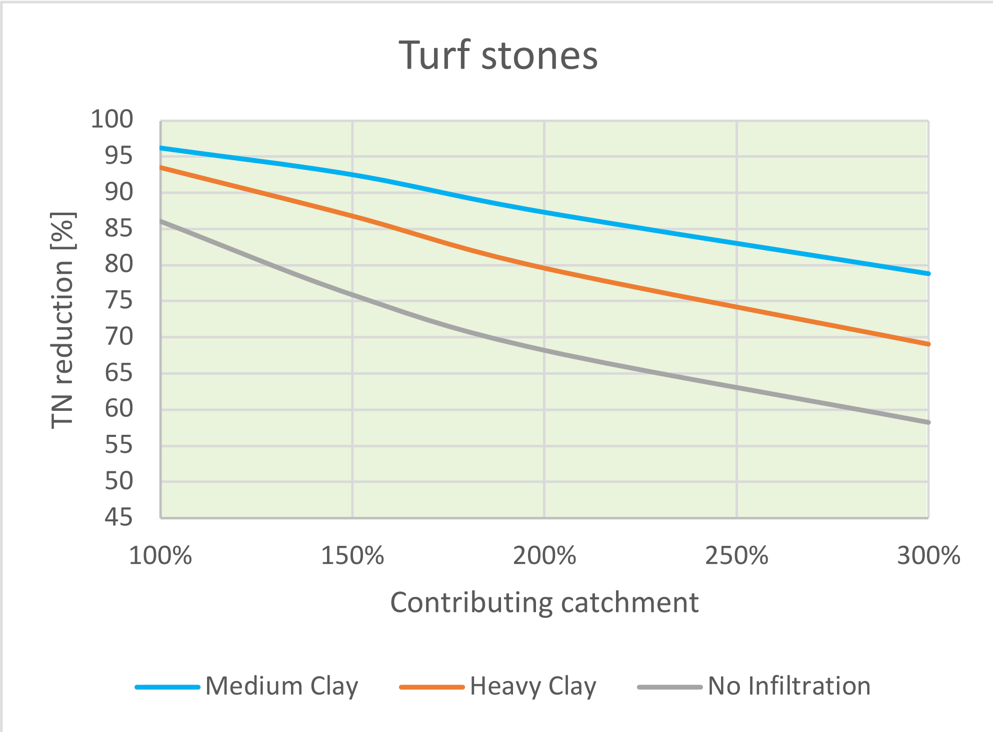
Design parameter	Dense pavers	Grids with gravel	Permeable pavers	Permeable asphalt or concrete	Grids with turf	Guidance
Depth below underdrain (%)	0-60% Typically 0-0.5 m					Depth below underdrain (entered as a % of the total filter depth in MUSIC). Set to zero per cent if no submerged zone below underdrainage. Set to an appropriate percentage where underdrainage is provided to encourage additional infiltration.
Saturated hydraulic conductivity (mm/hr)	100					Recommended to realistically represent long-term conditions allowing for clogging of the pavement surface over time with periodic maintenance. Recognises infiltration rates decline exponentially and long-term infiltration likely to be far below manufacturer specification for most of effective life. Cleaning recommended if measured infiltration <100 mm/hr.
Exfiltration rate (mm/hr)	0 to 100					The exfiltration rate applies to the underlying soil (not the filter media) and must be set using the guidance provided in the Melbourne Water's *MUSIC Guidelines.*
Filter median particle diameter (mm)	Recommended: 1 to 5					Set to median particle size, such as 2mm (a range of 1-5mm, depending on design, is acceptable).
Overflow weir width (m)	2-100 m					Indicatively set to width of overland flow path downslope of permeable paving. If unknown, set large (such as 100m to ensure significant ponding above permeable paving is simulated).
Voids ratio	0.4 recommended 0.15-0.45 typical					Adjust to <u>average</u> void ratio available for water storage of permeable paving surface, bedding and base course.

Table 14 Modelling guidance – Approach 2 Media filtration node



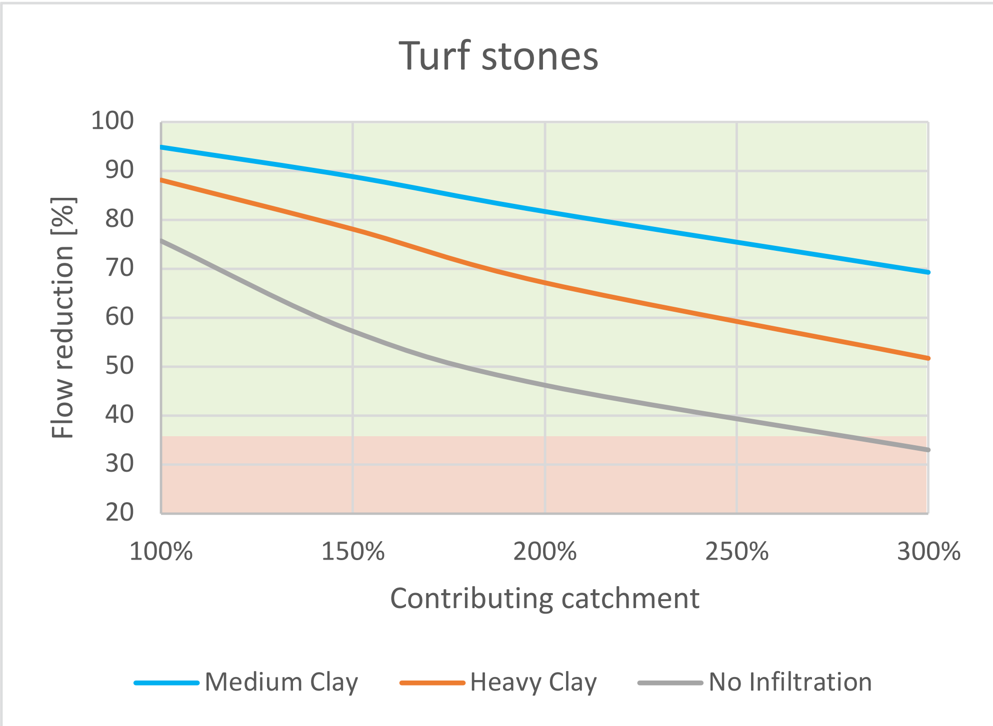
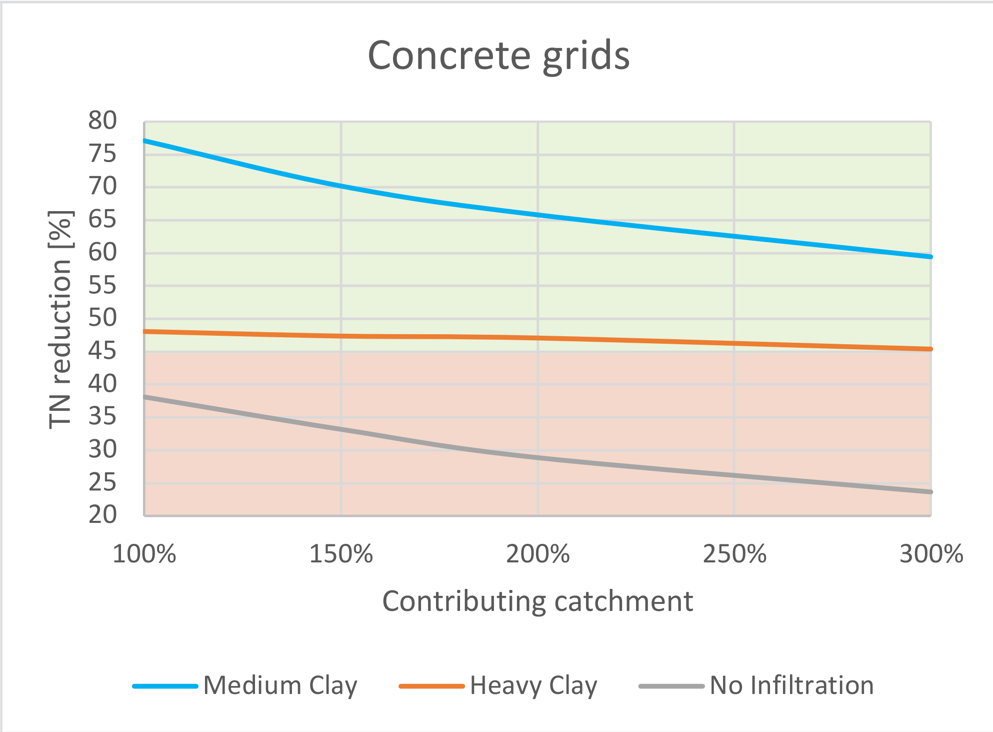


Figure 35 TN and flow reductions achievable by **turf stones** based on catchment size and soil type (for typical 300mm combined bedding + base course layer, at 3% CBR subgrade)



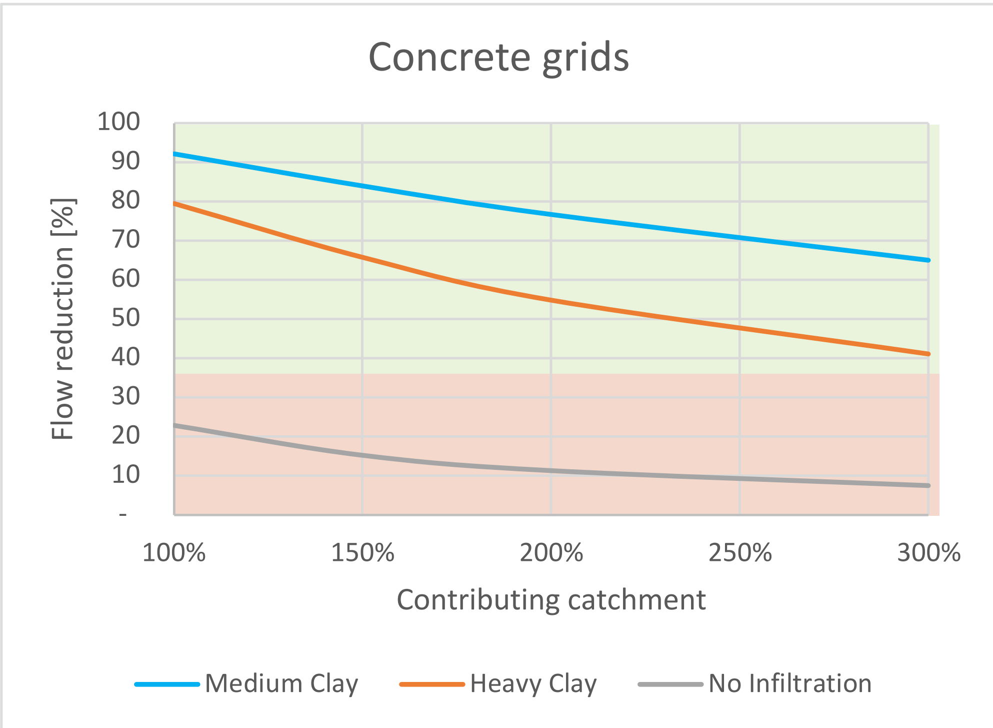
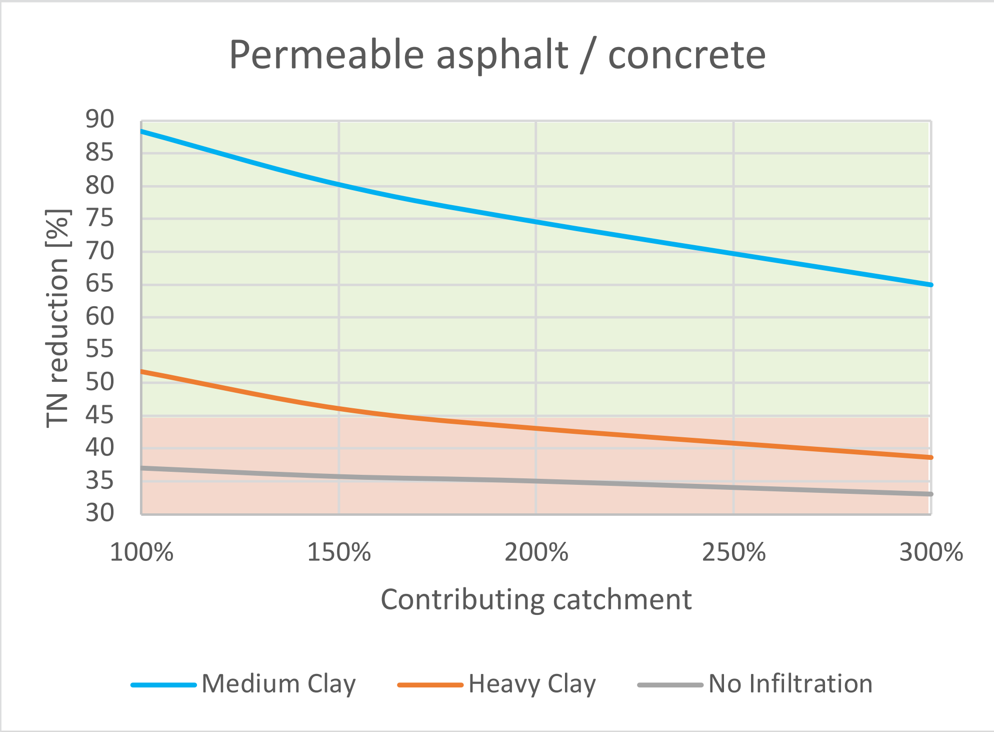


Figure 36 TN and flow reductions achievable by **concrete grids** based on catchment size and soil type (for typical 300mm combined bedding + base course layer, at 3% CBR subgrade)



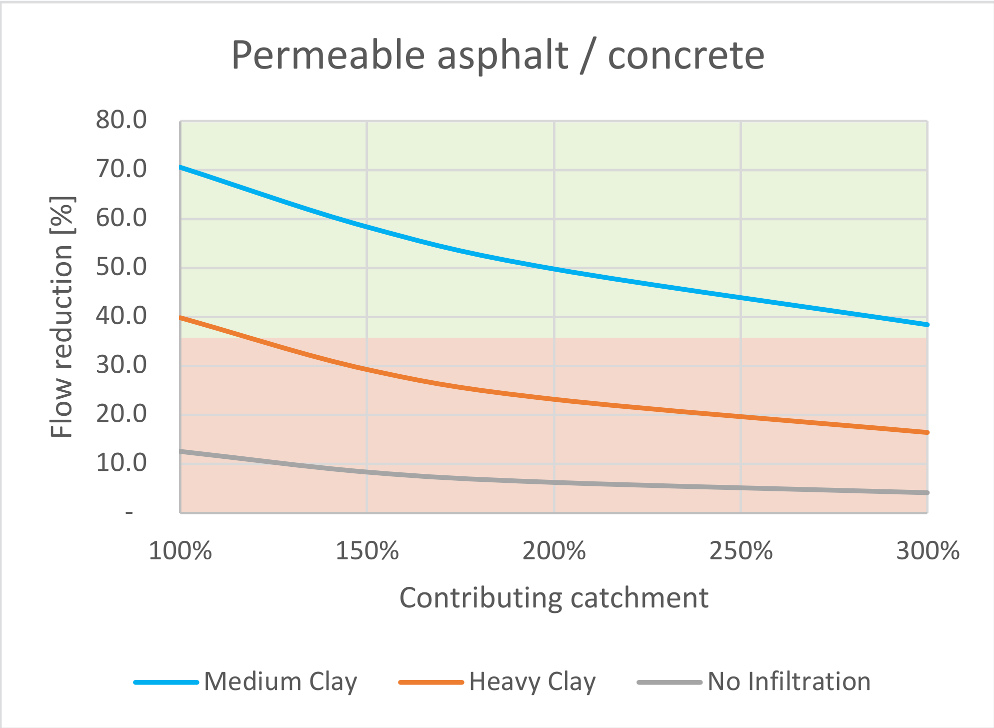
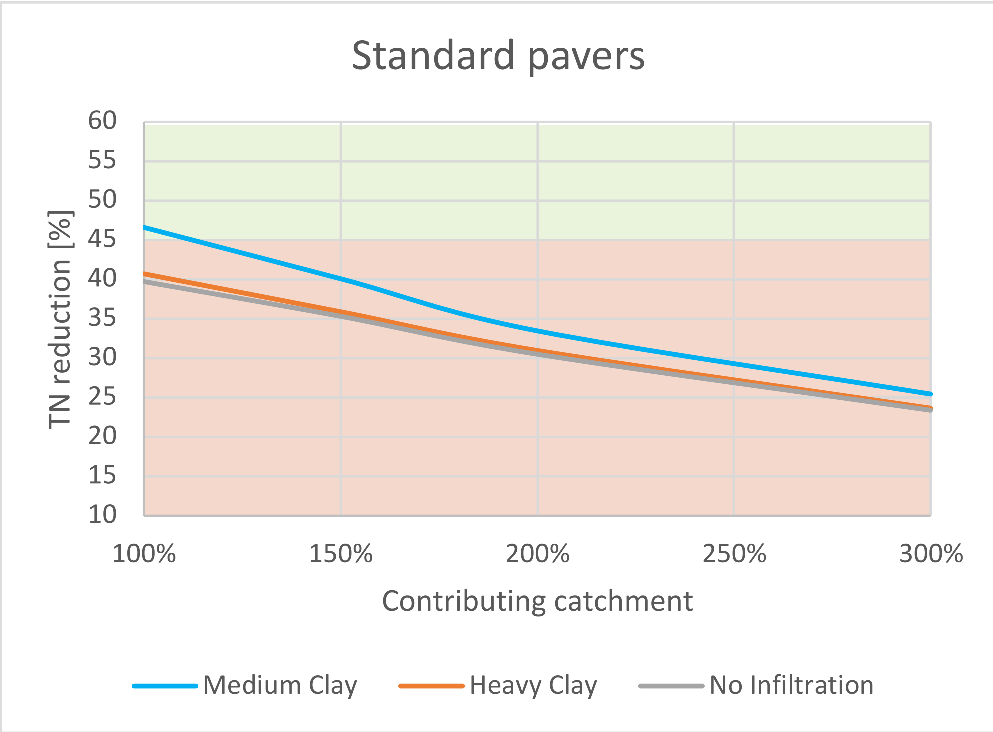


Figure 37 TN and flow reductions achievable by **permeable asphalt/concrete** based on catchment size and soil type (for typical 300mm combined bedding + base course layer, at 3% CBR subgrade)



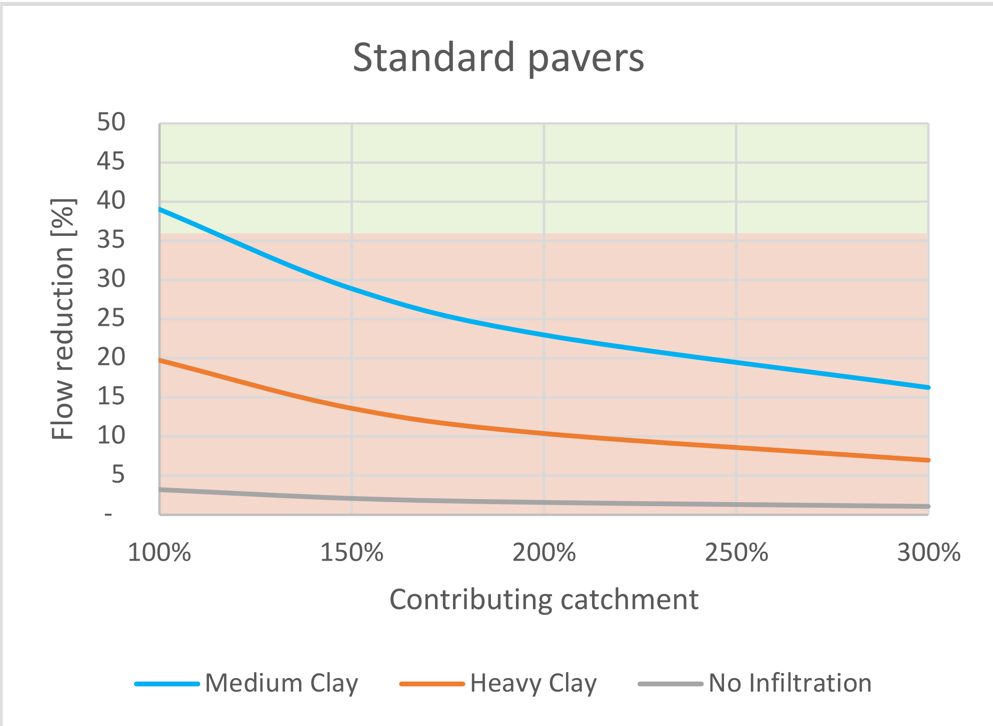
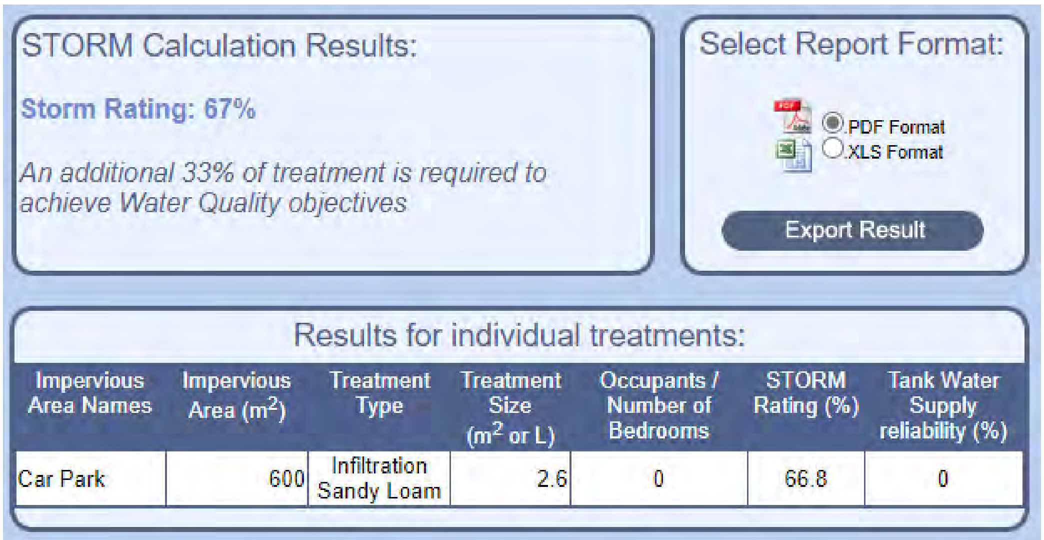


Figure 38 TN and flow reductions achievable by **interlocking block pavers** based on catchment size and soil type (for typical 300mm combined bedding + base course layer, at 3% CBR subgrade)

Example

On a commercial site with a 600m² car park and 24 parking bays, a standard paver finish is selected. Only the parking bays receive the pavers while the remaining asphalt surface drains towards the parking bays. The base of the pavement can drain to a subsoil drainage pipe preventing water to infiltrate the soil. The parking bays equate to an area of 311m² which is about 50% of total car park which in turn indicates the parking bays will receive 200% catchment contribution. The TN removal is 30% which equates to a STORM score of 67%. In the STORM Calculator the entire car park area is entered with a calibrated infiltration sand (loam) to achieve the 67% score.



Impervious Area Names	Impervious Area (m²)	Treatment Type	Treatment Size (m² or L)	Occupants / Number of Bedrooms	STORM Rating (%)	Tank Water Supply reliability (%)
Car Park	600	Infiltration Sandy Loam	2.6	0	66.8	0

Figure 39 STORM Calculator results

4.5.7 Submission requirements

The functional design package for the City of Whittlesea's assessment of permeable pavements must include the following documentation:

- Functional design drawings, including layout plans, typical sections and details:
    - Layout showing sufficient detail of pavement extents.
    - A detail on paving pattern and usual direction of traffic (applicable for pavers).
    - Pavement profile showing bedding, base and sub-base layers.
    - Typical subsurface drainage provisions, if applicable.
- *DesignPave* report showing structural loading assumptions and pavement make-up results.
- MUSIC modelling results, including SQZ file.
- Geotechnical report for the site's general subgrade suitability, with a minimum of the following reportable items:
    - Soil classification.
    - Resilient Modulus and California Bearing Ratio (CBR).
    - If soil infiltration is proposed, test results for soil hydraulic conductivity, sodicity and dispersivity must also be provided.
    - Groundwater levels.
- Demonstration of pavement detention, retention and water quality performances, where claimed.

The detailed design package for the City of Whittlesea's assessment of permeable pavements must include the following documentation:

- Detailed design drawings, including layout plans, system sections and relevant construction details:
    - Layout showing sufficient detail of pavement extents and edge definition.
    - A detail on paving pattern and usual direction of traffic (applicable for pavers).
    - Construction details, including edge definition, pavement profile and subsurface drainage provisions, where applicable.
- Material specifications for pavers or other wearing course, bedding, base and subbase layers; including minimum performance requirements.
- Demonstration of pavement layers filter stability, if applicable.
- Where applicable, resubmission of computations, modelling files and geotechnical reports to justify deviations from functional design submissions.

4.5.8 Construction and establishment

Construction must be in accordance with the design plans. Any proposed significant changes in products or materials must preserve the intended design performance, reliability and durability and be submitted to the City of Whittlesea's Surveillance Officer for approval prior to use.

During the construction and establishment phase, attention should be given to preserving the infiltration capacity of the asset by avoiding any unnecessary compaction or sediment intrusion to the underlying soils or the asset components and materials.

Private driveways are preferably installed when all building works have been completed on the site.

Site and ground preparations, as well as pavement installations, shall follow the guidance as contained in *PE01 Permeable Interlocking Concrete Pavements – Design and Construction Guide (2010)* published by the Concrete Masonry Association of Australia, to the extent they are applicable.

Construction hold points

Contractors must notify the City of Whittlesea's Construction Surveillance Unit 48 hours ahead of the following construction milestones, for witness points and documentation:

- Subgrade preparations to design specifications
- Finished edge restraints prior to base or subbase layer construction.
- Subsurface drainage installation and connections (if applicable) prior to base layer construction. Underdrains shall have appropriately-sized aggregate cover so as to protect the drain from upper layer compaction.
- Base course material sample test results evidencing compliance with design specifications prior to base layer construction.
- Levelness of base course layer prior to bedding application.
- Proof of supplied pavement product (surface layer) complying with design specifications.
- Uniform bedding thickness and pavement installation sample prior to finalisation.
- Paver compaction achieved uniformly (no linear compaction from one end of the surface to another).

Council handover

The City of Whittlesea requires digital (not hand-sketched) as-constructed plans, and all photo and video documentation of the construction and establishment, to be submitted to the Construction Surveillance Officer at Practical Completion stage.

Prior to asset handover, the permeable pavement will need to be completed, no ongoing discharges of sediment from the upstream catchment such as from building works are occurring (or the asset is appropriately protected) and the asset is infiltrating and draining as designed (rapid infiltration with no visible ponding on surface following testing or application of water).

At handover stage, the City of Whittlesea will be inspecting the finished permeable pavement installation to ensure:

- Finished surface levels match design intent (considering subsidence through vibration or compaction) and are level and even.
- No undesirable colour deviations exist.
- No visible damage or failure is present.
- No sediment accumulation or clogging is evident (in-situ infiltration testing may be requested).
- For pavers, all joint spaces are adequately refilled with the specified joint material after initial settling. Joint material subsidence is expected within the first six months and will require top-up.
- No individual pavers have cracked, dislodged or individually subsided.

Attention should also be given to the successful establishment of vegetation where it is intended that the permeable pavement is an instrument of passive irrigation.

Sediment or biological clogging can result in premature failure of the asset. Where ongoing development, construction or building activities are occurring within the catchment, the pavement must be protected with appropriate silt barriers to filter or divert runoff around the newly constructed asset.

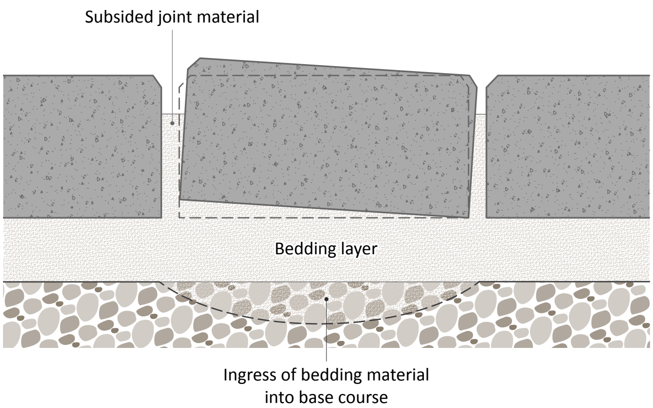


Figure 40 Importance of joint fill levels in interlocking block pavers

4.5.9 Asset operation and maintenance

Given their susceptibility to clogging, it is important that permeable pavements are cleaned frequently to ensure optimum performance.

Permeable pavements should be cleaned with a vacuum sweeper twice per year.

For pavers with granular joint space the first year of asset operation will mainly consist of monitoring and manual maintenance (if required) until materials have fully interlocked and subsided through regular use and loading.

Beginning from Year 2 of asset life, machine cleaning with vacuum sweepers shall be trialled to inform best ongoing maintenance regime. Vacuuming power and brushing angle should initially be trialled at test locations for calibration to avoid loss of joint material. This should be tested on different pavement products and noted for future attendance.

Surface pressure washing should use pressures sufficient to dislodge clogging materials, but avoid surface abrasion to maintain the anti-slip texture.

Cleaning pavements shortly following the main autumn leaf litter drop is recommended to minimise organic clogging. Indicative suggested cleaning frequencies and considerations for treatment to catchment area ratio (TCAR) and litter and sediment load risks factors are outlined in the table below. It is noted that these are based on limited testing to date and should be adapted to suit local conditions and observations.

Maintenance level	Treatment to catchment area ratio	Litter and sediment load risk factors	Suggested cleaning frequency
Low	Ratio ≤2:1	No deciduous trees within catchment. No overhanging trees. Most surfaces are vegetated or impermeable. Low to moderate traffic loads.	5 years
Medium	Ratio >2:1	Some trees within catchment or perennial trees overhanging permeable pavement. Minimal or no garden beds or paths with granitic sand or bare soil areas. Low to moderate traffic loads.	2-3 years
High	Ratio >5:1	Deciduous trees overhanging permeable pavement. Garden beds or paths with granitic sand or bare soil areas. High traffic loads.	1 year

Table 15 Indicative maintenance frequencies for pressure washing or suction

Every four years as part of an asset class audit, the pavement may be tested for its percolation performance using suitable infiltration rings and bentonite.
The pavement fulfils its permeability function with results above the 100mm/hr infiltration rate.

The long-term inspection and maintenance requirements of paver assets shall follow the CMAA's *PA04 Concrete Segmental Pavements – Maintenance Guide (2014)*.

4.6 Sediment ponds

4.6.1 Function

Sediment ponds are open water bodies designed to capture coarse to medium sediments from stormwater runoff. Treatment is provided primarily through the settling of suspended particles through reductions of flow velocities over temporary detention. They are considered a primary treatment asset and are critical in protecting downstream assets or water sources.

Figure 41 Sediment pond at Worchester Park, Bundoora

4.6.2 Adoption and constraints

Constraints and risks	Suggested cleaning frequency
Contaminant capture	Sediment ponds that are oversized for their catchment will capture fine metals and other contaminants, increasing the cost of silt disposal.
Difficult subsurface conditions	Ground conditions such as high groundwater tables, sandy soils and shallow bedrock can make sediment ponds difficult to construct and should be investigated as part of the asset design.

Sediment ponds are required upstream of constructed wetlands and substantial end-of-line biofiltration basins.

4.6.3 Design criteria

All sediment pond assets should generally be designed in accordance with Melbourne Water's *Wetland Design Manual* (Melbourne Water, 2020). The following design guidelines and references for sediment ponds should be utilised (in hierarchical order):

- *Wetland Design Manual* (Melbourne Water, 2020).
- *Wetland Design Manual Part A2: Deemed to Comply Design Criteria* (Melbourne Water, 2020).
- *Sediment pond design assessment checklist* (Melbourne Water, 2017).
- *WSUD Engineering Procedures: Stormwater* (Melbourne Water, 2005), Chapter 4.
- *Wetland Technical Design Guidelines* (Water by Design, 2017), Section 3.4.

It is recognised that some aspects of the *Wetland Design Manual* are specific to Melbourne Water assets and that the City of Whittlesea's requirements for sediment pond designs and documentation may vary from site to site to optimise the asset function, efficiencies in operations, as well as improved site logistics for maintenance.

The City of Whittlesea has additional design preferences to Melbourne Water's Deemed to Comply Design Criteria (as outlined in Part A2). These include:

- Vehicle swept paths demonstrated on designed access tracks and ramps. These must consider a 9.5m service vehicle length, fronting into and reversing out of the tracks and hardstands.
- New tree planting around access tracks, or access track constructions around existing trees must consider critical offsets to avoid branch overhang.
- Intersections between pedestrian pathways and site maintenance access tracks should be clearly marked (such as using markers or different coloured concrete on the pedestrian paths).
- At the road edge, have an industrial crossover to City of Whittlesea standards and rolled kerb adjoining it.
- Where access tracks traverse through substantial landscaping areas, the use of turf stones, grid pavers and other grass-reinforcing products may be considered (ensuring load capacities and maintainability) which are less aesthetically impacting the site.
- Design must allow for hydraulic isolation of the pond from upstream and downstream waters for maintenance purposes (with appropriate bypasses and avoidance of hydraulic linkages to wetlands, for example).
- Concrete base only (no interlocked rock) to be used for the pond base.
- The requirement of a HEC-RAS model for major and minor storm through-flows if a high-flow bypass is not provided.
- Sediment ponds must have a maintenance access ramp to pond base and avoid relying on 'edge cleaning' with an excavator
- Access ramps must be 4m wide, at a maximum slope of 1 in 5, extend above the EDD level by 0.5m and support a 22-tonne excavator. Consider removable barriers to prevent unauthorised vehicle access where warranted.
- Edge-cleanable (smaller) sediment ponds to have a maximum 7 metres reach from hardstands to any area of the pond. This must be demonstrated on plans.

- The sediment pond transfer pit must include a provision for the installation of a turbidity sensor (such as through conduits, brackets or shrouds secured to the internal pit walls).
- The outlet control pit may feature a suitable gate valve with extended spindle mechanism to allow for water level draw-down to 500mm depth below normal water level, for periodic inspection of silt levels.
- The narrowest width of the pond should be interpreted as the narrowest width for the sediment settling zone where water levels are deep enough to allow sediment settling. This means that exceedances of the criteria may be tolerated near the inlets and outlets (outside this zone) where the sediment pond is usually narrower.
- The sediment dewatering area should be located to drain back into the pond, be above the 20% AEP flood elevation, and be at least 15 metres away from residential property.
- The sediment dewatering area should be suitably sized to allow for silt placement up to 500mm depth.
- A drowning hazard signage should be provided at the location of access ramp gates. Where pedestrian access is a risk, consider installation of suitable removable barriers.
- All waterbodies require a gross pollutant trap installed upstream.

Figure 42 Access, ramping and sediment dewatering provisions at sediment ponds

4.6.4 Modelling approach

Sediment ponds must be sized and modelled using both MUSIC software and the Fair and Geyer equation.

Users are referred to the latest Melbourne Water MUSIC Guidelines as the primary source of guidance for modelling sediment ponds, either as isolated assets or as part of a treatment train.

- *MUSIC Guidelines*
- MUSIC Users Guide (eWater, 2022)

Fair and Geyer equation: target 95% removal of coarse sediment for the 4 EY storm event. Refer to Part C (Chapter 3.4) of the *Wetland Design Manual* for a worked example.

MUSIC modelling: target 80% removal of total suspended solids.

4.6.5 Submission requirements

The functional design package for the City of Whittlesea's assessment must include the following documentation:

- Functional design drawings, including layout plans, sections and typical details.
- Supporting calculations, hydrological models (such as RORB), MUSIC models and spreadsheets.
- MUSIC Auditor report.
- Supporting background documents such as a geotechnical report, masterplan and others.
- Completed all **concept** and **functional** design criteria in the Deemed to Comply checklist.

The detailed design package for the City of Whittlesea's assessment must include the following documentation:

- Detailed design drawings, including layout plans, sections and specific details.
- Landscape detailed design drawings.
- Maintenance agreement plan.
- Documentation from third-party authorities for any works impacting existing utilities.
- Completed detailed design checklist.
- HEC-RAS model where applicable to demonstrate velocities.
- Completed all **detailed** design criteria in the Deemed to Comply checklist.
- MUSIC model for asset performance verification.
- Asset polygons and catchment polygons in shape file format.
- Documentation of cleanout methodology to be provided (including dewatering methodology).
- Cleanout interval calculations demonstrated.

4.6.6 Construction and establishment

During the construction and establishment phase attention will be given to the elements of the sediment pond that impact water level control and elements which are at risk of leaking. These elements include the construction of the clay liner, pipe trenches, and the overflow pit or outlet weir finished levels.

Soils should be in accordance with Melbourne Water's *Specifications for soils and landscaping of constructed Melbourne Water assets*.

Construction hold points

The City of Whittlesea requires the following critical construction hold points to be documented on plans which allow the contractor to notify the City of Whittlesea's Surveillance Officer to inspect the milestones at a minimum of 48 hours' notice:

- **Subgrade levels:** level survey to confirm minimum depth excavations achieved.
- **Top of the clay liner:** level survey to confirm minimum thickness of clay liner achieved.
- **Finished hard base:** level survey to confirm base achieved to design specifications.
- **Access ramp:** level survey to verify design grades achieved.
- **Trench cut-off walls:** concrete cut-off walls within trench with sodium bentonite constructed.
- **Overflow pit or outlet weir finished level:** the finished level of the outlet will control the normal water level of the sediment pond.
- **Inlet scour protection:** inspect rock beaching installation, verify size range and interlocking properties.
- **Landscaping sample:** planting densities and stock health demonstrated prior to full batter vegetation planting.

Council handover

The City of Whittlesea requires digital (not hand-sketched) as-constructed plans, and all photo and video documentation of the construction, to be submitted to the Construction Surveillance Officer at Practical Completion stage.

Prior to asset handover, the sediment pond is required to be dewatered, all sediment to be removed and disposed of, and plants and surrounding landscaped areas to be re-established following the first desilt.

4.6.7 Asset operation and maintenance considerations

A major cleanout of sediment ponds is expected every five years. The following aspects should be considered for this routine performance reset:

- Desilting may be required prior to the scheduled year if silt levels reach into the 500mm clearance zone below normal water level.
- The site is investigated for Growling Grass Frog (GGF) presence prior to desilting routines. Each site is unique and requires an individualised operating procedure. GGF presence is best monitored during warmer summer months with assistance from a qualified ecologist. Where sites identify as GGF habitats, cleanout procedures are restricted to the months of April and May prior to hibernation and when specimens have reached maturity.
- Ideally, sediment pond sites should be investigated for fauna prior to desilting activities. A qualified ecologist should be engaged for the on-site salvaging and rehoming of wildlife, including relevant Authority to Control Wildlife and Fishery permits with state government departments.
- The dewatering area should be suitable for regular silt turnover by a swamp dozer or backhoe.
- Address public safety and potential impacts on public access to open space areas while cleanouts are performed. Consider installing educational signage on temporary fencing.
- Disturbed landscaping areas around the asset to be reinstated upon completion of the desilt.
- Melbourne Water's *guidance on resetting sediment ponds* shall be considered.

4.7 Constructed wetlands

4.7.1 Function

Constructed wetlands for stormwater treatment are designed to accept and treat stormwater runoff, typically from urbanised catchments. They consist of open water pools, typically located at the inlet and outlet, with a densely vegetated macrophyte zone in between. Wetlands use sedimentation, fine filtration, adhesion and biological uptake of nutrients to remove pollutants from stormwater. Water levels in the wetland fluctuate between a normal water level and extended detention depth during a precipitation and inflow event. Well-designed wetlands also provide significant biodiversity and community benefits, contributing to urban cooling and amenity.

Figure 43 Wetland at Sarissa Park, Lalor

4.7.2 Adoption and constraints

Preferred use	Non-preferred use
✓ Moderately flat sites	✗ Limited space available (wetlands typically need at least 500m^2)
✓ Public spaces that allow for passive recreation	✗ Small area available for treatment compared to catchment area <~2% which can result in sustained elevated water levels
✓ Close to natural areas to improve biodiversity values	✗ On-line wetlands which can be at risk of scour and elevated water levels
✓ Suitable ratio of treatment and catchment size to provide optimal water level conditions (ideally ~2.5-3.5%)	✗ Steep sites which make it difficult to incorporate larger wetland systems due to requirements for tall embankments
	✗ High water tables, sandy soils or shallow bedrock which can make construction difficult

4.7.3 Design criteria

There are many available design guidelines which can be used to inform the design of wetlands in the City of Whittlesea, including:

- *Wetland Design Manual* (Melbourne Water, 2020) – primary reference for design
  - *Wetland Design Manual Part A2: Deemed to Comply Design Criteria* (Melbourne Water, 2020) – refer to Design Checklist.
- *MUSIC Guidelines* – modelling guidance.
- *WSUD Audit Guidelines* (Browne et al, 2017) – refer to for asset inspections.
- Constructed wetland design checklists (Melbourne Water, 2017) – refer to Construction and Handover Checklists (Design Checklist superseded by *Wetland Design Manual*; Inspection and Maintenance Checklist superseded by *WSUD Audit Guidelines*).
- *WSUD Engineering Procedures: Stormwater* (Melbourne Water, 2005), Chapter 9 – useful for detailed engineering calculations.
- *Wetland Technical Design Guidelines* (Water by Design, 2017), Section 3.9 – additional information.
- *Guidelines for the construction and establishment of bioretention systems and wetlands* (Water by Design, 2022) – construction and handover checklists.

All wetland assets should generally be designed in accordance with Melbourne Water's *Wetland Design Manual* (Melbourne Water, 2020). These set out best practice principles and design guidelines for wetlands. It is recognised that some aspects of the *Wetland Design Manual* may be specific to Melbourne Water. On a case-by-case scenario, the City of Whittlesea's requirements for wetlands may vary from Melbourne Water's standard, subject to the developer demonstrating that the wetland will function effectively and be efficiently maintainable.

Wetland sizing

- As a rule of thumb, the water surface area of a wetland is typically 2.5-3. 5% of its impervious catchment.

Water levels

- Vegetation can be compromised if the wetland sustains high water levels for extended periods of time. Appropriate catchment ratio should be considered (see above) and an inundation frequency analysis should be completed to fully understand likely water level conditions and inform appropriate plant selections.

Velocities

- Calculations of velocities are required to demonstrate that the objectives are met using the manual checks or HEC-RAS as described in the *Wetland Design Manual* Part D Section 3.3.2.
- A HEC-RAS model and results for the minor and major storm flows must be produced where no high-flow bypass provisions are allowed for.
- Wildlife habitat features such as rocks and logs may form part of the design and need to be accounted for as flow obstructions in the velocity checks.

Wetland inlet

- Multi-inlet wetlands are typically proposed when:
  - The wetland is located too far downstream and is within the waterway land reserve.
  - The designer is experiencing difficulty meeting the velocity requirements for the wetland in the absence of appropriate bypass allowances.
- Multi-inlet wetlands are to be avoided where possible. A multi-inlet response should not be used to circumvent velocity requirements.
- Where a multi-inlet wetland is unavoidable:
  - Each inlet requires a sedimentation zone.
  - The design and size of each sediment pond should be in proportion to the stormwater runoff volumes entering from its immediate catchment.
  - The flow path length through the macrophyte zone, the macrophyte zone surface area at NWL, planting zone distribution and macrophyte coverage should be sized proportional to the volumes entering the asset at various entry points.
  - For example, if 1/3 of the flow enters at one point and 2/3 enters downstream, then at least 2/3 of the wetland area and volume should be downstream of the second inflow point.

Wetland outlet

- Locate wetland outlet and overflow structures outside open water zones to be accessible from land for ready inspection and cleaning – with connection pipe to outlet from deep water pool.
- Planted vegetation must be 900mm clear of the overflow pit all around.
- The wetland water level control configuration at the outlet may adopt Melbourne Water's standard sidewinder weir. Alternately, an orifice or weir outlet may be used where appropriate and approved by the City of Whittlesea. The design of the pit and orifice or weir plate should allow the plate to be removed and either modified or replaced. Any removable parts must be adequately marked for correct reinstatement.

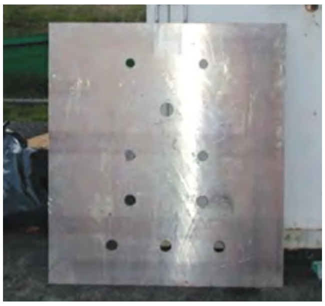


Figure 44 Removable orifice plate

- The outlet control pit must feature a suitable base gate valve with extended spindle mechanism to allow for the complete drawdown of the wetland as per Melbourne Water's 7251/12/005 standard drawing.
- Normal water level and maximum extended detention depth shall be marked and indicated on the wet side of the level control pit.
- A suitably sized and perforated PVC conduit must be secured to the wet side of the overflow structure to house a submersible level transducer and turbidity sensor.

Vegetation design

- Vegetation should be designed to ascertain high floristic species richness to maximise ecological benefits. Refer to the table below for suitable species. A minimum of 50% of highlighted high-nutrient absorbing species must be specified in the design.

Maintenance access

- At a minimum, maintenance vehicles should be able to access the wetland at key points, including the sediment pond, open water zones, and access to inlets and outlets, and any structures that may be prone to blockages.
- The access track shall consider low visual impact products and high level of permeability, where possible.
- Access to critical structures below the top of batters should be constructed of suitable rock steps or roll-out concrete matting, with one or two rows of vegetation screening to prevent general public access.
- The use of permeable paving, grass paving and reinforced grass type responses for maintenance access tracks may be considered to minimise impacts on amenity.
- All open water zones should have a narrow 600mm access ramp to allow for canoe launching, to the satisfaction of the City of Whittlesea. Acceptable products may include roll-out concrete matting or rock steps. The ramp may align with balance pipes for ease of locating, but may be closed off by one or two rows of batter planting to avoid general public access.
- All submerged structures to be identified with a marker post.

Community experience

- Where constructed wetlands form part of the urban landscape, designers are to consider user experience in form of boardwalks, viewing platforms, seating opportunities and educational signage in appropriate situations.

Figure 45 Janefield Wetland boardwalk, Bundoora

Species name	Common name	Lifeform	**Pool** [1-0.5m < NWL]	**Deep marsh** [0.5-0.35m < NWL]	**Marsh** [0.35-0.2m < NWL]	**Shallow marsh** [up to 0.2m < NWL]	**Ephemeral marsh** [up to 0.2m > NWL]	**Littoral** [up to 0.5m > NWL]	**Biofiltration**	Notes
Acacia verticillata subsp. verticillata	Prickly Moses	Shrub					✓	✓		
Alisma plantago-aquatica	Water Plantain	Forb			✓	✓				
Alternanthera denticulata s.s.	Lesser Joyweed	PS				✓	✓			***
Amphibromus nervosus	Common Swamp Wallaby-grass	Grass				✓				
Asperula conferta	Common Woodruff	Forb				✓	✓	✓		***
Asperula subsimplex	Water Woodruff	Forb			✓	✓				***
Bolboschoenus caldwellii	Marsh Club-rush	S/R				✓				
Bolboschoenus medianus	Marsh Club-sedge	S/R			✓	✓				
Brachyscome dentata	Lobe-seed Daisy	Forb					✓			***
Calocephalus lacteus	Milky Beauty-heads	Forb					✓	✓	✓	
Carex appressa	Tall Sedge	S/R				✓	✓		✓	
Carex gaudichaudiana	Fen Sedge	S/R					✓	✓		***
Carex tasmanica	Curly Sedge	S/R				✓	✓			***
Carex tereticaulis	Poong'ort	S/R				✓	✓		✓	
Carpobrotus modestus	Pigface	Succulent							✓	
Centella cordifolia	Centella	Forb				✓				***
Chrysocephalum apiculatum	Common Everlasting	Forb							✓	
Cladium procerum	Leafy Twig-sedge	S/R			✓	✓				
Coronidium gunnianum	Pale Swamp Everlasting	Forb					✓			***

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Species name	Common name	Lifeform	**Pool** [1-0.5m < NWL]	**Deep marsh** [0.5-0.35m < NWL]	**Marsh** [0.35-0.2m < NWL]	**Shallow marsh** [up to 0.2m < NWL]	**Ephemeral marsh** [up to 0.2m > NWL]	**Littoral** [up to 0.5m > NWL]	**Biofiltration**	Notes
Craspedia paludicola	Swamp Billy-buttons	Forb				✓				***
Crassula helmsii	Swamp Crassula	AqH				✓				
Cycnogeton alcockiae	Southern Water-ribbons	AqH			✓	✓				***
Cycnogeton procerum	Common Water-ribbons	AqH		✓	✓	✓				
Dichondra repens	**Kidney-weed**	**Forb**					✓	✓		***
Dianella admixta	Spreading Flax-lily	Lily						✓		
Dianella amoena	Matted Flax-lily	Lily						✓	✓	
Eleocharis acuta	**Common Spike-sedge**	**S/R**			✓	✓			✓	
Eleocharis pusilla	Small Spike-sedge	S/R				✓				
Eleocharis sphacelata	Tall Spike-sedge	S/R		✓	✓					
Elatine gratioloides	Waterwort	P/MH				✓				***
Epilobium hirtigerum	Hairy Willow-herb	Forb					✓			
Eryngium vesiculosum	Prickfoot	Forb				✓				
Eucalyptus camaldulensis var. camaldulensis	River Red-gum	Tree					✓	✓		Large canopy tree
Ficinia nodosa	Knobby Club-rush	S/R							✓	
Geranium aff. retrorsum (grassland)	Grassland Crane's-bill	Forb						✓		
Geranium solanderi var. solanderi	Austral Crane's-bill	Forb					✓	✓		
Glyceria australis	Australian Sweet-grass	Grass			✓	✓				

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Species name	Common name	Lifeform	Pool [1-0.5m < NWL]	Deep marsh [0.5-0.35m < NWL]	Marsh [0.35-0.2m < NWL]	Shallow marsh [up to 0.2m < NWL]	Ephemeral marsh [up to 0.2m > NWL]	Littoral [up to 0.5m > NWL]	Biofiltration	Notes
Goodenia ovata	Hop Goodenia	Shrub					✓		✓	
Gratiola peruviana	Austral Brooklime	Forb				✓				
Hemarthria uncinata var. uncinata	Mat Grass	Grass				✓	✓			
Hydrocotyle verticillata	Shield Pennywort	P/MH				✓				***
Hydrocotyle sibthorpioides	Shining Pennywort	P/MH				✓	✓			***
Isolepis cernua var. cernua	Nodding Club-sedge	S/R				✓				
Isolepis cernua var. platycarpa	Broad-fruit Club-sedge	S/R				✓				
Isolepis fluitans	Floating Club-sedge	S/R		✓	✓					
Isolepis inundata	Swamp Club-sedge	S/R				✓				
Isolepis producta	Nutty Club-sedge	S/R			✓	✓				
Juncus amabilis	Hollow Rush	S/R				✓	✓		✓	
Juncus australis	**Austral Rush**	**S/R**				✓		✓		
Juncus flavidus	**Gold Rush**	**S/R**				✓	✓	✓	✓	
Juncus holoschoenus	Joint-lead Rush	S/R				✓				***
Juncus kraussii subsp. australiensis	**Sea Rush**	**S/R**				✓			✓	
Juncus sarophorus	Broom Rush	S/R				✓	✓	✓	✓	
Juncus subsecundus	**Finger Rush**	**S/R**					✓	✓	✓	
Lemna disperma	Common Duckweed	AqH		✓	✓	✓				***
Leptospermum lanigerum	Woolly Tea-tree	Shrub					✓			
Lilaeopsis polyantha	Australian Lilaeopsis	Forb				✓				

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Species name	Common name	Lifeform	Pool [1-0.5m < NWL]	Deep marsh [0.5-0.35m < NWL]	Marsh [0.35-0.2m < NWL]	Shallow marsh [up to 0.2m < NWL]	Ephemeral marsh [up to 0.2m > NWL]	Littoral [up to 0.5m > NWL]	Biofiltration	Notes
Lobelia pratioides	Poison Lobelia	P/MH				✓	✓			
Lomandra longifolia subsp. longifolia	Spiny-headed Mat-rush	S/R					✓	✓	✓	
Marsilea drummondii	**Common Nardoo**	**Fern**				✓	✓			
Melicytus dentatus	Tree Violet	Shrub					✓	✓		
Mentha satureioides	Creeping mint	Forb				✓				***
Microlaena stipoides	Weeping Grass	Grass						✓		***
Microseris scapigera s.s.	Plains Yam-daisy	Forb				✓				Prone to slug and rabbit herbivoury ***
Montia australasica	White Purslane	Forb			✓	✓				
Myriophyllum crispatum	**Upright Water-milfoil**	**AqH**		✓	✓					
Myriophyllum salsugineum	Lake Water-milfoil	AqH	✓	✓						
Myriophyllum simulans	**Amphibious Water-milfoil**	**AqH**			✓	✓				
Persicaria decipiens	**Slender Knotweed**	**Forb**				✓				
Persicaria prostrata	Creeping Knotweed	P/MH				✓				
Poa labillardierei var. labillardierei	**Common Tussock-grass**	**Grass**				✓	✓	✓	✓	
Potamogeton cheesemanii	**Red Pondweed**	**AqH**	✓	✓	✓					
Potamogeton crispus	**Curly Pondweed**	**AqH**	✓	✓	✓					
Potamogeton ochreatus	**Blunt Pondweed**	**AqH**	✓	✓	✓					

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Species name	Common name	Lifeform	Pool [1-0.5m < NWL]	Deep marsh [0.5-0.35m < NWL]	Marsh [0.35-0.2m < NWL]	Shallow marsh [up to 0.2m < NWL]	Ephemeral marsh [up to 0.2m > NWL]	Littoral [up to 0.5m > NWL]	Biofiltration	Notes
Ranunculus amphitrichus	Small River Buttercup	Forb				✓				
Ranunculus inundatus	River Buttercup	Forb				✓				
Ranunculus lappaceus	Australian Buttercup	Forb					✓			***
Rumex bidens	Mud Dock	Forb			✓	✓				
Rytidosperma duttonianum	Brown-back Wallaby-grass	Grass				✓	✓	✓		
Rytidosperma semiannulare	Wetland Wallaby-grass	Grass				✓	✓			
Schoenoplectus tabernaemontani	River Club-sedge	S/R			✓	✓				
Selliera radicans	Shiny Swamp-mat	P/MH				✓				
Thyridia repens	Creeping Monkey-flower	Forb				✓				
Triglochin striata	Streaked Arrowgrass	Forb				✓				
Vallisnaria australis	Eel Grass	AqH	✓	✓						
Veronica gracilis	Slender Speedwell	Forb					✓			
Viminaria juncea	Golden Spray	Tree							✓	
Wahlenbergia communis	Tufted Bluebell	Forb							✓	
Xerochrysum palustre	Swamp Everlasting	Forb				✓				
Recommended minimum number of species to achieve for zone			**2**	**4**	**7**	**20**	**15**	**7**		

*** Choose when aiming to boost species diversity

The grey rows correspond to the recommended Engineering Procedures species

Table 16 Wetland planting species native to the City of Whittlesea

4.7.4 Modelling approach

Designers are referred to the latest Melbourne Water MUSIC Guidelines (2018) as the primary source of guidance for modelling wetlands.

- *MUSIC Guidelines*, as revised.
- MUSIC User Guide (eWater, 2022).
- MUSIC Auditor and wetland analysis tool.

Parameter	Recommended value	Guidance
Inlet properties		
Inlet pond volume (m^3)	-	If the wetland is represented by a single treatment node, the 'inlet pond volume' entered in the wetland treatment node must be equal to the sum of the volume of all associated sediment ponds up to NWL. If the wetland is represented by separate wetland and sedimentation basin nodes, a sedimentation basin node must be provided for each (inlet) sediment pond consistent with its design. Each of these should be sized in proportion to the flows entering at that inlet. For example, if 60% of flows enter at inlet A and 40% at inlet B, then 60% of the total sediment pond volume should be provided at inlet A and 40% at inlet B.
Storage properties		
Extended detention depth (m)	0.35	As per Melbourne Water's constructed wetland manual.
Exfiltration rate (mm/hr)	For lined wetlands: 0 For unlined wetlands: 0.18 – 100	For unlined wetlands, set value based on measured infiltration rate or soil type for underlying soils. Given requirements for stormwater volume reductions by EPA to address the General Environmental Duty, consideration may be given for partially unlined wetlands (above normal water level). These wetlands will exfiltrate treated stormwater into the underlying soils. Exfiltration rate assumptions should be supported by a geotechnical report and the inundation frequency of the wetland should be shown to have no negative impact on plants.

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Parameter	Recommended value	Guidance
Custom outflow and storage		
Pipe outlet flow (m^3/s)	Design flow through the outlet control structure	The pipe flow discharge should be based on an orifice calculation (or similar) up to the EDD. Once EDD is surpassed the flow rate should flatline. Enter pipe outlet at 50-100mm increments from NWL through to EDD + 2m.
Weir overflow (m^3/s)	Design flow through the overflow weir	The weir flow should represent the overflow infrastructure (pipe or weir) and only be activated once water levels surpass the EDD. Enter weir flows at 50-100mm water level increments from EDD through to EDD + 2m.
Residence time		
Notional detention time or residence time	72 hours	Design for a residence time of 72 hours – refer to wetland analysis tool for ready calculation of this and see also *Wetland Design Manual* (Melbourne Water, 2020) for manual calculation method. A reduced residence time of no less than 48 hours may be considered for retrofit designs where a lower residence time is necessary to provide good plant health outcomes based on consideration of inundation frequency curves.

Table 17 Modelling guidance for wetlands

4.7.5 Submission requirements

The functional design package for the City of Whittlesea should include:

- Functional design drawings, including layout plans, sections, and typical details.
- Supporting calculations and models, including stormwater models, such as RORB or HECRAS models and calculation spreadsheets.
- MUSIC model file (SQZ format).
  Copy of the MUSIC file must demonstrate:
  - the stage-storage-discharge relationships adopted from the bathymetry and inlets/ outlets arrangements (Appendix D) (for wetland and sedimentation basin).
  - the high-flow bypass configuration to the design.
  - the extended detention controlled outlet configuration to the design.
  - custom reuse demands, if adopted.
- An inundation frequency analysis of water levels in the macrophyte zone.
- Demonstration of the 90th percentile residence time in the macrophyte zone.
- Copy of the MUSIC Auditor report.
- Supporting background documents such as a geotechnical report, masterplan and others.
- Completed all **functional** design criteria of the Deemed to Comply checklist.

The detailed design package for review by the City of Whittlesea should include the following:

- Revised calculations and updated modelling results as per functional design stage, including submission of all model files.
- Detailed design drawings, including layout plans, system sections and specific construction details.
- Constructible detail on the wetland level control structure, including accurate orifice plate, notch weir or penstock details.
- Landscape detailed design drawings.
- Preliminary maintenance agreement plan where maintenance responsibilities of the proposed asset are shared between the City of Whittlesea and Melbourne Water.
- Documentation from authorities for any works impacting existing services.
- Asset polygons and catchment polygons in shape file format.
- Completed all detailed **design** criteria of the Deemed to Comply checklist.

4.7.6 Construction and establishment

The primary reference for construction and establishment is the *Wetland Design Manual* (Melbourne Water, 2020) with Part C Sections 6 and 7 being of most relevance.

During the construction and establishment phase, attention should be given to elements that impact the water level and elements that are at risk of leaking. Elements include the construction of the clay liner, pipe trenches and the outlet pit and overflow weir finished levels.

Wetlands plants are essential to effective function, and attention should be given to ensuring successful planting and establishment. This includes the use of well-developed and healthy plants, maintaining water levels at normal water level for the first year (overflow fully open) and use of bird netting where needed.

- The developer must sponsor the installation and maintenance of sensor technology post-Practical Completion, so as to verify the hydraulic performance of the asset meeting design intent (through 1x hydrostatic pressure sensor), and to monitor spikes in sediment contamination events for asset protection (through 1x turbidity sensor). It is the developer's responsibility to host live data online and sample results as RESTful API for a duration of two summers and three months. Data to be logged must include, as a minimum:
  - water level (+/- 5mm accuracy),
  - battery voltage level,
  - state of charge (%),
  - last sensor data update (date-time stamp)

  and be recorded hourly to permit monitoring of water level during extended detention engagement and draw down.

Construction hold points

Contractors must notify the City of Whittlesea's Construction Surveillance Unit 48 hours ahead of the following construction milestones, for witness inspections:

- **Bottom of the clay liner/subgrade:** level survey to confirm minimum depth excavation achieved. Set out of levels (+/- 50mm), including sediment pond, macrophyte zone and deep pools, with allowance for 300mm of topsoil and 300mm, or as designed, for impervious liner where required.
- **Top of the clay liner:** level survey to confirm minimum thickness of clay liner constructed.

  (Contractor should provide the superintendent with as-constructed survey levels of the clay liner to review and ensure it is within tolerable +/- range).
- **Trench cut-off walls:** concrete cut-off walls within trench with sodium bentonite constructed.
- **Topsoil:** level survey of wetland surrounding batters to confirm topsoil provided to a minimum of 300mm and surface levels after laying of topsoil are correct (+/- 50mm).
- **Inlet pipe and headwall:** check inlet pipe and headwall at correct location and levels +/- 25mm.
- **Outlet pit and drawdown control:** the finished level of the invert of the outlet weir or orifices will control the normal water level of the wetland, and the finished level of the overflow weir (or outlet pit as appropriate) will control the extended detention depth. Check finished levels of the outlet weir and orifices are within +/- 25mm of design intent.
- **Rock protection:** provided at correct locations and properly interlocked.
- **Plant stock:** Inspection of plant stock (size, quality) prior to planting. A detailed as-constructed planting layout must be submitted upon completion of the landscaping works.
- **Sensor technology** installed and supplied with electricity sources (such as battery or solar).

A comprehensive construction and establishment sign-off form for constructed wetlands can be downloaded from *Guidelines for the construction and establishment of bioretention systems and wetlands* (Water by Design, 2022), Section 5.2.

The macrophyte planting should be undertaken during the warm season (September to March) to ensure a higher success rate of plant survival and establishment. It is common for construction contracts to include a defects liability period of two summers and three months for plant growth and establishment.

All construction contractors are recommended to be green-card accredited (Site Environmental Awareness Training).

Protection measures during ongoing construction and building activities

Constructed wetlands should be protected from excessive sediment inflows during the construction and development buildout period. This can be achieved by:

- Appropriate site erosion and sediment controls within the catchment.
- Excavation of the wetland footprint and using it as a temporary sediment pond. The pond will be cleaned out and reset as a wetland once 90% of building within the catchment is complete. Progressive wetland establishment may need to be considered.
- Bypassing sediment laden flows around the wetland macrophyte zone via the high-flow bypass. Mechanical water treatment provisions need to be considered.

Further guidance on protection measures during the construction phase can be found in the *Guidelines for the construction and establishment of bioretention systems and wetlands* (Water by Design, 2022), Section 3.6.

Council handover

Prior to accepting handover of the wetland, the City of Whittlesea requires the following inspections be made and documentation be submitted:

- Is the hydraulic system working as designed based on visual inspection of water levels (water levels are at or just above normal water level, not at a significantly elevated level (>50 mm) at least three days after rainfall)? Where adopted the accumulated water level data may serve as the basis for hydraulic performance review.
- Are there any obvious signs of under-performance, inappropriate bypasses or overflows?
- Vegetation establishment period completed (two summers and three months as per landscaping defects liability period).
- No or minimal sediment accumulation in wetland.
- Design plant cover is established across 90% of all macrophyte zones of wetland.
- Design plant cover is established across 90% of all batter areas.
- Weeds are controlled to an acceptable level (<5% of surface extents).
- Inlets and outlets are not blocked. The overflow structure shall be opened and inspected, with removal of any debris.

Ensure that the City of Whittlesea has received the following plans and documents:

- As constructed plan of wetland in digital format.
- Documentation of construction and establishment.
- Planting plan and documentation clearly showing what plants and densities were used.
- Finalised maintenance plan for wetland (where ownership is shared between Melbourne Water and the City of Whittlesea) as per template, including polygon submission in shape file format.
- Digital files (as constructed drawings, proprietary information (if applicable).

4.7.7 Asset operation and maintenance

Wetlands are designed to minimise maintenance and to facilitate ready access for common inspection tasks. Key considerations for maintenance include:

- Removal of blockages at the outlet. Debris blocking the outlet can result in the drowning of plants and is a critical wetland failure risk. Prolonged inundation above normal water level beyond three days after rain indicates a blockage or hydraulic discharge restriction.
- Regular clean-out of sediment from the upstream sediment pond is critical to prolong wetland life.
- Prompt removal of invasive weeds prevents spread and minimises future renewal costs.
- Extensive vegetation cover is essential for effective treatment and any gaps in cover should be replaced in a timely manner.
- Wetland water drawdowns may be periodically required to manage invasive fish species. This may take several weeks and should be undertaken in the months of August and September to avoid frog and waterbird breeding seasons in spring and summer. Soil exposure should be limited to three weeks to reduce the risk of bioavailable phosphorous increases. Wetland drawdowns cannot occur during extended detention enabled events.

Further reference for maintenance considerations includes the *Waterbody Management Guideline – Module 4 – Maintenance and Operations* (Water by Design, 2013).

4.8 Biofiltration

4.8.1 Function

Biofiltration systems, often called biofilters, raingardens or bioretention systems, receive stormwater flows and allow them to temporarily pond onto and infiltrate through an engineered media. Biofilters can act as both filters and sponges for stormwater.

The filter media works in combination with dense vegetation and microbes within the media to mechanically filter the water, removing sediment, particulates and dissolved nutrients, as well as organic litter from runoff. Nutrient pollutants trapped within the media undergo chemical and biological processes through uptake by plants. Filtered water is either directed to the stormwater drainage network via an underdrain or infiltrated into underlying soils where percolation rates allow. Biofilters also allow water to be returned to the atmosphere via evaporation and plant transpiration (evapotranspiration). The reductions in flow volume and frequency as well as attenuation of flows allow biofilters to more closely represent the natural hydrology of a catchment prior to development.

Figure 43 Large-scale biofiltration system at Moffat Park, Lalor

4.8.2 Adoption and constraints

Preferred use	Non-preferred use
✓ At the downstream end of gutters or vegetated swales	✗ In the residential streetscape
✓ As end-of-line treatment	✗ In car parks where practical catchment to treatment ratios cannot be achieved
✓ In public spaces and reserves with ornamental benefit	✗ In close proximity to driveways with potential to obstruct sight lines
	✗ When terrain dictates requirement for a tiered or cascading system
	✗ In high traffic management zones requiring road or lane closures for maintenance
	✗ In locations where they cause a hazard for vehicle or pedestrian safety
	✗ Within reserves not owned by the City of Whittlesea (such as VicRoads road corridors)
	✗ Within retarding basins where they are exposed to major storm inundation without bypass provisions
	✗ Catchments that have high sediment loads (such as open industry or construction areas)

4.8.3 Design criteria

Industry guidelines which provide information on planning, design and implementation of biofilters include:

- *Biofiltration systems in Development Services Schemes Guideline* (Melbourne Water, 2020).
- *Adoption guidelines for stormwater biofiltration systems* (CRC for Water Sensitive Cities, 2015).
- *WSUD Engineering Procedures: Stormwater* (Melbourne Water, 2005), Chapter 6.
- *Specifications for bioretention filter media* (Water by Design, 2023).

To enable a biofilter to perform effectively and efficiently, the City of Whittlesea has the following requirements on design, functionality and operation, which are distinguishable by asset components:

Catchment

- The treatment to catchment size ratio should be with a 1-2% range to ensure a biofilter's hydrologic requirements for plant survival.
- Insufficient catchment sizes may be increased effectively using low-flow bypasses around upstream stormwater inlets.

Figure 44 Side entry pit low-flow bypass in Fernhill Road, Mount Evelyn

Inlet

- Piped inlets require scour velocities to be checked to reduce erosion risk.
- Large filter bed areas (>100m^2) require adequate distribution of flows to assist towards uniform media moisturisation. This can be achieved through C-channels and other level-spreading techniques.
- Inlets must be designed to bypass minor and major storm flows.
- Where the catchment's baseflow contributions to a biofilter location cannot be avoided, these must be adequately diverted around the asset allowing only elevated storm flow rates to enter the filter bed.

Figure 45 C-Channel flow distribution in Dawson Street, Brunswick

Sediment and litter control

- Sediment and litter control shall be managed at biofilter inlets to prevent premature clogging of the filter and ease of maintenance.
- Appropriate pre-treatment selection such as a gross pollutant traps, sediment forebays or sediment basins depends on the catchment size and characteristics.
- Sediment forebays must be designed so water can either drain into the remaining filter bed or evaporate within a period of five days to avoid attraction of mosquitos.

Figure 46 Sediment forebay at kerb entry (roadside biofilter in Fernhill Road, Mount Evelyn)

Extended detention depth

- Inlets, surface and overflow are designed so that water can spread and pond evenly across the surface of the level biofilter.
- Extended detention depth is adequate to attenuate flows and promote infiltration without resulting in excessive periods of ponding.
- Maximum acceptable extended detention depth is 300mm where risk of injury and drowning can be avoided through structural measures (such as fencing or landscaping).

Filtration media

- Soil media specifications balance the need for permeability and moisture holding capacity to support healthy vegetation and stormwater treatment.
- Filter media depth should be a minimum of 400mm (500mm preferred).
- Media specifications can be found in *Adoption Guidelines for Stormwater Biofiltration Systems*, (CRC for Water Sensitive Cities, 2015), Table 13.
- Rock mulch is not to be used.

Vegetation type

- Native species are preferred and must be able to withstand periods of both wetting and drying.
- Plants with strong root systems and high capacity to take up nutrients should be used, as this both stabilises the soil and filters stormwater.
- Vegetation which requires minimal pruning will increase maintenance efficiencies.
- At least 50% of plant cover should comprise plant species known to be effective for nutrient removal.

Species name	Common name	Lifeform
Calocephalus lacteus	Milky Beauty-heads	Forb
Carex appressa	Tall Sedge	S/R
Carex tereticaulis	Poong'ort	S/R
Carpobrotus modestus	Pigface	Succulent
Chrysocephalum apiculatum	Common Everlasting	Forb
Dianella amoena	Matted Flax-lily	Lily
Eleocharis acuta	**Common Spike-sedge**	**S/R**
Ficinia nodosa	Knobby Club-rush	S/R
Goodenia ovata	Hop Goodenia	Shrub
Juncus amabilis	Hollow Rush	S/R
Juncus flavidus	**Gold Rush**	**S/R**
Juncus kraussii subsp. australiensis	**Sea Rush**	**S/R**
Juncus sarophorus	Broom Rush	S/R
Juncus subsecundus	**Finger Rush**	**S/R**
Lomandra longifolia subsp. longifolia	Spiny-headed Mat-rush	S/R
Poa labillardierei var. labillardierei	**Common Tussock-grass**	**Grass**
Viminaria juncea	Golden Spray	Tree
Wahlenbergia communis	Tufted Bluebell	Forb

The grey rows correspond to the recommended Engineering Procedures species

Table 18 Preferred native plant selection for biofiltration systems

- Where plant variety is proposed instead of monocultures, a detailed planting layout is to be produced.

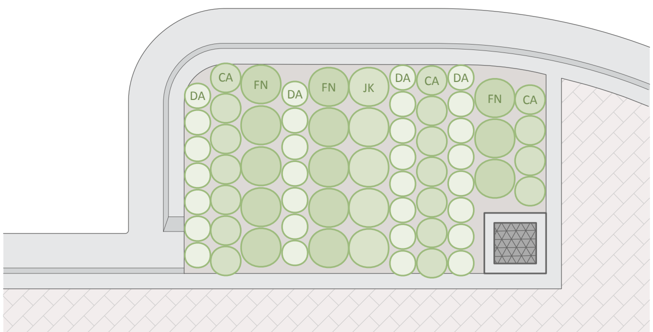

Figure 47 Example of a planting layout and species designation

Underdrainage

- Underdrain systems must be sized to achieve adequate intake and conveyance capacity for filtered water. Slot size, quantity of slots, as well as pipe size, grade, number of pipes and junctions need to achieve a hydraulic capacity equal to or exceeding the filtration rate of the above media.
- Underdrains must be manually slotted pipes with smooth internal walls. Corrugated AG drains are not accepted.
- Only straight drainage lines are to be used for underdrainage, minimising on deflections and avoiding curves.
- Underdrains should have inspection openings with screw-on end caps be secured with additional stainless steel screws.
- Underdrain flushing risers must either feature a long sweep bend or two 45 degree elbows for ease of jetting the pipe without energy losses.
- A minimum of one inspection opening must be raised above EDD level and adequately screened with vegetation.
- Underdrains may be raised within the overflow pit to achieve a submerged zone. The raise needs to have adequate protection from debris and must feature a scour opening.

Overflow structure

- Overflow pit capacity should be equal to or greater than the inflow capacity of the biofilter.
- Overflow pits should be designed in accordance with the City of Whittlesea's drainage standards and specifications.
- The outlet must be accessible for regular inspection and maintenance.
- The footprint of the overflow pit may depend on the depth and safe inspection and maintenance requirements.
- The pit surcharge grate must be hingeable and be lockable.

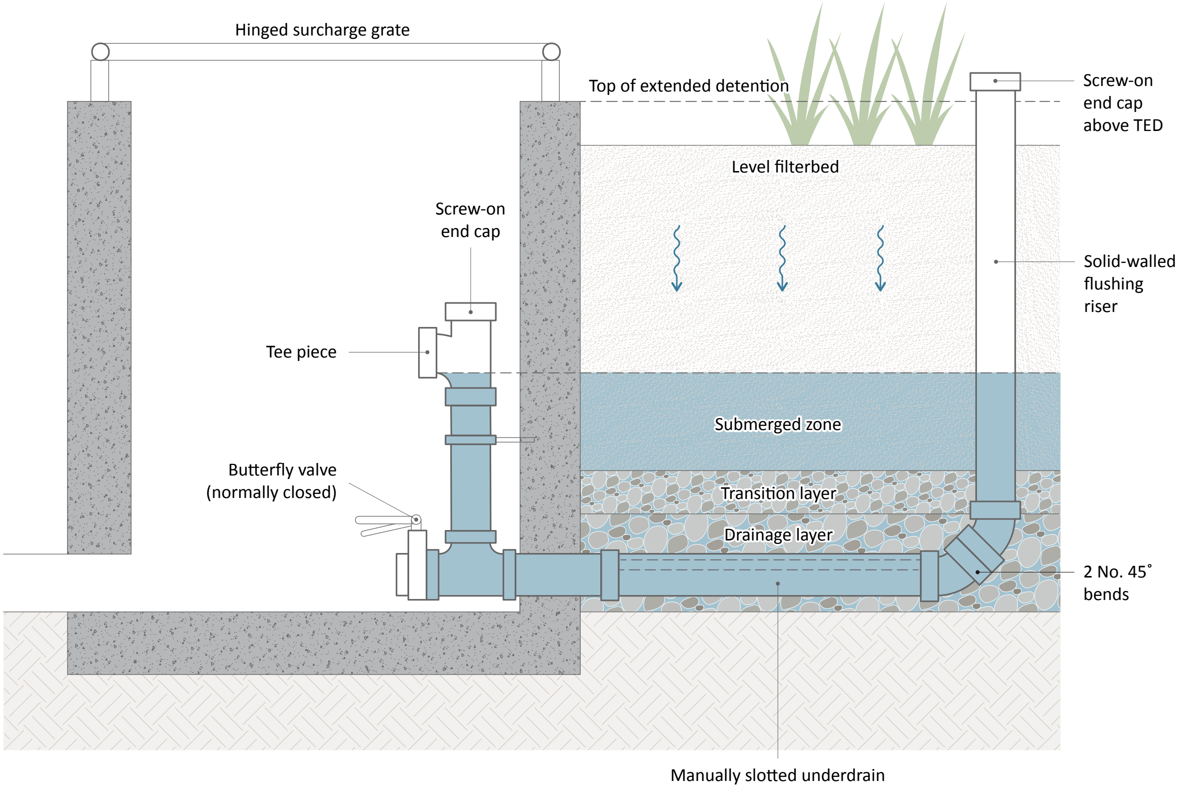

Figure 48 Preferred submerged zone creation in biofilter overflow pits

4.8.4 Modelling approach

Biofilters will be sized and modelled using a suitable stormwater model such as MUSIC or STORM Calculator.

Systems modelled in MUSIC shall generally conform with the *MUSIC Guidelines* as revised.

Key parameters to be used when modelling biofilters are summarised in the table below.

Design parameter	Value
Bypass	
Low-flow bypass (m^3/s)	Usually zero. This is only required if flows are bypassed such as is required for baseflows. Alternatively, the upstream catchment node may be modelled with a secondary link diverting baseflows past the bioretention node.
High-flow bypass (m^3/s)	Specify the inlet capacity where it is designed to be limited, otherwise treatable flow rates are determined by biofilter size.
Storage properties	
Extended detention depth (m)	For streetscape raingardens: 0.1 maximum. For large scale biofilter basins: 0.1-0.3 maximum.
Surface area (m^2)	This represents the area of the water surface at extended detention level.
Filter area (m^2)	This represents the filter media surface.
Filter media depth (m)	0.4-0.6 for a standard biofilter. 0.7-1.0 for a biofilter with trees.
Unlined filter media perimeter (m)	If the system is unlined, this is equal to the perimeter of the filter media minus any sides that are lined. If the system is lined (exfiltration is zero), this value has no effect.
Saturated hydraulic conductivity (mm/hr)	100mm/hr to account for long-term clogging effects of the media. An increase of this value must be justified with NATA-certified product specifications.
Filter media nitrogen content (mg/kg)	Total nitrogen = 800mg/kg.
Filter media orthophosphate content (mg/kg)	Available phosphorus = 50mg/kg. The designer may choose to reduce this to as low as 20-30mg/kg if the specification of a product with consistent NATA accredited testing can verify the lower value.

continued on next page >

Design parameter	Value
Infiltration properties	
Exfiltration rate (mm/hr)	If the asset is unlined, the exfiltration rate of the soil should be informed by a geotechnical report with a minimum of three percolation tests performed within the footprint of the asset. In the absence of geotechnical information, soils in the Whittlesea municipality are typically medium to heavy clays and an infiltration rate of 0.36mm/hr is suggested. If the asset is lined, the exfiltration rate should be set to 0.
Outlet properties	
Submerged zone depth (m)	0.3-0.5. If a submerged zone is used, a minimum depth of 0.3 is recommended.
Overflow weir width (m)	Typically based on the inner wall perimeter of the outlet pit.

Table 19 Biofilter modelling parameters

Vegetated sponges

Vegetated sponges, a subtype of biofilters, represent an emerging asset designed for stormwater volume management. Their primary function is to reduce stormwater flow volumes to waterways and enhance water quality as a secondary effect. Typically, vegetated sponges utilise imported filter media, include underdrainage systems with raised outlets, and an unlined saturated zone for water retention. Compared to standard filtration biofilters, they demand a notably larger footprint relative to their contributing catchment due to their focus on maximising volume retention over rapid filtration. This necessitates filter media with lower hydraulic conductivity and higher moisture retention properties. While utilising on-site soils minimises disruption and earthwork costs, the City of Whittlesea's clay-heavy soil composition steers designs away from in-situ solutions and relies on the import of suitable media.

The differences in the modelling approach compared to a standard biofiltration system is outlined in the table below.

Design parameter	Value
Extended detention depth (m)	0.01-0.15 (a shallow depth is preferred).
Filter media depth (m)	Where imported filter media is used (preferred): 0.3-0.6m for a standard vegetated sponge. 0.7-1m for a vegetated sponge with trees. Where in-situ soils are used (non-preferred): 0.4-0.6 based on the average effective root depth of vegetation.
Saturated hydraulic conductivity (mm/hr)	If imported filter media is used: 36-100mm/hr (preferred). If in-situ soils are used: A saturated hydraulic conductivity suitable for the surface soils should be adopted and should be determined by a geotechnical report.
Infiltration properties	
Exfiltration rate (mm/hr)	If the asset is unlined, the exfiltration rate of the soil should be determined by a geotechnical report. In the absence of geotechnical information, soils in the Whittlesea municipality are typically medium to heavy clays and an infiltration rate of 0.36mm/hr is suggested. If the asset is lined, the exfiltration rate should be set to 0.
Underdrain	Underdrainage is recommended. If in-situ soils are to be used, usually relief underdrainage to protect against oversaturation is provided.
Outlet properties	
Submerged zone depth (m)	0.3-0.5. This includes the depth of any filter media, transition media and drainage below underdrain invert. No submerged zone is usually present for in-situ soils.

Table 20 Modelling variations for vegetated sponges

4.8.5 Submission requirements

The functional design package for the City of Whittlesea's assessment must include the following documentation:

- Design drawings, including layout plans, system sections and typical details.
- Supporting stormwater modelling report and model file (MUSIC).
- Supporting background documents such as a geotechnical report.
- Completed Deemed to Comply design checklist as referenced under Melbourne Water's *Biofiltration systems in Development Services Schemes* covering items GN1-GN6, GN8, GN10 + GN11, SF1, BR1-BR12 for functional design elements.

The detailed design package for the City of Whittlesea's assessment must include the following documentation:

- Detailed design drawings, including layout plans, sections and specific details.
- Landscape detailed design drawings and specifications.
- Supporting stormwater modelling (MUSIC).
- Supporting calculations as needed to demonstrate all hydraulic component sizing as described in the Design criteria section.
- Documentation from third-party authorities for any works impacting existing utilities.
- Completed Deemed to Comply design checklist with Melbourne Water's *Biofiltration systems in Development Services Schemes* covering all remaining items (including MN1- MN15) not covered in the functional design submission. Exclusions are GN7 + GN9, as well as Construction and Establishment sections of the list.
- Soil moisture modelling for asset performance verification where required (such as vegetated sponges).
- Material specifications (such as filter, soil, plant species, densities and stock size) documented.
- Asset polygons and catchment polygons in shape file format.

4.8.6 Construction and establishment

Stormwater inflows which occur during the construction of a biofilter can cause costly damage, or even necessitate the need to remove and reinstall layers within the system. For instance, if runoff containing high sediment loads enters the biofilter before the installation of the drainage, transition or filter media layers are finalised, the layers can quickly become clogged. Therefore, construction should ideally be planned during dry periods and flows should be diverted around the biofilter during construction.

The City of Whittlesea advises that relevelling may be required after the first few rainfall events and after natural soil compaction has occurred.

To reduce the likelihood of erosion of filter media, landscape and vegetation works should usually commence as soon as the biofilter has been constructed. An exception to this is where the biofilter basin is formed and then covered with turf or any other surface textile for protection from high sediment loads during the build-out phase. The reinstatement of the surface and planting then commences at 90% of build-out.

An alternative approach to the establishment and functional transition of the asset to full development may be the partial planting of the filter bed at a defined lower density and grid alignment of plants. This would allow for an easier sediment removal process 'in between' plants at the reset milestone. The provision of a minimal vegetation cover at Practical Completion allows excess nutrients to be absorbed and prevent harmful algae from forming which would otherwise be flushed downstream. The remaining planting would occur at the 90% build-out stage.

Melbourne Water's guidance on biofilter construction elements shall be used, in particular items CN1-CN15 of the Deemed to Comply list.

Further information can also be found in the *Guidelines for the construction and establishment of bioretention systems and wetlands* (Water by Design, 2022). For filter media quality control, detailed specifications for construction can be found in the *Specifications for bioretention filter media* (Water by Design, 2023).

Construction hold points

The City of Whittlesea requires the following critical construction and establishment elements and steps to be witnessed and documented.

- **Protective measures:** ensure assets are protected (including sediment fences) during construction phase prior to landscape installation.
- **Bulk earthworks:** set out asset and locate any existing services. Ensure base levels are correct.
- **Impervious liner:** installation to specification (if required). Booted pipework.
- **Surrounding soil type:** if the system is unlined, testing of in-situ soil to determine soil type and infiltration rates match those in geotechnical report may be required by the City of Whittlesea for significant assets. Care should be taken to avoid compaction of underlying soils during earthworks to preserve infiltration capacity.
- **Hydraulic structures:** inlet and outlet pits and pipes (if applicable) are installed to specification and levels match those outlined in the civil design. Outlet pipes are free draining. Overflow weir (if required) is constructed to the correct level.
- **Underdrainage:** layout and size as per design (if required), with appropriate spacing between pipes. Underdrainage cleanout points extend to the required height above the filter media surface. A pipe slotting example may need to be demonstrated by the contractor prior to pipe installations.
- **Additional layers:** drainage layer and transition layer materials meet specifications and are installed with appropriate depths and levels.
- **Filter media:** bioretention filter media must be a certified and lab-tested product. Test results and report together with proof of purchase must be supplied to the City of Whittlesea prior to material installation.
- **Filter media:** material delivered to site meets specification and infiltration testing of in-situ material in line with the Facility for Advancing Water Biofiltration (FAWB) guidelines. A hold point should occur after filter placement and light compaction. This is to be undertaken in two to three locations across the filter bed depending on asset size.
- **Finished levels and hard landscape features:** levels as per design with appropriate 'step down' requirements met.
- **Geotextile removal:** ensure any protective geotextile is removed and surface reinstated and reprofiled prior to planting.
- **Vegetation installation:** plants are healthy and meet specifications, planting to density and layout as per landscape plans. Maintenance period for landscaping prior to handover is two full summers and three months (ending on 31 May of the given year). Plant height should be noted.

Council handover

The City of Whittlesea requires digital (not hand-sketched) as-constructed plans, and all photo and video documentation of the construction and establishment, to be submitted to the Construction Surveillance Officer at Practical Completion stage.

All hydraulic structures are to be inspected and any blockages removed, if required.

Coarse sediment forebays (where adopted) must be cleaned and have demonstrated no prolonged holding of water in excess of five days.

All pipework is documented and submitted to the City of Whittlesea to D-Spec standards.

The following establishment criteria applies for the landscaping components:

- Greater than 90% of all plants have survived.
- At least 50% increase in plant height is noted where planting height of a species is 50% or less than its maximum height.
- Propagation observed with more than two to three stems and seeding.
- No weeds present within the filter bed extents and on batters.

The filter media should undergo an infiltration testing of in-situ material in line with the Facility for Advancing Water Biofiltration (FAWB) guidelines. This is to be undertaken in two to three locations across the filter bed depending on asset size.

4.8.7 Asset operation and maintenance

These maintenance actions focus primarily on:

- Checking inlets and outlets for any blockage.
- Removing accumulated litter, excessive leaf litter and debris.
- Monitoring and removing any accumulated sediment from inlets, sediment forebays and ponds.
- Monitoring and removing any sediment accumulation on the filter media surface.
- Checking to ensure filter media is not clogged and infiltrates effectively.
- Pruning and maintaining any vegetation.
- Preventing the intrusion of invasive species such as weeds.
- Monitoring vegetation cover across the surface area of the filter media.
- Re-establishment of any plants which have died and infill planting of any gaps in coverage to minimise weed intrusion.
- Checking for erosion, particularly around the inlet and outlet.
- Checking for erosion throughout the vegetated base (and batters if applicable).
- Minor surface level adjustments.
- Monitoring for excessive ponding.
- Assessing presence of any vehicle or pedestrian damage.

4.9 Swales

4.9.1 Function

Swales are shallow, gently sloped open channels which are usually vegetated with either mowable grass or longer native grasses. They serve a dual purpose, conveying stormwater flows along their length while acting as natural filters for stormwater pollutants, trapping debris and suspended sediments; and promoting particle settling, water filtration and infiltration losses into the soil within the base of the swale. Swales can help attenuate flows and reduce stormwater flow volumes while also enhancing the aesthetics of an urban environment and mitigating urban heat through evaporation and plant transpiration.

A swale typically consists of a trapezoidal channel with a planted base and sides. They can be used in combination with overflow pits to allow high flows to enter the underground drainage network.

Flows may enter the swale either through direct runoff from adjacent impervious surfaces (such as a road or car park), or from a piped outlet of an upstream network.

Figure 49 Vegetated swale along Craigieburn Road East, Wollert

4.9.2 Adoption and constraints

Preferred use	Non-preferred use
✓ Moderate grades (1-5%)	✗ High parking demand streetscapes
✓ Areas where adequate space can be provided adjacent to roadways	✗ Steep sites (>5%) which may cause scour and erosion in the swale
✓ As median strips within wide road reserves	✗ Flat sites (<1%) which may result in boggy swales with standing water
✓ Car parks	✗ Locations where many driveway crossings are required
✓ Areas with free draining soils	✗ When a high water table is present
✓ Gardens and landscaped areas	✗ If there is an excessive risk of invasive plant species
✓ Public open space	✗ In locations where appropriate regular maintenance cannot be carried out
✓ Rural areas in place of an underground drainage network	✗ Property connections to swales in residential zones are not accepted
✓ Upstream of biofiltration assets	

4.9.3 Design criteria

Swales can also be designed with filter media incorporated into the base. These are usually referred to as bioretention swales or bioswales and are closer in operation to that of a biofilter.

For the purposes of this guideline, the design considerations are focused on stormwater quality and management for vegetated swales only. For details on bioretention swales please refer to the *Bio-filter swale design principles* (Clearwater, 2012).

Design guidelines which provide information regarding planning, design and implementation of swales are relatively limited and include:

- *WSUD Engineering Procedures: Stormwater* (Melbourne Water, 2005), Chapter 5.
- *Construction and Establishment Guidelines: Swales, Bioretention Systems and Wetlands* (Water by Design, 2019), Chapter 2.

To enable swales to perform effectively and efficiently, the following design features need to be considered:

Swale slope

- Slopes between 1 and 4% are preferred.
- If a slope exceeds this, use check dams where necessary to reduce the effective slope and decrease flow velocities. Concrete-based erosion control matting may be a suitable alternative where check dams are not feasible. The matting shall support a vegetative base.
- If the site is flat with low permeability soils, incorporate underdrainage to reduce the risk of standing water and boggy conditions.

Figure 50 Mowable swale with concrete edge strip on Chiton Way, Point Lonsdale

Swale dimensions

- Width requirements for maintenance (such as mowing) must be considered. For efficiency in mowing, the minimum mowable width is 1.2m.
- A broad and shallow swale form is preferred over a narrow and steep form to maximise treatment effectiveness, reduce scour and erosion risks and support effective maintenance.
- A minimum base width of 300mm is suggested.
- Swale depth and velocities should consider flood safety guidelines (DEECA) and should ensure that no hazards are presented to pedestrians and vehicles. A maximum depth of 0.3m for streetscape swales in residential developments is recommended.
- The flow depth for the design storm event for treated flows (4 EY) is less than the vegetation height within the swale, except for turfed swales.

Batter slopes

Batter slopes enable pedestrian and vehicular safety to be maintained in swales that are accessible to the public.

- For densely planted slopes, the batter slope should be no steeper than 1 in 3 to allow for healthy vegetation growth.
- For grassed slopes, the batter should be no steeper than 1 in 6 to allow for efficient and safe mowing

Soil type

- Where swales are adopted in poor gradients and heavy clay soils, an underdrain is recommended.
- A soil report by a geotechnical engineer is preferable. The soil test report must provide details of the soil type, its saturated hydraulic conductivity and the depth of the groundwater table at the site.
- With shallow grades, it is recommended that a highly permeable topsoil is used to help prevent ponding and boggy conditions and support vegetation growth.

Vegetation

- Vegetation height should be 0.1m for mown grass or 0.1-0.4m for native grasses, reeds or sedges.
- Selection of self-seeding species allows for increased design efficiency and reduced maintenance requirements.
- Vegetation height must result in no traffic sight obstructions.
- Dense vegetation cover (>80%) should be provided across the full extent (length and width) of the swale.
- Planting bands should be perpendicular to the direction of flow to avoid creating preferential flow paths.
- The vegetation height should preferably be as high as the design storm event for treated flows (4 EY).
- Scour velocity checks for the minor and major storm event shall be as per Chapter 8 of *WSUD Engineering Procedures: Stormwater* (Melbourne Water, 2005).

Inlets and outlets

- Overflow pits are designed in accordance with the City of Whittlesea's drainage standards and specifications.
- Erosion control such as dense vegetation or rock riprap must be provided at the inlet and outlet if required.
- Rock beaching sizing may be in accordance with the *Use of Rock in Waterway Engineering* (Catchments & Creeks, 2020).
- The outlet must be accessible for regular inspection and maintenance.

4.9.4 Modelling approach

Swales must be modelled for two purposes: firstly, their flow conveyance (and resulting flow depths, widths and velocities) and secondly, for stormwater treatment performance.

Flow conveyance modelling for both the minor and major flood events should be undertaken using an appropriate method, such as Mannings equation, while stormwater treatment performance should be carried out in MUSIC.

The following design guidelines provide a useful resource for modelling swales:

- *MUSIC guidelines; Input parameters and modelling approaches for MUSIC users in Melbourne Water's service area*.
- *WSUD Engineering Procedures: Stormwater* (Melbourne Water, 2005), Chapter 8.

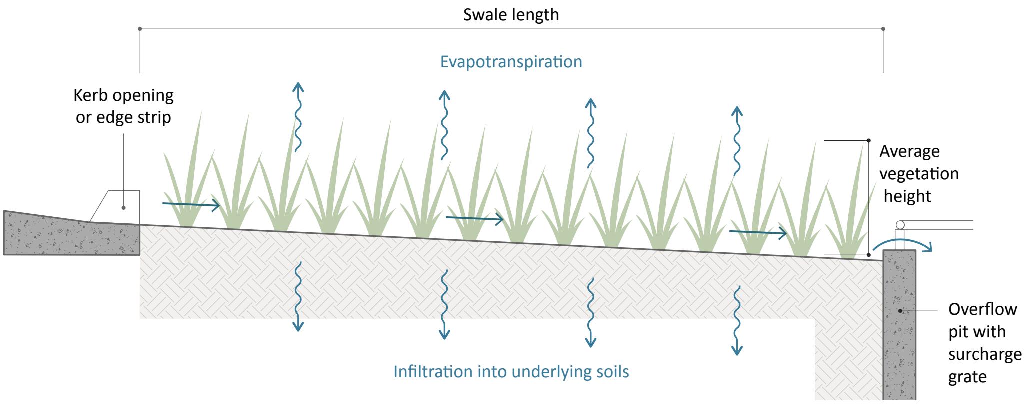

Figure 51 Key design parameters of a swale

The key parameters to be used when modelling swales are summarised in the table below.

Design parameter	Value
Bypass	
Low-flow bypass (m^3/s)	0
Storage properties	
Bed slope (%)	1-4% is preferred, although the bed slope will be determined by the site-specific location of the swale.
Base width (m)	This represents the flat base of the swale. If the swale is V-shaped rather than trapezoidal, the base width will be 0. 0.3-1.0 typical range. 0.3 minimum. ≥0.6 preferred. Note that while a broader base width is preferred, excessive base width relative to flow may increase the risk of a preferred flow path developing.
Top width (m)	This will vary depending on the base width, depth and batter slopes. Values between 1-5m are typical.
Depth (m)	0.3-0.5 typical.
Vegetation height (m)	0.1 for mown grass. 0.3 for native grasses or sedges.
Exfiltration rate (mm/hr)	0.36-100mm/hr depending on the soil type. The exact exfiltration rate will be determined based on soil type or a soil report by a geotechnical engineer. In the absence of geotechnical information, soils in the Whittlesea municipality are typically medium to heavy clays and an infiltration rate of 0.36mm/hr is suggested.

Table 21 Modelling parameters for swales

4.9.5 Submission requirements

The functional design package for the City of Whittlesea's assessment must include the following documentation:

- Functional design drawings, including layout plans, sections, and typical details.
- Supporting modelling in MUSIC.
- Hydraulic calculations demonstrating swales can convey design flows.
- Scour and erosion velocities demonstrated.
- Velocity check demonstrated for public safety ($<0.4m^2/s$).
- Supporting background documents such as a geotechnical report.

The detailed design package for the City of Whittlesea's assessment must include the following documentation:

- Detailed design drawings, including layout plans, sections and specific details.
- Updated calculations as demonstrated in functional design phase.
- Landscape detailed design drawings.
- Full material and product specifications, either captured on plans or specifications document.
- Documentation from third-party authorities for any works impacting existing utilities.
- MUSIC model resubmitted for treatment verification.

4.9.6 Construction and establishment

The swale must be safeguarded against erosion and sediment carried from upstream flows, usually done by diverting these flows around the swale whilst it is under construction. Heavy rainfall which occurs during construction may cause scour or erosion to the swale, and thus construction should ideally be undertaken during drier periods (November to April) or with appropriate diversions protecting the swale from upstream flows.

Care should be taken to avoid excessive compaction of soils by construction machinery, as this can reduce the infiltration capacity of the soils underlying the swale.

For a swale to provide successful stormwater management and to reduce the likelihood of erosion, landscaping and vegetation works should commence as soon as the swale has been constructed.

Construction hold points

The City of Whittlesea requires the following critical construction and establishment hold points to be documented:

- **Bulk earthworks:** set out system, location of existing services. Ensure base levels are correct.
- **Surrounding soil type:** testing of in-situ soil to determine soil type and ensure infiltration rates match those in geotechnical report (if swale infiltration performance is being claimed as part of the stormwater management system design or is otherwise important).
- **Underdrainage (if required):** layout and size as per design.

- **Hydraulic structures:** inlet and outlet pits and pipes (if applicable) are installed to specification and levels match those outlined in the civil design within design tolerances. Pipes are free-draining.
- **Inlet/outlet erosion control:** rock size range, layout and proper interlocking.
- **Check dams (if required):** installed to design levels within tolerances.
- **Topsoil:** minimum topsoil depths have been achieved.
- **Finished levels and hard landscape features:** levels as per design, no significant mounds, depressions or undulations along the length of the swale, minimum set downs from kerbs (if applicable) are achieved.
- **Swale reinforcements:** If applicable, swale reinforcements such as flexible concrete matting is pinned and anchored into the ground to manufacturer's specifications.
- **Landscape installation:** plant stock is healthy and meets specifications, planting density and layout adhered to.

Tolerances, landscape considerations and set out instructions can be found in Section 2.4 and 2.5 of the *Construction and Establishment Guidelines: Swales, Bioretention Systems and Wetlands* (Water by Design, 2010), with example hold-point sign-off forms provided in Section 2.13.

The City of Whittlesea requires digital (not hand-sketched) as-constructed plans, and all photo and video documentation of the construction and establishment, to be submitted to the Construction Surveillance Officer at Practical Completion stage.

Council handover

The defects liability period is accordance with the City of Whittlesea's development landscaping processes.

Upon handover of the swale asset to the City of Whittlesea, the following inspections will be conducted to ensure the swale has established to a functional level:

Vegetation establishment: plants are successfully established, with good coverage meeting specifications and ready to accept and withstand design flows.

Erosion: base and batters will be inspected for signs of erosion and preferential flow paths, and may require rectification where needed.

Inlet/outlet and other hydraulic structures: will be inspected for blockages, with all blockages needing to be removed prior to handover.

4.9.7 Asset operation and maintenance

Regular maintenance is required to ensure the ongoing functionality and plant health of swales. These maintenance actions focus primarily on:

- Pruning and maintaining vegetation cover.
- Regular mowing if the swales are grassed.
- Preventing the intrusion of invasive weed species.
- Re-establishment of any plants which have died to avoid prolonged loss of vegetation cover and risk of soil erosion.
- Removing any accumulated litter, debris and sediment, especially at swale entry points and outlets.
- Checking for excessive erosion around the inlet and outlet.
- Checking for erosion throughout the vegetated base and batters.
- Monitoring for standing water, ponding or boggy conditions.
- Monitoring if any vehicle damage has occurred, particularly in locations where vehicle crossings occur.

4.10 Proprietary products

The use of proprietary devices (beyond gross pollutant removal) is generally not supported by the City of Whittlesea due to concerns over a device's long-term maintainability and the verification of a device's performance to achieve the design intent of 'best practice' stormwater management. These concerns are, in detail:

- Independent verification of pollutant removal performance.

  In Victoria, no formal agreement on a product testing protocol exists.

  - The City of Whittlesea does not accept claims of nutrient reductions (neither in dissolved nor in particulate form). There is no sufficient local data available to verify target pollutant reductions in local climate, soil and rainfall conditions.
  - The City of Whittlesea may accept coarse sediment capture with proprietary devices where capture efficiencies have been verified through infield testing in Australia.

- Maintenance regime and supply guarantees.

  The maintenance and cleaning methodology must be assessed against the future asset owner's capabilities and OH&S policies. This includes considerations on whether a device requires:

  - Confined space entry for the temporary removal or replacement of any parts.
  - Specialist equipment or licences to access or operate any parts.
  - Isolation from upstream or downstream hydraulic systems prior to maintenance.
  - Designated pollutant draining facilities on site or off site.
  - Recurrent handling of contaminated material and how this is accomplished.
  - Recurrent disposal procedures for retrieved contaminated material.
  - Replacement of system-critical components such as filtration cartridges and the guarantee of supply of those parts over the asset's lifetime.

Private landowners may propose the use of proprietary products for the purpose of sediment capture and gross pollutant trapping only. For the City of Whittlesea to consider approval the applicant is required to submit, as a minimum, the following documentation to the City of Whittlesea's satisfaction:

- Evidence that the proposed proprietary product has been field-tested by an independent third party and that it meets BPEM objectives for TSS removal.
- Demonstration of appropriate device sizing for the respective catchment characteristics (hydrologically, hydraulically and contamination loading).
- Water quality (MUSIC) model demonstrating pollutant removal efficiencies in accordance with testing and the City of Whittlesea's requirements (nutrient reductions must be set to zero).
- A life cycle cost estimate documented for the proposed device.
- A comprehensive and supplier-independent maintenance plan documented. Where supplier-dependencies are proposed, the applicant needs to demonstrate that supplies can be guaranteed over the asset's life cycle of a minimum of 20 years, and that the device is replaceable at end-of-life.
- A defects liability period exclusively funded by the supplier for a minimum of two years.

4.11 Gross pollutant traps

4.11.1 Function

Gross pollutant traps (GPTs) are essential components of stormwater management systems and are designed to capture and remove large debris and coarse contaminants from stormwater runoff. These structures employ various physical mechanisms, such as screens and sedimentation, to prevent pollutants like litter, leaves and oil from entering water bodies and downstream natural ecosystems.

Figure 52 Gross pollutant capture in proprietary products

4.11.2 Adoption and constraints

Preferred use	Non-preferred use
✓ Residential catchments >5ha	✗ Cannot replace the requirements for sedimentation basins downstream
✓ Commercial precincts	✗ Residential catchments <5ha draining to end-of-line bioretention systems
✓ Industrial catchments	✗ Cannot be positioned within roads
✓ Outlets to conservation corridors	
✓ Upstream of all waterbodies	

4.11.3 Design criteria

For a GPT to function as an effective device to protect downstream assets, the structure or product must be designed and specified to:

- Capture litter above 5mm particle size.
- Treat the 4 EY peak flow rate in an off-line configuration (meaning high-flow bypasses have been allowed for upstream).
- Treat the minor storm peak flow rate in an on-line configuration (meaning no upstream high-flow bypass is provided).
- Devices can be utilised which account for treatment flow via diversion chambers in line with minor stormwater systems.
- Not be hydraulically linked to downstream waters causing permanent water levels within the GPT. The outlet invert of the GPT needs to sit a minimum of 100mm above the downstream normal water level. Where this cannot be achieved due to flat terrain, a provision to isolate the GPT is required.
- Diversion weirs (off-line scenario) or top of screens (in-line scenario) sit a minimum of 200mm above the downstream extended detention depth level (or upstream 4 EY HGL – whichever the greater) to avoid overspill of floatable debris.
- Proximity to waterways may warrant demonstration or testing of groundwater tables and require buoyancy checks.

- All GPTs in industrial zones require a downstream isolation mechanism such as surface operated penstocks for emergency drainage network shutdown during industrial fire hazard events. GPTs pose a unique access point to allow for contaminated water extraction. Isolation pits must be adequately marked at the surface for identification of their purpose.
- All GPT designs must also comply with the City of Whittlesea's GPT design checklist.

Product requirements

The City of Whittlesea has the following additional design requirements on a GPT product to allow for effective operation:

- There are no removable parts other than the structure surface lid. The City of Whittlesea does not accept products with removable baskets or other internal mechanical components needing cranes for lifting or confined space entry.
- The City of Whittlesea prefers hydrodynamic separators that use vortex action to separate pollutants from water.
- GPT sumps shall be sized to capture the twice-yearly sediment load of the catchment. Refer to the guidance on modelling.
- Internal screens must be able to be inspected with no visual obstructions.
- Structure lids must be removable without the use of cranes.

Access requirements

The City of Whittlesea has further requirements for the access of a GPT to optimise maintenance efficiencies:

- The GPT shall be located such that the maintenance vehicle can be parked off the road reservation for the period the maintenance is carried out and the ingress to the GPT will be in the normal direction of traffic flow.
- Design locations which require truck setup on road and with substantial traffic management implications may not be accepted.
- A suitable hardstand area of 11 x 3.5m is required to carry a maintenance vehicle of up to 30 tonnes gross vehicle mass (GVM).
- The hardstand position and orientation must allow for a service truck to have a maximum 4m reach and a maximum 6m vertical drop to the base of the GPT below surface. Designs that require hose extensions should be avoided.
- An all-weather maintenance access track from the roadside to the hardstand area along with an industrial standard vehicle crossing is required. The access track material may be permeable and blend in with the surrounding landscape following consultation with the City of Whittlesea's Landscape Approvals team.
- The access track may be gated, however, cannot be permanently fenced. Removable bollards are a cost-effective alternative solution.
- Access must be designed so as to discourage parking and blocking the access track by other vehicles.
- GPT access must be demonstrated on design plans with 9.5m service vehicle swept paths.
- Footpath crossings must be reinforced to industrial loading standard.
- Tree overhang and other road furniture and utilities need to be considered.

Figure 53 Service vehicle reach for gross pollutant traps

4.11.4 Modelling approach

A GPT has the primary function to separate litter, coarse organic material and particles down to 5mm size from water. The City of Whittlesea does not accept pollution reductions for total phosphorous and total nitrogen to be attributed to a product in a water quality model.

Many GPT products feature hydrodynamic separation mechanisms which allow sediments to be captured and stored in sumps. The City of Whittlesea may accept reductions in total suspended solids where the performance of a product has been independently verified and a sediment resuspension can be excluded based on the mechanical function of the device.

The sump of a GPT shall be sized to allow for the storage of the biannual gross pollutant load (at 98% removal efficiency) and the biannual TSS load (at a 70% removal efficiency). Removal efficiencies are entered in the GPT treatment node, while the sump volume requirements can be extracted from the node's lifecycle costing analysis, adopting a cleanout frequency of 2 and a redundancy factor of 1.

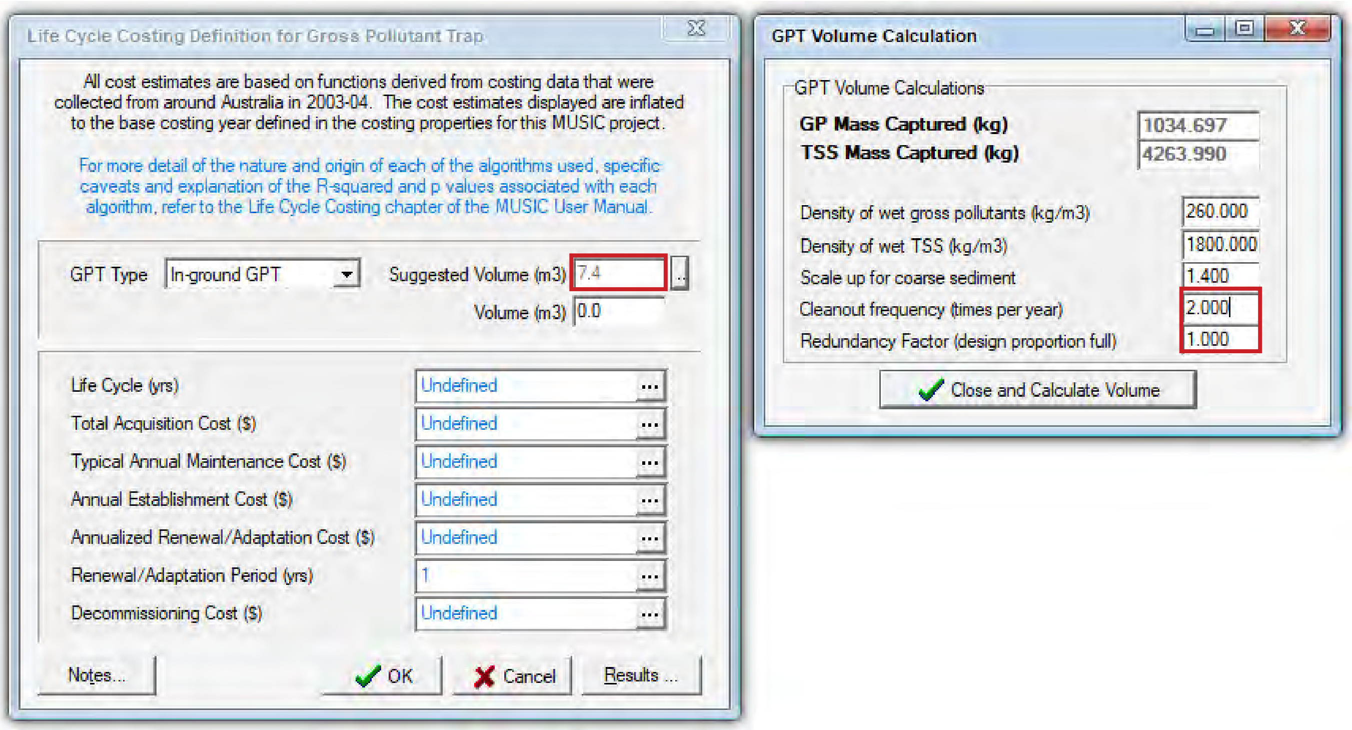

Figure 54 GPT volume calculations in MUSIC (eWater)

4.11.5 Submission requirements

The functional design package for the City of Whittlesea's assessment must include the following documentation:

- Product footprint, hardstand and access track shown on plans.
- Access vehicle swept path documented on plans.
- Product brochure and maintenance brochure sourced from supplier.
- Sizing calculations and water quality model (MUSIC file).

The detailed design package for the City of Whittlesea's assessment must include the following documentation:

- Access details documented on plans.
- Device longitudinal section showing integration with upstream and downstream assets and water level interactions (NWL, TED, HGL).
- Product installation specifications sourced from supplier.

4.11.6 Construction and establishment

Construction hold points

The City of Whittlesea requires the following critical construction hold points to be documented on plans which allow the contractor to notify the City of Whittlesea's Surveillance Officer to inspect the milestones at a minimum of 48 hours' notice:

- **Product supply:** submit certification or documentation from the manufacturer confirming that proprietary products are compliant with the specification.
- **Design levels:** in the course of the assembly of the product the contractor has to prove critical invert, base, weir or screen levels are in compliance with the design.

Council handover

A gross pollutant trap must be protected from sediment-laden runoff during the defects liability period. Upon handover of the asset to the City of Whittlesea, the contractor has to perform a complete cleanout of the device to the City of Whittlesea's satisfaction.

4.11.7 Asset operation and maintenance

The City of Whittlesea uses a mobile geospatial maintenance tracking application to record asset attendance over time, and to capture site observations related to the device's performance, access and cleanout efficiency.

5. General Design Considerations

General design considerations for integrated water management assets involve functionality, resilience, sustainability and adaptability. Irrespective of asset type, incorporating these additional principles into design processes helps IWM systems to address challenges effectively, promoting holistic and enduring solutions.

5.1 Sodic soils

5.1.1 Description

Sodic soils are soils with a relatively high presence of exchangeable sodium relative to other exchangeable cations. A soil is considered sodic when the amount of sodium compromises the structural integrity of soils. Sodic soils swell and the clay particles disperse rather than sticking together when they come into contact with freshwater. This can cause the soil structure to slump and collapse and the tiny clay particles block soil pores and reduce water permeability that creates soil crusts leading to increased runoff[1].

Exchangeable sodium percentage (ESP) is used to express the sodicity of soils as follows (Northcote and Skene, 1972[2]):

- Non-sodic: 0-6 ESP %
- Sodic: 6-15 ESP %
- Strongly sodic: >15 ESP %

Sodic soils are a natural feature and the distribution of them across Victoria is well known and documented (refer to Figure 55 for mapping of upper soil layer sodicity across Victoria).

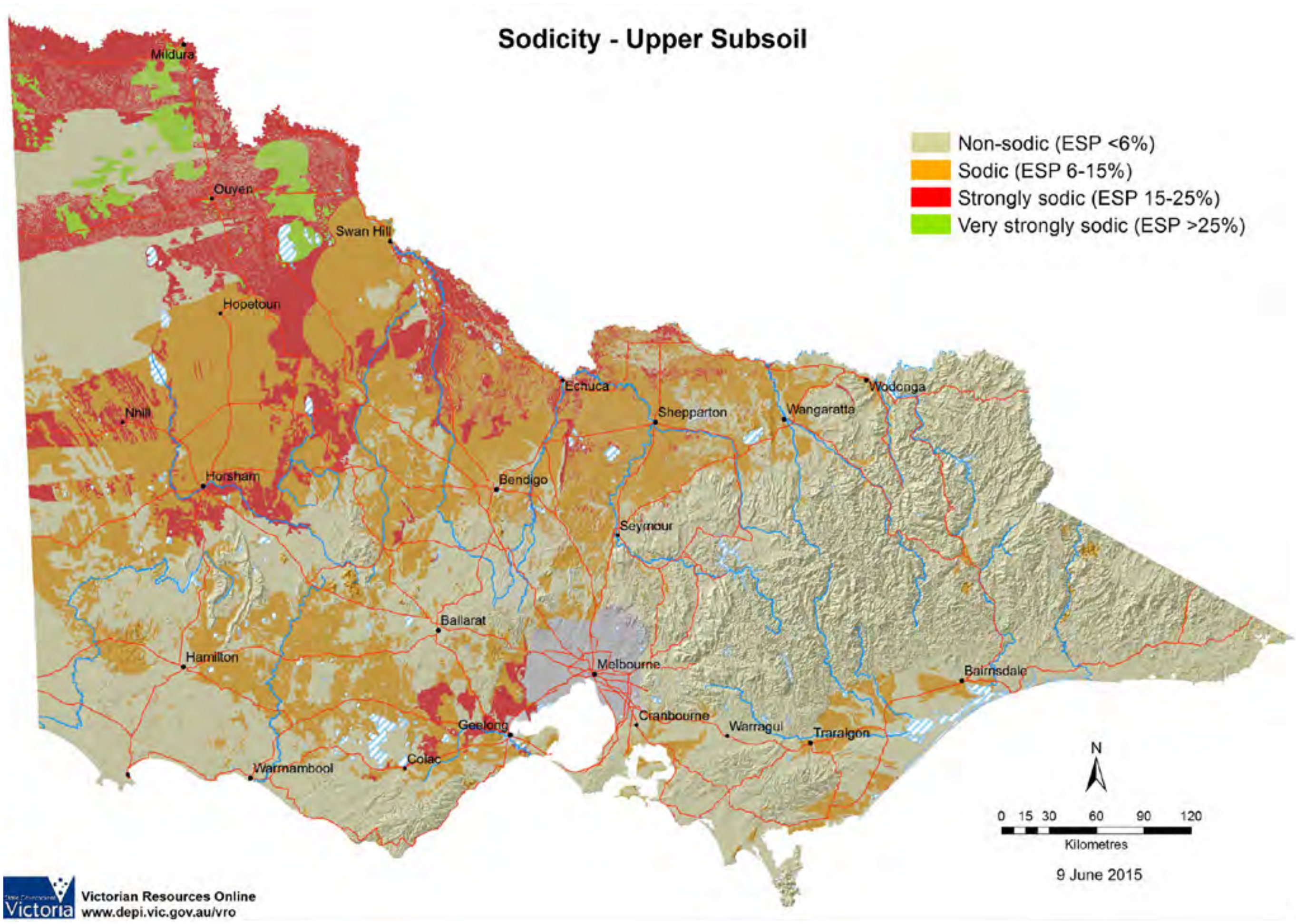

Figure 55 Mapping of upper subsoil sodicity across Victoria (source: Soil Sodicity, VRO, Agriculture Victoria)

1 *How do I manage the impact of sodic soils*? (ccmaknowledgebase.vic.gov.au)
2 Northcote, K.H. and Skene J.K.M., (1972). *Australian soils with saline and sodic properties, CSIRO Soil Publication 27.*

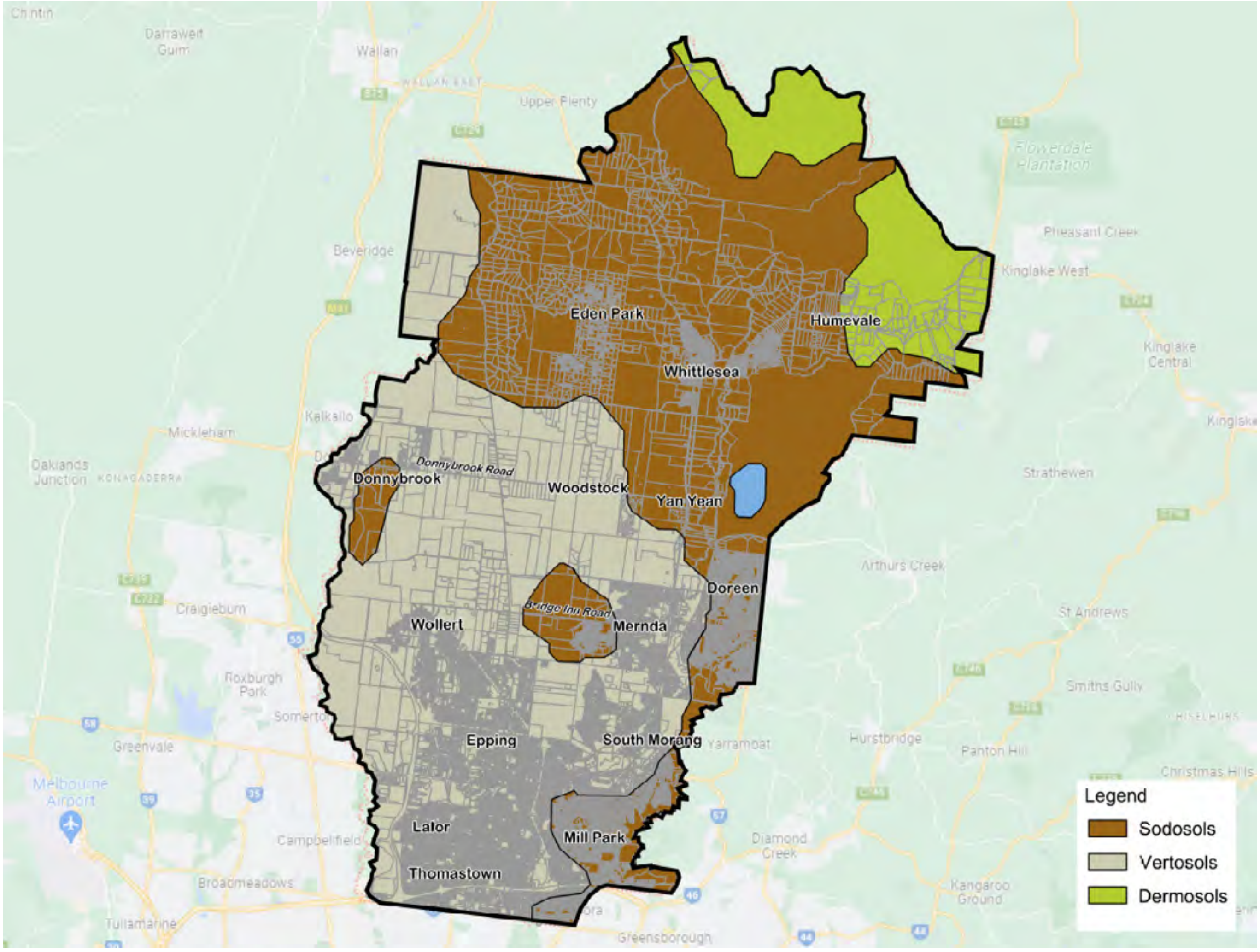

Figure 56 Atlas of Australian Soils on the Australian National Soil Information System (ANSIS)

A detailed description of soils can be found at the Second Edition of the Australian Soil Classification website (CSIRO, 2016).

More information on sodic soils in Victoria can be found on the Victorian Resources Online website, Sodic Soils, VRO, Agriculture Victoria.

The level of sodicity and corresponding risk can vary widely from mildly sodic soils (generally low ESP) to very sodic soils (generally high ESP) and risks can also be influenced by other factors such as soil structure and chemistry as well as vegetation. This can range from a minimal risk that can readily be managed through to areas where greater caution is needed to minimise disturbance and entry of fresh water through to extreme conditions where any form of earthworks and exposure of sodic soils can lead to uncontrollable impacts. In the latter case, it would be preferable not to undertake any works or development that may disturb overlying soils and vegetation and expose sodic soils. Land capability and suitability should therefore be assessed at an early stage of any planned works.

5.1.2 Indicators and impacts of sodic soils

Some common signs of sodic soils include:

- Poor vegetation growth.
- Shallow rooting depth.
- Poor water infiltration.
- Surface crusting.
- Dense or hard subsoil.
- Prismatic or columnar structure in the subsoil.
- Soapy feel when wetting and working up for soil textures.
- pH >8.5.
- Cloudy water in puddles.

Potential impacts of sodic soils on stormwater management assets:

- Reduced infiltration: sodic soils are highly dispersive and can form a surface crust, preventing water from infiltrating into the soils.
- High erosion: due to their dispersive nature, sodic soils will leach and erode when exposed to stormwater.
- Subsoil dispersion: dispersion in the subsoils leads to gully and tunnel erosion, impacting on the soil structure.
- Can cause chemical imbalances such as high pH impacting downstream WSUD assets, including stormwater harvesting schemes.

Sodicity versus salinity

Salinity is often confused with sodicity because both are associated with sodium. The salts in saline soils, however, prevent the dispersion of soil particles and therefore soil sodicity cannot be determined by the level of sodium alone and salinity levels should also be measured[3].

Sodicity is concerned with sodium only whereas salinity is not limited to just sodium and may have high levels of other cations/anions. Typically, high levels of sodium chloride pose the challenges.

It is important to note that if the soil is both sodic and saline it will not disperse.

3 Soil sodicity, Environment, land and water, Queensland Government (www.qld.gov.au)

5.1.3 Field observations and testing[4]

Preliminary field testing as outlined below can be undertaken to obtain an indication of dispersity.

1. **Dispersity:** dispersive risk can be assessed on site using the following approach (Carey, 2014)[5]:
    - Take a sample using a small spade or trowel of topsoil and subsoil.
    - Pour a small amount of distilled water or rainwater into a container.
    - Add 2-3 pea-solid soil aggregates from each soil layer.
    - Leave container on a table surface without disturbing it (DO NOT SHAKE).
    - Observe container and identify the scale of 'slacking' or dispersion based on the following information (note dispersion may be observed in as little as 10 minutes but may take up to 24 hours).

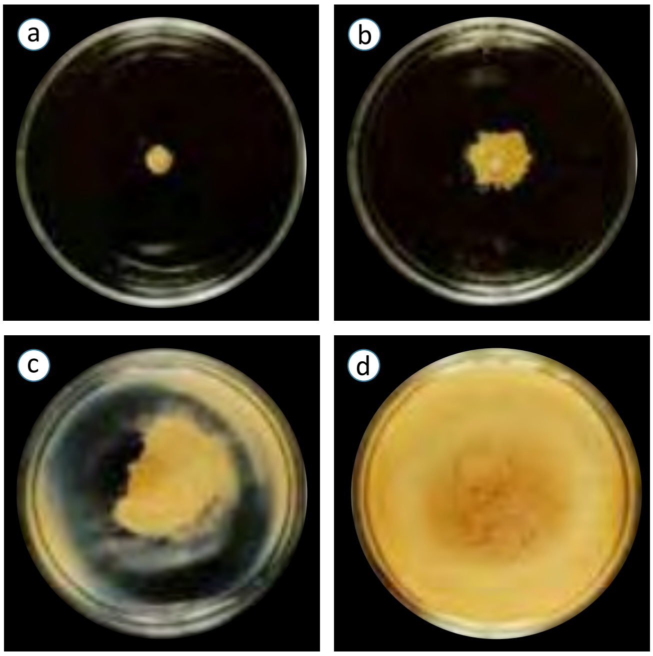

Figure 57 Soil slaking and dispersion test (source: Ipswich Soil Management Guidelines)

(a) If the aggregates stay together then the soil has good aggregate stability. The soil is largely stable in water.

(b) If the aggregates fall apart but the water remains clear, the aggregates have slaked. The soil is vulnerable to slaking (collapse) in water, but shows little or no clay dispersion.

(c) If the aggregates fall apart and some of the water is milky or cloudy, **the soil is dispersive**.

(d) If the aggregates fall apart and the water is milky or cloudy, **the soil is highly dispersive**.

4 *Soil Management Guidelines*, Ipswich City Council.
5 Carey B, (2014). *Understanding dispersive soils*, Landcare Queensland (www.landcare.org.au).

2. **pH:** soil pH can be estimated in the field using field pH kits.
    - Soils with a high pH (>8.5) can indicate presence of sodic soils.

If field assessments indicate the potential presence of sodic soils, a confirmation using laboratory testing is advised.

Note: Only suitably qualified and experienced geotechnical professionals should be engaged to undertake soil testing. The quick test described above can only be seen as a precursor to a legitimate testing report submitted to the City of Whittlesea as part of the development application.

5.1.4 Design considerations

Due to the risks associated with sodic soils coming in contact with freshwater, the design of stormwater management systems in areas with sodic soils requires careful planning.

While not specifically related to urban stormwater, there are many general guidelines which provide advice on sodic (or dispersive) soil management, including:

- *Dispersive Soils and their Management – Technical Reference Manual* (Government of Tasmania, 2009).
- *Soil Management Guidelines* (Ipswich City Council, 2014), Chapter 4.4.

For a regionally relevant findings report, also refer to *Wallan South Precinct Area Sodic Soils Assessment* (Victorian Planning Authority, 2021).

To appropriately manage sodic soils, the following key steps are required:

1. Identify if there are sodic soils present on the site or in the contributing catchment area of a proposed asset. Soils should be tested for both sodicity and salinity to determine dispersiveness.
2. If they are present, consider strategies for reducing risks associated with sodic soils. This includes considering a decentralised approach to stormwater volume reductions or runoff generation minimisation, promoting more permeable and absorbent surface textures across the catchment. Nominated treatment measures need to fulfill their function to mimic the natural hydrology of the catchment they receive.
3. Ongoing monitoring and management of the catchment and the asset to ensure the asset operates as intended.

The following outlines the preferred approach to working with sodic soils across the City of Whittlesea.

It is noted that these are design guidelines and that the designer must assess the risks based on the results of geotechnical testing, confirmed levels of sodicity, design considerations and an overall risk assessment. Designers are encouraged to discuss any proposed design responses for assets in areas with sodic soils with the City of Whittlesea.

Design consideration	City of Whittlesea preferred design response
Identifying presence of sodic soils	
Presence of sodic soils in the **contributing catchment**: • If sodic soils are likely to be present in the contributing catchment (based on available mapping), there is an increased risk of fine clay particles being transported in the stormwater and clogging downstream stormwater management assets. • If the catchment does contain sodic soils, consider use of WSUD systems which are more resilient to surface crusting (do not rely primarily on infiltration).	The type of stormwater management assets within sodic catchments can imply a disproportional increase in City of Whittlesea's operation and maintenance of stormwater assets. The following asset types are rendered as generally acceptable: End-of-line systems (preferred): ✓ Sediment ponds. The design of sediment ponds must take into consideration the settling of the sediments and the probable use of binding agents and other flocculation processes with the asset. ✓ Constructed stormwater treatment wetlands. At source systems: ✓ Passively irrigated street trees (lined). ✓ Swales. ✓ Permeable pavements (lined). ✓ Biofilters (lined). Assets located within a catchment with dispersive soils are at risk of receiving higher sediment loadings, and therefore, clogging of infiltration surfaces are likely to occur. This renders the following asset types as unsuitable for the catchment: ✗ Infiltration assets. ✗ Permeable pavements (unlined). ✗ Biofilters (unlined). ✗ Media filtration. For catchments with high sodicity levels, consideration should be given to whether the catchment is appropriate to be developed and whether erosion risks can be managed.
Presence of sodic soils **within the asset site**: • Soil tests should be undertaken on the site to determine if sodic soils are present. • This can include site observations and simple site-based tests through to taking soil cores and undertaking laboratory testing. • If sodic soils are present at the site (as determined through testing), there is an increased risk of concentrated infiltrated stormwater adversely impacting on the structure of underlying sodic soils.	Please see below for high level risk profiles and recommended mitigation approaches for stormwater management assets constructed in sodic soils.

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Design consideration	City of Whittlesea preferred design response
Consider strategies to reduce risk when working with sodic soils	
Avoid contact of sodic soils with water. • This can be achieved by minimising exposure of sodic soils during construction, diverting water around sodic soils, or creating a barrier to sodic soils.	Construction phase: ✗ Do not leave sodic soils exposed at the ground surface during construction. ✓ Divert stormwater flows away from and avoid ponded water on sodic soils. ✓ Ensure appropriate site management methods to maintain GED at all stages of development (addressing pre-DSS infrastructure flows and avoiding untreated discharge into waterways). Design and operational phase: ✓ Use of impermeable liners around the base and sides of assets proposed to sit within sodic soils. ✓ Use of engineered fill or other soil capping materials to cap sodic subsoils before planting into them. Minimum 300mm capping depth to be used where stormwater will be directed (such as swales, detention basins). **Note:** sodic soils can be ameliorated with gypsum to create a non-dispersive capping layer if there is a minimum of 100mm topsoil provided as cover (see below).
Soil **treatments**: • If avoidance is not possible, soils can be ameliorated with gypsum to increase salt levels and reduce the risk of dispersion. Gypsum displaces sodium from the cation exchange sites and replaces it with calcium. Soil particles can compact as they have thinner cation layers after reaction; this combined with the compressing nature of the released sodium in solution allows clay particles to densify. • Good surface cover through healthy vegetation establishment in quality topsoil reduces the risks in sodic soil areas.	• The use of gypsum is recommended to ameliorate sodic soils. Application rates can range from 2.5 to 25 t/ha[6] and should be determined by a qualified geotechnical practitioner. • Provide at least 75% cover of the soil (mulch or similar) for stability within 10 days of completing works and ensure dense coverage of vegetation for long-term surface protection. • There should be 100-300mm of non-dispersive topsoil provided to support vegetation growth above the capping layer. • Native sodic soils may also require compaction to reduce permeability and the potential for tunnel erosion to occur.

Table 22 Design considerations and preferred responses for working with sodic soils in the City of Whittlesea

6 Managing sodic, acidic and saline soils (agriculture.vic.gov.au); Best Practice Erosion & Sediment Control, Books 1-3 - International Erosion Control Association (austieca.com.au)

The concentration and infiltration of high volumes of stormwater into highly sodic soils must be avoided, particularly where this may put infrastructure and the environment at risk. However, the use of distributed assets that aim to absorb most of the volume while allowing infiltration rates comparable to natural conditions can be facilitated with good design and effective vegetation establishment. A considered design response could include:

- Ensure that the infiltration rate (mm/hr) of the WSUD asset into the underlying sodic soils is no more than would occur for that same footprint under natural conditions. Ways to achieve this may include:
  - Maximise the soil water retention capacity of the WSUD asset (soil volume and soil moisture retention capacity of the soil or media).
  - Maximise evapotranspiration from the WSUD asset.
  - Configure underdrains and submerged zones to ensure target infiltration rate is not exceeded.

  This generally applies to all vegetated sponges, passively irrigated tree pits and swales.
- Using topsoil or media combined with vegetation and trees to improve upper soil structure
- Allow water to be evapo-transpired to limit infiltration volumes.
- Ameliorating of underlying soils prior to placement of overlying soils or media.

There are many different stormwater management measures which have dissimilar risk profiles when exposed to sodic soils. The table to the right provides a high-level risk profile and proposed mitigation options based on available information. It is recommended that additional investigations are undertaken to more accurately identify the risk profile for a given site and asset design.

Asset type	Typical TCAR[7]	Typical hydraulic loading rate to underlying soil[8]	Sodic soil risk profile	Site risk mitigation recommendations
Infiltration trenches and basins	1-2%	High	Very high	Not preferred to use in sodic soils.
Permeable pavements	70-100% 20-70%	Medium-low High	Medium/high	Ensure capping layer is used to minimise risk of water entering sodic subsoils over larger areas.
Bioretention – lined	1-2%	Negligible	Low	The use of a liner reduces risk of localised reaction.**
Bioretention – unlined	1-2%	High-medium	High	This measure will require geotechnical investigation to inform sodic soil conditions and soil moisture modelling to understand the volume of water that may be entering the soil profile as a result of infiltration. Unlined bioretention systems may be acceptable where most of the volume is evapo-transpired or infiltrated depths are comparable to natural infiltration rates.
Passively irrigated street trees – lined	2-10%	Negligible	Low	The use of a liner reduces risk of localised reaction. Lining will limit potential size of the tree and canopy area. Increased risks of wind-throw and inadequate soil moisture due to containerisation of the tree will need to be considered.**
Passively irrigated street trees – unlined	2-10%	Medium-low	Medium	The risk is lower than bioretention as these systems are designed for water uptake by trees rather than act as a filtering system. However, geotechnical testing and soil moisture modelling is required to appropriately reduce the risk of native subsoil saturation. Unlined tree pits may be accepted where most of the volume is evapo-transpired, drained (via SSD) or infiltrated depths are comparable to natural infiltration rates.

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Asset type	Typical TCAR[7]	Typical hydraulic loading rate to underlying soil[8]	Sodic soil risk profile	Site risk mitigation recommendations
Sediment pond	0.5-1%	High	Medium/high	Must be lined with in-situ or imported materials. Geotechnical testing of soils is required to identify mitigation, including compaction, capping or soil amelioration.^ Additional flocculation practices need to be considered to ensure asset functionality.
Swale	1-3%	High-medium	Medium/high	Geotechnical testing of soils is required to identify mitigation, including compaction, capping or soil amelioration.^
Wetland	2-4%	Medium-low	Medium/high	Wetland must be lined with in-situ or imported materials. Geotechnical testing of soils is required to identify mitigation, including compaction, capping or soil amelioration.^
Ephemeral wetland	2-4%	Medium-low	Medium/high	Open water zones must be lined with in-situ or imported materials. Geotechnical testing of soils is required to identify mitigation, including compaction, capping or soil amelioration.^

** The lining of an asset must be supported by the assessment of a suitably qualified soil scientist.
^ Soil treatment/amelioration shall be verified by a qualified soil scientist.

Table 23 High-level risk profiles and recommended mitigation approaches for stormwater management assets constructed in sodic soils

7 Treatment to catchment area ratio
8 Volume of stormwater per m^2

5.1.5 Submission requirements

Where sodic soils are identified on a development site through a soil and land capability analysis, a sodic and dispersive soils investigation report must be prepared by a suitability qualified soil scientist with expertise and experience in sodic and dispersive soils, erosion and sedimentation control. The report must, as a minimum:

- Provide details of the location, classification and distribution of sodic or dispersive soils across the project area.
- Undertake a vulnerability assessment for the construction phase and post-development scenarios.
- Undertake an assessment of management actions required for all phases of the development and all assets, including modelling of the drainage scheme during interim and ultimate phases of construction, occupancy and post-development, and demonstrating how the Best Practice Environmental Management Guidelines and the Healthy Waterways Strategy will be delivered at all times.

5.1.6 Construction and establishment

Professionals managing or surveilling earthworks on any given site should demonstrate competencies in Site Environmental Management in accordance with AHCSAW203 and AHCWRK202 of the nationally recognised AHC16 training. When working on a site with sodic soils, it is important to ensure that the following general management principles are followed to reduce risks associated with dispersive soil reaction:

- **Retain** overlying **topsoil** and **vegetation cover** wherever possible as the best protection from soil erosion. High grasses and shrubs reduce runoff velocities.
- Minimise the **extent of exposure** by staging site clearing or topsoil stripping and construction works to smaller footprints and stabilising exposed soils as soon as practical.
- Do not leave sodic soils exposed. **Exposure times** are critical and may depend on soil sodicity levels and the resulting soil erodibility and soil loss factors. Further investigation is required to determine exact classifications. The City of Whittlesea recommends adherence to best practice land clearing and rehabilitation requirements (Table 4.4.7 in the *Best Practice Erosion & Sediment Control Guidelines* 2012, Book 1, Chapter 4), recommending:

  Non-sodic soils (<6 ESP) are to be classified as per Melbourne region erosion risk rating subject to monthly rainfall erosivity (Table 4.4.4 of above guidelines).

  Moderately sodic soils (<15 ESP) are to be treated as **high-risk** sites at any given time.

  Strongly sodic soils (>15 ESP) are to be treated as **extreme risk** sites at any given time.

- **Cover** dispersive subsoils with a 150mm gypsum-treated topsoil when works pause for critical durations.
- **Divert flows** away from disturbed areas and stockpiles.
- **Avoid ponding** to occur on dispersive soils. This includes backfill over trenches not resulting in minor depressions.
- Divert sediment laden runoff to designated treatment locations. Temporary sediment ponds may require flocculation processes for EPA-compliant water discharge quality.
- Ensure all water its treated to EPA levels at all times of the development process.
- **Limit** the extents of **open trenches** to a workable minimum at any given time.
- Use of **sealed pipes** in lieu of open channels where practical.
- Ensure dust is appropriately managed during dry periods.

Revegetate surfaces immediately upon completion of earthworks and speed up the process of vegetation establishment using appropriate fertilisers. A site-based erosion and sediment control plan is required as part of a Site Environmental Management Plan, to inform how these risks will be addressed during construction phase and asset establishment. An additional useful guideline to inform this plan is the *International Erosion Control Association (IECA) Best Practice Erosion & Sediment Control Guidelines* (2012), with associated standard drawings and technique fact sheets.

It is the contractor's responsibility to perform the General Environmental Duty in accordance with the *Environment Protection Act 2017* and ensure at all times during the construction activity that the site discharge is in agreement with the water quality normally found in Whittlesea's freshwater streams. Site discharge turbidity shall therefore not exceed the maximum Nephelometric Turbidity Units (NTU) as per the Environment Reference Standard.

5.1.7 Asset operation and maintenance considerations

Stormwater management assets which have been delivered on sites with sodic soils will require ongoing monitoring to identify if there is an erosion or sedimentation risk that needs to be addressed. Key items for inspection will include the presence of any tunnel or rill erosion around the site or the presence of fine clay or crusting on the surface of the asset.