WWL GUI MUSIC (Model for Urban Stormwater Improvement Conceptualisation)

Guideline

Water quality, harvesting, and infiltration

July 2026

VICTORIA State Government

Melbourne Water makes a vital contribution to the famous Melbourne lifestyle through the supply of high-quality water, reliable sewerage services, integrated drainage and flood management services and by enhancing our waterways and land for greater community use.

Melbourne Water
Enhancing Life and Liveability

Table of contents

Acronyms and Abbreviations

Term	Definition
AEP	Annual exceedance probability
ARI	Annual recurrence interval
Baseflow	The component of streamflow supplied by groundwater discharge
BPEM	Best practice environmental management, specifically the *Best Practice Environmental Guidelines for Urban Stormwater* (Victorian Stormwater Committee, 1999)
Development	Includes construction or carrying out of works, including building and road construction
EDD	Extended detention depth
EPA	Environment Protection Authority (Victoria)
EPA SWMM	Environment Protection Authority (United States) Storm Water Management Model
Evapotranspiration	Water that is lost to the atmosphere via evaporation from land and water surfaces plus transpiration from vegetation
EY	Exceedances per year
Flow regime	The range of flows that a waterway experiences throughout the seasons and years, which may include baseflows, low flows, high flows, overbank flow and cease to flow (drying) events
Groundwater dependent ecosystem (GDE)	Natural ecosystems that require access to groundwater to meet all or some of their water requirements to maintain their ecological processes
Gross pollutants	Material that would be retained by a five-millimetre mesh screen
Harvest	Rain that is captured for potential use and prevented from entering a waterway
Hectare (ha)	Ten thousand square metres
Hydrologic regime	Changes with time in the rates of flow and in the levels and volumes of water in rivers, lakes, and water sensitive urban design (WSUD assets; the hydrologic regime is closely related to seasonal changes in climate but is also influenced by catchment vegetation, soils and urban development)
Impervious	Impermeable; sealed surfaces that do not allow water to infiltrate or be absorbed
Infiltrate/filter	Runoff from impervious surfaces that soaks into the ground (infiltrates) or is slowly (mimics the infiltration rates of the surrounding soil) released to the drainage system from a stormwater management asset (filter)

Term	Definition
Integrated water management	Integrated water management is a collaborative approach to planning that brings together organisations that influence all elements of the water cycle, including waterways and bays, wastewater management, alternative and potable water supply, stormwater management and water treatment. It considers environmental, social and economic benefits.
Low flow	Water that creates a continuous flow over the bottom of the waterway channel but does not fill the channel to any great depth. The term is most often used in relation to baseflows that occur over the drier periods of the year that are sustained for some period (weeks to months), due to short bursts of rain.
Nature-based solutions	The use of natural features and processes, such as earthen physical form combined with vegetation, to manage stormwater as applied through stormwater wetlands or biofilters. Nature-based solutions are the preference of Melbourne Water within Development Services Schemes[1].
NWL	Normal water level
Overbank flows	Water that spills over the waterway channel onto the floodplain
Stormwater	Rainfall that runs off roofs, roads, and other urban surfaces into gutters, drains, creeks and rivers, and eventually into the sea
Treatment train	A sequence of stormwater treatment assets designed to manage potential impacts to downstream aquatic environments
Urban	Areas that are developed for residential, industrial, or commercial activities, including roads
Waterway	Has the same meaning as in the *Water Act 1989* and includes a river, creek, lake, or other body of water
WSUD	Water sensitive urban design – an approach to urban planning and design that aims to minimise the hydrologic impacts of urban development on the surrounding environment.

[1] https://www.melbournewater.com.au/building-and-works/developer-guides-and-resources/drainage-schemes-and-contribution-rates/find-your#/

1. Purpose

The purpose of this document is to provide guidance on modelling approaches and input parameters for stormwater models. The guideline assumes use of the MUSIC (Model for Urban Stormwater Improvement Conceptualisation) model but may also be used to inform other models.

MUSIC is a software that simulates rainfall, stormwater runoff, flows and pollution. It also simulates pollutant removal and flow reduction through stormwater management assets such as sediment ponds, stormwater wetlands, bioretention and stormwater harvesting.

The objectives of this guideline are to:

- provide clear guidance to users of MUSIC
- ensure that a consistent, fair, and evidence-based approach is applied to MUSIC models
- be specific to the climate and geology of the Melbourne region
- further the state of knowledge for urban stormwater management

The General Environmental Duty (GED) contained in the Environmental Protection Act 2017 states that:

A person who is engaging in an activity that may give rise to risk of harm to human health or the environment from pollution or waste must minimise those risks, so far as reasonably practicable.

Determining what is reasonably practicable relies on a number of factors, including the 'state of knowledge', which describes the body of accepted knowledge that is known or ought to be reasonably known about the harm or risks of harm to human health and the environment and the controls for eliminating or reducing those risks.

This document is industry guidance contributing to the state of knowledge; it furthers our understanding of what controls are available, suitable, and reasonably practicable.

2. Scope

This guideline is intended for use by members of the land development industry who submit stormwater models using MUSIC or equivalent to Melbourne Water to meet their statutory planning requirements for the design of stormwater treatment systems, for example in Development Services Schemes (DSS). It is also intended for stormwater management practitioners wishing to apply stormwater flow management measures in addition to stormwater quality measures. Users should check the applicability of this guideline when preparing models for other needs. Other professionals working within the stormwater management and land development industry may also find this resource useful.

This document covers catchment model set-up, model configuration, input parameters for source and treatment nodes, and how to use MUSIC to evaluate stormwater objectives. It also includes Melbourne Water's submission requirements for stormwater modelling, where required, as well as useful procedures for modelling. It does not cover design guidance or engineering standards. It does not cover the use of other models. Users should read this document alongside appropriate design guidelines such as:

- *WSUD Engineering Procedures: Stormwater* (Melbourne Water, 2005)[2]
- *Wetland Design Manual* (Melbourne Water, 2020)[3]
- *Biofiltration systems in Development Services Schemes Guideline* (Melbourne Water, 2020)[3]
- *Emerging assets for stormwater flow management – State of Knowledge document* (Melbourne Water, 2025).[4]

> Note, MUSIC can help predict potential flow volume and pollutant removal for a design but is not the only validation. MUSIC is not suitable for validating drainage design for flow conveyance and flood mitigation. Other referral authorities, including councils, may have their own additional MUSIC modelling requirements.

Version compatibility

This guideline was developed for use with MUSIC version 6.3. However, the underlying science within MUSIC X is unchanged. The same guidance and recommendations apply for MUSIC X, although the look of the interface and pathways to some functions may differ.

At the time of publication MUSIC X has a similar feature set to MUSIC version 6.3 with some variations in the features and functions available to users. Certain features including some that may be referenced within the guideline have been hidden or removed, while it is likely new features will be added over time. Users should refer to the MUSIC user manual for guidance on any new features.

Disclaimer

Melbourne Water and the guideline authors do not accept responsibility or liability for any use of, or reliance, on the guidelines by third parties.

---

2 https://www.publish.csiro.au/book/4974/
3 https://www.melbournewater.com.au/building-and-works/developer-guides-and-resources/guidelines-drawings-and-checklists/guidelines
4 https://clearwaterprod.prod.acquia-sites.com/news/emerging-assets-state-knowledge-stormwater-flow-reduction-guidance-melbourne-water

Updates to this guideline

This revision of the guideline provides new guidance, including:

- stormwater objectives including harvesting/evapotranspiration and infiltration objectives
- guidance on infiltration
- modelling approaches for emerging asset types that support harvesting/evapotranspiration and infiltration objectives and greater flexibility
- calculation methods for stormwater harvesting/evapotranspiration and infiltration objectives.

The emerging asset types covered in this document are:

- passively watered trees
- vegetated sponges
- ephemeral stormwater wetlands
- wicking beds
- slow release rainwater tanks
- permeable paving.

A *state of knowledge* document outlining the current understanding of these assets has been developed alongside this guideline. It is anticipated that further documents building on this will be released in the future, reflecting the evolving state of knowledge.

3. Stormwater objectives addressed by this guideline

Policy and statutory planning requirements

The *Best Practice Environmental Management Guidelines for Urban Stormwater* (Victoria Stormwater Committee, 1999)[5] (referred to as BPEM) set out objectives for stormwater management.

These objectives, referenced in the Victorian Planning Policy Framework, are to reduce typical urban stormwater pollutant loads by:

- 80% for total suspended solids (TSS)
- 45% for total phosphorus (TP)
- 45% for total nitrogen (TN)
- 70% for gross pollutants.

The objectives and statutory planning requirements apply to Melbourne Water's management district, including both the Port Phillip Bay and Western Port catchments. Designers addressing the BPEM objectives must clearly document and explain the design intent for any treatment asset with Melbourne Water early in the concept design stage.

It is usually expected that MUSIC will be used for the design of stormwater quality assets. Designers may alternately choose methods or models other than MUSIC (for example, EPA SWMM) to demonstrate performance targets are achieved. The intended approaches should be discussed and agreed with the relevant authority in advance. The acceptance of such methods may require additional review effort and time (which may include external review) and acceptance of alternatives is wholly at the discretion of the relevant authority.

Melbourne Water, councils, the EPA, and other authorities have legal obligations to protect the beneficial uses of receiving waters and may at their discretion further require additional stormwater management levels depending on the receiving environment.

In 2017, the *Environment Protection Act 2017* was amended. It introduced the *General Environmental Duty (GED)*, which came into effect on 1 July 2021. This duty requires all Victorians to "*minimise, so far as reasonably practicable, risks of harm to human health and the environment*". To do this, all Victorians have an obligation to practice under the *state of knowledge*.

In 2024, obligations relating to the management of urban stormwater were set for councils in the Obligations of managers of land or infrastructure (Urban stormwater management and On-site wastewater management) (the OMLI). Clause 5 of the OMLI continues the requirement from the now expired State Environment Protection Policy (Waters) for councils to develop, review, and update stormwater management plans (or their equivalent). These plans must identify stormwater risks and outline actions to address them, in consultation with relevant stakeholders.

Since publication of the BPEM Guidelines, the scientific and industry understanding of stormwater impacts and risk management approaches has evolved. This has led to a shift in focus from primarily managing stormwater quality to also managing stormwater flows.

---

[5] The latest BPEM information is available via the CSIRO website: https://www.publish.csiro.au/book/2190/#details

Melbourne Water Development Services Schemes provide for drainage, flood protection, and water quality as set out in the Principles for provision of waterway and drainage services for urban growth[6]. At the time of publication of this guideline, they do not generally provide for stormwater flow volume objectives for waterway protection.

Other strategies and guidance

The following state of knowledge and industry guidance provide information on managing stormwater flows in addition to stormwater quality.

Healthy Waterways Strategy

In 2018, Melbourne Water released the Healthy Waterways Strategy 2018-28 (HWS) which recognises that urbanisation increases stormwater volumes, intensity, and frequency of peak flows and that these are a key threat to waterway health. The strategy identifies new flow-based stormwater targets for priority catchments across Melbourne, made up of two elements:

1. Harvesting and evapotranspiration
2. Infiltration

The target for harvesting and evapotranspiration seeks to reduce the volume and frequency of uncontrolled urban excess stormwater flows from damaging downstream waterways by maximising the volumes and probability of stormwater excess flow events being retained and/or attenuated within the catchment during rainfall. The target for infiltration seeks to restore lost subsurface flows (infiltration to soil, groundwater recharge, and baseflow to waterways). Prior to urbanisation, this water would naturally have been absorbed by the soil before evapotranspiration or infiltration. These targets are calculated based on annual rainfall and therefore vary (with the climate) across the strategy area. In the HWS the targets are specific to each sub-catchment.

Following the release of the HWS, the EPA and Melbourne Water worked together to produce two new guidance documents:

- Environment Protection Authority's Publication 1739, Urban Stormwater Management Guidance (EPA, 2021)[7] ("EPA Guidance")
- Healthy Waterways Strategy Stormwater Targets Practitioner's Note[8] (Melbourne Water, 2021) ("HWS Practitioner's Note")

EPA Urban Stormwater Management Guidance (EPA, 2021)

Building on the BPEM objectives for stormwater quality, the EPA Guidance additionally sets out urban stormwater flow volume performance objectives. The objectives "can be used as a signal of the level of risk of waterway values being lost or impacted"; the risk management required is dependent on what is *reasonably practicable*[9]. Like the HWS targets, the flow objectives are made up of two components:

---

6 https://www.melbournewater.com.au/sites/default/files/Principles-for-provision-of-waterway-and-drainage-services-for-urban-growth.pdf
7 https://www.epa.vic.gov.au/about-epa/publications/1739-1
8 https://www.melbournewater.com.au/building-and-works/developer-guides-and-resources/guidelines-drawings-and-checklists/guidelines
9 https://www.epa.vic.gov.au/1856-reasonably-practicable

Harvesting/ evapotranspiration (expressed as a percentage of mean annual impervious runoff)

Infiltration/ filtering (expressed as a percentage of mean annual impervious runoff)

As with the HWS targets, these flow objectives account for regional variations in annual rainfall. The objectives set out in the EPA Guidance are specific to rainfall bands (in 100mm increments) to be applicable across the state.

> The EPA defines the infiltration and filtering as runoff from impervious surfaces that soaks into the ground (infiltrates) or is slowly released (mimics the infiltration rates of the surrounding soil) to the drainage system from a stormwater management system (filter).

Healthy Waterways Strategy Practitioner's Note (Melbourne Water, 2021)

The EPA and Melbourne Water produced the HWS Practitioner's Note to develop a consistent framework, whereby the targets within the HWS and the EPA Guidance are aligned. They reflect current scientific and industry knowledge, and enable the use of appropriate hydrological data. In priority stormwater areas, the flow targets are the combined equivalent of reducing impervious runoff by 70-80%; for other areas, reducing impervious runoff by ~35% (Figure 1).

The HWS Practitioner's Note provides specific stormwater targets for the rainfall templates used in Melbourne Water's operating area. The targets for the current rainfall templates (updated in 2024) are provided in Table 1. More information on the templates can be found in Chapter 4, Catchment model set-up - Climate data.

Refer to the HWS Practitioner's Note for full details of the stormwater targets for Melbourne's rainfall regions.

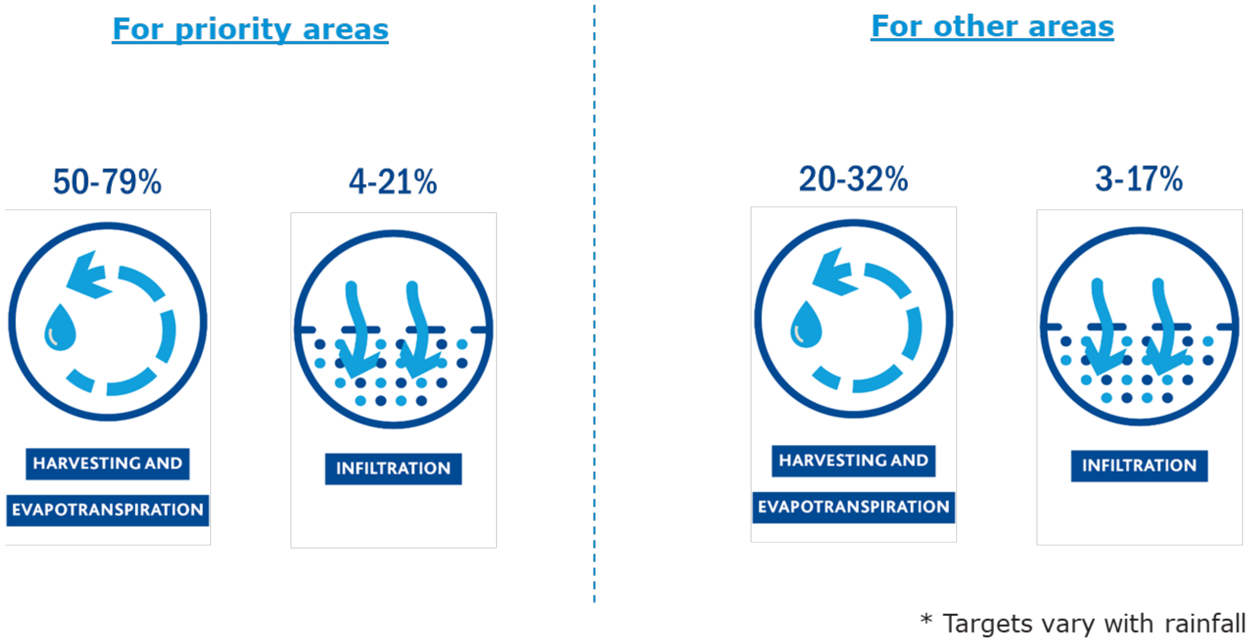


Figure 1 Harvesting/evapotranspiration and infiltration (including filtered flows) targets are set for priority and other areas and differ for each rainfall region.

Methods for assessing achievement of these objectives can be found in Chapter 9.

Principles for achieving infiltration or filtered flows

Infiltration and filtered flows may be defined as:

> **Infiltration** – Treated stormwater runoff from impervious surfaces that is allowed to infiltrate into the soils, recharge groundwater and potentially return to waterways as base flows between storm events.
>
> **Filtered flows** – Treated stormwater runoff that is slowly released to the stormwater drainage system in a controlled manner with a pattern that mimics the processes of infiltration and natural base flows.

The principles for achieving the infiltration targets in practice are explained to ensure practitioners can understand how to act in accordance with their intended purpose.

- **Infiltration should be the first priority** over filtered flows in achieving the target as this fits the purpose of restoring groundwater recharge and lost subsurface flows.
- Where infiltration objectives cannot be met through infiltration alone, filtered flows may additionally be used to contribute to the target.
- **Infiltration and filtered flows are expressed as a range**, indicating the range in potential natural infiltration from forested to grassland. This is set by the lower and upper range of the target curves in Figure 2 and expressed as stormwater runoff flow per impervious hectare (ML/ha/year) and as a percentage of the impervious stormwater runoff generated in the catchment. Refer to the EPA Guideline and HWS Practitioner's Note for further details.
- When using infiltration and filtered flows, it is particularly important to ensure flows credited towards the infiltration target do not exceed the base flow rates that would have occurred naturally. This is because filtered flows directly connected to waterways via drainage present a potential risk to waterways where they exceed the natural baseflow rate of the waterway and result in periods of persistent, potentially erosive or overbank flows that can be physically and ecologically damaging to waterways. Therefore, **for the combined total of infiltration and filtered flows, the upper threshold applies on a daily basis**. This is expressed in Table 1 as a daily upper limit in kL/ha/day.

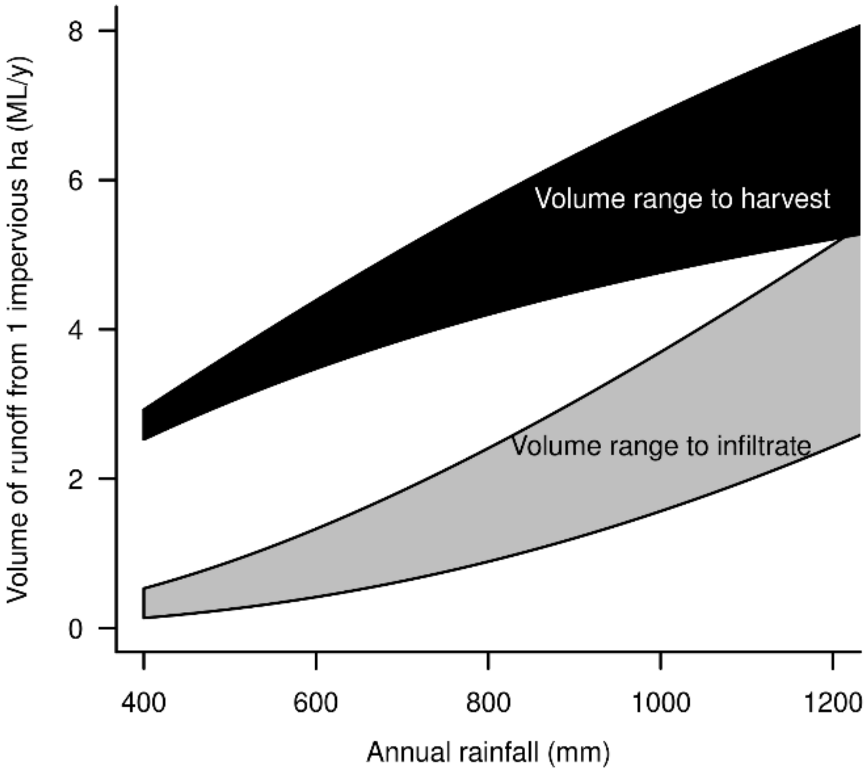


Figure 2 Impervious runoff volumes to harvest and infiltrate across rainfall gradients (Walsh, et al., 2012)

Table 1 Priority and other areas target applicable to Melbourne Water's rainfall templates

Template	Model ave. rainfall	Runoff	Priority areas				Other Areas				Infiltration upper limit
			Harvesting target		Infiltration target		Harvesting target		Infiltration target		
	mm/year	ML/year*	ML/year* (and %)								kL/day
Little River	472	3.7	2.9	(79 %)	0.1	(4 %)	1.2	(32 %)	0.1	(3 %)	2.0
Melbourne Airport	573	4.6	3.4	(74 %)	0.4	(8 %)	1.3	(29 %)	0.3	(6 %)	3.2
Melbourne Regional	708	5.8	3.9	(67 %)	0.7	(12 %)	1.6	(27 %)	0.5	(9 %)	5.1
Bullengarook East	770	6.3	4.1	(65 %)	0.8	(13 %)	1.6	(26 %)	0.7	(10 %)	6.0
Dandenong	773	6.4	4.1	(65 %)	0.8	(13 %)	1.7	(26 %)	0.7	(11 %)	6.1
Narre Warren North	932	7.8	4.6	(59 %)	1.3	(16 %)	1.8	(23 %)	1.0	(13 %)	8.7
Toolangi (Mount St Leonard DPI)	1221	10.6	5.3	(50 %)	2.2	(21 %)	2.1	(20 %)	1.8	(17 %)	14.4

*from 1 impervious hectare

4. Catchment model set-up

Climate data

Melbourne Water provides MUSIC rainfall templates for 10-year periods. Users can download these from Melbourne Water's website[10] under 'Tool Guidelines' and save them to a folder for ready access. All models submitted to Melbourne Water must use Melbourne Water's rainfall templates unless written permission is provided by Melbourne Water. To use the templates, click the 'Open template from a different directory' icon and navigate to the saved template location where the downloaded templates were saved (see Figure 3).

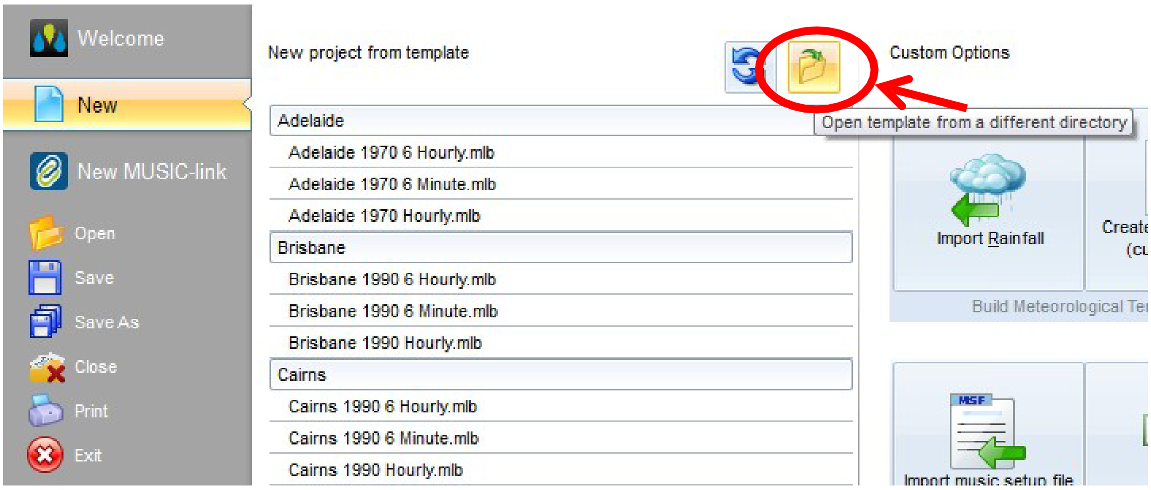


Figure 3 Step to select a Melbourne Water provided 10-year rainfall template

The rainfall distribution map (Figure 4) can be used to find the appropriate rainfall template and corresponding weather station for a site. The 'Tool Guidelines' website section provides a JPEG large-scale version of the map, ESRI and MapInfo layers, and the rainfall templates. A summary of the rainfall templates with mean annual rainfall and evapotranspiration is provided in Table 2.

10 https://www.melbournewater.com.au/building-and-works/developer-guides-and-resources/guidelines-drawings-and-checklists/guidelines

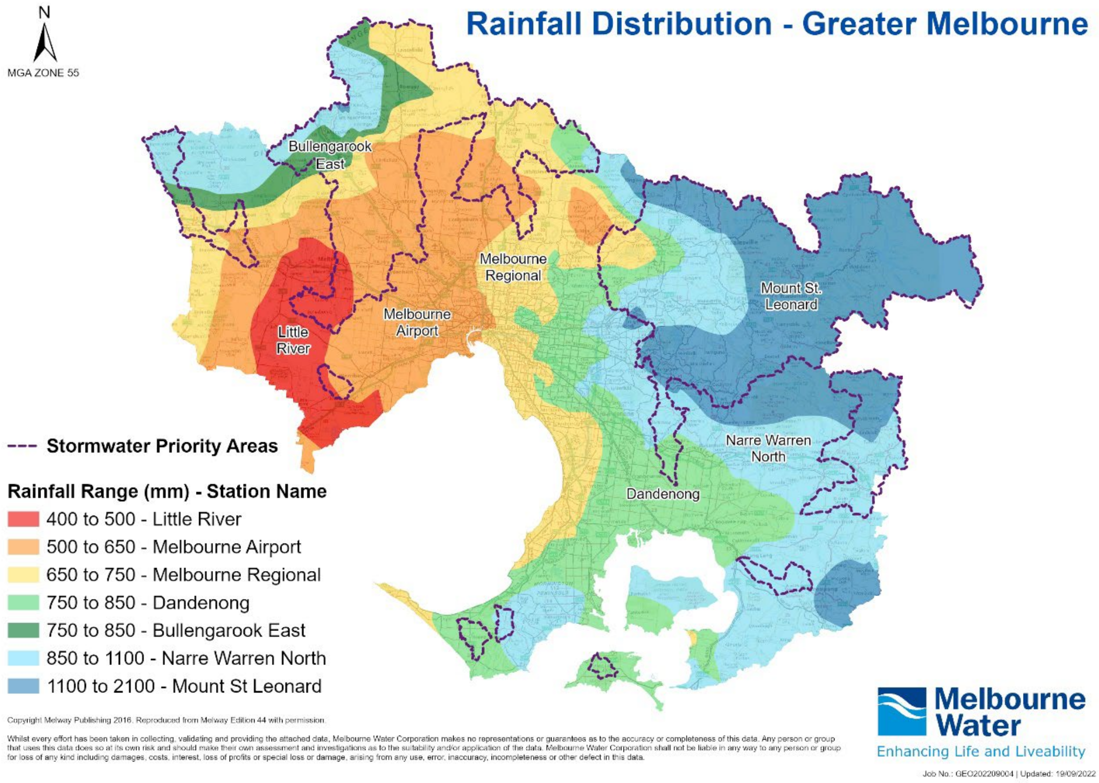


Figure 4 Rainfall template selection map

Table 2 Rainfall templates with mean annual rainfall and evapotranspiration

Rainfall band	Rainfall station	Period	Mean annual rainfall	Evapo-transpiration
400-500	87033 Little River	1992-2001	472	1067
500-650	86282 Melbourne Airport infilled	1987-1996	574	1047
650-750	86071 Melbourne Regional	1952-1961	708	995
750-850 West	87075 Bullengarook East	1990-1999	779	1043
750-850 East	86224 Dandenong	1967-1976	777	1027
850-1,100	86085 Narre Warren North	1984-1993	933	985
1,100-2,100	86142 Toolangi (Mount St Leonard DPI)	1995-2004	1,221	962

Climate data including rainfall and evapotranspiration are essential inputs to MUSIC. MUSIC is a continuous simulation model and requires an input time series of rainfall data.

Where alternate rainfall templates are proposed, these should be discussed and confirmed with the relevant authority. These require additional effort and should generally only be proposed where there is a clear need or demonstrable change in outcomes. These may require additional review time and effort. Acceptance of alternatives is wholly at the discretion of the relevant authority. If you intend to model using an alternate rainfall template, rainfall data is available from the Bureau of Meteorology at a 6-minute timestep for several gauges across Melbourne Water's service area[11]. The selection of a rainfall gauge and period should consider:

- Local rainfall patterns for the site of interest: This may include seasonal and annual variability. Check if the data sub-daily rainfall gauge and chosen period has a similar range of mean annual and mean monthly flows to the observed data from relevant daily gauges. Regions with more variable rainfall (such as arid areas) may warrant using a longer time series (e.g. 20 years) to ensure a representative range of conditions are modelled.
- Completeness of record: Check if the gauge chosen has significant missing or accumulated data. If so, can these be infilled with data from another gauge with a good statistical correlation to the gauge of interest. Some gaps are acceptable for stormwater quality assessment, but when assessing yields and drying spells, it is essential that these gaps are filled. The Bureau of Meteorology flags most missing and accumulated data. Some gaps during which stations are not recording may remain unflagged although these are usually a small proportion of most datasets. Care must be taken when infilling to not over infill periods of zero rainfall and inappropriately remove valid periods where no rainfall occurred.
- Representation of a range of conditions including wet and dry periods and a variety of storm events of varying size and antecedent dry periods: Does the period chosen include both wet and dry years and at least some storm events that are less frequent?
- Purpose of the model: A relatively short period (5-10 years) may be adequate for assessment of stormwater quality and percentage reductions in mean annual loads. At least 10 years is desirable for assessing rainwater or stormwater harvesting yields. Wetter or dryer periods may also be used as a sensitivity check. A longer period may be preferred for assessment of effects on downstream hydrology and flow duration curves.

The choice of meteorological data is a balance between the level of accuracy required and the time and effort required for modelling. The templates Melbourne Water provides represent the rainfall variations across metropolitan Melbourne.

[11] http://www.bom.gov.au/climate/data/stations/

The following periods are recommended for different applications:

≥10 years

- all Development Services Scheme designs and precinct-scale integrated water management strategies
- modelling of areas including significant areas of pre-development, rural or pervious land
- analysis of flow frequency objectives such as number of flow days, stream erosion index and flow frequency curves.

20+ years (optional)

- regional and catchment-scale integrated water management strategies
- waterway flow analyses
- analysis of large pervious catchments (>100 ha).

Timestep

All models must be run at a 6-minute timestep where possible. Using longer timesteps (particularly daily) can result in significant errors and increase the variability of the results. Where a different timestep is adopted, it must comply with the following:

The timestep must be equal to or less than:

- the time of concentration of the smallest sub-catchment
- the shortest detention time (under design flows) of the treatment measures being modelled.

Circumstances where a different modelling timestep may be appropriate include:

- concept level modelling of systems that have long times of concentration and detention times, such as rivers or lakes, where no representative 6-minute data is available
- where a larger timestep is required to interface with another model and allow consistent rainfall to be used. Usually, it is preferred to run MUSIC at a 6-minute timestep and export results at an appropriate longer timestep.

Catchments and source nodes

Source node selection

For most catchment modelling purposes, urban land uses, and surface types can be combined and represented with a single set of pollutant concentration data.

The following nodes are recommended for representation of catchments:

- urban node with “mixed” zoning/surface type for most modelling purposes to represent existing and new urban areas (including a mix of residential, commercial, industrial, parkland and other land uses within an urban area)
- forest nodes should be used only for representing catchments that are mostly old growth or well-established forested areas
- agricultural nodes for actively farmed rural areas which may have elevated nutrient concentrations.

The use of these land use pollutant concentrations (mostly the urban node) is generally recommended for most modelling of greenfield developments since most of the treatment assets are usually receiving flows from a mix of surface types. For these conditions, there is limited value in developing a detailed breakdown of surface types.

Pollutant concentrations differ significantly between road and roof surface types, and some stormwater management responses focus strongly on one or both. To provide more representative outcomes when modelling these responses, it is preferable to adopt separate source nodes representing different surface types. This should be done when most of the overall treatment performance comes from the following:

- roof water harvesting (roof runoff to rainwater tanks)
- direct streetscape treatments treating only roads and not a mix of surface types
- catchments with a mix of surface types that is very different to a typical urban area (for example, mostly roof or mostly road).

These are most applicable for smaller infill, brownfield and retrofit sites which may have significantly skewed surface types.

For guidance on representing pollutant concentrations for these surface types refer to *Pollutant concentration data* within this document.

Impervious fraction

Total impervious area

The impervious fraction is the proportion of a catchment that is impervious to rainfall and produces significant amounts of surface runoff. This impervious area is commonly referred to as total impervious area (TIA) or total imperviousness (TI).

Directly connected imperviousness

Directly connected imperviousness (DCI) or directly connected impervious area (DCIA) is the proportion of the impervious surfaces that are directly connected to conventional drainage.

The directly connected impervious area may be lower than the total impervious area due to impervious areas discharging over adjacent pervious and vegetated areas.

The DCI is often assumed to be analogous or similar to the effective imperviousness (EI)[12] or effective impervious area (EIA).

The effective impervious area may be further influenced by leakage from drains, channels and waterways, retention by stormwater treatment measures and other factors before it reaches a waterway flow. The EI is difficult to estimate for a new development area. In practice, it is more practical to use DCI as a surrogate.

The total imperviousness must be used for all water quality modelling in MUSIC including sizing of stormwater quality treatment assets and development planning applications. This will help to reduce the potential for under-sizing of stormwater quality assets.

[12] Note that some guidelines refer to effective impervious area and use it in a similar way to directly connected imperviousness as defined here

New greenfield and infill development

New development areas often have a relatively high total impervious fraction with large buildings and other paved areas. The corresponding permeable surface area, which provides potential opportunity for disconnection to occur, is much less than for historical residential development. Modern construction approaches are also more likely to provide effective drainage for most impervious surfaces given the larger buildings and limited opportunities to leave impervious surfaces disconnected.

It is recognised there may still be disconnection occurring through leaky drains or waterway losses which are reflected in calibration to waterway flows. However, the extent of these is uncertain and given that treatment needs to occur prior to discharge to waterways, waterway losses should not be relied upon.

As a general principle for new development the *total imperviousness (TI) should be assumed to be equal to the directly connected imperviousness (DCI)* and modelled as impervious. This helps ensure that stormwater quality treatment assets are adequately sized to treat all of their likely catchment.

Directly connected impervious fractions for stormwater harvesting in existing urban areas

The guidance within this section is intended specifically for stormwater harvesting in existing urban areas with mostly older (>20 years) housing stock.

In existing urban areas, the directly connected impervious area, as estimated through flow calibration may be significantly less than the total impervious area. This may be due to intentional and incidental disconnection of impervious areas, leakage from existing drainage and infiltration losses in waterways.

Disconnection may occur due to some structures being identifiable as impervious but not connected to drainage, intentional disconnections, or the use of rainwater tanks and other WSUD responses.

Total impervious area may over-estimate flow volumes and harvesting yields from existing urban areas. Specifically, for the design and estimation of yield for retrofit stormwater harvesting schemes within existing urban areas, stormwater reuse volumes should be estimated using directly connected imperviousness.

To estimate DCI in existing urban areas, Melbourne Water may be able to supply impervious area mapping for a catchment of interest upon request. Alternatively, users can assume directly connected imperviousness makes up two-thirds (67%) of total imperviousness. This assumption is based on previous mapping of total and directly connected imperviousness by Melbourne Water, which suggests that on average DCI in existing areas may make up around two-thirds of total imperviousness, although this varies widely.

Users should exercise caution and judgement in applying the above assumption or undertake a more thorough assessment where warranted.

At-source WSUD and disconnection responses

The total impervious areas draining to any recognised WSUD asset such as a raingarden should be represented in the model as impervious areas.

If an impervious area is to be intentionally ‘disconnected’ through drainage over a vegetated pervious surface, the proposed disconnection may be explicitly designed and modelled with the pervious area represented using a modified bioretention, buffer or swale node as appropriate.

This may be used to represent a 'downspout disconnection' where a roof drains to a garden or a driveway drains via sheet flow over an adjacent lawn area. In these cases, the ownership and assurance of ongoing retention and maintenance arrangements for the vegetated pervious area should be confirmed to the satisfaction of the relevant authority.

General guidance

Use Table 3 to estimate the total impervious area for different land uses in new development areas. Any significant deviation from the figures in Table 3 must be supported by a rationale and relevant information such as plans and description of proposed urban form or alternately a model calibrated to long-term (ideally at least 5 years) flow data as described below in the section on how to *Determine directly connected imperviousness through calibration*.

Subject to agreement with Melbourne Water, users may adopt an alternative approach of undertaking a detailed assessment of proposed and potential future effective impervious fractions where the proposed and likely future impervious areas can be identified with a high degree of confidence (see example below in *Detailed calculation of directly connected imperviousness*).

Table 3 Total impervious fractions for source nodes by land use (continues over page)

Zone	Zone code	Brief description and examples	Normal range	Typical value
Residential zones				
Residential growth zone, general residential zone, and neighbourhood residential zone	RGZ, GRZ and NRZ	Large residential (allotment size 601m^2 to 1000m^2)	0.50 – 0.80	0.60
		Standard densities (allotment size 300m^2 to 600m^2)	0.70 – 0.80	0.75
		High densities (allotment size <300m^2)	0.80 – 0.95	0.85
Low density residential zone	LDRZ	Allotment size >1000m^2	0.10 – 0.30	0.20
Mixed use zone	MUZ	Mix of residential, commercial, industrial and hospitals.	0.6 – 0.90	0.75
Township zone	TZ	Small townships with no specific zoning structures	0.40 – 0.70	0.55
Industrial zones				
Industrial 1 zone	IN1Z	Main zone to be applied in most industrial areas	0.70 – 0.95	0.90
Industrial 2 zone	IN2Z	Large industrial zones away from residential areas	0.70 – 0.95	0.90
Industrial 3 zone	IN3Z	Buffer between zone 1 and zone 3	0.70 – 0.95	0.90
		For garden suppliers/nurseries	0.30 – 0.60	0.50
		For quarries	0.10 – 0.30	0.20
Commercial zones				
Commercial 1 zone	C1Z	Main zone to be applied in most commercial areas	0.70 – 0.95	0.90

Zone	Zone code	Brief description and examples	Normal range	Typical value
Commercial 2 zone	C2Z	Offices, manufacturing industries and associated uses	0.70 – 0.95	0.90
Rural zones				
Rural zone	RUZ	Main zone to be applied in most rural areas	0.05 – 0.20	0.10
Rural living zone	RLZ	Main residential use in rural areas	0.10 – 0.30	0.20
Public land zones				
Education	PU2Z	Schools and universities	0.60 – 0.80	0.70
Service and Utility	PU1Z	Power lines, pipe tracks and retarding basins	0.00 – 0.10	0.05
		Reservoirs	0.40 – 0.60	0.50
Health and community	PU3Z	Hospitals	0.80 – 0.90	0.85
Transport	PU4Z	Railways and tramways	0.60 – 0.80	0.70
Cemetery or crematorium	PU5Z	Cemeteries and crematoriums	0.50 – 0.70	0.60
Local government	PU6Z	Libraries, sports complexes, and offices/depots	0.50 – 0.90	0.70
Other public use	PU7Z	Museums	0.50 – 0.80	0.60
Public park and recreation zone	PPRZ	Main zone for public open space, including golf courses	0.00 – 0.20	0.10
Public conservation and resource zone	PCRZ	Protection of natural environment or resources	0.00 – 0.05	0.00
Road zone, category 1	RDZ1	Major roads and freeways	0.60 – 0.90	0.70
Road zone, category 2	RDZ2	Secondary and local roads	0.50 – 0.80	0.60
Special purpose zones				
Special use zone	SUZn	Development for specific purposes	0.50 – 0.80	0.60
Comprehensive development zone	CDZn	Large and complex developments – residential	0.40 – 0.80	n/a
Urban floodway zone	UFZ	Land identified as part of an active floodway	0.00 – 0.05	0.00
Capital city zone	CCZn	Special use zone for land in Melbourne's central city	0.70 – 0.90	0.80
Docklands zone	DZn	Special use Zone for land in Docklands area	0.70 – 0.90	0.80
Commonwealth land	CA	Army Barracks, CSIRO	0.50 – 0.80	0.60

Note: values included in this table are impervious fractions, not runoff coefficients and should not be used as runoff coefficients for flood modelling.

Detailed calculation of directly connected imperviousness

An alternative method is to determine the directly connected impervious area and corresponding directly connected impervious fraction. This is done by mapping all impervious surfaces and determining which of these are effectively connected to the drainage system using detailed data. This approach may be used for small developing or developed catchments up to 10 ha where accurate details of the existing or proposed drainage system, land-uses and lot layouts are known. However, it is considered most appropriate for use within existing urban areas where the impervious surfaces are likely to be fairly stable with limited change.

For an area to be considered not part of the directly connected impervious area, it must drain to a permeable vegetated area that is nominally at least half as large as the impervious area and certain to remain both permeable and vegetated for the foreseeable future.

A reasonable allowance must be made for potential future changes by landowners to replace permeable vegetated areas with other surfaces such as decks, patios and paving except where there are covenants or similar restrictions explicitly protecting the retention of permeable vegetated areas.

An example estimate of directly connected imperviousness for a small catchment is shown in Figure 5 and Table 4.

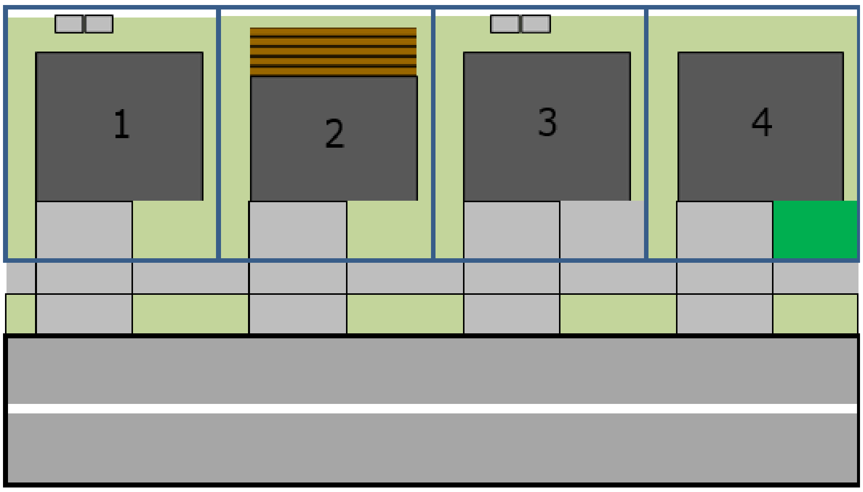


Figure 5 Directly connected imperviousness example

Property 1 has a 20m² paved area in the backyard that drains to an equivalent area of surrounding grass, not directly connected to the drainage system.

Property 2 has a wooden deck in the back yard with limited surrounding vegetation and an overflow pit to manage any stormwater excess. Decks, patios and similar structures are to be considered an impervious surface.

Property 3 has additional paved area in the front yard connected to the drainage system and a 20m² paved area in the backyard that drains to an equivalent area of surrounding grass, not directly connected to the drainage system.

Property 4 has synthetic grass in the front yard that connects to the drainage system. Synthetic turf is to be considered an impervious surface.

Table 4 Directly connected imperviousness calculation example

Surface area	Area (m^2)
Directly connected impervious area	
All roofs	750
Road	920
Driveways	390
Footpath	100
House 1 deck	20
House 3 additional front yard paving	40
House 4 synthetic turf	40
Impervious area not directly connected	
House 1 and 3 backyard paving	40
Pervious area	
Lawn and gardens	700
Total area	3000
Total impervious fraction = (750 + 920 + 390 + 100 + 20 + 40 + 40) / 3000	77%
Directly connected imperviousness (may be used in MUSIC) = (750 + 920 + 390 + 100 + 40 + 40) / 3000	75%

Note: all impervious areas that drain to WSUD features must be counted as impervious area for calculating the directly connected imperviousness since they are explicitly represented.

Determine directly connected imperviousness through calibration

If the catchment of interest is fully developed, directly connected imperviousness may be determined through calibration using rainfall and flow data for a drain or waterway[13]. This is most relevant for use in the design of stormwater harvesting systems for existing urban areas where flow data may exist or be collected to support design.

Soil parameters

In MUSIC, the pervious area soil properties must be altered to reflect properties recommended for use in Melbourne. Any proposed deviation from the Melbourne parameters listed here should be described in the report provided with the model. Supporting evidence must be provided.

[13] For an example of calibrating directly connected imperviousness through calibration, see *Analysis of parameter uncertainty of a flow and quality stormwater model* (Dotto, et al., 2009)

The soil input parameters recommended here are based on a review of twelve catchment calibrations undertaken for Melbourne catchments in recent years. They are generally suitable for clay soils prevalent throughout Greater Melbourne.

Soil storage capacity = 120 mm, Field capacity = 50 mm

Pollutant concentration data

Stormwater pollutant concentrations were estimated for use in MUSIC based on a study of worldwide data (Duncan, 1999) and these – as well as minor updates drawing on Fletcher et al. (2005) – provide the basis for the default parameters recommended below.

TSS, TP, and TN concentrations should use either:

- the default parameters for the urban (mixed surface type), agricultural, and forest nodes
- the concentrations set out in Table 5 below, if the split surface type approach is used

unless written permission is provided by Melbourne Water to use alternative inputs.

Where the split surface types are adopted for a given sub-catchment, these are complementary and preferably should be used consistently across the sub-catchment and within a model, where possible. That is, either ‘mixed’ urban or the three surface types (roof, road, all other urban areas) should be used. If necessary, different subcatchments may use different approaches, for example, where an upstream catchment was modelled by another party or has different treatment approaches at different scales.

When using the split surface type approach, the ‘all other urban areas’ concentrations should be used for any surface that is not clearly either a roof or a road (including the road reserve).

Table 5 Pollutant concentration data for source nodes where surface types are split (Fletcher, 2007)

Pollutant	Surface type	Storm flow (log mg/L)		Baseflow (log mg/L)	
		Mean	SD	Mean	SD
TSS	Roof	1.301	0.333	n/a*	n/a
	Road	2.431	0.333	n/a	n/a
	All other urban areas	1.882	0.333	0.96	0.401
TP	Roof	-0.886	0.242	n/a	n/a
	Road	-0.301	0.242	n/a	n/a
	All other urban areas	-0.680	0.242	-0.731	0.360
TN	Roof	0.301	0.205	n/a	n/a
	Road	0.342	0.205	n/a	n/a
	All other urban areas	0.224	0.205	0.346	0.309

* n/a indicates that baseflow does not occur from these surfaces since they are entirely impervious (Baseflow values for 'All other urban areas' may be used for related pervious areas such as natures strips adjacent to roads)

Serial correlation

The serial correlation (R squared) must be zero for all pollutants for analysis of stormwater quality treatment performance.

Stochastic versus mean generated data

MUSIC allows stormwater pollutant concentrations to be predicted in one of two ways:

> **Mean pollutant concentrations:** use a single mean concentration.
>
> **Stochastic pollutant generation:** predicts a new pollutant concentration for each timestep using a mean and standard deviation to produce a distribution of concentrations that is consistent with the input parameters of the model, which are in turn based on monitored data.

Stochastically generated pollutant concentrations must be used.

Subject to agreement, Melbourne Water may allow the use of mean concentrations for specific purposes, such as examining behaviour for a particular storm event or set of operating conditions, but not general stormwater treatment design.

5. Routing and drainage links

Water will flow through a catchment into drains, stormwater treatment assets and receiving waterways. In MUSIC, drainage links are used to direct water flows to and from each node.

Routing

Drainage links can also be used to set how long water will take to travel through a link and describe the links behaviour, which is defined as routing.

A link may represent either:

Catchment time of concentration: Water flows from the furthest upstream point in a catchment to its outlet or the point at which flows reach a confluence with flows from other catchments. The longest time it takes water to reach the outlet is called the time of concentration of the catchment. It depends on the size and shape of the catchment and the corresponding length and slope of the longest flow path within it. It may also be influenced by whether flows will occur along natural depressions and waterways or piped drainage. *The time of concentration is represented using the first link downstream of a catchment node.*

Travel time: Water flows from one point to another which may be a confluence, treatment asset, or another point of interest within the drainage network. Routing in this instance represents the travel time between these points.

Routing times may be estimated using standard methods for drainage design and input into MUSIC (MUSIC does not calculate these).

When should routing be used?

- Routing may be omitted for most MUSIC models for the design of stormwater treatment assets as well as for small catchments. This simplifies the model and is usually conservative for stormwater quality models. Routing is unlikely to have much effect in small catchments where the time of concentration is less than 10 minutes given that times are rounded to the nearest modelling timestep interval which is usually 6-minute increments.
- Routing is recommended for analyses that are sensitive to peak flows. These include flow rate diversions (for example, stormwater wetland high flow bypasses and pumping to stormwater harvesting assets).
- Routing is also recommended for large catchments (e.g. > 500 ha) where the travel time through the catchment may significantly influence behaviour of treatment assets.

If routing is used, it must be calculated and applied consistently across a model to ensure timing of peak flows and possible coincident peaks are modelled appropriately.

In MUSIC, three types of routing are available:

1. Select ‘no routing’ for simple models where routing is to be omitted. This assumes water flows instantaneously from one point to another.
2. Select ‘translation only’ for flows in pipes and concrete channels. This assumes water flows through the reach with no or minimal attenuation.

3. Select 'Muskingum Cunge' for overland flows and flows in natural channels and waterways where attenuation would be expected (typically theta = 0.25 is adopted unless informed by further analysis or calibration).

Routing through drainage links can be specified via a double click to access the properties dialogue box, see Figure 6.

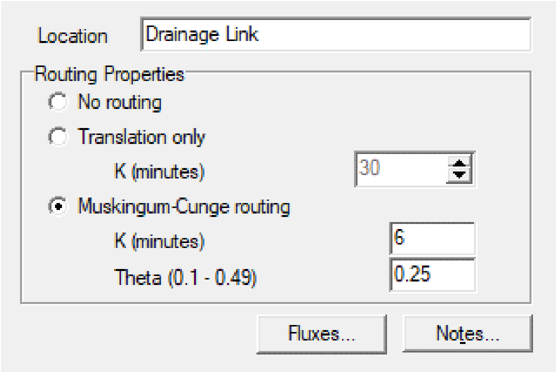


Figure 6 Setting routing parameters in MUSIC

Primary and secondary drainage links

In MUSIC both primary and secondary links may be defined.

A primary drainage link from a node must be used first. Secondary links may then optionally be used to direct selected flows to another destination.

Primary drainage links

When only a primary drainage link is used, all flows from the node are directed through that link. For primary links from source nodes (catchments), this includes by default:

- baseflow
- pervious storm flow
- impervious storm flow.

MUSIC assumes deep seepage and evapotranspiration are directed out of the model as losses.

MUSIC assumes that flows diverted around a treatment and those passing through it are recombined at the outlet from the asset. Primary drainage links (see Figure 7) from a treatment by default include:

- low flow bypass
- high flow bypass
- pipe flow
- weir overflow.

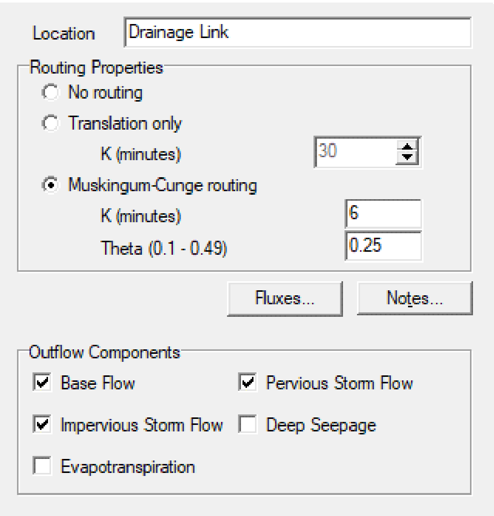


Figure 7 Primary drainage link parameters in MUSIC

Secondary drainage links

Secondary drainage links may be used to divert and redirect flows from source nodes and treatment nodes in MUSIC to a different point than the primary link. This is useful for separating and directing specific components of the total flow to or around downstream treatment nodes.

Secondary links must be used to more realistically represent actual conditions where flows are split or diverted.

Secondary drainage links from source nodes

Secondary drainage links separate and redirect flows from source nodes that are otherwise combined. Available flow components to be redirected include:

- baseflow
- pervious storm flow
- impervious storm flow
- deep seepage
- evapotranspiration.

For example, surface flows may be directed through a treatment asset while baseflows may infiltrate to groundwater and discharge directly into the receiving water. This can be modelled by adding a secondary link to a catchment node and routing it around the treatment to the receiving node (Figure 8).

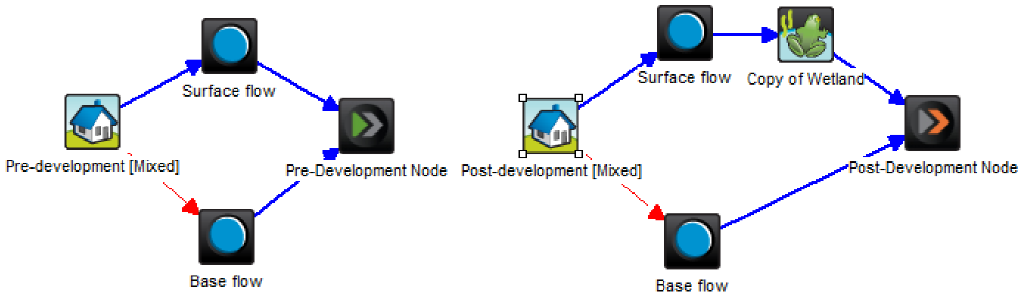


Figure 8 Directing only surface flows to treatment while baseflows are assumed to infiltrate and enter the waterway via groundwater

Secondary drainage links from treatment nodes

Secondary drainage links can separate and redirect flows from a treatment node and this can be particularly useful for representing different treatment and outlet configurations.

The range of outflow components depends on the type of treatment node and may include:

- outflow (pipe outflow)
- overflow (weir overflow)
- low flow bypass
- high flow bypass
- reuse
- infiltration
- evapotranspiration.

Some examples of the use of secondary links include:

- Routing overflows or bypass flows from a treatment asset around a downstream asset. For example, diversion of 'Weir Overflow' and 'High Flow Bypass' flows from a sediment pond around the macrophyte zone of a stormwater wetland. This is needed when a separate sedimentation basin node is used upstream of a wetland node. Refer to Figure 9.
- Routing flows from a treatment into or around a downstream stormwater reuse storage so that only treated flows are captured for reuse.
- Representing pumped flows using a constant reuse demand in the model and directing the resulting reuse flows to a different treatment or storage. See Figure 10 for an example.
- Representing the high flow bypass for a typical stormwater wetland

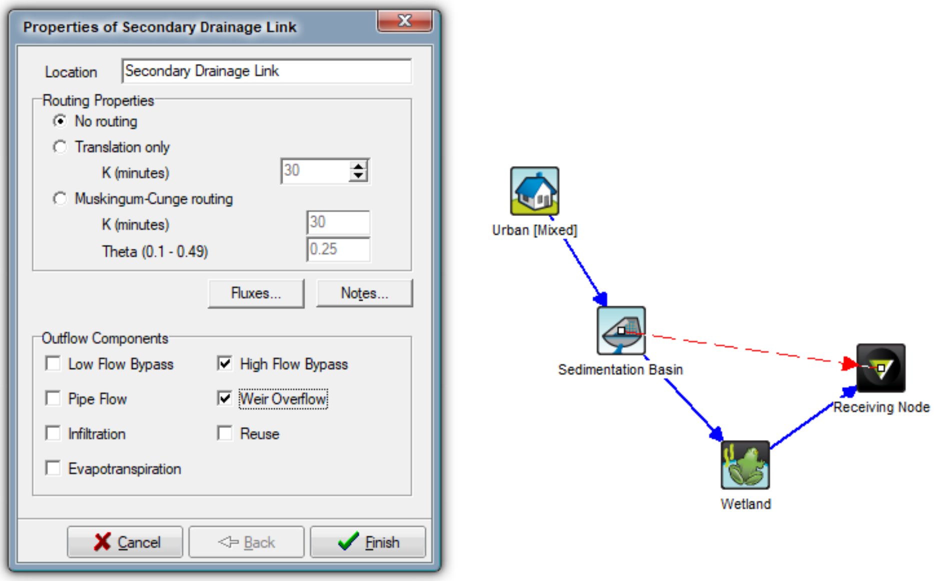


Figure 9 A MUSIC model containing a secondary link redirecting overflows and high flow bypass around a downstream stormwater wetland

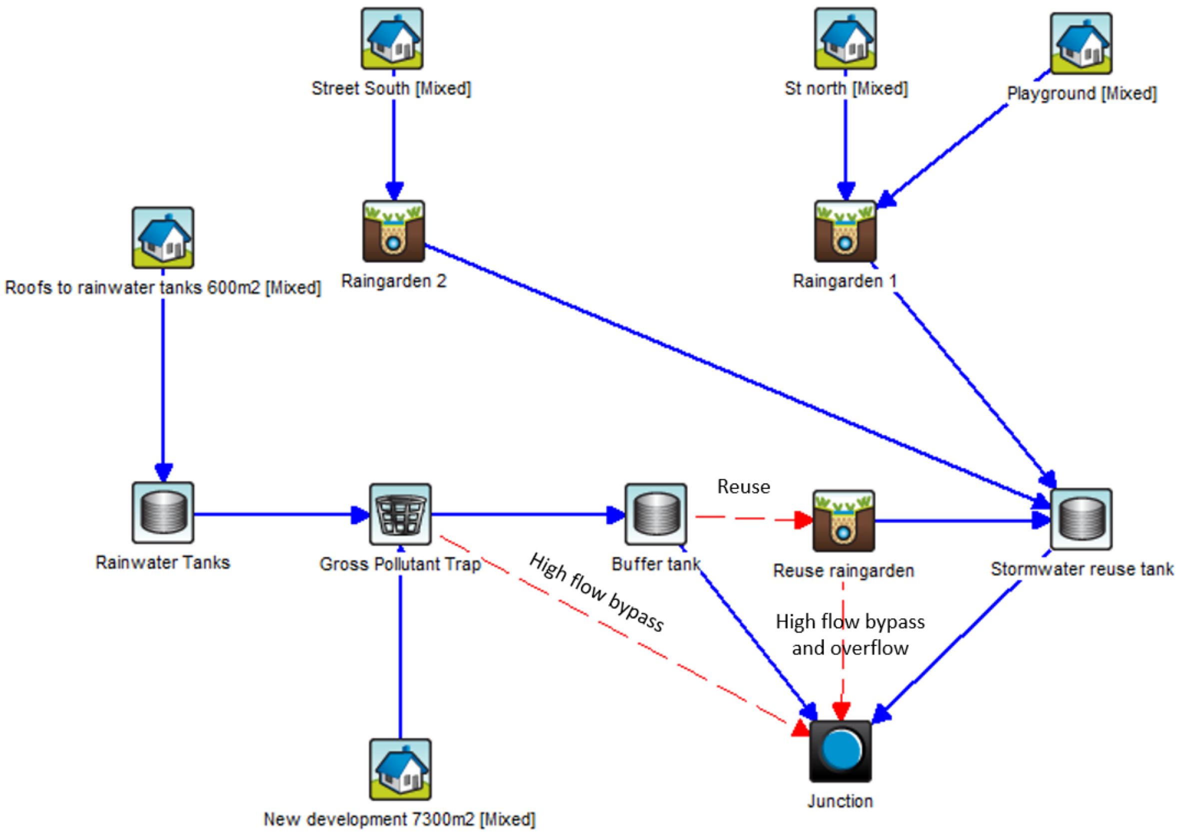


Figure 10 Directing high flow bypasses and overflows to outlet, pumped reuse from a buffer to a raingarden and outflows to a stormwater reuse storage

When using secondary links, it is important to ensure that flows are directed back into the final receiving node before reporting, to ensure flows are not lost.

Tip: If the treatment train effectiveness is to be used, users must ensure all flows normally routed within primary drainage links are redirected back into the model before the point where treatment train effectiveness is assessed. For source nodes, these are: baseflow, pervious storm flow, impervious storm flow. For treatment nodes these are: low flow bypass, high flow bypass, pipe flow and weir overflow.

If users do not direct these flows back into the model, treatment train effectiveness results will not be available.

Modelling high flow bypasses and overflows

The following guidance is relevant to all treatment nodes, except buffers and swales. It is intended to provide greater clarity on this topic, in addition to guidance available from the MUSIC help menu.

There are three common configurations for high flow bypasses and overflows:

1. no flow rate based high-flow bypass (Figure 11 and Figure 12)
2. high-flow bypass occurs upstream of the treatment asset represented by a single node (Figure 13 and Figure 14)

3. high-flow bypass occurs at an asset and bypasses other treatment asset(s) downstream (Figure 15 and Figure 16).

1. No flow rate based high-flow bypass

How to model: Set high flow bypass to default of 100 m^3/s (or an arbitrary large number greater than all flows).

All inflows flow into the asset. High flows exceeding the outlet capacity spill over an overflow weir after treatment (for example, a small streetscape raingarden with internal overflow pit).

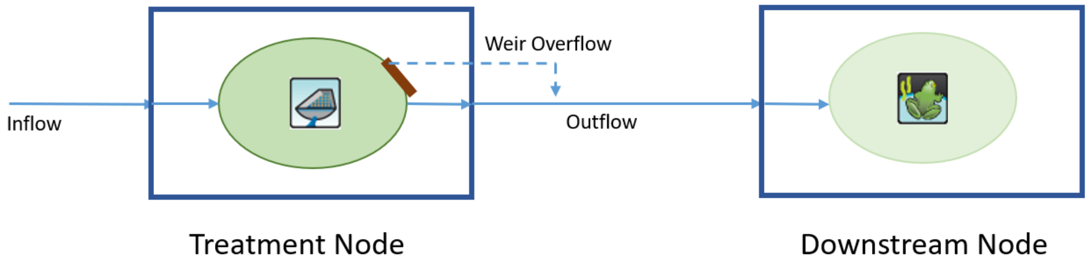


Figure 11 Behaviour of treatment nodes with no high flow bypass rate set and weir overflows from downstream end for most treatment nodes

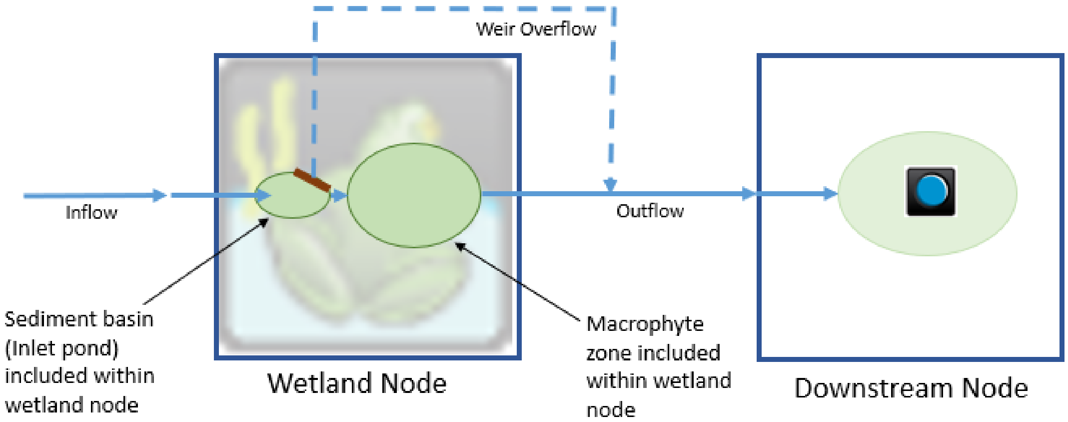


Figure 12 Behaviour of wetland node with no high flow bypass set and weir overflows from sedimentation basin node

2. High-flow bypass occurs upstream of treatment asset represented by a single node

How to model: Set high flow bypass to design bypass flow rate for asset.

Bypassed flows are directed untreated to the immediate downstream node.

This configuration applies, for example, to treatment nodes that are sized to fit into a given area rather than sized to treat their full upstream catchment.

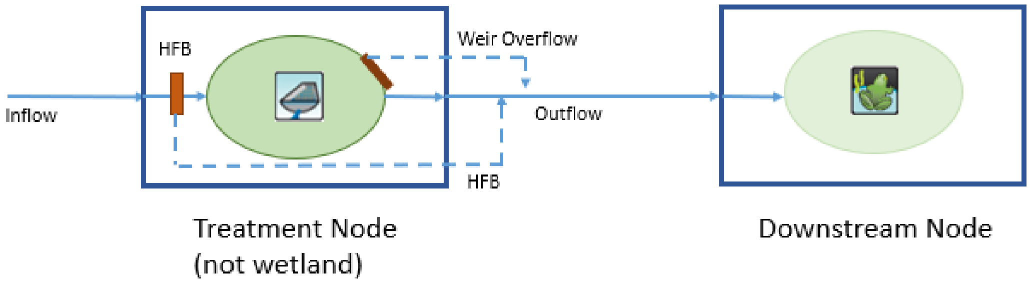


Figure 13 Behaviour of most treatment nodes with high flow bypass upstream (HFB) and weir overflows from downstream end of asset for most treatment nodes

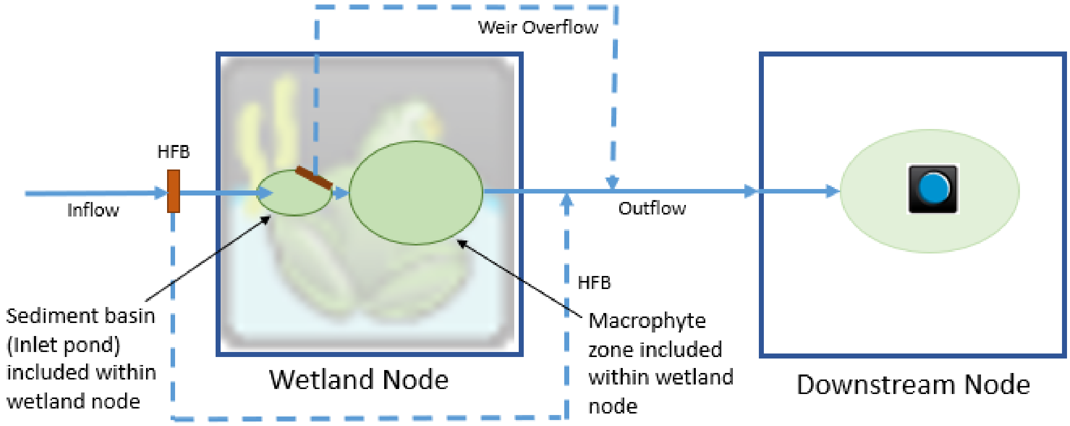


Figure 14 Behaviour for wetland with high flow bypass upstream (HFB) around wetland and weir overflows from downstream end of sediment basin (inlet pond) for a single wetland node

3. High-flow bypass occurs at an asset and bypasses other treatment asset(s) downstream

How to model: Set high flow bypass to design flow rate for asset and use secondary link to direct bypassed flows (and usually weir overflows as well) around treatment assets as required to represent design.

The bypassed flow will be directed to a node downstream of the treatment node via the secondary link. This is useful when flows are bypassed upstream of an asset then continue to be bypassed for downstream assets (e.g. high flow bypass upstream of a sediment pond and stormwater wetland or sediment pond and bioretention).

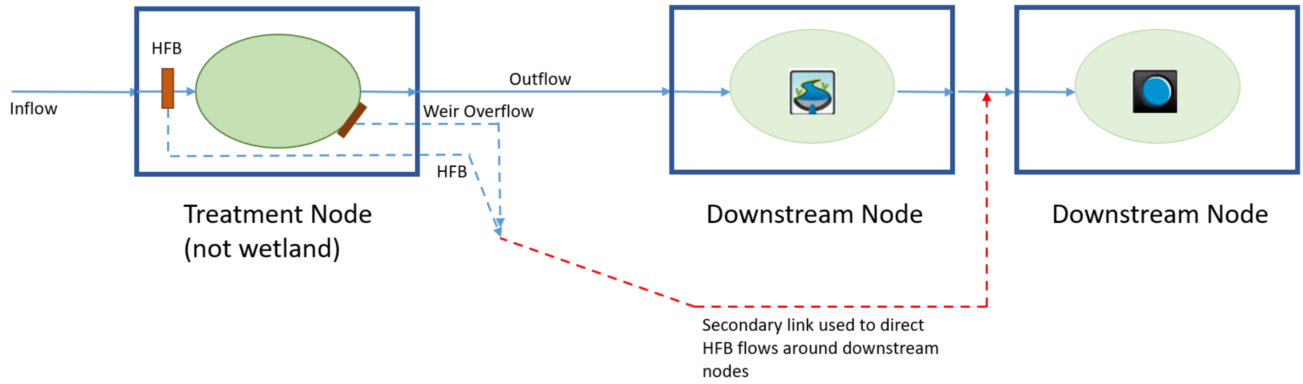


Figure 15 Behaviour of most treatment nodes with high flow bypass directed around both a treatment node and downstream node(s)

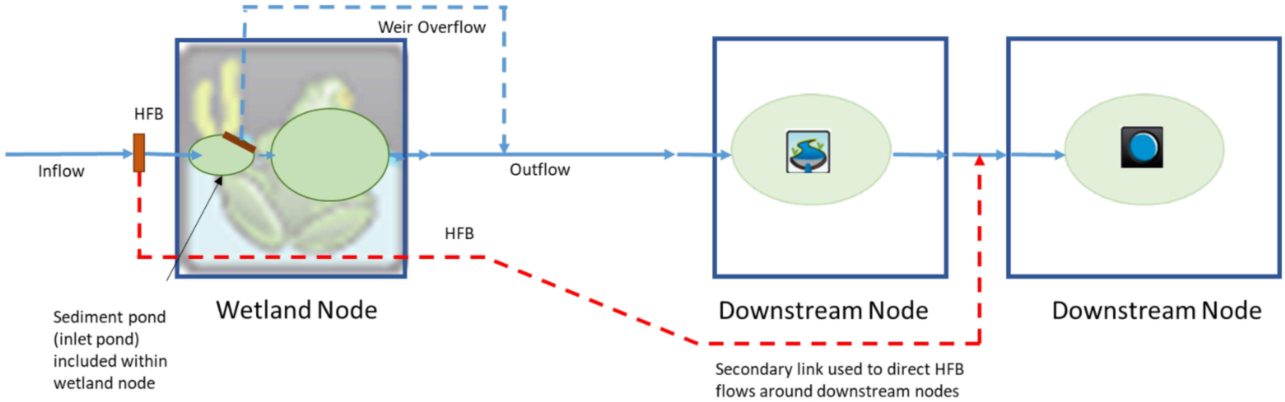


Figure 16 Behaviour of wetland with high flow bypass directed around both wetland node and downstream node(s)

Similar approaches may be adopted for weir overflows as appropriate.

Low flow bypasses may be configured and managed similar to high-flow bypasses where they are relevant, such as for diversions and bypassing of low flows to ensure baseflows are maintained.

6. General modelling guidance

This section provides general modelling guidance applicable across the model, treatment trains or a range of treatment types.

Infiltration into surrounding soils (exfiltration rate)

MUSIC modelling treatment node terminology

- The 'exfiltration rate' (mm/hr) in MUSIC refers to the infiltration rate, seepage rate or saturated hydraulic conductivity of the soil surrounding and underlying a treatment asset. It is used to represent infiltration of water from a treatment asset into the surrounding soils.
- The 'saturated hydraulic conductivity' (mm/hr) refers to the saturated hydraulic conductivity of the filter media within the treatment asset itself.

Infiltration into the surrounding soils can provide a range of benefits including reducing the frequency and volume of stormwater discharged to waterways.

Where only stormwater quality objectives are considered, infiltration may be ignored (set to 0) as a simple and conservative approach. Alternately, it may be included to provide a more realistic understanding of flow pathways, treatment asset performance, and operation.

Infiltration may also be pursued and represented within the model to help achieve objectives for infiltration described in the EPA Guidance, HWS and HWS Practitioner's Note.

In some areas it may be particularly desirable to increase infiltration; for example, to restore groundwater recharge in natural high-recharge areas and support groundwater dependent ecosystems (GDEs). Further information may be found in Infiltration resources below.

These benefits shall be balanced with the recognition that groundwater is a receiving environment, and that the environmental values and potential beneficial uses of groundwater must be protected. There are potential risks associated with infiltration depending on local conditions, soils and geology.

The following is intended to set out general guidance and indicative ranges only. Infiltration and groundwater are complex; competent geotechnical advice should be sought to support the assessment of geotechnical properties, risks, likely infiltration behaviour, and performance as appropriate.

Guiding principles for infiltration

- Use the guidance on acceptable infiltration rates in Table 6.
- Obtain a supporting geotechnical assessment to support adopted infiltration rates except in minor cases as outlined below. See Table 7 for infiltration testing requirements and other recommended tests.
- Assess potential benefits of infiltration in context, considering available information on recharge, waterways and groundwater dependent ecosystems.
- Assess risks related to the catchment, pollutants, soils, geology and receiving waters and apply risk management approaches. See Table 8 for risk assessment requirements.

- Beneficial uses of groundwater must be protected. As a minimum, typical urban stormwater flows must be treated to at least best practice standards before infiltration, as predicted using MUSIC. This includes any inflows to an unvegetated infiltration asset such as an infiltration trench or basin. Additional risks and pollutants may need consideration to meet obligations related to EPA's General Environmental Duty.
- Infiltration is supported where it is practical, safe and expected to provide net benefits.

Geotechnical testing

Geotechnical testing is recommended but not required:

1. During preliminary planning (prior to site investigations, decisions on asset footprint or a planning application); OR
2. Where all the following hold true:
   - Risks including those outlined in Table 8 are assessed as low.
   - Infiltration rates are expected to be low (medium or heavy clay or sandy loam soils expected).
   - Mean annual infiltration volumes (ML/year) are small relative to the development size, for example infiltration ≤15% mean annual runoff volume generated by the development.
   - No WSUD assets intentionally designed to promote and concentrate infiltration from a larger catchment that may generate a groundwater mound are proposed.[14]
   - No direct infiltration of stormwater from non-roof sources into groundwater through a sub-surface asset (such as infiltration trenches or wells) without prior treatment or passage through a vegetated root zone is proposed.

Where the above criteria hold true, designers may adopt a conservative infiltration rate based on soil type as set out in Table 6. at the discretion of the relevant authority, although infiltration rates based on geotechnical testing are preferred.

Table 6 Acceptable infiltration rates for MUSIC modelling

Soil type	Modelled infiltration rate
Where no site-specific infiltration testing or desktop analysis of soil type has been undertaken.	0.1 mm/hour
Where soil type is identified based on desktop soil data or geotechnical assessment to identify soil type (without infiltration testing).	The lesser of 100 mm/hour to allow for potential clogging and the lower end of the literature range[15]: • 0 to 0.36 mm/hour for heavy clay (0.1 mm/hour may be used for this range)

[14] Examples where groundwater mounds may potentially be generated include larger bioretention or vegetated sponges >500 m^2, ephemeral stormwater wetlands with catchments >50 ha or infiltration rates >3.6 mm/hour, as well as large infiltration storages, trenches or wells of >100 m^3 in aggregate. Small raingardens <100 m^2, tree pits, and permeable pavement are relatively unlikely to generate groundwater mounds since volumes are typically small and/or well distributed.

[15] Sensitivity testing of high infiltration rates may be undertaken to understand the potential effects on groundwater.

Soil type	Modelled infiltration rate
	• 0.36 to 3.6 mm/hour for medium clay • 3.6 to 36 mm/hour for sandy clay • 36 to 180 mm/hour for sandy loam • 180 to 360 mm/hour for sand • 360 to 3600 mm/hour for coarse sand
Where geotechnical assessment including infiltration testing has been undertaken.	All infiltration rates are subject to agreement with the relevant authorities. Use the lesser of 100 mm/hour to allow for potential clogging and: • for heavy, medium, and sandy clays, the measured infiltration rate • for sandy loam, sand, and coarse sand, no more than 50% of the measured infiltration rate

The designer should determine appropriate geotechnical testing needs based on the proposed assets, design configurations and context including geology and soils and is responsible for seeking appropriate geotechnical advice if needed.

Where geotechnical testing is needed, typical requirements, standards and recommendations are outlined in Table 7.

At a minimum, saturated hydraulic conductivity testing should be undertaken for underlying soils when infiltration is proposed, except for low-risk sites meeting the criteria above.

The designer is also responsible to ensure that potential risks to soil structure such as dispersion and swelling have been considered and are within acceptable ranges that do not present a hazard to life or infrastructure.

Table 7 Typical geotechnical testing requirements, standards and recommendations

Application	Typical requirements	Testing standards	Benefits
All	Saturated hydraulic conductivity for setting the infiltration rate. Infiltration rate or saturated hydraulic conductivity testing for the subsoil at a depth of at least one metre and below the anticipated base of the anticipated base of the WSUD asset, rather than the topsoil. This is to better reflect conditions at the depth at which exfiltration is likely to occur. It should be demonstrated that in-situ soils will not be compacted during earthworks, or the exfiltration rate modelled is discounted to allow for potential impacts of construction activity.	*AS 1289.6.7.1-2001* Method 6.7.1: Methods of testing soils for engineering purposes Soil strength and consolidation tests - Determination of permeability of a soil - Constant head method for a remoulded specimen (Reconfirmed 2013); OR *AS1289.6.7.2-2001* Method 6.7.2: Soil strength and consolidation tests - Determination of permeability of a soil - Falling head method for a remoulded specimen *AS 1289.6.7.3-2016* Method 6.7.3: Soil strength and consolidation tests-Determination of permeability of a soil - Constant head method using a flexible wall permeameter	Understand the flow rate of water through voids within a soil block media. Hydrogeological assessment of sites and understanding of design's potential influence on and interaction with aquifers.
All	Groundwater depth		Understand whether water can infiltrate freely or is likely to be impeded by underlying groundwater levels.
All	Salinity Electrical Conductivity pH	*AS1289.4.3.1-1997* Soil chemical tests - Determination of the pH value of a soil - Electrometric method *Chemical Test* pH (1:5) and EC (1:5)	EC (1:5) provides a measure of the content of salts in a 1:5 soil water suspension, pH (1:5) provides a measure of the acidity of a soil when suspended in water. The outcome of the test allows for the assessment of mineralogy within soil blocks, used for assessing how aggressively the minerals within the soil will react with

Application	Typical requirements	Testing standards	Benefits
			concrete and steel structures (pipes, culverts, abutments, footings). The salinity of a soil, when combined with water, will permeate the ground, depositing salts into the soil block. Over time, this leads to a reduction in nutrient uptake, reducing the fertility of the land. Where increases in water flow are present, the soil structure is damaged, and any standing aquifers are susceptible to increased salinity, further reducing beneficial use. May be considered in the selection of plant types for differing ground conditions where WSUD structures are formed and there is potential for groundwater ingress (e.g. wetlands).
Clay soils	Sodicity and dispersivity	*AS1289.3.8.1-2017* Soil classification tests – Dispersion – Determination of Emerson class number of a soil *Chemical Test* CEC, ESP, P Sorp, pH (1:5), EC (1:5)	Understand how fine-grained soils will respond to the application of water. The Emerson Class test verifies whether the soils are prone to disperse in the presence of water. Understand the site risk of creating slope instability and site scouring. Exchangeable Sodium Potential (ESP) is the measure of the cation exchange of sodium within a soil. This measure is used to further refine the level of dispersion identified through an Emerson test. Cation Exchange Capacity (CEC) and Phosphorus sorption (P Sorp) relates to the soils ability to react with positively charged ions and absorb phosphorus, a key component for healthy plant growth. Potentially also useful for plant selection.
Clay soils	Reactivity	*AS1289.7.1.1-2003* Methods of testing soils for engineering purposes Method 7.1.1: Soil reactivity tests — Determination of the shrinkage index of a soil — Shrink-swell index	Assess to what level the site surface soils are prone to volumetric increase (swell) or decrease (shrink) in the presence of moisture. Used to quantify the impacts of placing water onto reactive material (clays), for water infrastructure. Impacts to the site may involve:

Application	Typical requirements	Testing standards	Benefits
			▪ Disturbance to surface levels such as pavement and hardstand levels, altering surface runoff directions, surface levels of WSUD structures, inhibiting flow or altering flow out of design conditions. ▪ Disturbances to pipe grades due to localised shrinking or swelling of soils.
Clay soils	General Material Properties	*AS1289.3.1.1, 3.1.2, 3.2.1, 3.3.1* Soil classification tests—Determination of the liquid limit of a soil — One-point Casagrande method *AS1289.3.6.1-2009* Methods of testing soils for engineering purposes Soil classification tests - Determination of the particle size distribution of a soil - Standard method of analysis by sieving *AS1289.3.6.3-2020* Methods of testing soils for engineering purposes, Part 3.6.3: Soil classification tests - Determination of the particle size distribution of a soil - Standard method of fine analysis using a hydrometer	Understand the soil composition within the soil block matrix. Atterberg limits testing is conducted on fine grained soils to measure the behaviour of the silt or clay material. The test relates the plasticity, liquidity, and linear shrinkage of the material. Particle Size Distribution testing is performed via sieve method to differentiate coarse grained from fine grained soils. Fines may be further differentiated via hydrometer method to quantify silt and clay soils. These properties are used to assess how the soils will respond the addition of water, the maximum uptake of moisture content (liquid limit) and the moisture content at which a 3.2mm diameter rod of soil will crumble. Benefit to WSUD infrastructure as infiltration measures are informed by the percentage composition of fine and coarse grained material, further strengthening design assumptions.

Application	Typical requirements	Testing standards	Benefits
Aquifer storage and recharge Construction in floodplains with potential acid sulphate soils	Acid sulphate	*Chemical Test* pH, pH-FOX, SPOCAS Suite	Assessment of whether the soils, when exposed to oxygen, are susceptible to becoming acidic. An initial field test suite is performed (pH, pH-FOX) to understand if soils are potentially acid-sulphate. A further testing suite (SPOCAS) is performed to detail the extent of acidity within the soil media. Where acid sulphate soils are located below an aquifer, the addition of water applied through stormwater disposal has the potential to raise groundwater acidity, impacting on the beneficial uses of groundwater aquifers.

Risk assessment

Table 8 Items to consider in risk assessment

Category	Items
Catchment pollutant risks	• Low pollutant risk: roofs • Moderate pollutant risk: typical urban catchment including residential catchments, commercial, mixed use, education, parks and open space and low to moderate traffic roads • High pollutant risk: industrial areas. Any roads that are managed by vicroads or have more than four lanes in total (as a proxy for roads with higher traffic loads which usually translate to higher pollutant loads and potentially greater spill risks).
Site risks	• salinity and sodicity: where infiltration may significantly increase groundwater levels and salinity in proximity to the surface, which can impact structures, soil stability and vegetation • shallow soils over rock • slopes where infiltrated water may re-emerge at surface, within erosive areas, weaken slopes, or impact other infrastructure • infrastructure such as buildings or pavement in close proximity • groundwater levels within 1 m of base of proposed asset
Treatment	• Whether or not a vegetated root zone is provided to effectively mitigate risks of pollutants passing through to receiving waters or soils • Whether or not storage and/or controls are available to allow risks from spills to be managed and mitigated • Likelihood of effective maintenance of treatments being provided • Whether or not pre-treatment is provided to mitigate potential clogging risks
Receiving water risks	• Potential for dissolved pollutants (such as nitrates) to be conveyed to waterways via groundwater flow paths risks to beneficial uses of groundwater and environmental values. • Groundwater is a receiving water. The quality of the groundwater resources must be protected as for visible surface receiving waters. • As a general principle, groundwater should always be treated as a receiving water for assessment of stormwater quality and pollutant load reductions. • Any runoff potentially entering groundwater must be treated to meet Best practice Environmental Management objectives for stormwater quality[16], before infiltrating to surrounding soils.

[16] Best Practice Environmental Management Guidelines (Victoria Stormwater Committee, 1999)

Where intentional infiltration should be avoided

Promoting infiltration (beyond representing what would naturally occur without any additional measures) should be avoided where:

- land or water contamination are identified as significant risks
- groundwater is within close proximity to base level of WSUD assets (groundwater within 1 m depth below base level may be used as an indicator of risk)
- salinity risks exist, such as a likelihood of infiltration increasing saline groundwater levels within an unconfined aquifer in proximity to the surface or buildings
- underlying or proximate soils are highly dispersive soils at risk of erosion when exposed to water, and infiltration rates and volumes will be significantly higher than natural conditions
- infiltration is likely to put built infrastructure at risk[17].

Sensitivity testing

In some cases, potential risks to groundwater may be identified, including but not limited to raising a high groundwater table, creating a perched water table, or impacting sodic soils.

- Where infiltration is proposed in these conditions, it is recommended that sensitivity testing of the modelling is undertaken to understand the potential range of infiltration volumes and associated risks.
- The most critical parameter to test is the exfiltration rate, although other parameters such as submerged zone depth and saturated hydraulic conductivity may also have an influence.
- At minimum, it is recommended testing is undertaken using an exfiltration rate that is:
    - At the upper end of measured values from geotechnical testing; or
    - 50% greater than the parameter value adopted for modelling if there are less than three measured values available.

Modelling infiltration of flows and pollutant loads

Increased surface runoff due to urbanisation via overland flows, connected drainage and rapid interflow through soils can result in a significant increase in the frequency, volume and magnitude of waterway flows. It can also reduce infiltration, groundwater recharge and waterway baseflows. The purpose of stormwater infiltration is to mitigate these hydrologic impacts.

Therefore, flows that are infiltrated, or flows that are filtered and below a threshold level comparable to baseflows may be accounted to estimate infiltrated and filtered stormwater flow volumes.

Further guidance on assessing flow volumes is provided in Chapter 9.

However, there is potential for infiltrated flows to carry pollutants which may pollute downstream receiving waters including, but not limited to, waterways and groundwater.

While these may be attenuated through the soil, this depends upon many factors such as the specific pollutants, soil type and chemistry, flow pathways, potential short-circuiting such as

---

[17] Refer to *Biofiltration Systems in Development Services Schemes Guideline* Deemed to Comply Criteria BR8 for additional detail

service trenches and depth to groundwater. Groundwater may have a range of environmental values and potential beneficial uses, and under existing conditions may be less impacted by stormwater. It is therefore important to ensure that groundwater is protected. While many pollutants may be effectively managed by vegetated or other treatment assets, or absorbed into soils, some (such as soluble heavy metals, pesticides and nitrates) have greater potential to break-through and pollute receiving waters.

For these reasons*, a precautionary approach is adopted whereby all infiltrated pollutant loads are assumed to reach a receiving water* and therefore *must be included in the accounting of outlet or outflow pollutant loads*.

This can be assessed by routing infiltrated flows from treatments to an outlet node so that the pollutant loads are accounted.

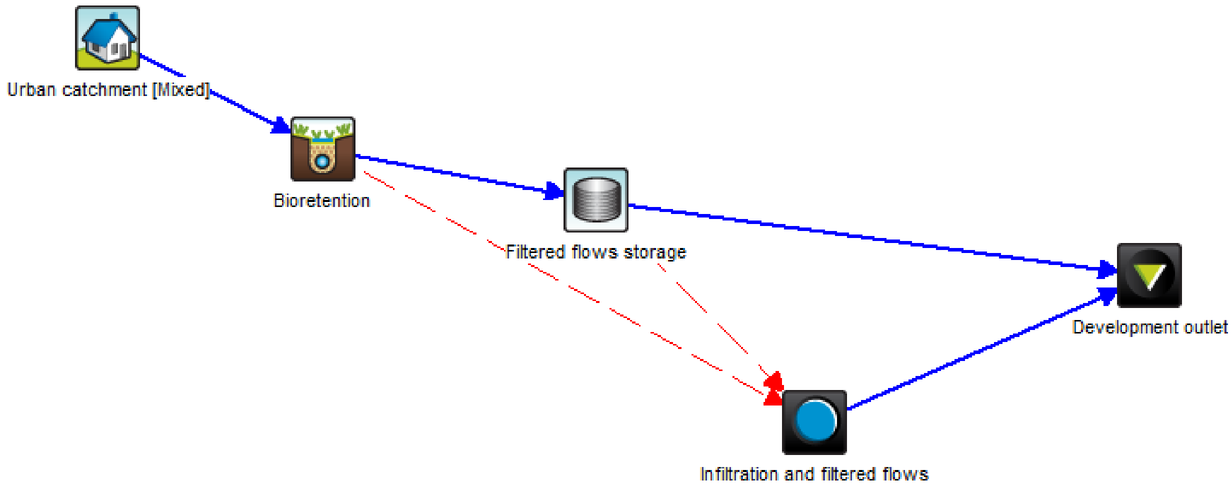


Figure 17 Example model configuration set up to extract outputs for assessing compliance with flow objectives

Infiltration resources

- EPA map of groundwater quality restricted use zones in Victoria[18]
- Victoria Unearthed government map about potential land or groundwater contamination sites[19]
- Visualising Victoria's Groundwater[20]
- Southern Rural Water groundwater information[21]

---

18 https://www.epa.vic.gov.au/for-community/environmental-information/land-groundwater-pollution/gqruz-map
19 https://www.environment.vic.gov.au/sustainability/victoria-unearthed
20 https://www.vvg.org.au/
21 https://www.srw.com.au/water-and-storage/groundwater-and-bores/groundwater

- Groundwater dependent ecosystems Bureau of Meteorology GDE Atlas[22]

Melbourne Water has a GDE atlas. Please refer to Melbourne Water for further details on GDEs and groundwater catchments.

Treatment trains

Treatment nodes within a MUSIC model must be linked in an appropriate order (see example in Figure 18), with primary treatment devices first, followed by secondary treatment devices and tertiary treatment devices last (if present).

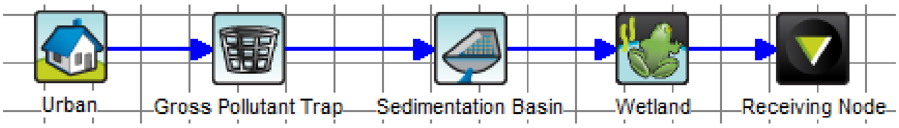


Figure 18 Example treatment train

K, C*, C**

The default k and C* values must not be adjusted without prior written approval from Melbourne Water. An exception to this is the nitrogen k value for stand-alone sediment ponds as these should be excluded from nitrogen treatment performance reporting (refer also to *Sediment ponds* within this document). In this instance the nitrogen k value for stand-alone sediment ponds should be set to zero, reflecting that these assets on their own are not viable systems for temporary or long-term nitrogen removal.

In addition to requiring written approval from Melbourne Water, any data used to modify these parameters must be peer-reviewed publications and/or research that has been undertaken according to scientific and ethical norms (for example, Australian Code for the Responsible Conduct of Research) and be appropriate for the circumstances being modelled.

Plant survival

MUSIC cannot model plant death due to long dry periods, or more commonly, excessive water depth. Further analysis and input from practitioners with knowledge of aquatic ecology are needed to make sure the plants selected will survive and contribute to pollutant removal over the life of the treatment node if non-standard designs are used. Melbourne Water's *Biofiltration systems in Development Services Schemes Guideline* (Melbourne Water, 2020) and *Wetland Design Manual* (Melbourne Water, 2020) provide guidance on appropriate plant selection. Designers may also use the wetland analysis tool on the MUSIC Auditor website as an initial screen to identify obvious risks to plant survival based on inundation frequency patterns.

Number of CSTR cells

The CSTR input parameter in MUSIC represents the hydrodynamics or hydraulic mixing behaviour of treatment nodes. The default number of CSTR cells for a treatment node can be changed through the 'More' button. The number of CSTR cells for sediment ponds can also be changed through the 'Estimate Parameters' button.

---

22 http://www.bom.gov.au/water/groundwater/gde/

These are usually only changed to more accurately represent sediment ponds of a given shape. The length to width ratios for the shapes used to estimate the number of CSTR cells is listed in Figure 19 below.

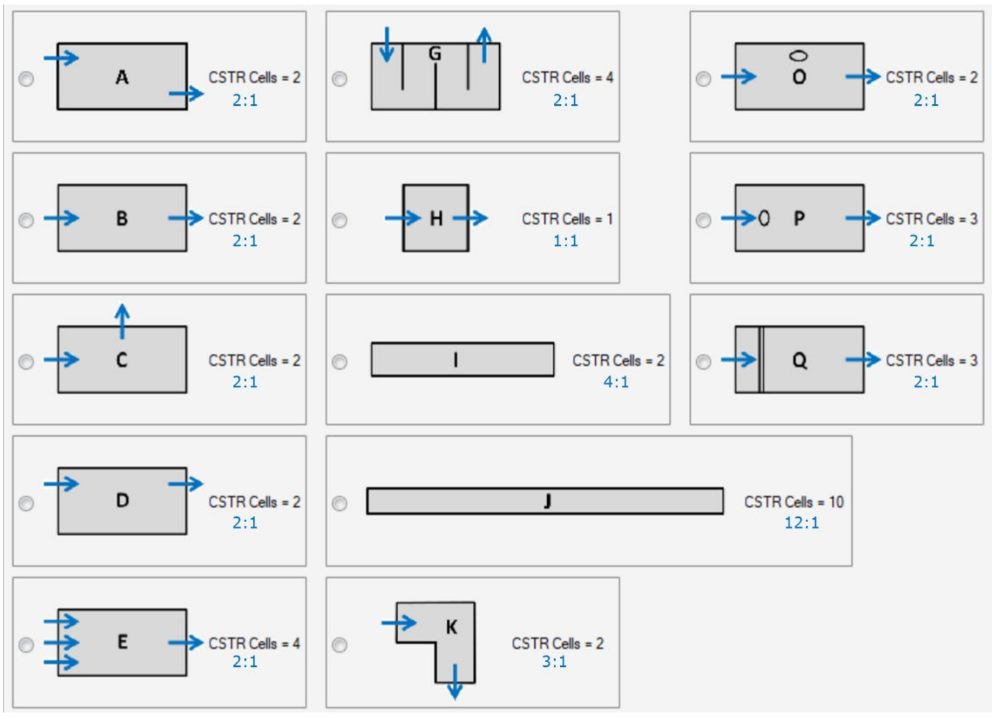


Figure 19 Treatment node shapes and length to width ratio to determine the number of CSTR cells (Persson, 2000). P contains an island blocking the central flow path and Q contains a structure to distribute the flows evenly.

Instream works and waterways

Do not include constructed or natural waterways, natural wetlands or grassed retarding basins as treatment nodes.

Direct rainfall on treatment

MUSIC does not represent direct rainfall onto a treatment node. Rather, it is assumed the area of the treatment is included within an upstream catchment area. This may be insignificant when assets are small relative to catchment. However, it becomes more material for assets that are larger relative to catchment, such as ephemeral stormwater wetlands, vegetated sponges, wicking beds, and particularly permeable pavements and green roofs. In some cases, this may also apply for wetlands, ponds and lakes.

Direct rainfall may comprise a significant portion of the total flow treated and therefore has an influence on treatment outcomes and treatment water balance.

Since all rainfall falling on a WSUD asset will enter it, the area should be represented as a 100% impervious surface area to ensure a correct water balance with all direct rainfall becoming inflow.

In these cases, direct rainfall landing on the treatment should be represented within the MUSIC model to ensure an accurate water balance. There are two ways to do this:

- The catchment impervious fraction can be adjusted to ensure the asset or water surface area within it is represented as impervious.
- The catchment draining to the treatment is split into two (or more) source nodes:
  - One node represents direct rainfall on the treatment (100% impervious), and
  - the other node represents upstream catchment flows draining to the treatment.
  - Note that the treatment area may need to be subtracted from the upstream catchment source node if it was already included.

It is further recommended to revise the rainfall threshold from 1 mm to 0 mm for treatments with a water surface area to ensure all rainfall reaches the asset.

For reference, evapotranspiration is represented for most treatment nodes with a water surface area including sediment ponds, wetlands, ponds, bioretention and detention basins. It is not represented for swales, media filtration (used for permeable paving) or buffers.

Pollutant concentrations for direct rainfall

Where split surface type concentrations are used, roof concentrations may be used for direct rainfall on water surface areas.

For permeable paving in public roads or commercial/industrial car parks, a 'road' surface type should usually be adopted as the best approximation of pollutant concentrations.

Justification should be provided where a different surface type is proposed (for example, 'all other urban' surface concentrations may be used for pedestrian or residential driveway areas with permeable paving).

Stormwater harvesting and reuse

Developers will need to apply for a stormwater harvesting licence if they connect to new or modified stormwater drains, watercourse or open channel or harvest any quantity of stormwater from a waterway controlled by Melbourne Water. Details on Melbourne Water's process for stormwater harvesting can be found on Melbourne Water's website[23].

For large scale stormwater harvesting, a reuse master plan must be provided which is to be signed off by all relevant authorities (Local Government, Retail Water Company, Melbourne Water). Calculations should be provided to support estimated volumes of harvested stormwater. All harvested stormwater should be treated to a fit-for-purpose standard that also supports the long-term sustainability of the reuse infrastructure (including irrigation infrastructure).

Guidelines on quality of harvested stormwater and treatment for public health can be found online by searching for "Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2) Stormwater Harvesting and Reuse".

Rainwater or stormwater harvesting may contribute to treatment train performance if the demands are reliable (for example, toilet flushing at 20 litres per person per day and laundry at 80 litres per household per day). Irrigation of residential blocks is encouraged, although it is

---

[23] https://www.melbournewater.com.au/building-and-works/stormwater-management/stormwater-harvesting/stormwater-harvesting-licence

not considered a reliable demand. On-site treatment claims on the *Stormwater Quality Offset Contribution Form* cannot include residential irrigation.

For stormwater harvesting to be accepted as part of a MUSIC model, there needs to be a suitable agreement for construction and operation of the scheme between the relevant stakeholders.

A minimum of ten years of six-minute rainfall data (which is included in the provided rainfall templates) must be used to model all stages of a design that includes stormwater harvesting.

7. Specific guidance for treatment nodes

The following sections contain specific guidance and advice for each stormwater treatment type.

Sediment ponds

Sediment ponds are also referred to as sediment basins or sedimentation basins in MUSIC.

Sediment pond sizing

Calculate the modelled sediment pond volume from halfway up the sediment accumulation zone to the normal water level, as illustrated in Figure 20.

Do not design the size of the sediment pond with MUSIC alone. Sediment ponds must be designed to meet the sediment pond requirements of Melbourne Water's *Wetland Design Manual* (Melbourne Water, 2020).

Do not use the 'Estimate Inlet Volume' or 'Estimate Storage Properties' function in MUSIC as it is not set up for Melbourne Water's requirements.

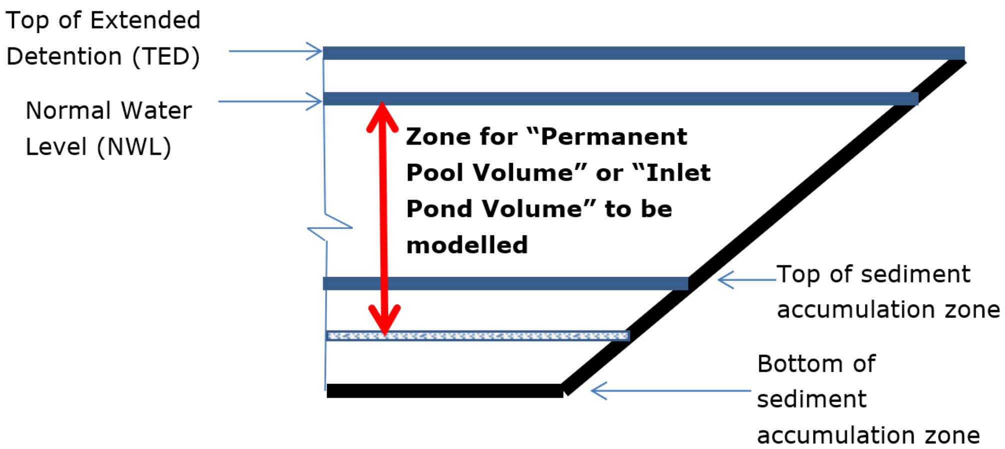


Figure 20 Calculate the modelled sediment pond volume from halfway up the sediment accumulation zone to the normal water level

Stand-alone sediment pond treatment

Sediment ponds are primary treatment measures in a stormwater treatment train that remove (via settling) coarse to medium-sized sediments (≥ 125 μm). Their function is to protect and operate in conjunction with downstream secondary or tertiary measures, such as stormwater wetlands or biofilters. These systems use enhanced sedimentation, fine filtration and pollutant uptake processes to remove pollutants such as phosphorus and nitrogen, and fine sediments from stormwater. The removal of coarse sediments prior to secondary and tertiary treatment measures is crucial for their effective operation. There is insufficient evidence to confirm that temporary or permanent nitrogen removal is facilitated by sediment ponds. This is due to research findings that nitrogen removal declines with the age of sediment ponds, coupled with a lack of reliable long-term data. To take a conservative approach to minimise the risks to human health and the environment, based on the current state of knowledge, Melbourne

Water does not accept nitrogen removal modelled for stand-alone sediment ponds when these do not form part of a treatment system that includes downstream secondary or tertiary treatment (refer also to *K, C*, C*** within this document). To be considered part of a treatment system, the sediment pond must be directly connected to the downstream secondary or tertiary treatment measure to form part of the system's overall treatment process.

Modelling sediment ponds connected to stormwater wetlands

Sediment ponds must be modelled either as part of the wetland node or as a separate upstream sedimentation basin node depending on whether the pond outlet flow is influenced by the water level in the stormwater wetland macrophyte zone. If the sediment pond is likely to be influenced by the water level within the stormwater wetland, then a single wetland node with an inlet pond should be used to represent the sediment pond and stormwater wetland.

Guidance on determining whether the stormwater wetland water level is likely to significantly influence the outlet flow in the sediment pond is shown in Figure 21 and described below.

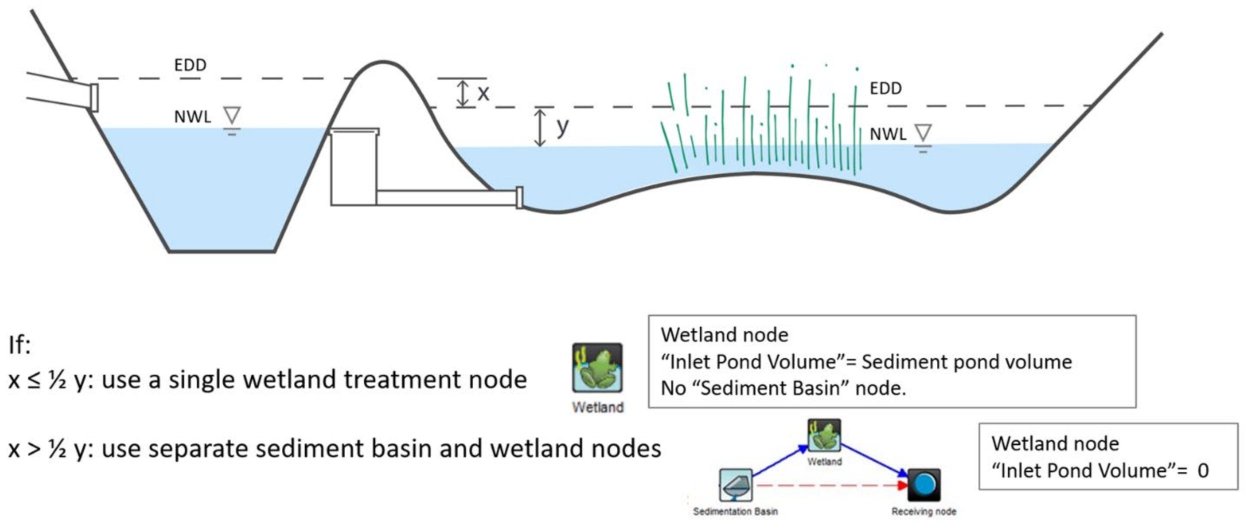


Figure 21 Sediment pond and stormwater wetland extended detention levels

Choosing whether to use a single wetland node or separate sedimentation basin and wetland nodes:

A single wetland node must be used where the difference between the sediment pond and stormwater wetland macrophyte zone extended detention levels (x) is less than half of the total EDD of the macrophyte zone (y) or where there is uncertainty as to whether the sediment pond outflow may be significantly influenced by the stormwater wetland water level.

Separate sedimentation basin and wetland nodes must be used where the difference between the sediment pond and stormwater wetland macrophyte zone extended detention levels (x) is greater than half the stormwater wetland macrophyte zone EDD (y).

Where separate sedimentation basin and wetland nodes are used:

- Set the wetland node 'Inlet Pond Volume' to zero.

- The sedimentation basin node weir overflow must be directed around the wetland node using a secondary drainage link (refer to *Modelling high flow bypasses and overflows* in this document).
- The sedimentation basin node equivalent pipe diameter must reflect the hydraulic control between the sediment pond and stormwater wetland macrophyte zone (this is likely to need to be defined using the custom outflow function).

Melbourne Water's Deemed to Comply Criteria in the *Wetland Design Manual* (Melbourne Water, 2020) require the sediment pond normal water level (NWL) to be a minimum 100 mm higher than the macrophyte zone NWL and sediment pond and the macrophyte zone extended detention depth (EDD) less than or equal to 350 mm. The single wetland treatment node approach would apply under these conditions.

A more detailed approach is as follows:

- Model the sediment pond and stormwater wetland using a single wetland node.
- Obtain an inundation frequency curve.
- Assess the level of interaction using the inundation frequency curve for the stormwater wetland.

Where the inundation frequency curve indicates that the water levels will spend a significant proportion of time above the sediment NWL, this would indicate significant interaction. Where the water levels are below the sediment pond NWL most of the time, the interaction is less significant. It is recommended that the water levels should not be above the sediment pond NWL for more than 15% of the time to justify use of a separate sediment pond. Ideally this should be zero, however a small level of interaction has been allowed for practicality as this would not have a significant impact on outcomes.

Worked example 1 for detailed approach

A typical inundation frequency curve for a stormwater wetland is shown in Figure 22. In this example the sediment pond NWL is 200 mm above the stormwater wetland NWL and both have an independent EDD of 350 millimetres. y = 350 mm and x = 200 mm.

$x > \frac{1}{2} y$

Figure 22 shows that the stormwater wetland water levels would only exceed the NWL of the sediment pond and interact with those in the sediment pond for 8% of the time. This is within the acceptable range. The water level interactions and impact on hydraulics and treatment performance are likely to be relatively minimal. This asset may be modelled as a separate sediment pond and wetland.

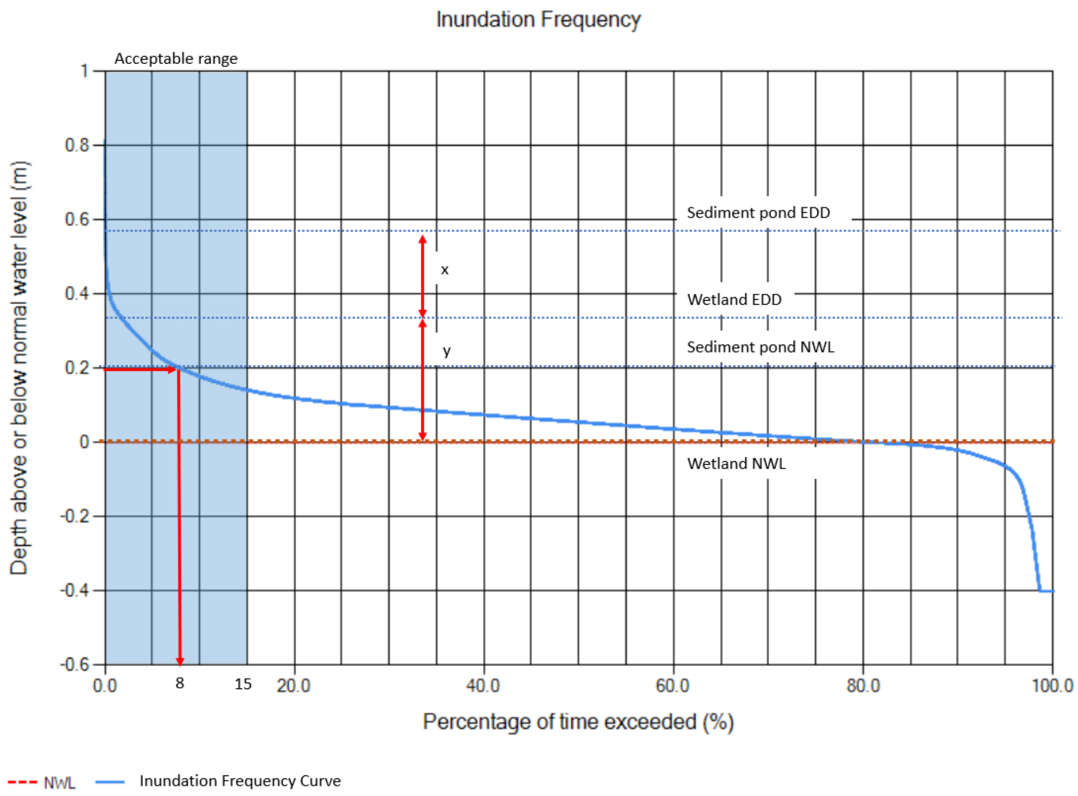


Figure 22 Typical inundation frequency curve for a stormwater wetland (sediment pond NWL and EDD 200 mm above stormwater wetland NWL and EDD). Separate sediment pond and wetland.

Worked example 2 for detailed approach

A typical inundation frequency curve for a stormwater wetland is shown in Figure 23. In this example the sediment pond NWL is 100 mm above the stormwater wetland NWL and that both have an independent EDD of 350 millimetres. y = 350 mm and x = 100 mm.

$x < ½ y$

Figure 23 shows that the stormwater wetland water levels would exceed the NWL of the sediment pond and interact with those in the sediment pond for 25% of the time. This exceeds the acceptable range. The water level interactions and impact on hydraulics and treatment performance may be significant. This asset should be modelled as a combined sediment pond and wetland.

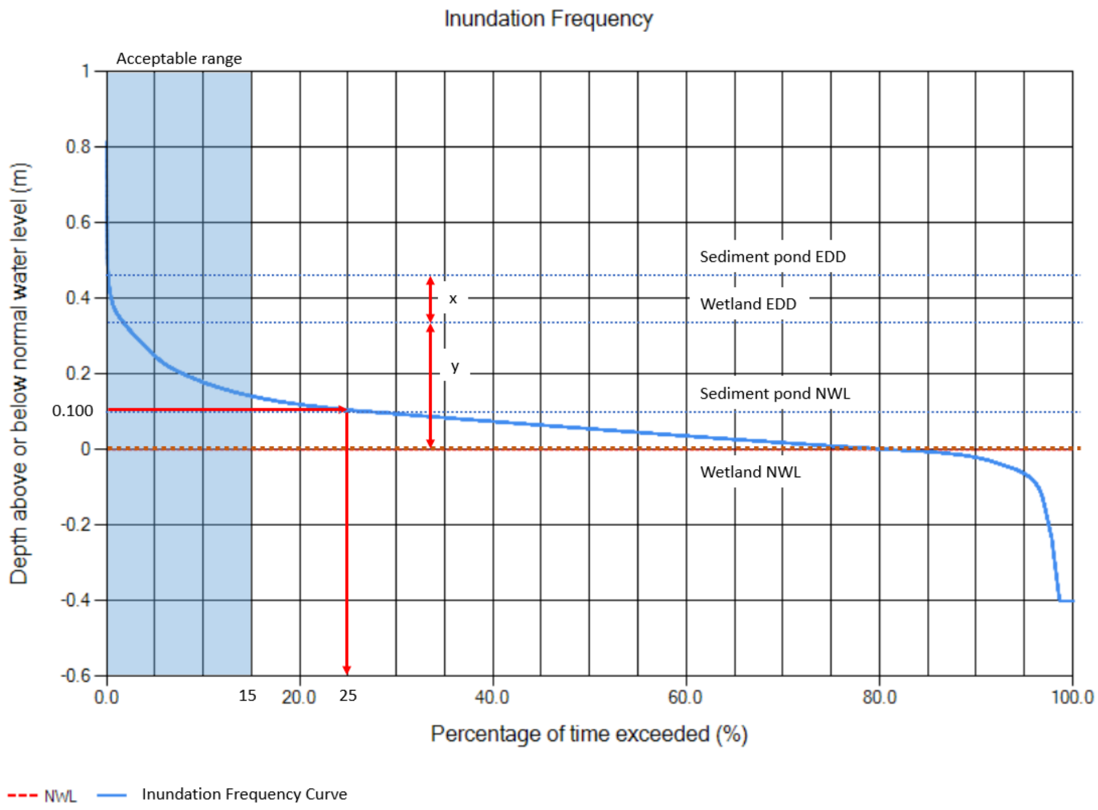


Figure 23: Typical inundation frequency curve for a stormwater wetland with sediment pond NWL and EDD 100 mm above stormwater wetland NWL and EDD). Combined sediment pond and wetland.

Stormwater wetlands

Stormwater wetland assets must be designed in accordance with Melbourne Water's *Wetland Design Manual* (Melbourne Water, 2020)[24].

MUSIC can predict the potential pollutant removal outcomes of a design.

The recommendations for modelling with an inlet pond or separate sedimentation basin node are provided in the *Sediment ponds* section of this document.

For functional and detailed design stages, the stage-storage-discharge relationships of the stormwater wetland extended detention must be represented using MUSIC's custom outflow and storage relationship function. Where the stormwater wetland is within a retarding basin, the MUSIC model must also reflect the stage-storage-discharge relationship of the retarding basin (when the water level exceeds top of extended detention).

In MUSIC the surface area and permanent pool volume of the stormwater wetland are provided as inputs.

> In MUSIC, the average permanent pool depth is assumed to be the permanent pool volume divided by the surface area (unless a custom stage storage discharge relationship is used).

This should consider Deemed to Comply Criteria MZ1 in the *Wetland Design Manual* (Melbourne Water, 2020). This will usually not be more than 400 millimetres in complying designs.

Stormwater wetland user defined outlet

For concept designs, it is usually sufficient to model a notional detention time of 72 hours. However, for functional and detailed designs, the stormwater wetland outlet properties must use custom outflow and storage relationships. These may be defined externally and the process to bring these into MUSIC is described in *Defining custom outflow and storage properties* in this document.

Modelling stormwater wetlands with multiple inlets

The MUSIC modelling software was developed with the assumption that the wetland treatment node represents a single inlet pond feeding flows to a macrophyte zone. Stormwater wetlands with multiple inlets where inflows are split between multiple sediment ponds before flowing through the attached macrophyte zone require special consideration. This type of stormwater wetland configuration can be difficult to reasonably represent in MUSIC.

The flow path length through the macrophyte zone must also be sized proportional to the volume entering the system. The macrophyte zone surface area at NWL, planting zone distribution and macrophyte coverage must also be proportional.

[24] https://www.melbournewater.com.au/building-and-works/developer-guides-and-resources/standards-and-specifications/constructed-wetlands

The design of each inlet pond should be generally in proportion to stormwater runoff volumes entering from its direct catchment.

To model a stormwater wetland treatment with multiple inlets in MUSIC, the following approach must be applied (with reference to *Modelling sediment ponds connected to stormwater wetlands*):

> **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.

Wetland analysis tool

The wetland analysis tool on the MUSIC Auditor website should be used to check the appropriateness of the design response. The tool provides the following checks:

- Effective water depth does not exceed half plant height more than 20% of the time
- Average water level is not more than 50 mm above normal water level
- The 90th percentile residence time should be 72 hours (3 days). A lower detention time, of no less than 48 hours, may be considered in retrofit circumstances to achieve the plant inundation frequency criteria.
- Shallow marsh plants are unlikely to persist with water levels 300 millimetres above NWL for greater than 10 days occurring. A check is made that no more than one spell of 10 days or more occurs where water levels are greater than 300 mm above normal water level in 10 years (see spells example in Figure 24).

The following should also be checked:

- Relevant velocity checks should be undertaken as indicated in the *Wetland Design Manual* (Melbourne Water, 2020).
- Check the frequency and periods of drawdown below normal water level (resulting in drying of large areas of planted macrophyte zone) are acceptable with respect to plant health and potential for mosquito breeding.

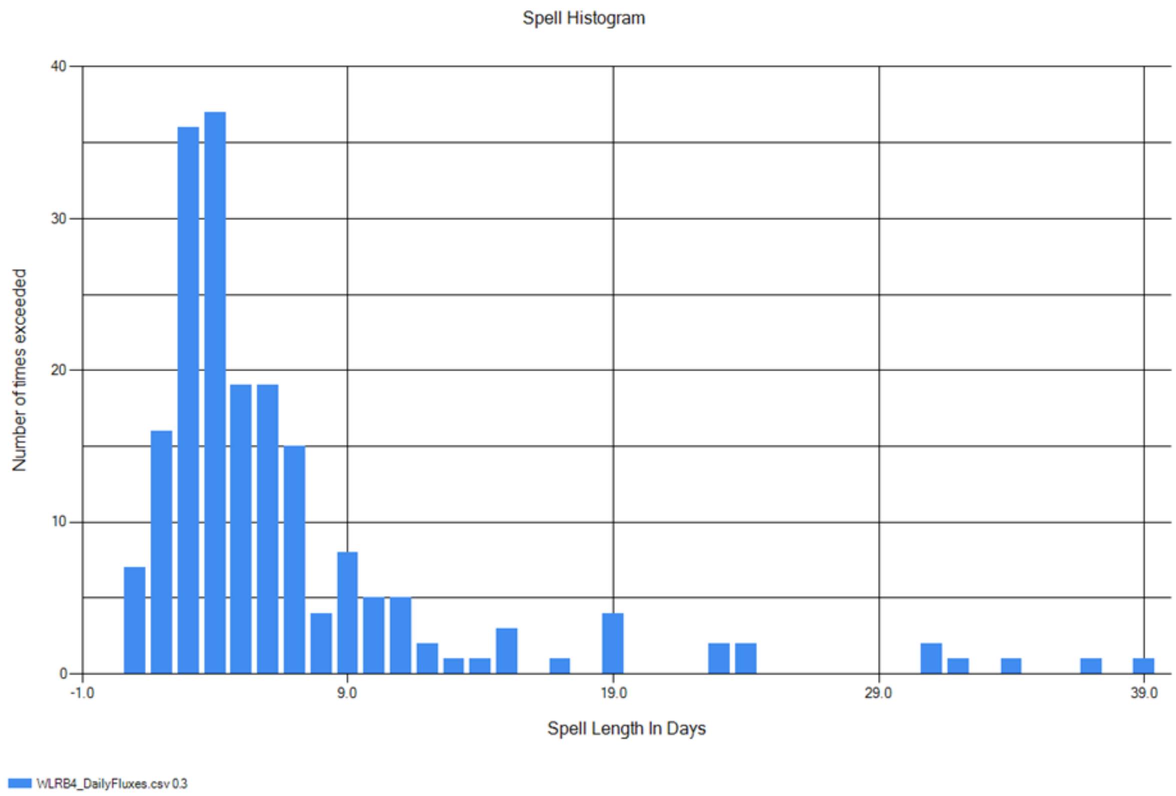


Figure 24 Spells where water level is greater than 300 millimetres above NWL in a wetland where the planting is likely to be compromised. In this non-complying example, spells of 10 days occur five times and longer spells also occur multiple times in the analysis period.

Online stormwater wetlands

Melbourne Water does not provide MUSIC guidance for online stormwater wetlands. For Melbourne Water's position on online stormwater wetlands please see the Wetland Design Manual Part A2: Deemed to Comply Design Criteria (Melbourne Water, 2020), Deemed to Comply Criteria MZ3 and the Wetland Design Manual Part A3: Design Considerations for Wetlands Manual (Melbourne Water, 2020), Section 3.4

Ephemeral stormwater wetlands

Ephemeral stormwater wetlands temporarily hold water following rain events with limited or no permanent ponding. They can be designed and constructed to function like standard stormwater wetlands[25] in that they are densely planted, allowing for filtering and treatment of stormwater runoff prior to discharge into downstream waterways or infiltration into the ground. However, the wetting and drying regime for ephemeral stormwater wetlands is very different with much of the wetland experiencing significant periods of both wetting and complete drying.

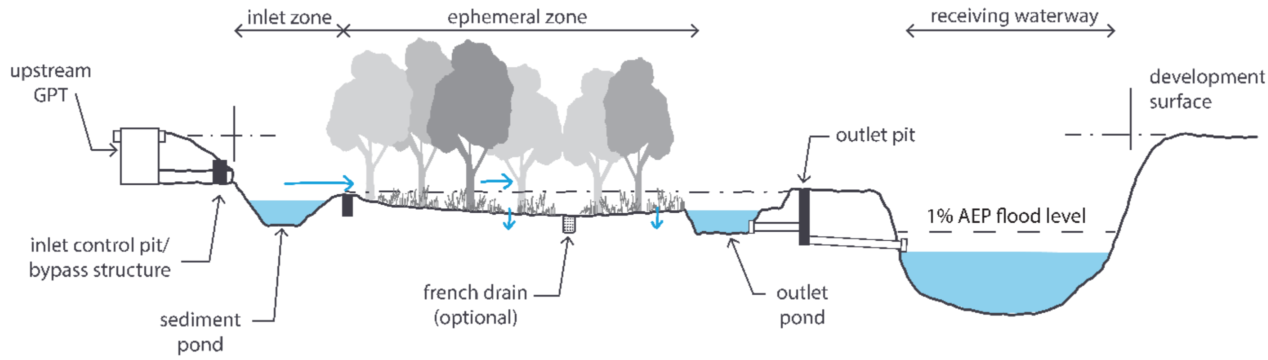


Figure 25 Ephemeral stormwater wetland concept section

Key principles

The general design principles of standard stormwater wetlands outlined in Melbourne Water's *Wetland Design Manual*[26] may be used as a starting point when designing an ephemeral stormwater wetland. Specifically, sections relating to general maintenance, sediment control and drainage structures can be adopted for ephemeral stormwater wetlands.

The following considerations and recommendations are provided for modelling ephemeral stormwater wetlands:

- An ephemeral stormwater wetland may be modelled as a wetland. The permanent pool and extended detention dimensions will need to be varied to represent the proposed design.
- An ephemeral stormwater wetland receiving stormwater must have upstream pre-treatment such as a gross pollutant trap and sediment pond to ensure it is protected from incoming gross pollutants and sediment.
- Direct rainfall should be accounted by representing the surface area as an impervious catchment area.
- All infiltrated loads must be counted as reaching a receiving water and included in the outflow loads for comparing with best practice pollutant load reduction objectives. This can be done by routing infiltration via a secondary drainage link to an outlet represented with a junction or receiving node. Note that the infiltrated flows can still be counted towards the flow objectives.

---

[25] https://www.melbournewater.com.au/building-and-works/developer-guides-and-resources/standards-and-specifications/constructed-wetlands
[26] https://www.melbournewater.com.au/building-and-works/developer-guides-and-resources/standards-and-specifications/constructed-wetlands

- Designers should use model outputs to undertake inundation frequency and spells analysis to help understand the wetting and drying regime and select suitable vegetation. This may be done using MUSIC and the supporting *Wetland Analysis Tool*[27].
- Unlined ephemeral wetlands with a lined permanent pool cannot be directly modelled in MUSIC at the time of publication. These may need to be approximated with consideration of the likely behaviour (i.e. does the wetland have water levels within the permanent pools or across the ephemeral areas for most of the time) with sensitivity testing using no infiltration, an appropriate infiltration rate for the ephemeral zone and a reasonable estimate between these.

Model input parameters

Guidance on design and modelling parameters for ephemeral stormwater wetlands are provided in Table 9.

Table 9 Indicative design and modelling parameters for ephemeral stormwater wetlands (modelled with wetland node)

Parameter	Value	Guidance
Proportion of deep pools (%)	Required: Up to 20% of ephemeral stormwater wetland area	No more than half of the deep pool areas should be at the ephemeral stormwater wetland inlet to ensure frequent events reach the ephemeral areas.
Extended detention depth (m)	Required: Up to 0.35	As per standard stormwater wetland.
Exfiltration rate (mm/hr)	Recommended: 0 to 100	An exfiltration rate suitable for the underlying soils should be adopted and must be set using the guidance provided in *Infiltration into surrounding soils (exfiltration rate)*.
Notional detention time (hrs)	Required: 72	The outlet orifice should be sized to allow a detention time of 72 hours.

27 https://musicauditor.com.au/

Parameter	Value	Guidance
Inundation frequency (%)	Recommended: Inundated (water levels >0) for 40% - 60% of the time and dry for the remainder. Water levels not exceeding 100 mm above NWL for spells greater than 60 days. Water levels not exceeding 50% plant height for more than 20% of time. Water levels not >400 mm below NWL for spells greater than 30 days*	An inundation frequency analysis and assessment of planting is to be completed using the *Wetland Analysis Tool*. Plant selection should consider wetting and drying patterns and spells and may benefit from sensitivity analysis using a range of infiltration rates. *For more than one spell in 10 years. Note this could potentially be addressed through provision for supplemental watering.
Velocities (m/s)	Required: Less than 0.5 m/s for 1% AEP storm event	Refer to Melbourne Water's *Wetland Design Manual* Part A2: Deemed to Comply Criteria for further detail. Variations may be justified through a shear analysis. Note the biofilm stripping criteria does not apply.

The stormwater treatment provided within an ephemeral stormwater wetland may be included as contributing towards meeting stormwater pollutant load reduction objectives.

Within the wetland node, MUSIC accounts for evapotranspiration from the surface water components comprising the permanent pool and extended detention. No evapotranspiration from the underlying soils is considered since standard stormwater wetlands rarely dry out. However, in practice ephemeral stormwater wetlands would have continued evapotranspiration from the underlying soils. This means current modelling practice may understate the evapotranspiration performance of ephemeral stormwater wetlands relative to alternative standard stormwater wetlands, biofilters or vegetated sponges. This is recognised as a limitation of the model at present that may be resolved through future research and development.

It is recognised that ephemeral stormwater wetlands are an emerging asset type, and design guidance will evolve as further research, data and monitoring outcomes become available to better understand their potential for stormwater flow management and pollutant reduction.

Bioretention (raingardens, biofilters)

Bioretention assets must be modelled in accordance with Melbourne Water's *Biofiltration systems in Development Services Schemes Guideline* (Melbourne Water, 2020) which provides guidance on appropriate design ranges for various parameters. Designers should familiarise themselves with and consider the Deemed to Comply Criteria in Part B of the guideline. References to these criteria are made throughout this section of the modelling guide.

> Note, MUSIC models must reflect the design and expected behaviour of the asset (refer to Deemed to Comply Criteria GN4).

Inlet properties

The high flow bypass in MUSIC must be configured based on the inlet capacity and Deemed to Comply Criteria BR2.

Infiltration properties

The exfiltration rate applies to the underlying soil (not the filter media) and Deemed to Comply Criteria BR8. Where an exfiltration rate of greater than 0 mm/hour is proposed this should be supported by relevant geotechnical testing for the site or requested. At a minimum, it must be based on representative rates for the underlying soil types for incidental infiltration. The use of infiltration shall be subject to agreement by the relevant authority. Where infiltration is used, all pollutant loads infiltrated must be counted as contributing towards outflow pollutant loads.

Filter media properties

Default values for nitrogen and orthophosphate content of the filter media must be used. A lower orthophosphate concentration than the default value may be used. It is recommended this is reduced to 50 mg/kg in the first instance. The proponent may (at their own risk) choose to reduce this further to as low as 20 milligrams per kilogram. Where a value less than 50 mg/kg is used, evidence that the filter media used in construction achieves the specified concentration, or less, must be provided on the filter media sign-off form as part of the construction documentation.

Outlet properties

The overflow weir width must be based on the designed length for the overflow weir or pit crest and in accordance with Deemed to Comply Criteria GN5.

Sediment removal

All coarse sediment removal pre-treatment assets must be designed and sized in accordance with Deemed to Comply Criteria CS1 and CS6.

Filter media

An acceptable design range for the design hydraulic conductivity of a biofilter is 100 to 300 millimetres per hour, as recommended in the Adoption Guidelines for Stormwater Biofiltration Systems (Payne, et al., 2015)[28].

---

[28] https://watersensitivecities.org.au/content/stormwater-biofilter-design/

The modelled hydraulic conductivity of the filter media must either match the design specification, or preferably be a conservatively low figure. A maximum of 100 millimetres per hour is recommended for all typical assets, and 150 millimetres per hour may be adopted for high priority assets with guaranteed maintenance such as stormwater reuse biofilters. These are based on the recognition that some sediment clogging of the surface is likely to occur, as well as plant perturbation, meaning higher infiltration rates may not be reliably sustained, irrespective of initial hydraulic conductivity.

Submerged zone

A Submerged zones with a minimum depth of 300 mm is recommended and preferred where site conditions permit, refer to Deemed to Comply Criteria BR7.

The filter media depth in MUSIC should include the filter media from the surface to the base of the filter media, or the invert level of the outlet pipe if this is higher. It must not include the transition or drainage layers.

If a submerged zone is used, the submerged zone depth in MUSIC may include the drainage and transition layers below the invert of the outlet pipe.

Plant species selection

The *Biofiltration systems in Development Services Schemes Guideline* (Melbourne Water, 2020) identifies specific plant species to be used, including plants that provide effective nutrient removal. If 'effective nutrient removal plants' are selected under 'Vegetation Properties' (recommended), the planting specification must support this with at least the minimum numbers of plant species, proportion effective for nutrient removal and densities as set out in VG2 to VG6.

The design must provide sufficient soil moisture to sustain plants. This can be achieved through:

- a minimum filter media depth of 400 millimetres (500 millimetres preferred)
- a submerged zone with an elevated underdrain outlet
- no underdrain (where underlying soils have adequate infiltration rates)
- appropriate size treatment area relative to the catchment (generally a biofilter will be 1-5% of catchment)
- a reliable source of irrigation to be used occasionally during extended dry periods.

Extended detention depth

The user should set an extended detention depth taking into consideration climatic conditions and likely wetting and drying behaviour and that is safe for construction, operation and maintenance of the system and the public, see Table 10. Bioretention assets with a longitudinal slope will not have a uniform extended detention depth and in these cases an average depth must be adopted.

The extended detention depth for Melbourne's different climatic regions must be in accordance with that advised in the *Biofiltration systems in Development Services Schemes Guideline* (Melbourne Water, 2020), see Table 10 and refer to Deemed to Comply Criteria BR4.

Table 10 Recommended biofilter extended detention depth ranges

Rainfall region	Extended detention depth (mm)
Melbourne City Dandenong Bullengarook East Narre Warren North Toolangi (Mt St Leonard)	100 to 300[29]
Little River Melbourne Airport	100 to 500[30]

Model input parameters

Guidance on recommended model input parameters for bioretention are provided in Table 11.

Table 11 Input parameters for bioretention

Parameter	Value	Guidance
Low flow bypass (m^3/s)	0 or design bypass flow rate	Should be set to appropriate value if lower flows will bypass the bioretention. For example, if a kerb cut-out sits higher than the base of the kerb resulting in some water bypassing. Otherwise set to 0. Avoid low flow bypasses where possible.
High flow bypass (m^3/s)	100 or design high flow bypass	Set to inlet capacity where limited. This is important for piped inflows, kerb cuts and inlets. Otherwise, set to arbitrary high number and treatable flow rates are determined by the extended detention depth and corresponding surface storage volume.
Extended detention depth (m)	Recommended: 0.1 to 0.3 Required: 0.01 to 0.5	Typical range. This should be based on ensuring the correct volume of surface water storage.
Filter depth (m)	Recommended: 0.4 to 0.6 or 0.7 to 1.0 with trees* Required: 0.3 to 0.6	Filter depth is the depth of filter media above underdrain invert. Total filter media depth including submerged zone greater than or equal to 400 mm with at least 700 mm recommended for trees.

29 Based on *Adoption Guidelines for Biofiltration Systems* (CRC for Water Sensitive Cities, 2015).

30 Based on *Bioretention in the West – Phase 1, Design for Sustained Health of Plants through Consideration of Soil Moisture Behaviour* (E2DesignLab, 2013).

Parameter	Value	Guidance
Saturated hydraulic conductivity (mm/hr)	Required: 100	Assume lesser of design hydraulic conductivity or 100 mm/hr for modelling. Bioretention filter media design range: 100-300 mm/hour (100-200 mm/hour preferred) Media with greater soil moisture retention preferred.
PET scaling factor	2.1	This influences the evapotranspiration rate.
Exfiltration rate (mm/hr)	Recommended: 0.18 to 100	An exfiltration rate suitable for the underlying soils should be adopted and must be set using the guidance provided in *Infiltration into surrounding soils (exfiltration rate)*. If groundwater risks are identified, refer to the guidance in that section on sensitivity testing of the input parameters
Underdrain	Recommended: Yes	Include above a submerged zone
Submerged zone depth (m)	Recommended: 0.3 to 0.5	Include depth of filter media, transition media and drainage below underdrain invert Sand is preferred over gravel to support capillary rise.
Total nitrogen (mg/kg)	800	Design total nitrogen concentration <800 recommended. Media with low nutrients preferred.
Orthophosphate content (mg/kg)	Recommended: 50 Required: 30	Design orthophosphate content <50 recommended. Media with low nutrients preferred. May be lowered if total phosphorus is limiting pollutant. If reduced, evidence that filter media meets this specification must be provided at construction.

Vegetated sponges

Vegetated sponges are vegetated areas that filter and reduce the volume of runoff discharged. They include dense planting of native sedges, shrubs and trees (such as Melaleuca) into a soil or filter media that can drain stormwater runoff. They are usually set into the ground or may be surrounded by a shallow bund (subject to risk assessment) to create an extended detention depth for temporary water storage, promoting infiltration and evapotranspiration. They can also be designed to contribute towards best practice stormwater treatment objectives with upstream pre-treatment for litter and sediment at a minimum.

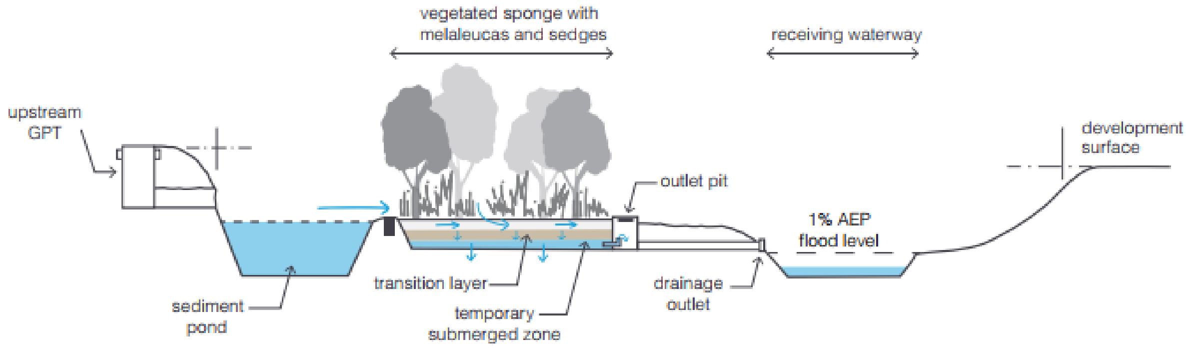


Figure 26 Vegetated sponge concept section

The following considerations and recommendations are provided for modelling sponges:

- Vegetated sponges may be modelled as a bioretention node. The bioretention node is most suitable for representing typical sponges, as they have a dry surface most of the time and allow evapotranspiration from the filter media or soils. Bioretention is the only node representing evapotranspiration from soils, which is critical for the water balance.
- A vegetated sponge receiving stormwater must have upstream pre-treatment such as a gross pollutant trap and sediment pond to ensure it is protected from incoming gross pollutants and sediment.
- An overflow pathway or pit must be provided for flows exceeding the capacity of the sponge. Within an allotment or streetscape, this may be an overflow pit returning to the drainage. At the precinct or sub-catchment scale, it may be a weir set within a retaining wall or earth berm to provide controlled overflows or sheet flow to the waterway. This is particularly important for vegetated sponges within urban settings.
- Direct rainfall on vegetated sponges should be accounted by representing the surface area as an impervious catchment area.
- All infiltrated loads must be counted as reaching a receiving water and included in the outflow loads for comparing with best practice pollutant load reduction objectives. This can be done by routing infiltration via a secondary drainage link to an outlet represented with a junction or receiving node. Note, that the infiltrated flows can still be counted towards the flow objectives.

It is recognised that vegetated sponges are an emerging asset type, and design guidance will evolve as further research, data, and monitoring outcomes become available to better understand their potential for stormwater volume and pollutant reduction.

A summary of indicative design and modelling parameters for vegetated sponges with imported filter media is provided in Table 12 and for vegetated sponges with in-situ soils in Table 13.

Table 12 – Indicative design and modelling parameters for vegetated sponges with imported filter media (modelled using bioretention node)

Parameter	Value	Guidance
Extended detention depth (m)	Required: 0.0 to 0.5 Recommended: 0.0 to 0.15	For modelling use a nominal depth of 10-20 mm if design has zero extended detention depth with water overflowing freely). Maximum depth of 500 mm.
Filter depth (m)	Required: 0.3 to 0.6 Recommended: 0.4 to 0.6 or 0.7 to 1.0 with trees*	Depth above underdrain invert. Total filter media depth including submerged zone greater or equal 400 mm.
Saturated hydraulic conductivity (mm/hr)	Recommended: 36 to 100 Required: 36 to 300	Assume lesser of design hydraulic conductivity or 100 mm/hr for modelling. Broad range to allow raingarden media to be used. Media with greater soil moisture retention (and low nutrients) preferred.
Exfiltration rate (mm/hr)	Recommended: 0.18 to 100	An exfiltration rate suitable for the underlying soils should be adopted and must be set using the guidance provided in *Infiltration into surrounding soils (exfiltration rate)*.
Underdrain	Recommended: Yes	Include above a submerged zone.
Submerged zone depth (m)	Recommended: 0.3 to 0.5	Include depth of filter media, transition media and drainage below underdrain invert. Sand is preferred over gravel to support capillary rise.

*Avoid placing underdrainage or drainage layer material directly beneath trees

Table 13 – Indicative design and modelling parameters for vegetated sponges with in-situ soil (modelled with bioretention node)

Parameter	**Value**	**Guidance**
Extended detention depth (m)	Required: 0.0 to 0.5 Recommended: 0.0 to 0.15	For modelling use a nominal depth of 10-20 mm if design has zero extended detention depth with water overflowing freely). Shallow depth of up to 150 mm preferred. Maximum depth of 500 mm.
Filter depth (m)	Required: 0.3 to 0.6 Recommended: 0.4 to 0.6	Set based on the average effective root depth of the vegetation.
Saturated hydraulic conductivity (mm/hr)	Recommended: 3.6 to 100 Required: 3.6 to 300	A saturated hydraulic conductivity suitable for the surface soils should be adopted and set using the guidance provided in the *MUSIC Guideline*. These are likely to be sandy loam, sandy clay or medium clay in the range 0.36 to 36 millimetres per hour). For modelling assume lesser of design hydraulic conductivity or 100 mm/hr.
Exfiltration rate (mm/hr)	Recommended: 0.18 to 100	An exfiltration rate suitable for the underlying soils should be adopted and set using the guidance provided in *Infiltration into surrounding soils (exfiltration rate).*
Underdrain	Recommended: Yes	Usually, only relief under-drainage to protect against over-saturation may be provided.
Submerged zone depth (m)	Recommended: 0	Usually no submerged zone for in-situ soils.

Wicking beds

A wicking bed is a vegetated system (turf open space or vegetated garden bed) that has a reservoir of water or wicking layer at the base, from which water is draw upwards like a wick to the soil layer above. The wicking bed uses the natural process of soil capillary rise, driven by evapotranspiration, to irrigate the active root zone. As the vegetation removes water from the soil, it is replaced by water replenished from the storage below by capillary action thereby ensuring optimal soil moisture conditions for healthy growth. The depth and composition of the wicking layer is governed by capillary rise distance and storage volume. Wicking beds are most likely to be used in combination with sports fields but may also be used for passive recreational lawns or garden beds.

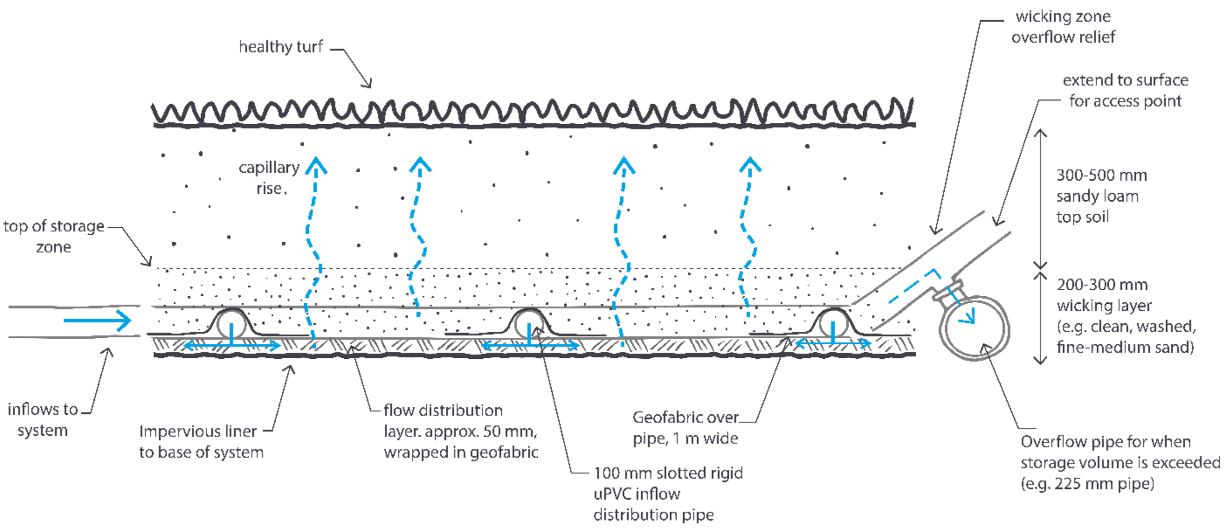


Figure 27 Turf wicking bed typical section

Modelling approach

In wicking beds, stormwater enters directly into the wicking storage zone at the base of the system, rather than entering onto the surface like bioretention systems. Within MUSIC, there are currently no treatment nodes which can represent this subsurface flow path, direct rainfall falling on the surface and the capillary rise from submerged zone to the filter media.

Two different modelling approaches may be used to set an upper and lower bound for water quality results, and to assess different aspects of performance:

Bioretention node. This approach also allows users to make an indicative assessment of stormwater quality, potential stormwater volume reductions and soil moisture. In the case of a turf cover, 'vegetation with ineffective nutrient removal plants' should be selected.

Rainwater tank node (where potential evapotranspiration rates and crop factors are used to calculate the reuse demand). This approach can provide a lower estimate of potential stormwater quality performance and allows users to assess the storage volume and supply reliability.

It is recognised that wicking beds are an emerging asset type, and design guidance will evolve as further research, data and monitoring outcomes become available to better understand their potential for stormwater flow management and pollutant reduction.

Modelling using a bioretention node

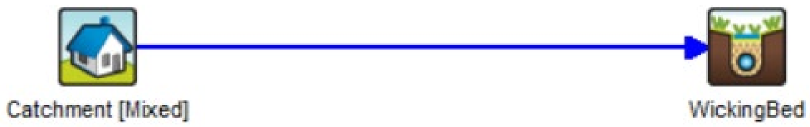


Figure 28 Wicking bed schematic when modelling using bioretention node

Modelling using rainwater tank node

All flows entering the aquifer storage zone of a wicking system require pre-treatment. In the example treatment train shown in Figure 29, a porous pavement pre-treatment is modelled using a filter media node. The wicking bed is modelled using a rainwater tank to represent the wicking bed (submerged zone) storage volume with a calculated seasonal (annual) demand applied to represent evapotranspiration from the wicking bed.

Figure 29 Wicking bed schematic when modelling using rainwater tank node

Model input parameters

Starting points for input parameters for the design of wicking beds are provided in Table 14

Table 14 Indicative design and modelling parameters for wicking beds (modelled using bioretention node or rainwater tank node respectively)

Parameter	Value	Guidance
Bioretention approach		
Catchment area	External upstream catchment area plus wicking bed surface area	To improve the accuracy of soil moisture and evapotranspiration modelling in MUSIC, the surface area of the wicking bed should be modelled as an additional catchment area with 100% imperviousness representing direct rainfall on the surface.

Parameter	Value	Guidance
Surface area of wicking bed	User defined	Set to the surface area of the wicking system's landscape. This area will determine the irrigation demand and the storage volume available.
PET Factor (water demand)	User defined	The potential irrigation demand for a lawn is determined by several factors including: • Climatic conditions - temperature, humidity, wind, sunshine • Crop factor – volume of water required for a specific species to grow. This can vary through a season and different growth phases of a plant. • Surface area –larger wicking lawns will have a higher demand. Irrigation demands may be estimated using standard textbook methods[31], an appropriate crop factor for the planting and assuming a high irrigation efficiency. An example demand is shown below considering the minimum factors: $\boldsymbol{Demand = PET \times crop\ factor \times irrigation\ efficiency - rainfall}$
Extended detention depth (m)	Recommended: 0.3 to 0.5	The extended detention will function similarly to the storage zone of the wicking system, so the depth should be calculated based on the storage zone of the wicking system. $EDD = (wicking\ layer\ depth) \times (porosity\ of\ wicking\ media)$
Filter depth (m)	Recommended: 0.3 to 0.5	Depth of the sandy loam topsoil (typically 300-500mm).
Saturated hydraulic conductivity (mm/hr)	Required: 36 to 100	As per design if <100 mm/hr or 100 mm/hr for loamy sand top-soil or filter media.
Exfiltration rate (mm/hr)	Recommended: 0	Usually no exfiltration allowed.
Underdrain	Required: Yes	
Wicking layer media	N/A	The wicking layer media choice (for example sand, scoria) will influence the maximum wicking layer depth and porosity. Storage volume (relates to both wicking layer depth and porosity).

[31] For example: Connellan, G., 2013, Water use efficiency for irrigated turf and landscape

Parameter	Value	Guidance
Wicking layer (Submerged zone) depth (m)	Recommended: Nominally 0.3 to 0.5	The maximum depth of the storage zone is determined by the capillary rise or wicking ability of the media while a minimum depth is required to incorporate a flow distribution network.
Wicking layer storage volume (m^3)	Varies	The storage zone or aquifer for the wicking lawn extends under the full surface area of the system, such that all turf/landscape can have equal access to the soil moisture stores. The depth of the storage zone (wicking layer) and the porosity of the wicking media will determine the volume of water that can be stored. $\boldsymbol{Storage\ volume}\ (\boldsymbol{m^3}) = (\boldsymbol{surface\ area, m^2}) \times (\boldsymbol{depth\ of\ wicking\ layer, m}) \times (\boldsymbol{porosity\ of\ wicking\ media})$ If the storage zone of the wicking system contains several layers of varying porosity, a weighted average of porosity should be adopted. Note, this is only applicable if modelling the wicking bed using a rainwater tank node.
Wicking layer porosity (-)	Recommended: 0.35-0.95	The porosity will depend on the chosen wicking media. Sand and most natural materials will have a relatively low porosity of 0.35, whereas wicking storage cells can have a porosity of up to 0.95.
Rainwater tank approach		
Catchment area	Upstream catchment area	The direct rainfall on the surface does not need to be modelled in a rainwater tank model, because this rainfall is factored into the demand calculation of the tank.
Tank volume (kL)	User defined	$Storage\ volume = (surface\ area) \times (depth\ of\ wicking\ layer) \times (porosity\ )$
Overflow pipe diameter (mm)	User defined	Set to the overflow pipe outlet size of the wicking system.

Parameter	Value	Guidance
Annual demand	User defined	Annual demand using PET distribution. The potential irrigation demand for a lawn is determined by several factors including: • Climatic conditions - temperature, humidity, wind, sunshine. • Crop factor – volume of water required for a specific species to grow. This can vary through a season and different growth phases of a plant. • Surface area – larger wicking lawns will have a higher demand. Irrigation demands may be estimated using standard textbook methods[32], an appropriate crop factor for the planting and assuming a high irrigation efficiency. An example demand is shown below considering the minimum factors: $Demand = PET \times crop\ factor \times irrigation\ efficiency - rainfall$

Slow release rainwater tanks

A slow release rainwater tank is a traditional rainwater tank that releases water very slowly via a garden hose or drip irrigation into a nearby garden or lawn area. This area can be regarded and represented in MUSIC as a 'vegetated sponge' asset as described in the *Vegetated sponges* section. The slow rate of irrigation allows the water to be absorbed into the passively irrigated area, allowing time for evapotranspiration and infiltration, and avoiding saturating the area excessively. The consistent and predictable draw-down of the tank ensures that there is available storage volume for the next rainfall event. In this way, incorporating passive irrigation for all or part of a storage tank's capacity can help meet stormwater flow volume

32 For example: Connellan, G., 2013, Water use efficiency for irrigated turf and landscape

objectives for harvesting/evapotranspiration and infiltration as well as flood mitigation.

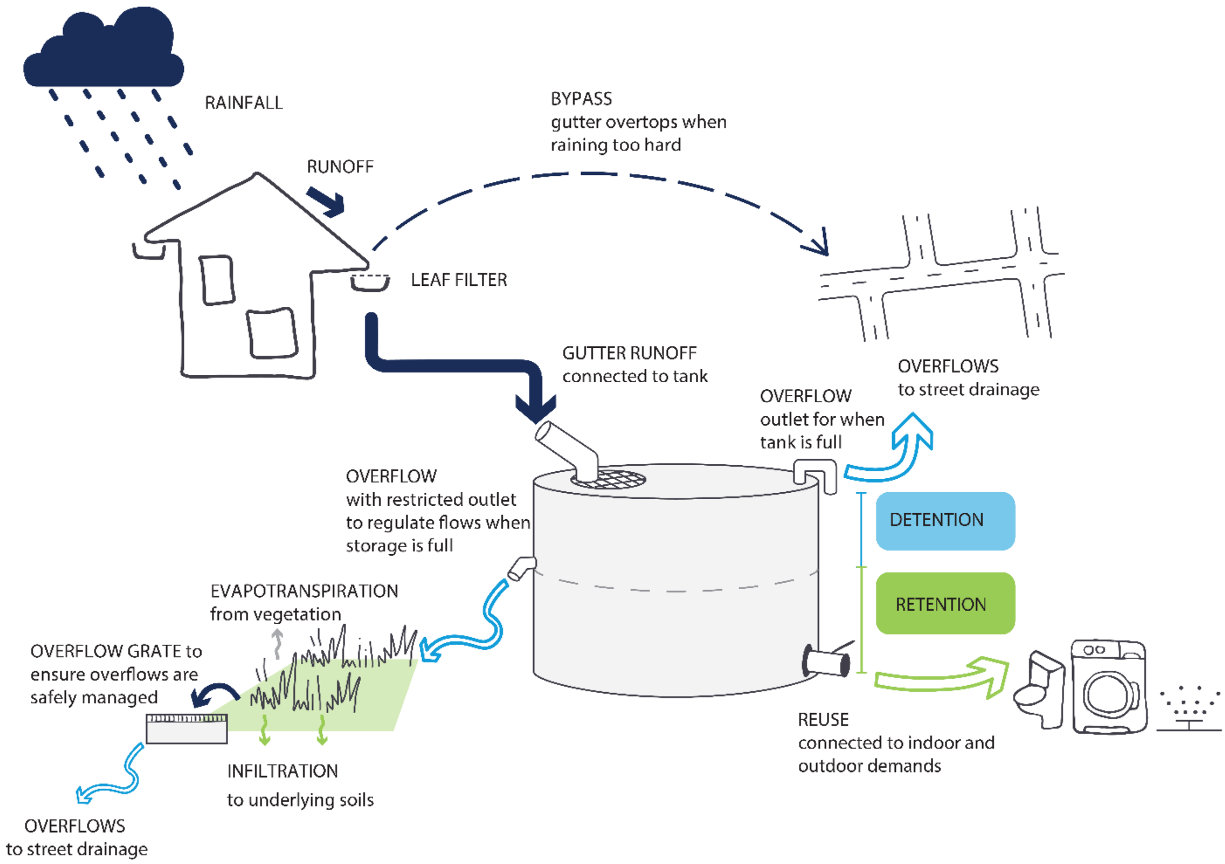


Figure 30 Slow release rainwater tank schematic

Further information on the design of slow release rainwater tanks is provided in the *Emerging assets for stormwater flow management* document.

It is important to represent both the slow release rainwater tank itself and the vegetated area to which it drains in MUSIC.

Modelling approach

There are at least two ways the slow release rainwater tank itself can be represented in MUSIC with the choice depending on whether the outlet is a controlled orifice plate with a constant outflow rate or a simple outlet pipe:

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 detention portion of storage) with a controlled release fixed at a flow rate that can be accommodated by the downstream vegetated area or WSUD asset (represented as constant reuse).

Simple outlet pipe. Represented as a storage volume defined by 'Depth above overflow' and '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.

Modelling a controlled orifice plate with constant outflow rate

A secondary link for reuse flows, as shown in Figure 31, may be used to direct flows from the slow release rainwater tank to the vegetated area.

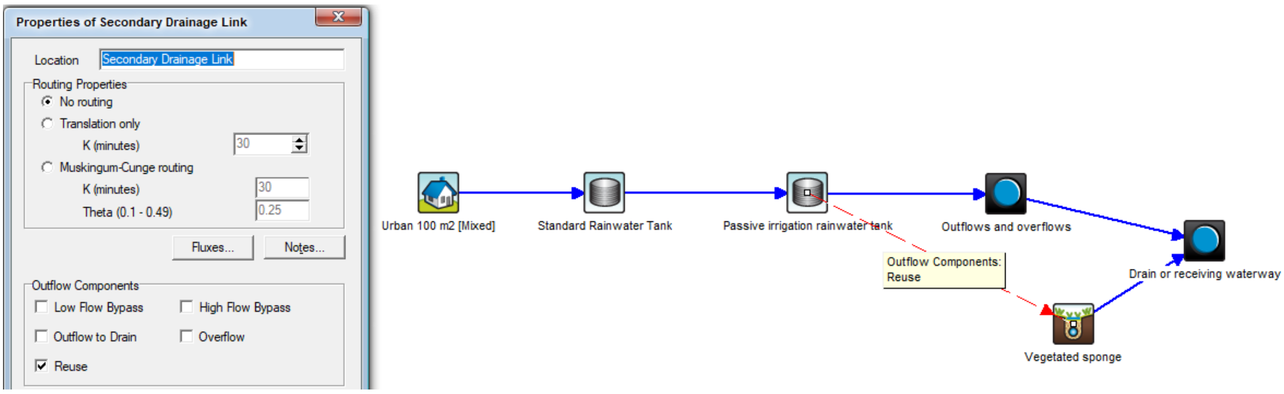


Figure 31: Representation of the passive irrigation storage component of a rainwater tank as a second tank within the model using reuse to limit discharge flow rates

Modelling the simple outlet pipe

A primary link with overflows and secondary link with outflows, as represented in Figure 31 and Figure 33 may be used to direct outflows from the slow release rainwater tank to the vegetated sponge.

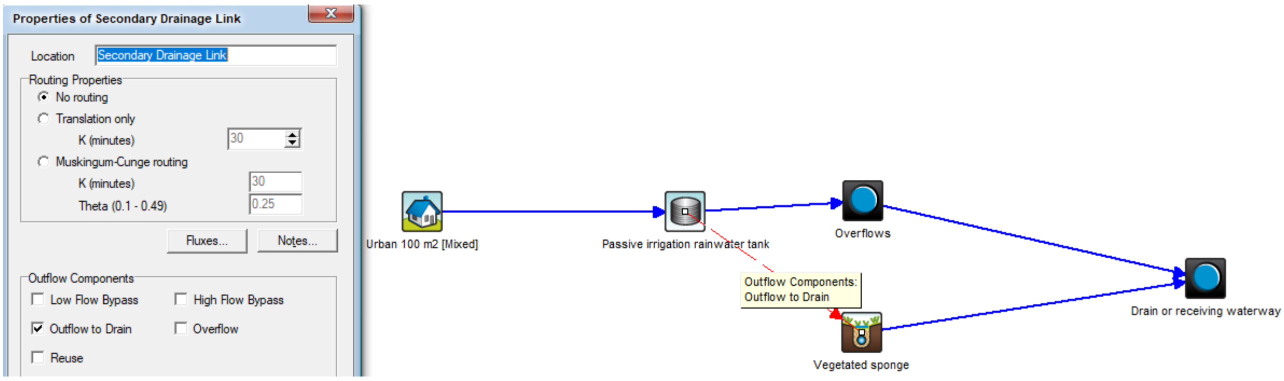


Figure 32 Representation of the passive irrigation storage component of a rainwater tank using the depth above overflow and a constrained overflow pipe diameter to limit outflow rates

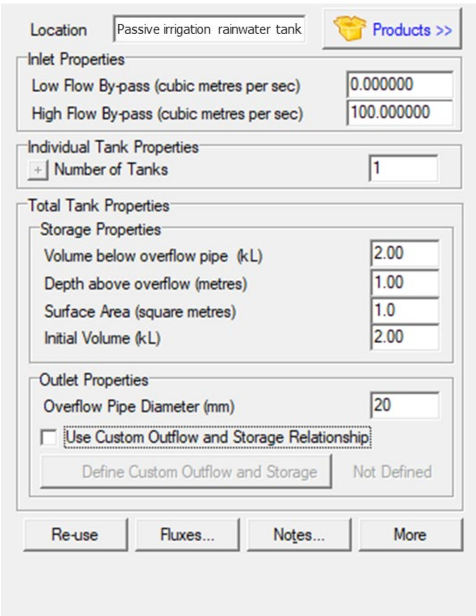


Figure 33: MUSIC parameterisation of the passive irrigation storage component of a rainwater tank using the depth above overflow and a constrained overflow pipe diameter to limit discharge flow rates

The volumes of inflows and outflows for various flow pathways may be checked in the 'Node Water Balance' for the vegetated sponge treatment node.

It is recognised that slow release rainwater tanks are an emerging asset type, and design guidance will evolve as further research, data, and monitoring outcomes become available to better understand their potential for stormwater flow management and pollutant reduction.

Passively watered trees

Trees can be passively watered with stormwater, particularly those integrated into streetscapes or paved areas. Stormwater runoff from these surfaces is directed towards the tree, where it temporarily ponds and infiltrates into a permeable zone around its base. The water is absorbed into the root zone, providing an opportunity for treatment and for the tree to uptake water, which is later returned to the atmosphere through evapotranspiration. Any excess water then infiltrates into the subsoil through a filter media installed beneath the paving.

Passively watered trees can be considered a variant of bioretention for modelling purposes. In the MUSIC bioretention node:

> **Surface area** – defines the area of the surface pond or extended detention volume above the filter media.
>
> **Filter area** – defines the area of the filter media over which water infiltrates into the media, water exfiltrates from the base of the filter media and evapotranspiration occurs from the filter media.

There are several key physical characteristics of passively watered trees that need to be represented in MUSIC. These are illustrated in Figure 34.

1. The area over which water can infiltrate from the surface pond into the filter media.
2. The area over which water exfiltrates from the filter media to the underlying soil.
3. The tree canopy area or vegetated surface area over which evapotranspiration can occur.
4. The effective filter media volume which is calculated as the filter area multiplied by filter media depth.
5. The effective volume of extended detention storage (calculated as extended detention depth multiplied by surface area).

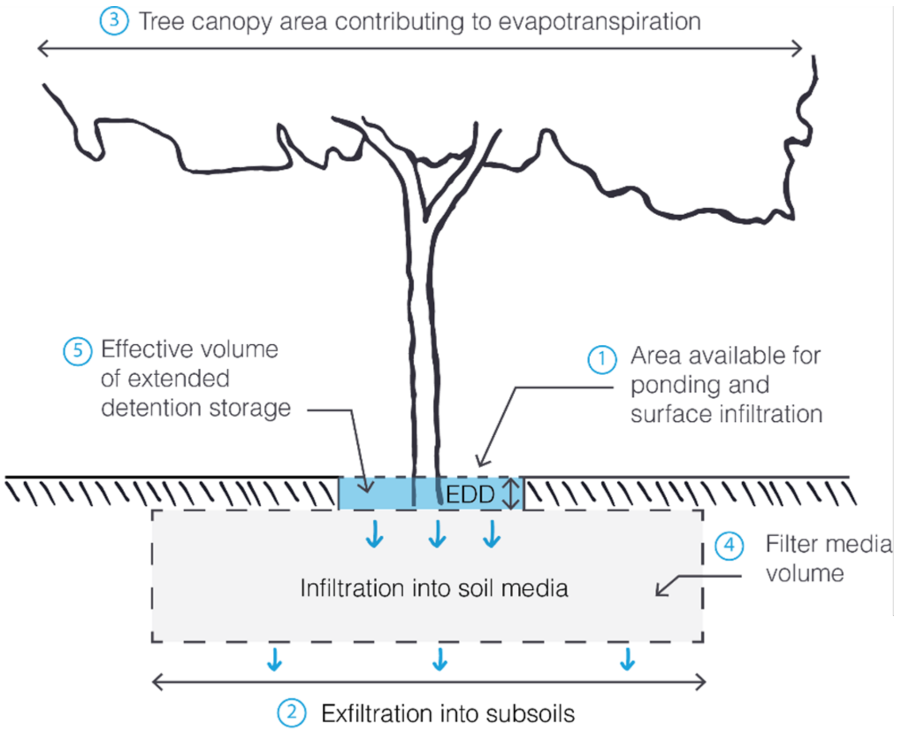


Figure 34 Physical characteristics of passively watered trees to be represented in MUSIC

There are two common types of passively watered tree arrangements:

- Area for ponding and surface infiltration greater than or equal to filter area.
- Area for ponding and surface infiltration less than filter area.

Approaches for modelling these are described below.

Area for ponding and surface infiltration greater than or equal to filter area

For one configuration of passively watered trees, water can spread over the whole surface of the soil or filter media (either across a vegetated or permeable surface or below a suspended pavement), see Figure 35. For these designs, model as follows:

- The effective filter media volume and extended detention storage volumes are calculated directly from the filter area and surface area respectively.
- The filter area is used to represent both the surface area for infiltration and exfiltration.
- Adjustments to represent evapotranspiration from the tree canopy are discussed below.

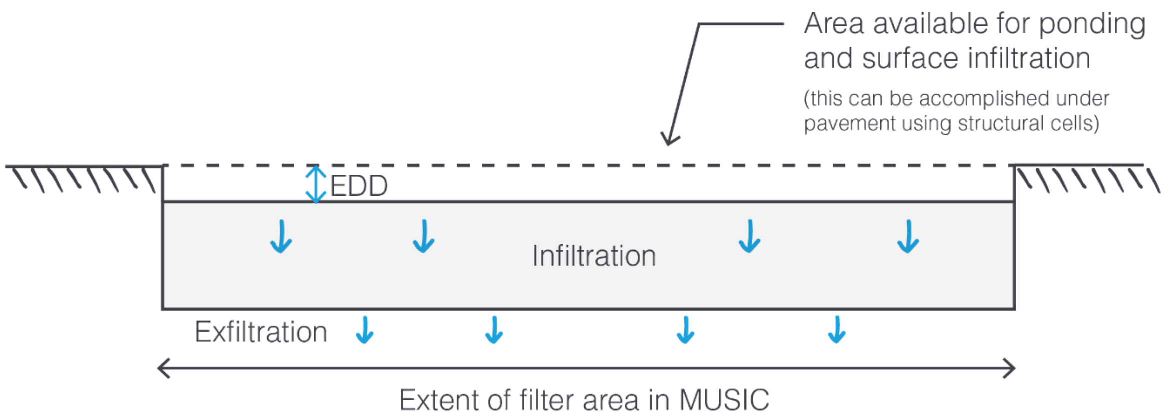


Figure 35 Tree planter where area available for ponding and surface infiltration ≥ filter area

Area for ponding and surface infiltration less than filter area

For an alternate configuration of passively watered trees, the extended detention is constrained to a tree pit, while the underlying filter media or tree planting soil and expected tree root zone extends out beyond the pit. This type of asset is more difficult to directly represent in MUSIC as the available node (bioretention) does not anticipate this scenario.

Ideally, the ‘surface area’ would be set to the area over which water can infiltrate into the filter media, and the filter media set to the area over which water can exfiltrate into the underlying soil. However, the surface area cannot be set to less than the filter area in MUSIC. As an approximation the following interim approach should be taken until MUSIC is revised to support this type of asset:

- The filter area is set to the surface infiltration area of the filter media.
- The filter depth is increased to provide the correct volume of filter media, including filter media or other installed soils surrounding the tree pit by multiplying filter depth by total filter volume divided by the surface area for infiltration (with further adjustment for structural soils if applicable).

- The exfiltration rate is factored up:

$$exfiltration\ rate = \frac{exfiltration\ rate \times base\ exfiltration\ area}{surface\ infiltration\ area}$$

Adjustments to represent evapotranspiration from the tree canopy are discussed below.

Since the model parameters will no longer correspond to the physical dimension of the asset it is essential that clear model notes are provided on the bioretention node and in any report.

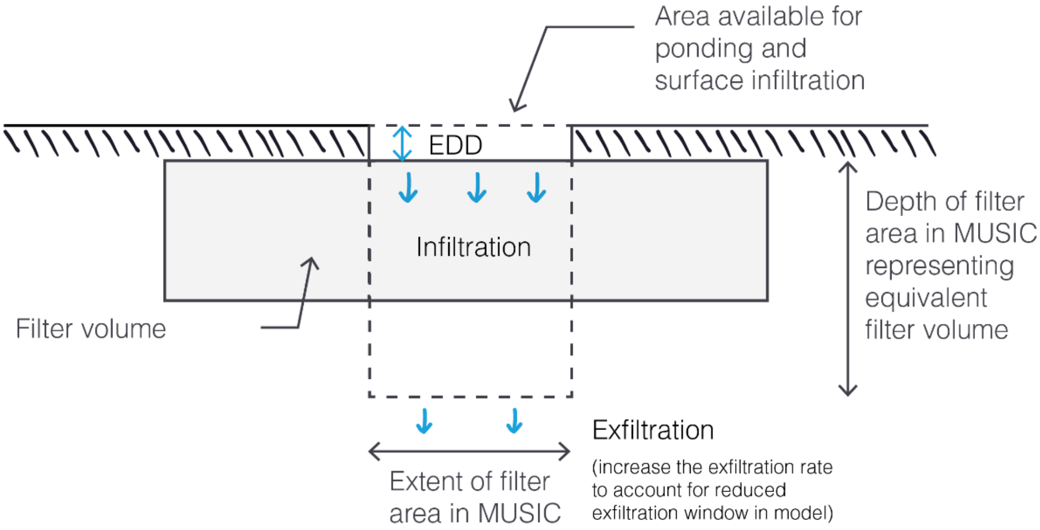


Figure 36 Representing a tree planter where the soil extends beyond the tree pit and area available for ponding and surface infiltration is less than the filter area.

Adjustment of potential evapotranspiration

MUSIC estimates evapotranspiration rates based on the filter area of the bioretention node. For a raingarden, the evapotranspiration surface area is approximately the same as the surface and filter areas. For trees, the evapotranspiration surface is the tree canopy area, which may be larger than the filter area and therefore evapotranspiration may be underestimated by MUSIC.

This adjustment is made using a PET scaling factor which accounts for the difference in the tree canopy area and filter area. In the bioretention node, the PET scaling factor can be adjusted in the advanced properties section.

$$PET\ scaling\ factor = Base\ PET\ scaling\ factor \times \frac{tree\ canopy\ area\ (m^2)}{filter\ area\ (m^2)}$$

For a raingarden, the base PET scaling factor has a default of 2.1. This represents the relatively high potential evapotranspiration of raingarden plants such as *Carex appressa* growing in columns. This would be appropriate for streetscape raingardens but may over-estimate evapotranspiration for very large assets, other vegetation and most trees, based on current understanding of typical tree water use. The values provided in Table 15 should be used in preference for tree pits.

It is recommended to consult with Council for suitable tree species within streetscapes. These should consider local climate, context as well as capacity to cope with both extended wet and dry conditions. Specific guidance is not provided here due to the wide variation in preferences between Councils.

Table 15 Base PET scaling factors according to plant type

Plant Type	Base PET Scaling Factor
Raingarden plants	2.1 (default in MUSIC)
Trees with high potential water use	1.8
Trees with moderate potential water use	1.5

The design of the ultimate canopy area of the tree should be used for modelling.

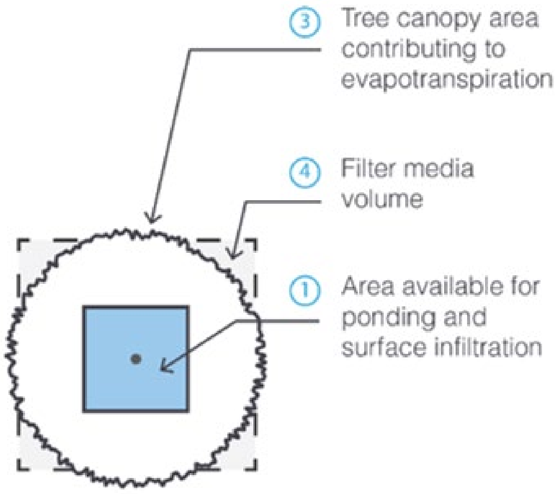


Figure 37 Tree canopy and evapotranspiration surface relative to filter area for a tree planter

Representation of tree planting soils

A passively watered tree may be planted with either raingarden filter media or a suitable tree planting media. Tree planting media may have a lower saturated hydraulic conductivity (the typical range may be 30 to 50 millimetres per hour). The saturated hydraulic conductivity to adopt in the model would then be 100 millimetres per hour for raingarden filter media or 30 millimetres per hour for alternate tree planting media.

Representation of structural soils

Passively watered trees may be constructed incorporating surrounding structural soils. Where these are within the expected canopy footprint of the tree and it is realistic to expect that good root establishment may occur throughout, they may be counted as part of the filter media storage volume.

Structural soils have an effective soil volume after taking account of the structural component which is usually aggregate or a proprietary product. For structural soils with aggregate, a 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. For proprietary products, an appropriate percentage of soil must be adopted. This is usually much higher (80-90%) but depends upon the product specifications.

Users should adjust filter depth in the bioretention node (rather than filter area) to account for the total effective soil or filter media volume.

Model input parameters

Guidance on input parameters for the design of permeable paving are provided in Table 11.

Table 16 Indicative design and modelling parameters for passively watered trees (modelled using bioretention node)

Parameter	Value	Guidance
Low flow bypass (m^3/s)	0 or design bypass flow rate	Should be set to appropriate value 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. Otherwise set to 0.
High flow bypass (m^3/s)	Inlet capacity or 100 if no restriction	Set model input value to inlet capacity where limited. This is important for kerb cuts and inlets. Otherwise, where not restricted, set to arbitrary high number and treatable flow rates are determined by the extended detention depth and corresponding surface storage volume.
Extended detention depth (m)	Required: 0.01 to 0.5 Recommended: 0.1 to 0.3	Typical range. This should be based on ensuring the correct volume of surface water storage.
Filter depth (m)	Required: 0.3 to 0.6 Recommended: 0.4 to 0.6 or 0.7 to 1.0 with trees*	Filter depth is the depth of filter media or tree pit soil above underdrain invert. Total filter media depth including submerged zone greater than or equal to 400 mm. Total filter media depth including submerged zone greater than or equal to 400 mm with at least 700 mm recommended for trees.
Saturated hydraulic conductivity (mm/hr)	Required: 30 to 300 Recommended: Tree pit soils: 30 Bioretention filter media: 100	Assume lesser of design hydraulic conductivity or 100 mm/hr for modelling. Tree pit soils design range: 30-50 mm/hour Bioretention filter media design range: 100-300 mm/hour (100-200 mm/hour preferred) Media with greater soil moisture retention preferred.
PET scaling factor	High water use tree: 1.8	This influences the evapotranspiration rate. This base factor should be revised by multiplying it by canopy area / filter area

Parameter	Value	Guidance
	Moderate water use tree: 1.5	
Exfiltration rate (mm/hr)	Recommended: 0.18 to 100	An exfiltration rate suitable for the underlying soils should be adopted and must be set using the guidance provided in *Infiltration into surrounding soils (exfiltration rate)*. If groundwater risks are identified, refer to the guidance in that section on sensitivity testing of the input parameters
Underdrain	Recommended: Yes	Include above a submerged zone
Submerged zone depth (m)	Recommended: 0.3 to 0.5	Include depth of filter media, transition media and drainage below underdrain invert Sand is preferred over gravel to support capillary rise.
Total nitrogen (mg/kg)	800	Design total nitrogen concentration <800 recommended. Media with low nutrients preferred.
Orthophosphate content (mg/kg)	Required: ≤50 Recommended: ≤30	Design orthophosphate content ≤30 recommended and ≤ 50 mg/kg required. Model with upper end of design range. Media with low nutrients preferred. May be lowered subject to agreement if total phosphorus is limiting pollutant. Evidence that filter media meets this specification must be provided at construction.

Permeable or porous paving

Permeable paving allows runoff to drain through, or between, a paved surface and infiltrate the underlying media. It can provide some degree of stormwater treatment but more importantly increases the pervious area of the developed catchment that can infiltrate into the soil. An example of a typical permeable pavement cross-section is shown in Figure 38. Permeable paving is considered a type of unvegetated filter and may be modelled using the media filtration node.

Further information is available in the *Emerging assets for stormwater flow management State-of-Knowledge document.*

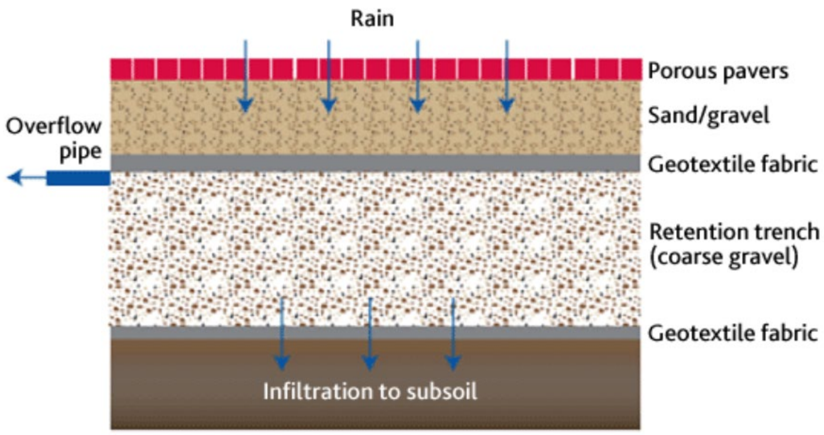


Figure 38 A typical permeable paving cross section

Catchment (source) node set up

MUSIC does not represent direct rainfall onto a treatment node (see 'Direct rainfall on treatment'). For assets like permeable pavement, where the asset's own treatment area will be a significant part of its catchment, it is important that this treatment area is represented as an impervious catchment draining to the asset.

For permeable paving in public roads or commercial/industrial car parks, a 'road' surface type should usually be adopted as the best approximation of pollutant concentrations. Justification must be provided where a different surface type is proposed (for example, 'all other urban' surface concentrations for a pedestrian or residential driveway area with permeable paving).

Model input parameters

In MUSIC, the media filtration node is generally recommended to model permeable paving.

Permeable paving must be modelled taking the relevant manufacturer's guidelines into account. Documentation supporting the modelling must be submitted for review.

General guidance on input parameters for the design and modelling of permeable paving are provided in Table 17.

Table 17 Indicative design and modelling parameters for permeable paving using the media filtration node

Parameter	Value	Guidance
Extended detention depth (m)	Design recommended: 0.0 Model recommended: Nominal 0.01-0.02	Assumes water overflows freely from the permeable pavement. May be set higher if there is a specific design intent to allow frequent ponding above the paving.
Exfiltration rate (mm/hr)	Required: 0 to 100	The exfiltration rate applies to the underlying soil (not the filter media) and must be set using the guidance provided in *Infiltration into surrounding soils (exfiltration rate)*. Designs including infiltration must consider site suitability as well as constraints for infiltration such as reactive clay soils, bedrock, groundwater, slope, soil contamination and nearby infrastructure.
Surface area (m^2)	User defined	The total surface area of the permeable pavement. This includes both pavers and permeable openings for permeable interlocking pavers or similar.
Filter area (m^2)	User defined	For permeable interlocking pavers or similar with openings to allow infiltration, the opening area of the permeable pavement (not the total surface area) should be set as the filter area. This must be estimated based on the product specifications.
Filter depth (m)	User defined	Set the filter depth to represent the depth of the treatment zone, nominally the depth of permeable pavement and underlying sand and gravel supporting layers including the base course, see Figure 38.
Filter median particle diameter (mm)	Recommended: 1 to 5	Set to median particle size, such as 2 millimetres (a range of 1 to 5 millimetres depending on design is acceptable).
Saturated hydraulic conductivity (mm/hr)	Required: 100 to 200	Range recommended to realistically represent long term conditions allowing for clogging of the pavement surface over time with periodic maintenance. Permeable pavement specifications often detail high infiltration rates, commonly thousands of millimetres per hour, however these can be expected to decline exponentially over time.
Depth below underdrain pipe (% of filter depth)	User defined	Set to zero per cent if no submerged zone below underdrainage. Set to an appropriate percentage where a submerged or storage zone below underdrainage is provided to encourage additional infiltration.

Swales

Suggested vegetation heights:

- Grass swale (mowed) height range: 10 to 100 millimetres
- Vegetation (not mowed): 100 to 400 millimetres

In the case where unmown vegetation is being used, the proponent should identify what type of vegetation is proposed, and how it will be managed within the landscape and maintenance requirements of the development. Waterways within developments cannot be deemed as swales and shall not be included in the treatment train model.

Ponds

MUSIC is not a suitable model for in-lake processes, other than water balance assessments. Guidance on this topic can be found in Melbourne Water's *Constructed Shallow Lake Systems: Design Guidelines for Developers* (Melbourne Water, 2005)[33]. Ponds will not be accepted as treatment nodes.

Imported data nodes

Supporting documentation will be required to justify and explain the use of any imported data nodes in models.

Generic treatment nodes

A generic treatment node can be used to simulate a pump, by setting the flow rate passing through the node (the high flow bypass rate) to the maximum pump flow rate. Flows exceeding the pump flow rate must then be accounted for using a secondary link, to direct the high flows above the high flow bypass rate, to an appropriate downstream node.

Generic nodes can be used to simulate the splitting of flows and are most useful where a flow rate-based diversion is used. Appropriate documentation and calculations must be provided to justify the split of flows where generic nodes are used for this purpose. Many flow splits can more easily be modelled using a secondary link to split flows from a catchment or treatment outlet.

For generic nodes, the outflows or pollutant concentrations from a transfer curve must not exceed the inflows or pollutant concentrations entering in. The pollutant balance should be checked using Mean Annual Loads for the node to ensure that pollutants are not created or lost, as generic treatment node outputs can easily be misinterpreted.

33 https://www.melbournewater.com.au/media/607/download

8. Proprietary stormwater treatment devices

Proprietary stormwater treatment devices are manufactured products aimed at improving stormwater quality.

Most of these devices fit into the following categories:

- gross pollutant/litter traps
- sedimentation devices
- oil separators
- man-made floating wetlands
- media filtration devices.

Melbourne Water is not a proprietary stormwater treatment device regulator and does not undertake reviews or provide endorsements of proprietary stormwater treatment devices and their performance. Proprietary manufactured devices may not be considered a replacement of nature-based solutions in Development Services Schemes.

Outside of Development Services Schemes the selection and adoption of proprietary stormwater treatment devices is to be discussed and agreed upon with the relevant responsible body, for example, councils, road authorities, body corporates, golf courses etc.

In circumstances that require alternative solutions, Melbourne Water may investigate or accept the implementation of a proprietary stormwater treatment device, however this does not constitute endorsement of the device.

9. Evaluating performance against stormwater objectives

Stormwater quality

Obtaining results to demonstrate compliance with stormwater quality objectives in MUSIC is straight-forward. This is outlined in Chapter 6 in the section on *Modelling infiltration of flows and pollutant loads*.

All flows leaving the development site may be directed to a single outlet node. This should include all outflows, overflows, bypasses, untreated areas and also *all infiltration from treatment assets*.

Secondary drainage links, see Chapter 5: *Routing and drainage links*, should be used to convey infiltrated flows and pollutant loads downstream within models, back to the development outlet node (as shown in Figure 39), such that they are accounted for in load reduction targets (or alternate calculation methods used to account for these).

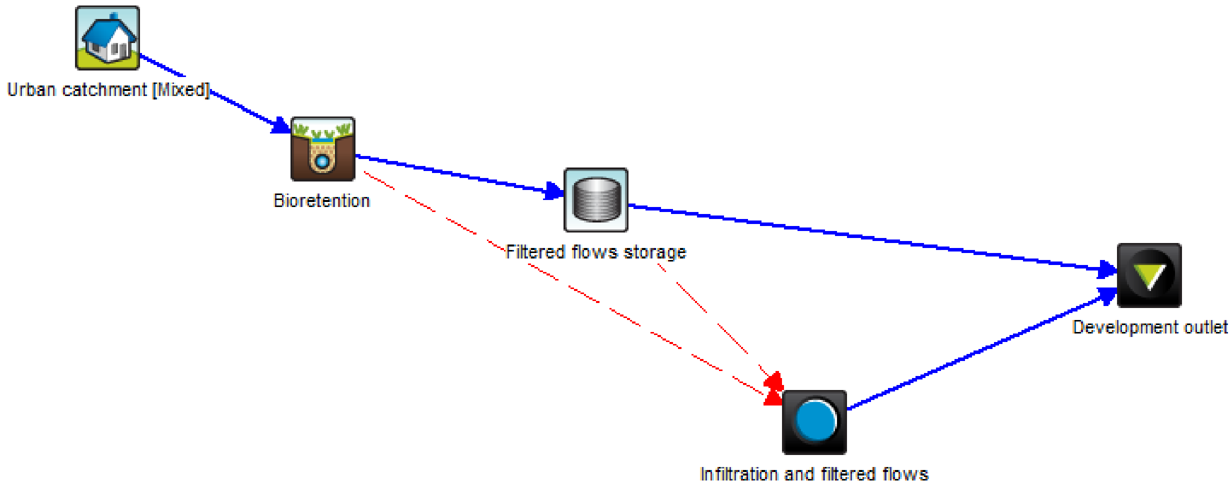


Figure 39 Example model configuration set up to extract outputs for assessing compliance with flow objectives

Stormwater volumes

To demonstrate achievement of the stormwater volume objectives for harvesting/evapotranspiration and for infiltration/filtered flows, the following data is required:

- **Total impervious area runoff volume (mega litres per year):** Surface runoff from all impervious areas. This does not include either surface runoff or baseflows from vegetated pervious areas (although these will often be directed to treatment nodes).
- **Total stormwater harvested and evapotranspired by WSUD assets (mega litres per year):** May include rainwater and stormwater harvesting, evaporation from water surface areas and soil and plant transpiration.
- **Total stormwater infiltrated or filtered by WSUD assets (mega litres per year):** Includes infiltration to underlying soils for potential groundwater recharge and/or waterway baseflows plus filtered flows released below a threshold in a pattern approximating natural baseflows.

The outcomes may be calculated as follows for comparison with the targets:

$$Harvesting\ reduction\ (\%) = \frac{Total\ stormwater\ harvested\ and\ evapotranspired\ (ML/year)}{Total\ impervious\ area\ runoff\ volume\ (ML/year)}$$

$$Infiltration\ reduction\ (\%) = \frac{Total\ stormwater\ infiltrated\ and/or\ filtered\ flow\ (ML/year)}{Total\ impervious\ area\ runoff\ volume\ (ML/year)}$$

$$Harvesting\ reduction\ (ML/ha/year) = \frac{Total\ stormwater\ harvested\ and\ evapotranspired\ (ML/year)}{Total\ impervious\ area\ (ha)}$$

$$Infiltration\ reduction\ (ML/ha/year) = \frac{Total\ stormwater\ infiltrated\ and/or\ filtered\ flow\ (ML/year)}{Total\ impervious\ area\ (ha)}$$

The resulting outcomes must fall within the target range set out in the HWS Practitioner's Note.

Obtaining the data from MUSIC

While MUSIC does not directly report outcomes for these objectives, the data for impervious surface runoff, harvesting (reuse), evapotranspiration, infiltration and filtered flows can be obtained from any MUSIC model through one of the following methods:

3. node water balance outputs for each node
4. from nodes configured to collate the total impervious area runoff, total infiltration, and filtered flows at an outlet
5. a MUSIC summary report (*.mrt) file.

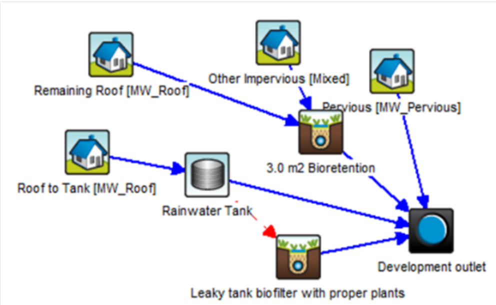
Method 1: Calculate based on node water balance

Use the node water balance outputs for each node to obtain 'impervious stormwater out' for catchment nodes, and 'reuse supplied', 'ET loss', and 'infiltration' for treatment nodes (see Figure 40). Sum these together for all catchment and for all treatment nodes.

Node Water Balance - Roof to Tank

	Flow (ML/yr)	TSS (kg/yr)
Rain In	0.106011	
ET Loss	0.018592	
Deep Seepage Loss	0.000000	
Baseflow Out	0.000000	0.000000
Imp. Stormflow Out	0.087419	
Perv. Stormflow Out	0.000000	
Total Stormflow Out	0.087419	2.335730
Total Outflow	0.087419	2.335730
Delta Soil Storage	0.000000	
Warmup is ON		

Obtain 'Impervious stormflow out' for catchment nodes



Node Water Balance - Rainwater Tank

	Flow (ML/yr)
Flow In	0.087413
ET Loss	0.000000
Infiltration Loss	0.000000
Low Flow Bypass Out	0.000000
High Flow Bypass Out	0.000000
Pipe Out	0.039027
Weir Out	0.000000
Transfer Function Out	0.000000
Reuse Supplied	0.048562
Reuse Requested	0.062022
% Reuse Demand Met	78.298668
% Load Reduction	55.353793

Node Water Balance - 3.0 m2 Bioretention

	Flow (ML/yr)	TSS (kg/yr)
Flow In	0.128966	8.737418
ET Loss	0.005648	0.000000
Infiltration Loss	0.004362	0.013077
Low Flow Bypass Out	0.000000	0.000000
High Flow Bypass Out	0.000000	0.000000
Pipe Out	0.097190	0.224867
Weir Out	0.021741	0.705029
Transfer Function Out	0.000000	0.000000
Reuse Supplied	0.000000	0.000000
Reuse Requested	0.000000	0.000000
% Reuse Demand Met	0.000000	0.000000
% Load Reduction	7.780375	89.357316

Obtain 'Reuse Supplied', 'ET Loss' and 'Infiltration' for treatment nodes

Figure 40 Determination of performance relative to volume objectives

Method 2: Configure nodes to collate required volumes

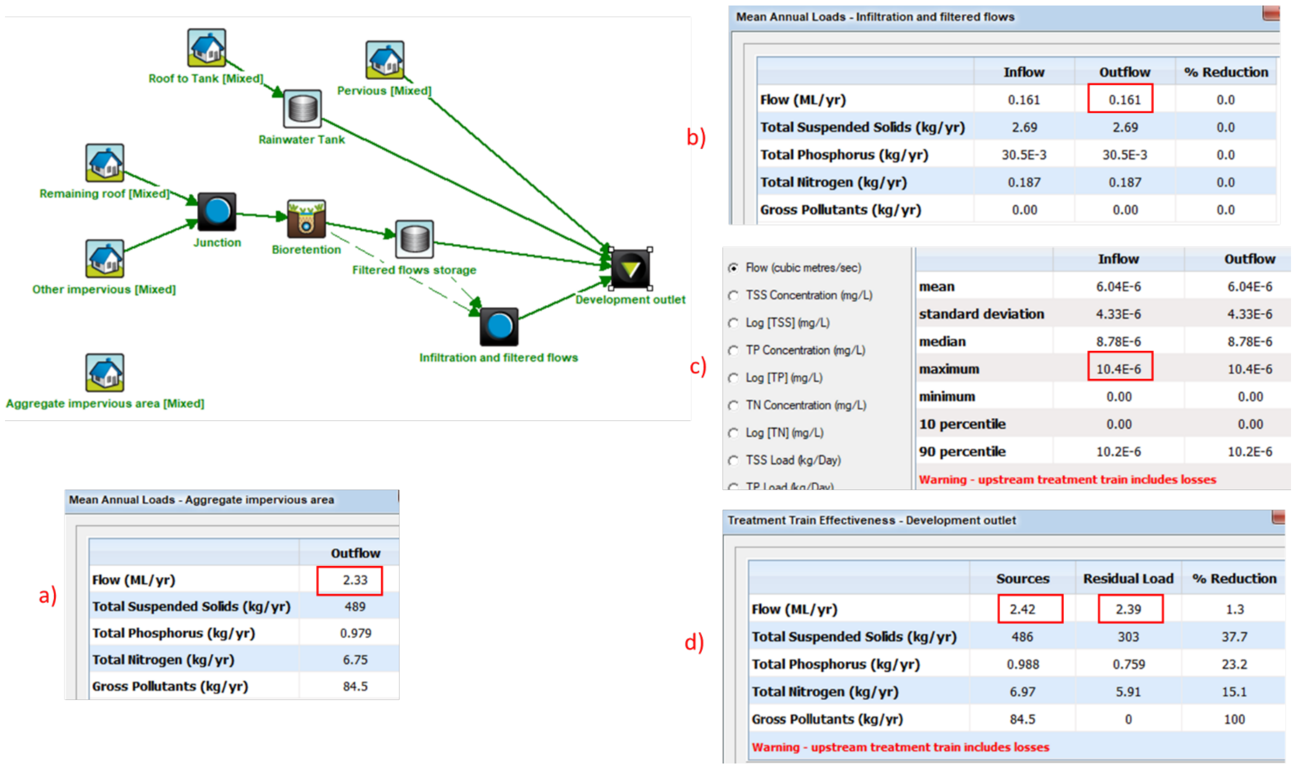
A model may be configured to make it easier to obtain the data as follows (Figure 41):

a) **Calculate total impervious runoff (mega litres per year):** Create a single disconnected source node representing the total catchment impervious area and obtain the total impervious runoff as the flow volume from 'Mean Annual Loads'. Alternativly, this can be estimated using the unit runoff rate in the HWS Practitioner's Note and the impervious area.

b) **Calculate infiltrated and filtered flows (mega litres per year):** Create secondary drainage links to convey all infiltrated and filtered flows to one or more junction nodes. The total flow in the 'Mean Annual Loads' for these nodes will be the total infiltration and filtered flow volumes needed to assess outcomes for the 'infiltration and filtered flows' objective. These node(s) can then be connected to the catchment outlet to assess pollutant load reductions.

c) **Calculate maximum daily infiltrated and filtered flows (kilolitres per day):** This is necessary when filtered flows are being used to achieve infiltration targets to ensure they do not exceed the upper end of the infiltration/filtered flows range. These flows can be viewed in the 'Daily Maxima' for this junction node.

d) **Calculate harvested and evapotranspired flows (mega litres per day):** The reduction in surface runoff volumes through harvesting and evapotranspiration can then be assessed as the difference in mean annual runoff volumes (*Sources – Residual Load*) for the 'Treatment Train Effectiveness' at the catchment outlet node (Note that infiltration is returned to this node so the only losses are harvesting and evapotranspiration).



a) Mean Annual Loads - Aggregate impervious area

	Outflow
Flow (ML/yr)	2.33
Total Suspended Solids (kg/yr)	489
Total Phosphorus (kg/yr)	0.979
Total Nitrogen (kg/yr)	6.75
Gross Pollutants (kg/yr)	84.5

b) Mean Annual Loads - Infiltration and filtered flows

	Inflow	Outflow	% Reduction
Flow (ML/yr)	0.161	0.161	0.0
Total Suspended Solids (kg/yr)	2.69	2.69	0.0
Total Phosphorus (kg/yr)	30.5E-3	30.5E-3	0.0
Total Nitrogen (kg/yr)	0.187	0.187	0.0
Gross Pollutants (kg/yr)	0.00	0.00	0.0

c)

	Inflow	Outflow
mean	6.04E-6	6.04E-6
standard deviation	4.33E-6	4.33E-6
median	8.78E-6	8.78E-6
maximum	10.4E-6	10.4E-6
minimum	0.00	0.00
10 percentile	0.00	0.00
90 percentile	10.2E-6	10.2E-6

Warning - upstream treatment train includes losses

d) Treatment Train Effectiveness - Development outlet

	Sources	Residual Load	% Reduction
Flow (ML/yr)	2.42	2.39	1.3
Total Suspended Solids (kg/yr)	486	303	37.7
Total Phosphorus (kg/yr)	0.988	0.759	23.2
Total Nitrogen (kg/yr)	6.97	5.91	15.1
Gross Pollutants (kg/yr)	84.5	0	100

Warning - upstream treatment train includes losses

Figure 41 Model configuration to simplify extraction of data

Method 3: Generate a summary report file

For larger models, it will be simpler to obtain data from the summary report file (*.mrt). This can be opened in Excel and the relevant data can be obtained by summing the corresponding rows for impervious stormwater flow, evapotranspiration, infiltration, and reuse.

If filtered flows are used, these will need to be obtained from the specific nodes set up by the user. These will typically be a junction node and the mean annual flows as these can be obtained from the summary report file, for this junction node. The summary report file does not report daily maxima statistics, so users will need to rely on separately extracting the statistics at a node (Right click node: Statistics: Daily maxima: Maximum) to calculate the daily maximum infiltrated and filtered flows (kilolitres per day) (point (c) in Method 2 above).

	A	B	C	D	E	F	G	H
1	Source nodes							
2	Location	Pervious	Other Impervious	Remaining Roof	Roof to Tank	Direct rainfall on vegetated sponge	Total	Formula
6	Total Area (ha)	0.01	0.005	0.005	0.015	0.001	0.036	=Sum(B6:F6)
7	Area Impervious (ha)	0	0.005	0.005	0.015	0.001	0.026	=Sum(B7:F7)
58	Imp. Stormflow Out (ML/yr)	0	0.0291377	0.0291377	0.087413	0.007067	0.152756	=Sum(B58:F58)
61	Total Outflow (ML/yr)	0.0130926	0.0291377	0.0291377	0.087413	0.007067	0.165848	=Sum(B61:F61)
76	USTM treatment nodes							
77	Location	Rainwater Tank	Vegetated sponge				Total	Formula
174	ET Loss (ML/yr)	0	0.0073786				0.007379	=Sum(B174:F174)
175	Infiltration Loss (ML/yr)	0	0.0094694				0.009469	=Sum(B175:F175)
181	Reuse Supplied (ML/yr)	0.0369488	0				0.036949	=Sum(B181:F181)
285	% ET						4.8%	ET Loss / Impervious Stormflow Out
286	% Harvesting						24.2%	Harvesting / Impervious Stormflow Out
287	% Harvesting and ET						29.0%	(Harvesting + ET Loss) / Impervious Stormflow Out
288	% Infiltration						6.2%	Infiltration / Impervious Stormflow Out

Figure 42 Calculation of outcomes from summary report file (*.mrt)

10. Submission requirements for MUSIC modelling

All submissions

All submissions must include:

1. A copy of the MUSIC model
2. A report from the MUSIC Auditor
3. A copy of any non-standard rainfall template (*.mlb) file
4. A copy of any background images to support interpretation of the model.

Stormwater wetlands

Melbourne Water's submission requirements for stormwater wetlands are in Part B of the *Wetland Design Manual* (Melbourne Water, 2020). An excerpt of the submission requirements that directly relate to MUSIC modelling are provided below.

Stormwater wetland concept design

The submission requirements for a stormwater wetland concept design include:

- summary of MUSIC (or alternative model), including:
  - version of MUSIC or model used
  - meteorological data used
  - map outlining catchment areas and direction of flows
  - justification for choice of source node impervious percentage and any routing used
  - treatment node parameters
  - any modelling parameters that are not in accordance with Melbourne Water's *MUSIC Guideline* (this document)
  - pollutant reduction results
- drawings of the treatment system, including placements, which match the model.

Stormwater wetland functional design

The submission requirements for a stormwater wetland functional design include:

- a description of the updated MUSIC (or alternative model), including:
  - the inlet pond volume in MUSIC to the sediment pond volume shown on plans (from halfway up the sediment accumulation zone)
  - the permanent pool volume to the proposed bathymetry (using the user defined stage-storage relationship)
  - the high flow bypass configuration to the design
  - the extended detention-controlled outlet configuration to the design (using the user defined stage-storage relationship)
- an inundation frequency analysis of water levels in the macrophyte zone showing that it meets target thresholds for plant survivability (the *Wetland Analysis Tool* on the MUSIC Auditor website may be used)

- the 90th percentile residence time in the macrophyte zone (the *Wetland Analysis Tool* on the MUSIC Auditor website may be used)
- drawings of the treatment system, including placements, which match the model.

Other treatment devices

In general, the functional design report should incorporate the following information for assets (other than stormwater wetlands) modelled in MUSIC:

- description of the function and intent of the treatment system
- description of how fraction impervious was calculated (what figures were used for different zonings)
- drawings of the treatment system, including placements, that match the model
- specification for the treatment system, including any soil or filter media
- vegetation specification for bioretention systems
- description of any updates to the MUSIC model at each stage of the design
- summary of MUSIC modelling (or alternative model), including:
  - version of MUSIC or model used
  - meteorological data used
  - catchment areas with impervious percentage
  - any routing used
  - treatment node parameters
  - any modelling parameters that are not in accordance with Melbourne Water's *MUSIC Guideline* (this document).

Custom outflow and storage relationships

For custom outflow and storage relationships, the following information must be provided for review and comment as part of the design submission:

- output from earthworks modelling software of stage-storage relationship
- stage-storage-discharge relationships for treatment used in MUSIC (table and graph)
- area and volume at normal water level and extended detention
- calculations used for stage-discharge relationship for both outflows and overflows
- maximum water level reached for the design storm event (such as 4 EY) and maximum flows through treatment as per design.

11. Useful procedures

Defining custom outflow and storage properties

MUSIC requires the following three relationships for stormwater wetland and other waterbody outflow and residence time calculations:

- stage-storage (how water storage volume varies with depth)
- stage-discharge for outlet (how outlet rate varies with depth)
- stage-discharge for overflow (how overflow rate varies with depth).

Where:

- stage (metres): height or depth of water in the stormwater wetland
- storage (cubic metres): water storage volume for a given stage
- discharge (cubic metres per second): outflow rate (for outflow pipe or weir and for overflow pipe or weir).

When the standard input parameters are used, MUSIC automatically estimates the stage-storage-discharge relationships using the permanent pool volume, surface area, extended detention depth, outlet pipe diameter, and overflow weir length.

The default approach is generally acceptable for concept level design.

MUSIC by default assumes the stormwater wetland or other treatment has vertical sides. If that is not a reasonable assumption for the design, it needs to be changed using the custom storage properties.

Melbourne Water's *Wetland Design Manual* (Melbourne Water, 2020) requires that the stage-storage-discharge relationships are defined by the user to provide greater accuracy for functional and detailed design of stormwater wetlands. This is especially important for understanding inundation frequency, duration patterns and residence time of a stormwater wetland.

> Stormwater wetland outlet and storage properties must be defined using custom outflow and storage relationships for functional and detailed designs.

Defining and submitting stage-storage relationships

The stage-storage relationship of a treatments custom outflow and storage function is used to define the physical topographic conditions of the proposed asset. The values entered in the model must be consistent with the submitted design.

Where a 3D earthworks model of the treatment is available, designers can use a design package to calculate the stage-storage relationship above NWL. Generally, the data exported from a design model will be heights above a vertical site datum such as Australian Height Datum (AHD) or reduced level (RL). These must be converted to heights above NWL where zero metres represents NWL. To make this conversion, the NWL (RL) is subtracted from the height (RL) at each stage. See Figure 43 for an example output from an earthworks model and Figure 44 for the corresponding MUSIC input.

PANEL SETTINGS

Tin	DESN
Minimum height	56.500
Maximum height	58.000
Height increment	0.100
Fence name	STG1C D WETLAND
Fence model	STG1C D WETLAND

Height	Delta height	Volume to height	Delta volume	Plan area	Delta plan	Slope area	Delta slope
58.000	0.100	1739.201	365.648	4184.814	1005.813	4234.260	1009.685
57.900	0.100	1373.553	275.939	3179.002	786.264	3224.575	789.695
57.800	0.100	1097.614	204.761	2392.738	647.809	2434.880	650.748
57.700	0.100	892.853	151.460	1744.928	446.834	1784.132	450.228
57.600	0.100	741.393	112.877	1298.095	484.060	1333.903	487.944
57.500	0.100	628.515	79.408	814.035	39.751	845.959	43.374
57.400	0.100	549.107	75.480	774.284	38.815	802.585	42.345
57.300	0.100	473.627	71.645	735.469	37.879	760.240	41.315
57.200	0.100	401.982	67.904	697.590	36.944	718.925	40.286
57.100	0.100	334.078	64.256	660.646	36.012	678.639	39.257
57.000	0.100	269.822	60.702	624.634	35.081	639.382	38.228
56.900	0.100	209.120	57.240	589.553	34.150	601.154	37.199
56.800	0.100	151.880	53.872	555.403	33.221	563.955	36.171
56.700	0.100	98.009	50.596	522.182	32.293	527.784	35.144
56.600	0.100	47.413	47.413	489.889	489.889	492.640	492.640
56.500	11.739	0.000	0.000	0.000	0.000	0.000	0.000

Figure 43 Example output from earthworks model

Height (m)	Storage Volume (m^3)
0 (NWL)	1000.000
0.1	1147.413
0.2	1198.009
0.3	2151.880
0.4	2209.120
0.5	2268.822
0.6	2334.078
0.7	2401.982
0.8	2473.627
0.9	2549.107
1.0	2628.515
1.1	2741.393
1.2	2892.853
1.3	3097.614
1.4	3373.553
1.5	3739.201
2.35	5108.008

Permanent pool volume

Extrapolated storage volume

Figure 44 Corresponding MUSIC input based on earthworks model output

The data output from an earthworks model can be imported into MUSIC using the open button (note 2, Figure 45), or copied to the clipboard and pasted using the paste button (note 3, Figure 45). This data must be saved with a *.csv file extension and opened in a text editor to ensure it does not contain additional formatting or formulas. The data must be presented in the following format before input into the MUSIC model:

- no header line
- comma or space delineated
- height increments of 100 millimetres to 4 decimal places (to avoid rounding errors) (note 1, Figure 45), before pasting or importing the data
- stage-storage relationship must extend at least two metres above the extended detention level (rounded up to the nearest 100 millimetres)
- standard number format for .csv (MUSIC will convert these to scientific format)
- starting height = zero metres (represents NWL of the stormwater wetland)
- starting volume = storage below NWL (permanent pool volume)

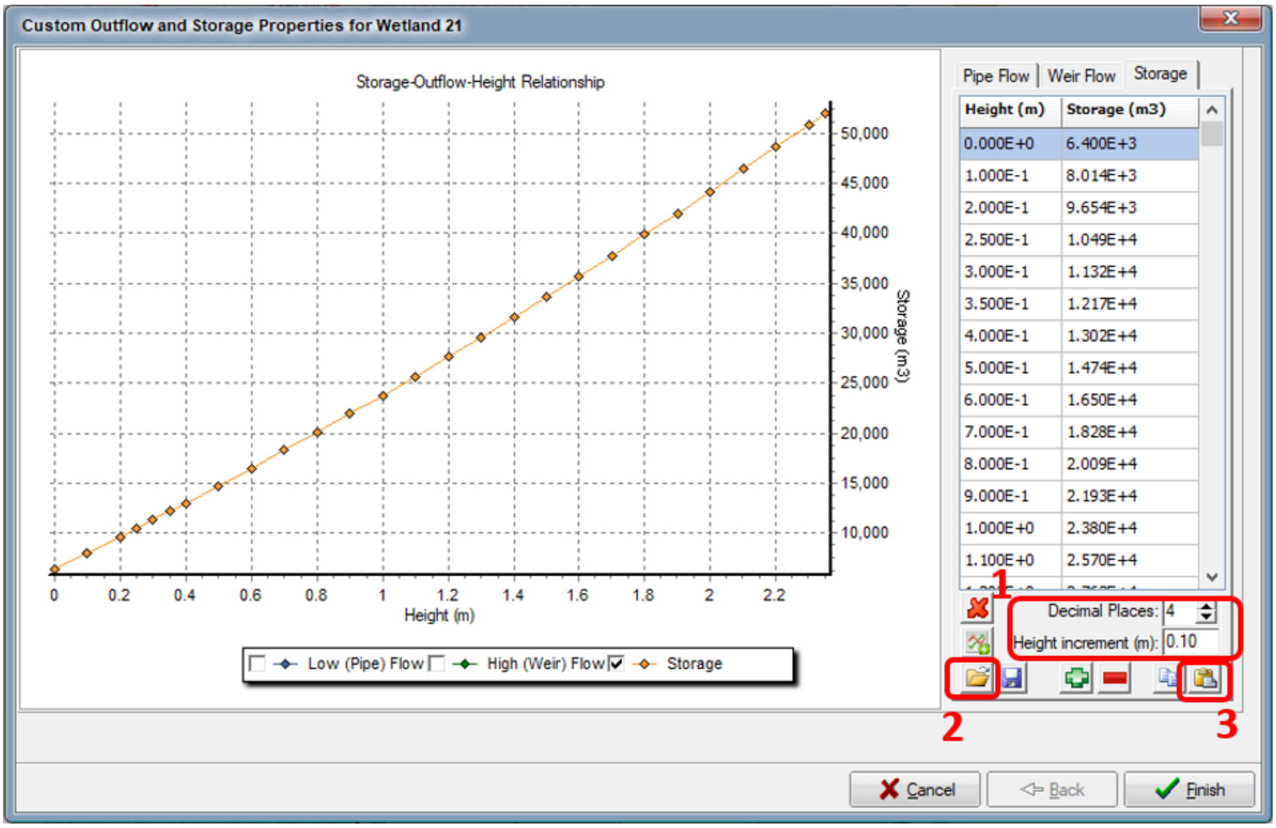


Figure 45 Example stage-storage relationship

When creating a new custom stage-storage relationship:

- Enter the correct EDD in the treatment properties dialogue before entering the custom stage-storage relationship dialogue.
- Enter the stage-storage relationship prior to defining the stage-discharge relationships.
- Set 100 millimetres increments at a maximum to 4 decimal places to avoid rounding errors (note 1, Figure 45), before pasting or importing the data.
- Represent the stormwater wetland permanent pond volume at the stage value of zero (NWL).
- Provide values in the stage-storage-discharge relationships for at least two meters above the EDD value (specified prior to selecting 'Use custom outflow and storage relationship'). Where these cannot be derived from the earthworks model (where the stormwater wetland is not located in a retarding basin), the stage-storage curve must be extrapolated linearly based on the slope of the curve from the last two data points from the earthworks model. *Failure to adhere to this may result in the model not running.*

Defining stage-discharge relationship

The stage-discharge relationships of a treatments custom discharge function are used to define the outflow and overflow behaviour of the proposed asset.

Note that MUSIC refers to pipe outflow and weir overflow. However, in practice both outflows and overflows, or low and high flows may consist of either pipes or weirs.

MUSIC requires the stage (water level) and total discharge (the sum of pipe and weir flow at a given stage) inputs to have unique values. This enables MUSIC to interpolate from any given stage to a single total discharge, and from any given total discharge to a single stage, as needed. In effect, this means that the sum of the 'pipe flow' and 'weir flow' curves, and the storage curve must never be vertical or horizontal. For the same reason, there must be no negative slopes that will result in two or more points having the same value.

Figure 46 and Figure 47 show example stage-discharge curves for low ('pipe') flows and high ('weir') flows respectively.

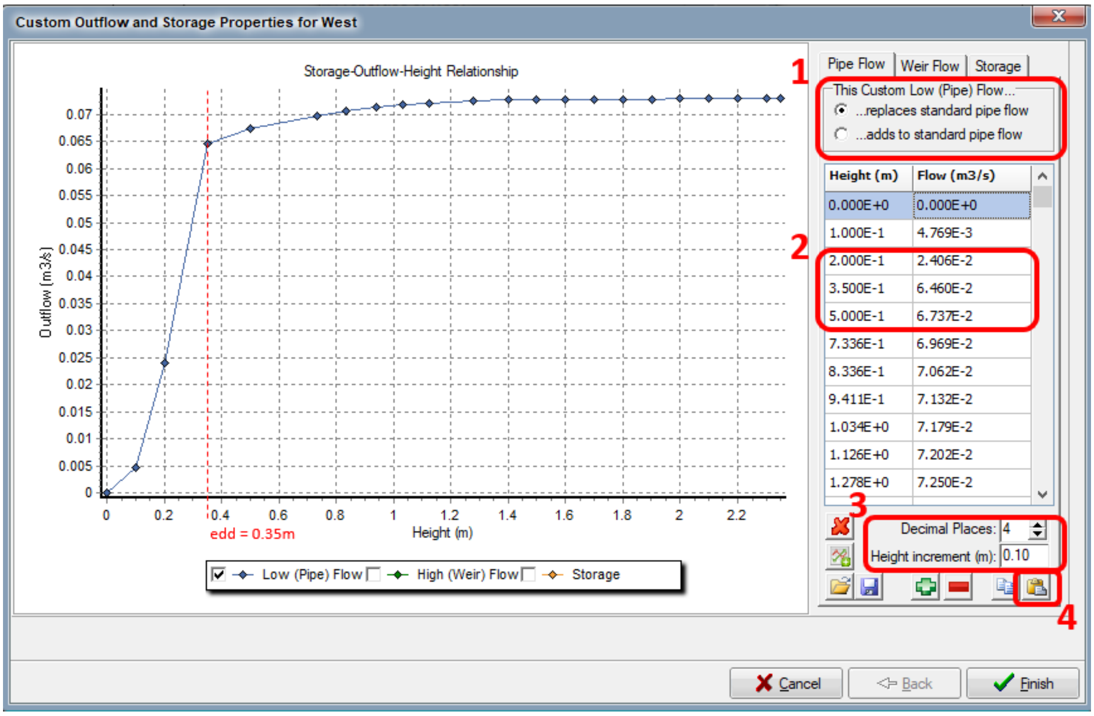


Figure 46 Example stage-discharge relationship for pipe flow

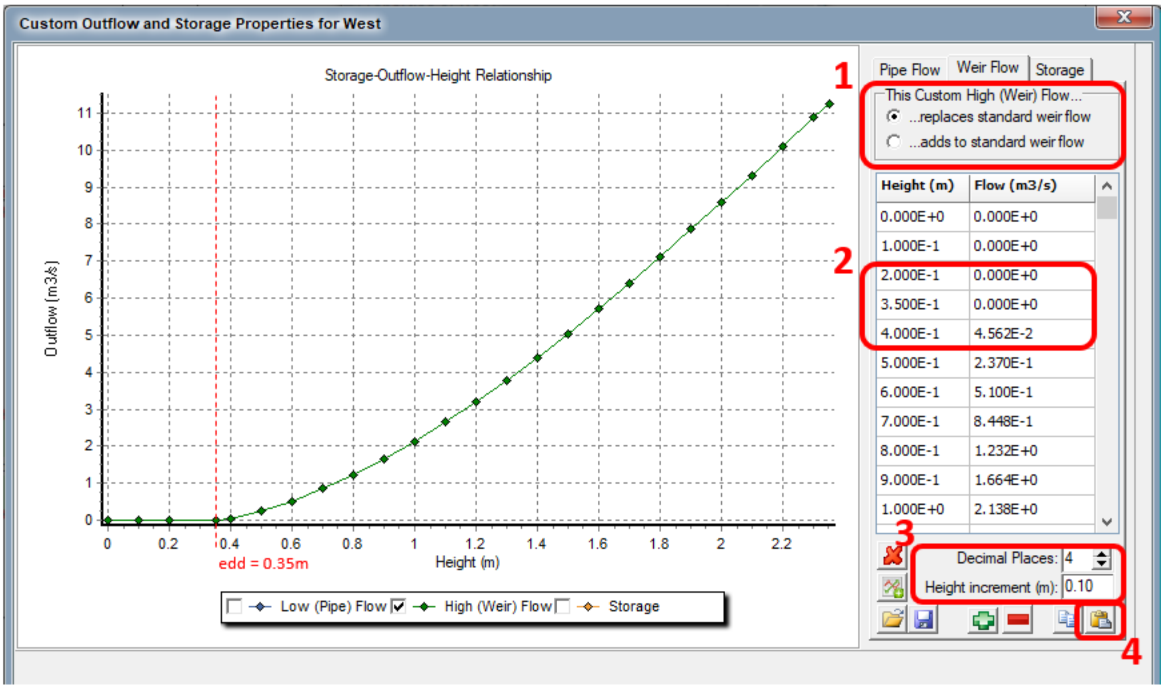


Figure 47 Example stage-discharge relationship for weir flow

Inputs for the stage-discharge curves must be calculated using standard and accepted equations for weir and orifice design as prescribed Part C of the *Wetland Design Manual* (Melbourne Water, 2020). The designer must consider the type of outlet structure and the resulting outflow behaviour, and adopt the appropriate equations accordingly.

Note 1 in Figure 46 and Figure 47 must be set such that the calculated outflows replace standard flows.

The adopted relationships for low and high flows can be verified by observing the curves of the respective data and noting changes at the stage that corresponds to the adopted EDD of the stormwater wetland (note 2, Figure 46 and Figure 47).

For the low (pipe) flow relationship, it is expected that outflows will increase up to and above EDD. The flow rates will typically be much lower than for weir flows. In most cases, the design will have a narrow slot weir plate instead of an orifice plate. The narrow slot weir outlet properties must be defined using custom outflow properties.

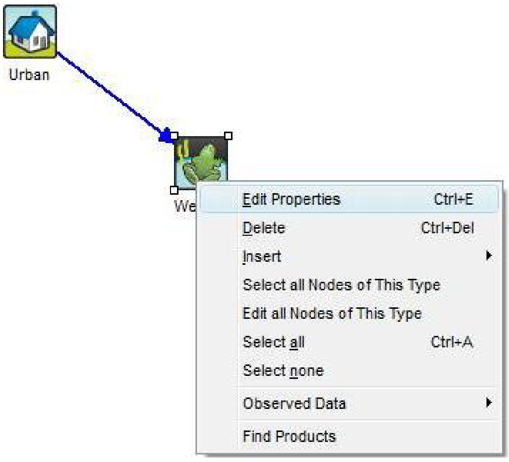
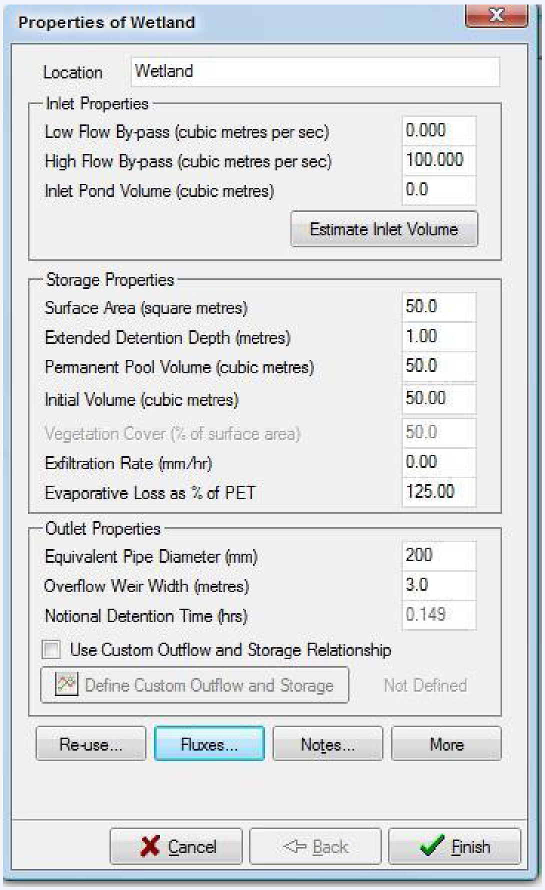
For the high (weir) flow relationship, outflows should be zero up to EDD, then increase with stage above the EDD level.

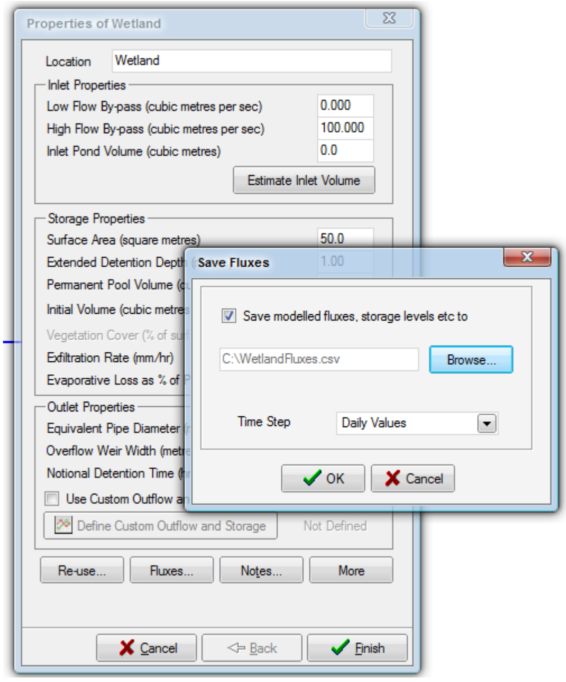
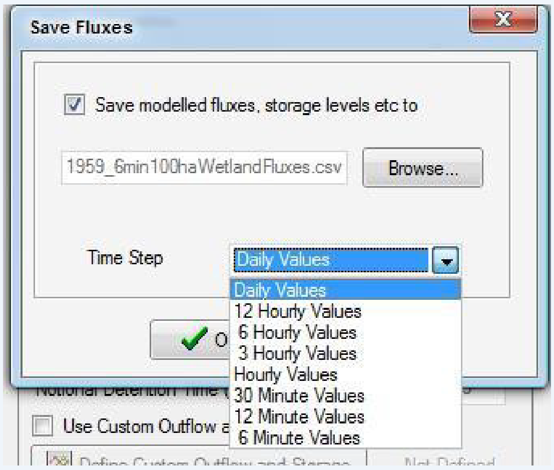
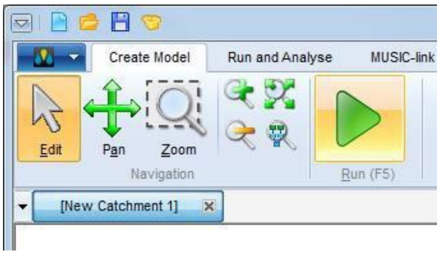
Creating a flux file for inundation frequency analyses

An inundation frequency curve illustrates the frequency with which certain depths are exceeded within a treatment system, such as a stormwater wetland.

To undertake a frequency analysis, the treatment system depth data must be exported from MUSIC using the 'flux file'. Recent versions of MUSIC can export the data at an hourly or daily timestep that is easier to handle. The process for creating a flux file is shown in Table 18.

Table 18 Creating a flux file

Instruction	Example
Right click on wetland node and select 'Edit properties'	
Click on 'Fluxes'	

Instruction	Example
Tick 'Save modelled fluxes' and set a filename	
Change the timestep to 'Daily' or 'Hourly' (Recommended)	
Run the MUSIC model	

Once the flux file is created, an inundation frequency curve can be created automatically from a flux file using the *Wetland Analysis Tool* on the MUSIC Auditor website or manually in a spreadsheet following the guidance provided in Part D of the *Wetland Design Manual* (Melbourne Water, 2020).

Determining pipe flow rates for tanks

The pipe flow rate is determined by the equation $Q = C_d \sqrt{2gh} \times \pi \frac{(d^2)}{4}$ (for a circular sharp-crested orifice), where:

C_d = orifice discharge coefficient

d = pipe diameter (m)

h = depth of orifice centre below free surface (nominally depth above overflow) (m)

g = gravitational acceleration (m/s^2)

Q = discharge (m^3/s)

12. References

Document title
Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019, *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia.
Connellan, G., 2013, Water use efficiency for irrigated turf and landscape
Dotto, C B S, Deletic, A & Fletcher, T D, 2009, 'Analysis of parameter uncertainty of a flow and quality stormwater model' in Water Science & Technology, Vol 6, No 3, pp. 717–725.
Dotto, C B S, Deletic, A., McCarthy, D T & Fletcher, T D, 2011, 'Calibration and Sensitivity Analysis of Urban Drainage Models: Music Rainfall/Runoff Module and a Simple Stormwater Quality Model' in Australasian Journal of Water Resources, Vol 15, No 1, pp. 85–94.
Duncan, H P, 1999, *Urban stormwater quality: A statistical overview,* Melbourne: Cooperative Research Centre for Catchment Hydrology.
E2Designlab, 2013, *Bioretention in the West – Phase 1, Design for Sustained Health of Plants through Consideration of Soil Moisture Behaviour*. Unpublished.
EPA, 2021, *Urban stormwater management guidance,* Melbourne: State of Victoria (Environment Protection Authority Victoria) 2021.
Fletcher, T D, Duncan, H P, Poelsma, P & Lloyd, S D, 2005, *Stormwater flow and quality, and the effectiveness of non-proprietary stormwater treatment measures - a review and gap analysis,* Melbourne: Cooperative Research Centre for Catchment Hydrology.
Fletcher, 2007, *Background Study for the Revision of Melbourne Water's MUSIC Input Parameter Guidelines.* Unpublished.
Melbourne Water, 2005, *Constructed Shallow Lake Systems: Design Guidelines for Developers Version 2,* Melbourne: Melbourne Water.
Melbourne Water, 2005, *WSUD Engineering Procedures: Stormwater,* Melbourne: Melbourne Water.
Melbourne Water, 2020, *Wetland Design Manual,* Melbourne: Melbourne Water.
Melbourne Water, 2020, *Biofiltration systems in Development Services Schemes Guideline,* Melbourne, Victoria: Melbourne Water.
Melbourne Water, 2021, *Healthy Waterways Strategy - Stormwater Targets - Practitioner's Note,* Melbourne: Melbourne Water.
Microburst, 2023, Music Auditor website: https://musicauditor.com.au/
Payne, E. et al., 2015, *Adoption Guidelines for Stormwater Biofiltration Systems,* Melbourne: Cooperative Research Centre for Water Sensitive Cities.
Persson, J., 2000, 'The hydraulic performance of ponds of various layouts' in Urban Water, Vol 2, No 3, pp. 243-250.
Victoria Government, 2018, *State Environment Protection Policy (Waters),* Melbourne: Victoria Government.

Document title
Victoria Stormwater Committee, 1999, *Best Practice Environmental Management Guidelines.* Melbourne: CSIRO Publishing.
Walsh, C J, Fletcher, T D & Burns, M J, 2012, 'Urban Stormwater Runoff: A New Class of Environmental Flow Problem' in PLOS ONE, Vol 7, No 9.

13. Document History

Date	Reviewed/ Actioned By	Version	Action
July 2026	Stormwater and Environmental Water Program Lead	12	This update includes information on Emerging Assets and SWH&I target performance.
September 2025	Stormwater Advisor	0	Draft for consultation

ISBN 978-1-921603-47-1 (Online)