



Healthy
Land & Water

MUSIC Modelling Guidelines

April 2026

Working Draft V4.0

Version history

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Citation

Water by Design (2026) *MUSIC Modelling Guidelines*, Healthy Land & Water, Brisbane.

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Healthy Land & Water's Water by Design initiative works with individuals and organisations to identify and fill knowledge gaps and facilitate the uptake of improved practices in sustainable water management. For more information, visit www.waterbydesign.com.au.

About Healthy Land & Water

Healthy Land & Water is the peak environmental group for South East Queensland. For over 20 years it has been dedicated to investing in and leading initiatives to build the prosperity, liveability, and sustainability of our 'future region'. A healthy environment also supports a vibrant economy, strong livelihoods, great lifestyles and the happiness and well-being of the community. Healthy Land & Water is focused on **delivering an environment for future generations to thrive**.

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Land & Water **leads and connects through science, big data and actions that will preserve and enhance our natural assets and support resilient regions long into the future.**

Traditional Owner acknowledgement

We acknowledge that the place we now live in has been nurtured by Australia's First Peoples for tens of thousands of years. We believe the spiritual, cultural and physical consciousness gained through this custodianship is vital to maintaining the future of our region.

Funding acknowledgement

These guideline updates have been funded by Healthy Waterways member contributions to the Water by Design program.

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LIST OF ACRONYMS AND ABBREVIATIONS

EP	Equivalent person
ET	Equivalent tenement
MCU	Material change of use
PET	Potential evapotranspiration
ROL	Reconfiguration of a lot
TN	Total nitrogen
TP	Total phosphorous
TSS	Total suspended solids
OW	Operational works

1 Introduction

The urbanisation of our cities places increasing pressure on both our valued local waterways and receiving environments such as Moreton Bay and the Great Barrier Reef. These impacts, combined with increasing demand for urban green space highlight the importance of urban green infrastructure delivered using a water sensitive urban design (WSUD) approach.

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) is a software tool that simulates the behaviour of stormwater in urban catchments and is commonly used for demonstrating the performance of stormwater quality treatment systems. It can assist in the planning and design of WSUD approaches and can help create an understanding of how a development might impact stormwater, and how a particular WSUD approach might help mitigate those impacts.

The purpose of the MUSIC Modelling Guidelines is to provide consistent and uniform guidance on MUSIC model configuration and parameterisation. Nothing in the guideline prohibits the use of other software to simulate stormwater in urban catchments or the performance of stormwater quality treatment systems providing it is appropriately justified.

1.1 History and context of the guidelines

A comprehensive suite of tools and guidelines developed by Water by Design is available to support the planning, design and implementation of WSUD in Queensland. Figure 1 illustrates these tools and how they can be used in the context of a typical urban development process.

Planning	Concept design	Detailed design	Construction	Establishment	Operation & maintenance
Strategic waterways Water by Design (2019)					
Living waterways Water by Design (2019)					
Concept design guidelines for water sensitive urban design Water by Design (2009)					
	MUSIC modelling guidelines Water by Design (2018)				
	Bioretention technical design guidelines Water by Design (2014)				
	Wetland technical design guidelines Water by Design (2017)				
	Deemed to comply solutions Water by Design (2010)				
	Drainage and water quality standard drawings Institute of Public Works Engineering Australasia (IPWEA) (2017)				
	Stormwater harvesting guidelines Water by Design (2009)				
			Best practice erosion and sediment control International Erosion Control Association (IECA) (2008)		
			Erosion and sediment control fact sheets Water by Design (2021)		
			Guidelines for improving the biology of bioretention systems Water by Design (2022)		
			Guidelines for the construction and establishment of bioretention systems and wetlands Water by Design (2022)		
			Transferring ownership of vegetated stormwater assets Water by Design (2012)		
					Maintaining vegetated stormwater assets Water by Design (2012)
					Rectifying vegetated stormwater assets Water by Design (2012)

Figure 1 The WSUD timeline and supporting guidelines.

The *MUSIC Modelling Guidelines* (Water by Design) were first published in 2010. They provide guidance on appropriate modelling practices using MUSIC, with a focus on MUSIC modelling for compliance with stormwater treatment objectives (refer to Section 2).

Over several years, Water by Design worked to refine and update the *MUSIC Modelling Guidelines*, with a second and third version developed for public consultation but never finalised. Version 3 was released in draft form for consultation in 2018 and remained publicly available on the Water by Design website (alongside the original 2010 version) until the release of this document.

With the release of this version of the *MUSIC Modelling Guidelines* (Version 4), all previous versions of the guidelines are superseded.

The *MUSIC User Manual* (eWater) provides details and important technical information on how to use MUSIC. It should be read in conjunction with this guideline.

Note: Local authority requirements take precedence over this guideline.

1.2 Structure of the guidelines

Section 2: Stormwater management design objectives – discusses the stormwater management design objectives for Queensland.

Section 3: Catchment configuration – specifies the preferred meteorological data; source node, rainfall-runoff, pollutant export parameters; and the definition of MUSIC catchments (note that locally specific information can be found in **Error! Bookmark not defined.0**).

Section 4: Stormwater treatment nodes – provides guidance on the configuration and parameters for modelling stormwater treatment nodes.

Section 5: Life cycle cost – summarises the method for estimating life cycle cost information with MUSIC and discusses the important cost information for reporting.

Section 6: Results – describes how to analyse model results to determine whether the treatment strategy complies with stormwater quality objectives.

Section 7: Lodgement, reporting and assessment – outlines the information about MUSIC modelling required by assessment authorities for development applications.

1.3 Key changes

The key changes in Version 4 of the guideline are summarised below.

Table 1 Key changes from previous versions of the guidelines.

Item	Key change
Total Permissible Loads approach	Inclusion of a methodology to apply the Total Permissible Loads (TPL) approach, which can assist sites with low pollutant loads achieve load-based reduction targets. Refer to Section 2.1.
Rainwater tanks	Updated guidance on typical indoor and irrigation demand rates. Refer to Section 4.2.2 and Section 4.2.3.
Wetland node	Updated k and C* parameters for total nitrogen to better reflect monitoring data. Refer to Table 16 and Section 4.3.4.
Bioretention node	Updated notes on bioretention water losses. Refer to Section 4.5.4.
Water wise street trees	Clarification on guidance for modelling basic water wise street trees. Refer to Section 4.12.

Climatic data	Provides recommended climatic data for eight additional centres (Cairns, Townsville, Mackay, Rockhampton, Gladstone, Bundaberg, Hervey Bay and Gympie) not covered in previous versions of the guideline. Refer to Appendix A.
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1.4 Transition arrangements

This guideline provides a suite of approaches and model parameters that update both the original 2010 version and the draft 2018 version of the *MUSIC Modelling Guidelines*. It is recommended that for development applications submitted up to 12 months after the release date of this document, applicants use either the 2010 version of the *MUSIC Modelling Guidelines* or this version, but not a hybrid of both. 12 months after the release date of this version, all previous versions of the guidelines are considered superseded and should no longer be used.

2 Stormwater management objectives

Stormwater management objectives may be specified in a range of planning documents (including state planning policies, regional plans, local government planning schemes, etc.). Please refer to the relevant authority to obtain the most up to date information on design objectives.

In Queensland, stormwater management design objectives (SMDOs) are specified in the State Planning Policy (DILGP, 2017), which sets out requirements for stormwater quality and waterway stability.

The State Planning Policy (DILGP, 2017) also sets out requirements for new development to achieve 'liveable communities' and requires that development achieves, for example "attractive, adaptable and accessible built environments..., providing attractive and accessible natural environments and public open space and facilitating vibrant places and spaces, diverse communities, and good neighbourhood planning and centres design that meets lifestyle needs." Recently updated local government planning scheme policies also reflect these principles.

Table 2 indicates the extent to which MUSIC and this guideline can be used to demonstrate compliance with the SMDOs and liveable communities objectives.

Table 2 Suitability of MUSIC to address stormwater management objectives.

Objective	Objective description	Suitability of MUSIC to demonstrate compliance	Where to find information
Stormwater quality	Stormwater quality objectives aim to protect waterway health by limiting the amount of stormwater pollutants that are discharged to receiving waters. In Queensland, they are typically expressed as percentage load reductions, but can also be expressed as total permissible loads (See Section 2.1).	Suitable	This guideline
Waterway stability	Waterway stability objectives aim to prevent in-stream erosion downstream of urban areas by controlling the size and duration of sediment-transporting flows.	Not suitable	Queensland Urban Drainage Manual
Living environment	The purpose of this objective is to protect and enhance natural areas adjacent to waterways.	Not suitable	Living Waterways

Living communities	The purpose of this objective is to create versatile places that enable safe, healthy, inclusive and resilient communities.	Not suitable	Living Waterways
Living water	The purpose of this objective is to protect and enhance our water systems and their environments such as riparian zones.	Suitable for water quality part (LW1.2)	Living Waterways
Living local economies	The purpose of this objective is to provide affordable, enduring solutions that are viable to build, use and maintain.	Life cycle costing module in MUSIC (Section 5)	Living Waterways and life cycle costing in MUSIC

2.1 Total permissible loads approach

At the time of writing, the stormwater quality objectives in the State Planning Policy (DILGP, 2017) are expressed as percentage load reductions. To comply with this style of objective, proponents of new developments must first determine the quantity of pollution that their development will generate and then implement treatment measures that reduce that amount by specified percentages. The modelling approaches described in this guideline were developed with this style of objective in mind.

Percentage load reduction style stormwater quality objectives are simple to express in policy and to demonstrate compliance with, but disincentivise a low impact design (LID) approach to development. Additionally, they do not always well represent the environmental needs of receiving environments.

An alternative method for expressing stormwater quality objectives are total permissible loads style objectives (often referred to as total annual loads objectives). This style of objective specifies the total amount of stormwater pollution that may be discharged from a given area over a given amount of time (e.g. X kg of pollution per hectare per year).

Total permissible loads style objectives can be more challenging to express succinctly in policy, but are advantageous in that they:

- Allow authorities to more easily set objectives based on what's needed to protect receiving waters.
- Create a level playing field for LID approaches when compared to business as usual (BaU) high impact development.

There are two situations under which modelling is likely to be undertaken in compliance with a total permissible load style objective:

- The development is occurring in a location where the assessment authority has developed a total permissible loads style objective (refer to Section 2.1.1); or
- The development is occurring in a location where a percentage load reduction style objective applies, but the proponents of the development wish to model using a total permissible loads style approach to gain credit for a low impact design approach to development (refer to Section 2.1.2).

The modelling approaches described in this guideline are generally appropriate for total permissible loads style objectives, with minor modifications as detailed in Sections 2.1.1 and 2.1.2.

The total permissible loads approach is discussed in more detail in the discussion paper *Total annual loads: An alternative methodology for complying with Queensland's post-construction phase stormwater management design objectives that incentivises low impact design* (Healthy Land & Water 2022).

NOTE: Total permissible loads terminology

This guideline uses the term 'total permissible loads' to refer to the style of objective discussed in this section. Previous Water by Design documents such as *Total annual loads: An alternative methodology*

for complying with Queensland's post-construction phase stormwater management design objectives that incentivises low impact design (Healthy Land & Water 2022) used a different term, 'total annual loads' to refer to this style of objective.

Regardless of the terminology used, the two key features of this style of objective are that they specify (a) a maximum pollutant load that may be discharged (e.g. X kg); and (b) a time period over which that discharge may occur (e.g. per year).

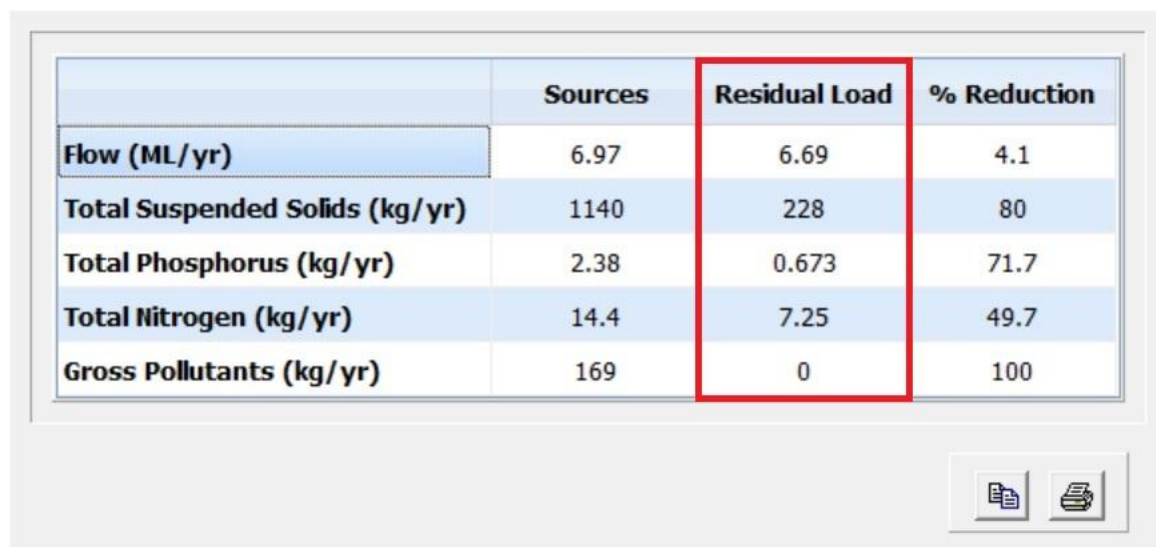
Total annual loads style objectives, do this by expressing the discharge load per year, but it is just as valid to express the discharge over other timeframes (days, weeks, decades etc).

This guideline adopts the term 'total permissible loads' because it is more inclusive of all possible representations of this style of objective.

2.1.1 Total permissible loads objective is specified

Where an assessment authority has developed a total permissible loads objective, modelling is simple:

1. Build and run a MUSIC model in accordance with this guideline.
2. After running the model, open the 'Treatment Train Effectiveness' box and compare the residual loads with the specified total permissible loads objectives. Refer to Figure 2.



	Sources	Residual Load	% Reduction
Flow (ML/yr)	6.97	6.69	4.1
Total Suspended Solids (kg/yr)	1140	228	80
Total Phosphorus (kg/yr)	2.38	0.673	71.7
Total Nitrogen (kg/yr)	14.4	7.25	49.7
Gross Pollutants (kg/yr)	169	0	100

Figure 2 Assessing compliance where the total permissible loads objectives are specified.

2.1.2 Generating total permissible loads objectives from percentage load reduction objectives

Where a percentage load reduction style objective applies, but the proponents of a development wish to model using a total permissible loads style objective to gain credit for a low impact design approach to development, demonstrating compliance with that objective is completed in four steps:

1. Deriving objectives using a BAU model.
2. Building the LID model – copying the source nodes.
3. Building the LID model – LID and treatment measures.
4. Comparing results and refining.

Step 1: Deriving objectives using a BAU model

Deriving total permissible loads objectives from percentage load reduction objectives is done using a BAU model of the development. The BAU model must reflect how a development on the site would be

expected to occur without any treatment measures or LID approaches. The BAU model must terminate with all flows directed to a generic treatment node and then a pre-development node. See Figure 3 for an example of the BAU model.

Configure the generic treatment node within the BAU model to reflect the standard percentage load reduction targets for all pollutants of interest. For example, in Figure 4, a target total suspended solids (TSS) load reduction of 80% is modelled by making the generic node reduce TSS concentrations to 20% of the inflows.

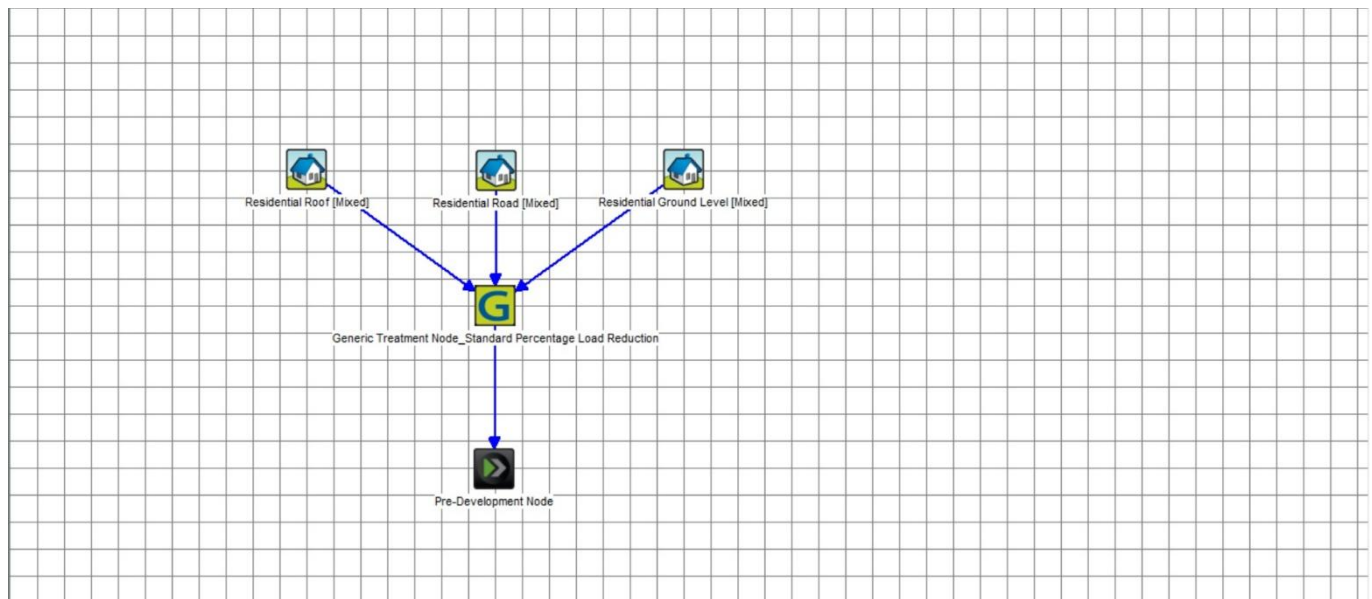
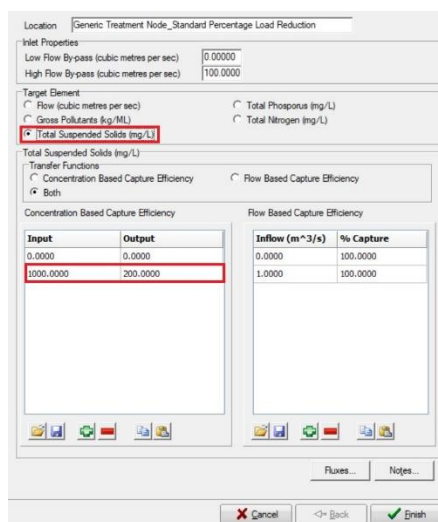


Figure 3 Configuration of the BAU model using the pre-development node and generic treatment node.



Location: Generic Treatment Node_Standard Percentage Load Reduction

Inlet Properties
 Low Flow Bypass (cubic metres per sec): 0.00000
 High Flow Bypass (cubic metres per sec): 100.0000

Target Element
 Flow (cubic metres per sec)
 Gross Pollutants (kg/ML)
 Total Suspended Solids (mg/L)
 Total Phosphorus (mg/L)
 Total Nitrogen (mg/L)

Total Suspended Solids (mg/L)
 Transfer Functions
 Concentration Based Capture Efficiency
 Both
 Flow Based Capture Efficiency

Concentration Based Capture Efficiency		Flow Based Capture Efficiency	
Input	Output	Inflow (m ³ /s)	% Capture
0.0000	0.0000	0.0000	100.0000
1000.0000	200.0000	1.0000	100.0000

Buttons: Cancel, Back, Finish

Figure 4 Configuring the generic treatment node.

Step 2: Building the LID model – copying the source nodes

To begin building the LID model, copy the source nodes from the BAU model. Place a post-development node ready for later use. See Figure 5.

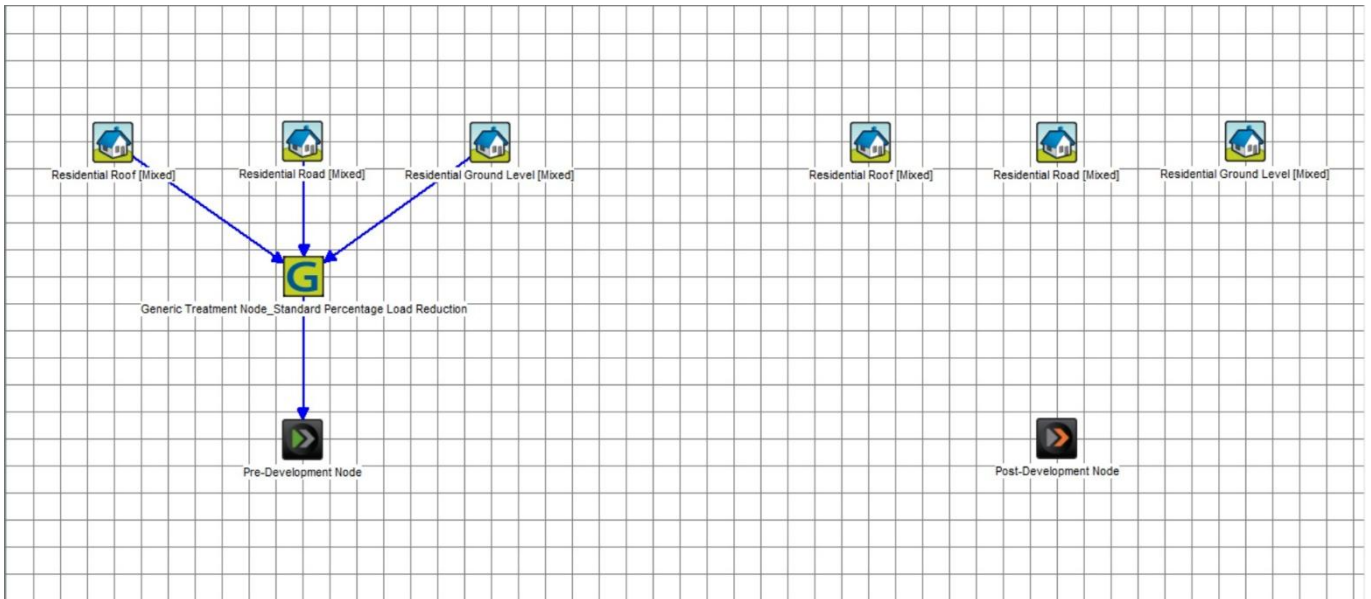


Figure 5 Copying the source nodes ready to build the LID model.

Step 3: Building the LID model – LID and treatment measures

Implement treatment measures and LID solutions in the LID model. In the example shown in Figure 6, a bioretention system and rainwater tanks have been implemented as stormwater treatment and reuse, while the impervious fraction of the road level source node has been reduced to reflect narrower than normal paved surfaces implemented as a part of an LID approach.

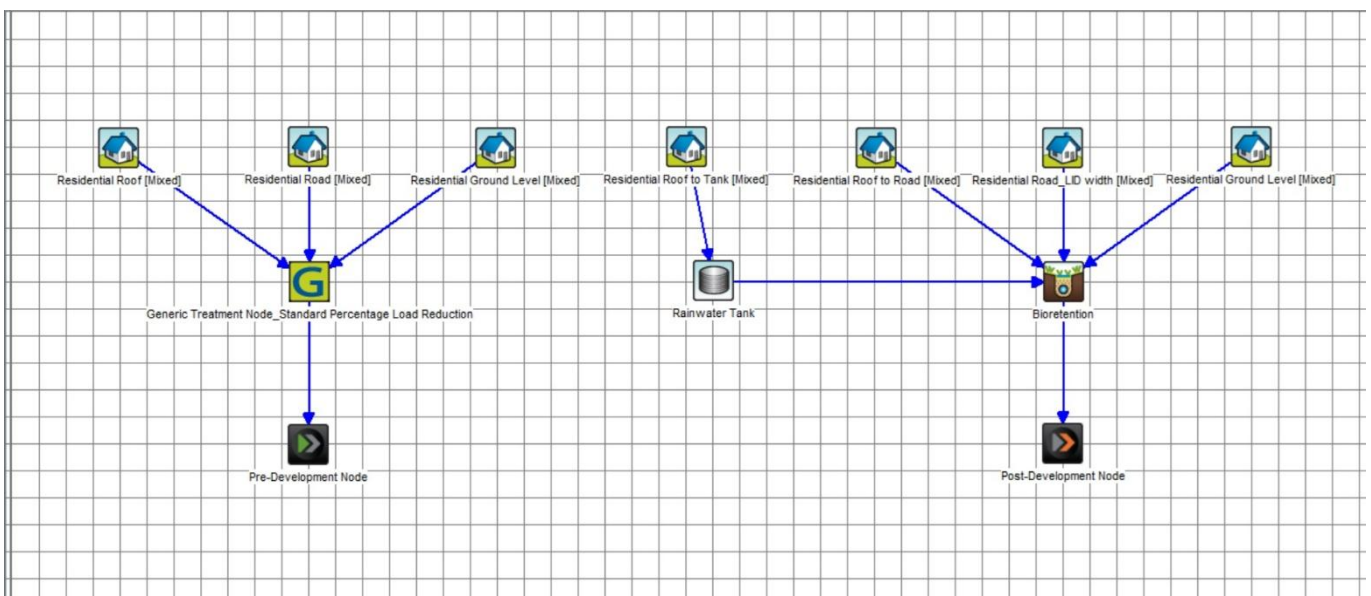


Figure 6 Configuration of the LID model using the post-development node.

Step 4: Comparing results and refining

After running the models, open the 'Treatment Train Effectiveness' box and ensure the 'Include Pre-Development' checkbox has been checked (Refer to Figure 7). Compare the modelling results to ensure residual pollution loads from the LID approach (post-development node) are less than or equal to the total permissible loads objectives (pre-development node). If non-compliant, revise the LID model.

Note that due to the stochastic nature of the pollution generation on MUSIC, source node pollutant generation will vary slightly from one model run to another. It is prudent to run the model several times to ensure compliance with objectives under multiple source node pollutant load scenarios.

	Sources		Residual Load		% Reduction	
	Pre	Post	Pre	Post	Pre	Post
Flow (ML/yr)	6.97	6.57	6.97	6.36	0	3.2
Total Suspended Solids (kg/yr)	1140	954	228	227	80	76.2
Total Phosphorus (kg/yr)	2.4	2.09	0.961	0.645	60	69.1
Total Nitrogen (kg/yr)	14.6	13.6	8.01	6.81	45.1	49.9
Gross Pollutants (kg/yr)	169	160	169	0	0	100

Include Pre-Development

Figure 7 Assessing development performance.

NOTE: Sensitivity to source node parameters

When modelling using either approach described within this section, results are highly sensitive to the source node parameters adopted. Realistic parameters must be selected for rainfall and evapotranspiration (refer to Section 3.1), rainfall-runoff parameters (refer to Section 3.3.4), source catchment types and sizes (refer to Section 3.3.2 and Section 3.3.3) and pollutant export parameters (refer to Section 3.3.5). In particular, care must be taken when specifying source catchment types and sizes because this guideline gives modellers discretion to pick from a range of acceptable values. Any choice that (A) deviates from recommended values, (B) increases pollutant loads generated in pre-development scenarios or (C) reduces loads generated in post-development scenarios must be justified. Proponents must also demonstrate that regulatory mechanisms exist to ensure that any low impact design approaches specified are delivered on site in accordance with the MUSIC model.

3 Catchment configuration

Catchment model setup information that applies across Queensland can be found in this section. Locally specific information for catchment model setup can be found in Appendix A (including meteorological data and rainfall-runoff parameters).

3.1 Meteorological data

MUSIC uses recorded meteorological data as the primary input for rainfall-runoff and pollutant generation at a source node. Runoff, represented as surface runoff and baseflow, is generated in MUSIC through the interaction of rainfall, evapotranspiration, surface properties and soil behaviour.

Selecting appropriate climatic data for the modelled region ensures that reasonable runoff and constituent predictions are made.

This section provides advice on appropriate meteorological data for different climatic regions. Note that meteorological data is specific to regions (please refer to Appendix A for regional climatic data).

Use the regional maps to determine the closest rainfall station to the catchment being modelled and then use the Rainfall Data and Modelling Periods Tables to determine the appropriate rainfall period and potential evapotranspiration (PET) data to construct a suitable MUSIC climate template. Rainfall and evapotranspiration data for these locations are either supplied directly with MUSIC or available from the Bureau of Meteorology. For guidance on creating a meteorological template for MUSIC, refer to the *MUSIC User Manual* (eWater).

3.1.1 Climate change

We are in a changing climate where the historical rainfall record is not necessarily a useful indicator of future climate. There is now strong evidence on how climate change is likely to impact major storms and how this should be accounted for in modelling flood events (refer to Australian Rainfall and Runoff). However, it is not yet clear how climate change will impact rainfall patterns, dry spells and smaller rainfall events that are often the focus of water sensitive urban design practice. Further consideration and research is required to develop a recommended approach that accounts for climate change in this context. Thus, the approach to meteorological data outlined in this guideline remains consistent with the 2010 and draft 2018 versions of the *MUSIC Modelling Guidelines*.

3.2 Modelling period and time step

For all development applications use the 10-year modelling period provided in Appendix A and adopt a six-minute time step.

Using a 10-year climate period ensures the model captures sufficient data to represent a range of rainfall patterns over time. It allows a reasonable balance between model accuracy, computer capability and memory requirements, simulation run time, and the size of the output file. Where 10 years of suitable data is not available, use the highest number of years available (ensuring that a minimum of five years of continuous data is used).

The chosen rainfall series should be of good quality and representative of the site, including some wet and dry years and a comparable mean rainfall. Using time steps greater than six minutes (e.g. 30 minutes), is generally only appropriate during the early development of the model to reduce run times. The final version of the model and final simulations must use a six-minute time step.

NOTE: Ensuring water storages in MUSIC are stable and reflect in-situ conditions

To ensure the water storages modelled in MUSIC are stable and reflective of in-situ conditions, the auto warm-up option for source nodes is on by default. The auto warm-up option can be found under:

> Settings > Preferences

3.3 Catchment properties

Defining the characteristics of the MUSIC source nodes (catchment nodes) involves:

- Defining the total area, sub catchment areas and total catchment areas.
- Splitting the catchments into similar land use or surface types (e.g. separating roofs, roads and other pervious and impervious areas, or lumping land uses together).
- Defining the percentage of impervious areas for each land use or surface type.
- Selecting rainfall-runoff parameters.
- Selecting pollutant export parameters.

These steps are detailed in the following sections together with the MUSIC catchment (source node) parameters.

3.3.1 Defining sub catchments

Include all areas of the development in the model, including surfaces that will not receive treatment.

In defining the catchment, consider each of the following:

- The boundary of the proposed development site and proposed road or allotment layout.
- The topography, in particular the post-development earthworks, reflecting the road levels, earthworks levels, sub-catchments and proposed stormwater drainage system (Note: Best practice is to minimise changes to topography, maintain native vegetation, and integrate new development into the natural landscape along with stormwater treatment).
- The conceptual stormwater drainage design (locate point of discharge in a way that minimises hydraulic and erosion impacts on receiving waterways).
- If the development layout has been designed to minimise impact e.g. reduced impervious surfaces.
- The location of stormwater treatment measures – ensure they will not cause adverse impacts to natural waterways and riparian zones, and consider opportunities to connect people with the landscape (see *Living Waterways (Water by Design)* for more information)
- The location and extent of external catchments and how these catchments drain through the development site.
- Passive recreation areas, preserved vegetation, waterways, riparian areas and revegetation areas do not need to be included in the MUSIC model catchment source nodes as they are not considered part of the development footprint causing pollution.

Establish the catchment area for each sub catchment from development plans. Clearly depict the location and extent of the catchments and associated development contours, earthworks and drainage on a plan for reporting to the assessment authority.

3.3.2 Defining land uses and surface types

MUSIC offers five general types of land use or 'source nodes': urban, forest, agricultural, user-defined and imported data.

This section details the characteristics of the land and surface types that can be modelled in MUSIC. The recommended imperviousness, rainfall-runoff and pollutant export parameters are provided.

Urban land uses can be lumped into residential, industrial and commercial land uses. Catchments can then be split into nodes representing different surface types, including roofs, roads (or carparks) and ground level for split catchment modelling. Modelling of split land uses is only required when routing runoff from one surface type to a treatment node separately from the others (e.g. roof to rainwater tank).

All source nodes should be reconfigured according to these guidelines and not left with default parameters.

3.3.2.1 Defining source nodes (for split or lumped catchments)

Define the area (in hectares) for each land use type within each sub catchment (e.g. residential, commercial, industrial, etc.). Source nodes are then created in the MUSIC model for each land use type.

Appropriate source node parameters for each type of source node (lumped and split) are outlined in detail in this section.

Appendix B offers six quick reference source node parameter summaries.

When rainwater tanks are proposed to form part of the stormwater treatment strategy, source nodes must be split into roof, ground and road surface types. This will ensure the model considers the appropriate flow and pollutant load reduction attributable to the tanks.

LUMPED CATCHMENT APPROACH

The lumped catchment approach is an appropriate method for modelling development applications in MUSIC (including MCU, ROL and OPW applications). It is suitable for broad-scale master planning and conceptual planning, or catchment planning, development planning and other applications where splitting catchment surface types is not required.

Table 3 Lumped catchment approach.

Lumped land use	MUSIC source node	Encompassing land uses
Residential	Urban source node	Majority of land use is residential dwellings but also includes activities servicing residential needs such as roads, parks*, schools, small commercial areas, etc.
Rural residential	Urban source node	Residential uses on large lots with a high proportion of pervious area (< 10% total impervious area). Activities servicing local needs (schools, parks*, roads, etc.) are included. Areas of broad hectare, low-intensity farming activities (where soils are not exposed) and semi-natural broad hectare land may also be included.
Industrial	Urban source node	Includes areas of light and general industry, including activities associated with the manufacture or distribution of goods (e.g. heavy machinery). The industrial node includes building envelopes and parking areas. It is typified by a high percentage of impervious area.
Commercial	Urban source node	Includes activities such as shops, offices and restaurants, with buildings, parking areas/driveways, adjacent roads and road reserves. Commercial source nodes can be used to model special purpose or multipurpose centres such as hospitals, major educational facilities, shopping centres and community centres. Commercial areas are typified by a high percentage of impervious area.
Forest	Forest source node	Undisturbed, natural bushland areas.
Agriculture	Agricultural source node	Includes large scale cropping or grazing land.

*For park land uses, impervious areas > 100 m² should be modelled as separate source nodes (e.g. carpark, community centres). To account for minor park infrastructure such as paths and small shelters, adjust the fraction imperviousness of the parkland node rather than modelling these areas as separate nodes.

SPLIT CATCHMENT APPROACH

The splitting of lumped land uses into specific surface types (e.g. road, ground level, roof areas) is required when:

- Parts of the catchment are diverted to different locations (e.g. where the roof and road areas drain to a treatment system but not ground level areas or where roof runoff is directed to a rainwater tank).
- Sub catchment land use does not reflect the typical land use split (e.g. a commercial sub catchment with 15% road and 5% ground level).

Where the above requirements are met, split the MUSIC model catchments into relevant surface types as per Table 4.

Table 4 Split catchment approach.

Land use	MUSIC source node	Encompassing land uses
Roof	Urban source node	Roof of any residential, industrial and commercial building. If applying rainwater tanks, split the roof area between that going to the tank and going to the stormwater drain.
Road/carpark	Urban source node	Roads and carparks that are majority impervious ¹ . A small section of pervious area may be applied if there are vegetated areas as part of road verges or carpark landscaping.
Ground level	Urban source node	Applies to any remaining area within the development after roofs and roads are accounted for. These are largely pervious (e.g. parks, backyards, landscaping, etc.) but can contain small impervious areas such as patios, paving, pergolas and residential driveways.

¹ Commercial and industrial driveways should be considered as part of car parking areas and modelled as road source nodes.

Figure 8 and Table 5 demonstrate how the three different surface type nodes can be applied to a residential property.



Figure 8 Surface types.

Table 5 Surface types and appropriate nodes.

Surface type	MUSIC surface type node
House and garage roof to tank	Roof (100% impervious).
House to external drainage	Roof (100% impervious).
Ground level (driveway, shed and yard)	Included as part of ground level surface node with the percentage imperviousness adjusted accordingly.
Half of road and verge	Included as part of road surface node with the percentage imperviousness adjusted accordingly. Note that 50% of the road width would generally be modelled with the property on the opposite side of the road.

3.3.2.2 Measuring the area of surface types

The area of each surface type within the relevant catchment must be measured from development layout plans.

Surface type areas within each catchment can be grouped into a single surface type node (i.e. multiples of the same surface type can be grouped together).

Where a development plan is not available (e.g. during conceptual design or broad master planning), adopt the typical surface type area values for residential, industrial and commercial developments shown in Table 6.

Table 6 Typical proportions of each surface type for split catchment land use.

Development type	Surface type area		
	Road (%)	Roof (%)	Ground level (%)
Residential – 10 dwellings/ha	25	25 (based on 250 m ² roof area)	50
Residential – 15 dwellings/ha	25	32.5 (based on 215 m ² roof area)	42.5
Residential – 40 dwellings/ha	30	35	35
Residential – 80+ dwellings/ha	32.5	35	32.5
Industrial	30	50	20
Commercial	30	50	20

NOTE – Undefined source nodes

There are two source nodes for which parameters cannot be defined in this guideline.

USER DEFINED SOURCE NODE

The user-defined source node is similar to the catchment nodes in that MUSIC generates runoff based on defined rainfall-runoff and pollutant parameters. The main purpose of this node is as a visual reminder that data other than default rainfall-runoff and pollutant export data is being used. If the parameters used differ from the recommended parameters for the general source nodes, they must be referenced in the MUSIC reporting.

IMPORTED DATA NODE

The imported data node allows historical or computer-generated runoff and flow data to be used as input in the model. One possible application of this node is combining multiple MUSIC models into one. Rather than including all the source nodes from each model (which can make the model complicated and large), the results from the smaller models are imported into one overall model, which can reduce the complexity and run time of the one larger model. Refer to the *MUSIC Help* for information on using the imported data node.

3.3.3 Calculating the imperviousness of the catchment

Impervious areas dominate the rainfall-runoff process in urban catchments because they generate much more runoff and more frequent runoff than pervious areas. Therefore, it is important to ensure impervious areas are accurately represented in MUSIC models.

Use Table 7 to identify the appropriate method for determining the impervious fraction. For all development applications the impervious fraction in MUSIC models must be equal to the total impervious fraction measured from development plans.

Table 7 Methods for determining the impervious fraction of catchments.

Purpose of modelling	MUSIC surface type node	Method for determining impervious fraction
Development application	Split	Development plans (preferably digital, i.e. ACAD or GIS).
	Lumped	Development plans (preferably digital, i.e. ACAD or GIS).
	Split	Table 6 and Table 8.

Broadscale master planning and conceptual design (generally not for development applications)	Lumped	Table 9.
Existing catchment¹	Split	1 – Aerial photography (for existing catchments). 2 – Table 6 and Table 8. 3 – Information from similar developments.
	Lumped	1 – Table 9. 2 – Aerial photography (for existing catchments). 3 – Information from similar developments.

¹ Option 1 is the preferred method and option 3 is the least preferred method.

Table 8 Typical impervious fraction for split catchment land use.

Development type ¹	Surface type impervious fraction (%)		
	Road	Roof	Ground level
Residential – 10 dwellings/ha	60	100	15
Residential – 15 dwellings/ha	60	100	20
Residential – 40 dwellings/ha	70	100	30
Residential – 80+ dwellings/ha	80	100	50
Industrial	75	100	60
Commercial	75	100	80

¹ Read with Table 6.

Table 9 shows typical impervious fraction values for lumped catchment land use. However, you should ensure impervious percentages chosen for your development reflect your development layout and the maximum allowable dwelling size.

Table 9 Typical impervious fraction for lumped catchment land use.

Surface type	Impervious fraction (%)	
	Range	Preferred minimum
Residential or mixed use		
Residential – 10 dwellings/ha	40 – 55	45
Residential – 15 dwellings/ha	50 – 60	55
Residential – 40 dwellings/ha	60 – 70	65
Residential – 80+ dwellings/ha	70 – 95	85
Industrial		
Typical industrial (warehouse, manufacturing, workshop, etc.)	70 – 95	90
Garden and landscape suppliers	30 – 60	50
Commercial		
Business or town centre	70 – 95	90
Offices	70 – 95	90
Bulky goods	70 – 95	90
Public zones		
Public open space	5 – 50	20
Carparks	70 – 95	90
Library, sporting, depots	50 – 90	70
Schools and universities	50 – 80	70
Infrastructure projects		
Highway and roads	60 – 90	70
Rail	50 – 80	65
Other		
Rural residential (greater than 0.4 ha lots)	5 – 20	10
Rural residential (smaller than 0.4 ha lots)	10 – 25	20
Rural	0 – 5	2
Forest or conservation	0 – 5	0

3.3.4 Rainfall-runoff parameters

Use the rainfall-runoff parameters specific to your region (presented in Appendix A) to model development applications unless:

- Alternative parameters are supported by the assessment authority.
- Comprehensive calibration of the parameters has been undertaken to local stream records. See Section 3.3.6 for further discussion on calibration.

3.3.5 Pollutant export parameters

Lumped land use pollutant export parameters

Table 10 provides pollutant export parameters for use when modelling lumped catchments.

These parameters have been calculated for stormflows and baseflows based on the default MUSIC parameters (derived from Duncan, 1999), information provided by Brisbane City Council, and research on agricultural land uses (BMT WBM, 2009).

NOTE: Modelling rural or low-intensity grazing land

When modelling rural or low-intensity grazing land, the rural residential node should be used with the fraction impervious set to zero. The figures in Table 10 for the agriculture land use should only be used for active cropping or high-intensity grazing.

Table 10 Pollutant export parameters for lumped catchment land uses (log¹⁰ values).

Land use	Flow type	TSS log ¹⁰ values		TP log ¹⁰ values		TN log ¹⁰ values	
		Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Urban residential	Baseflow	1.00	0.34	-0.97	0.31	0.20	0.20
	Stormflow	2.18	0.39	-0.47	0.32	0.26	0.23
Industrial	Baseflow	0.78	0.45	-1.11	0.48	0.14	0.20
	Stormflow	1.92	0.44	-0.59	0.36	0.25	0.32
Commercial	Baseflow	0.78	0.39	-0.60	0.50	0.32	0.30
	Stormflow	2.16	0.38	-0.39	0.34	0.37	0.34
Rural residential	Baseflow	0.53	0.24	-1.54	0.38	-0.52	0.39
	Stormflow	2.26	0.51	-0.56	0.28	0.32	0.30
Forest	Baseflow	0.51	0.28	-1.79	0.28	-0.59	0.22
	Stormflow	1.90	0.20	-1.10	0.22	-0.075	0.24
Agriculture ¹	Baseflow	1.00	0.13	-1.155	0.13	-0.155	0.13
	Stormflow	2.477	0.31	-0.495	0.30	0.29	0.26

¹ Only use for active cropping and high-intensity grazing agricultural land uses.

If alternative pollutant concentrations to those outlined in Table 10 are proposed by an applicant, they must provide independently peer-reviewed monitoring results to the assessment authority.

These results are required to substantiate the proposed alternative parameters and demonstrate to the assessment authority that the proposed data is more scientifically robust than the monitoring results referenced in this guideline.

Split catchment surface type pollutant export parameters

Use the split catchment pollutant export parameters provided in Table 11 for all climatic regions unless alternative parameters are supported by the assessment authority.

Table 11 Pollutant export parameters for split catchment land use (log¹⁰ values).

Flow type	Surface type	TSS log ¹⁰ values		TP log ¹⁰ values		TN log ¹⁰ values	
		Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Urban residential							
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Road	1.00	0.34	-0.97	0.31	0.20	0.20

	Ground level	1.00	0.34	-0.97	0.31	0.20	0.20
Stormflow parameters	Roof	1.30	0.39	-0.89	0.31	0.26	0.23
	Road	2.43	0.39	-0.30	0.31	0.26	0.23
	Ground level	2.18	0.39	-0.47	0.31	0.26	0.23
Industrial							
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Road	0.78	0.45	-1.11	0.48	0.14	0.20
	Ground level	0.78	0.45	-1.11	0.48	0.14	0.20
Stormflow parameters	Roof	1.30	0.44	-0.89	0.36	0.25	0.32
	Road	2.43	0.44	-0.30	0.36	0.25	0.32
	Ground level	1.92	0.44	-0.59	0.36	0.25	0.32
Commercial							
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Road	0.78	0.39	-0.60	0.50	0.32	0.30
	Ground level	0.78	0.39	-0.60	0.50	0.32	0.30
Stormflow parameters	Roof	1.30	0.38	-0.89	0.34	0.37	0.34
	Road	2.43	0.38	-0.30	0.34	0.37	0.34
	Ground level	2.16	0.38	-0.39	0.34	0.37	0.34

Stochastic pollutant generation

Runoff pollutant concentrations can be generated either stochastically (from a defined mean and standard deviation) or by a constant mean concentration. For development applications the stochastic option must be used for modelling stormwater runoff and treatment.

The serial correlation coefficient must be used and the values left as default in accordance with the *Editing Source Node Properties* section under the *Creating a Stormwater Treatment Train* chapter of the *MUSIC Help*.

The serial correlation coefficient will not have any effect on the pollutant loads generated, however it will ensure that the pollutant concentrations at any one time step are related to the previous time step. This will ensure that pollutant generation simulated by MUSIC during any one event will be more consistent with what occurs during real events and may therefore provide better estimates of device performance.

3.3.6 Calibration

Calibration to local data should be undertaken if good quality data sets are available. MUSIC calibration is important for models incorporating land use types that are more than 90% pervious.

Most urban developments are less than 90% pervious. While the calibration of a MUSIC model is desirable, it is not necessary for development applications due to the dominant influence of impervious area on hydrology.

MUSIC model calibration (and calibration of hydrologic models generally) is complex and beyond the scope of these guidelines.

When undertaking calibration, care is needed when:

- Selecting suitable data sets.
- Analysing catchment characteristics.

- Determining the period of calibration.
- Verifying and validating the calibrated model.
- Selecting the objective functions used for assessment.
- Transferring the parameters to ungauged catchments.

The impact of hydrologic calibration on the predictive capability of the water quality model must be considered. It may impact treatment sizing, event responses and compliance with mean annual pollutant load performance objectives.

Where calibration is undertaken and revised source node parameters are used in development applications, a full calibration report outlining responses to these issues should be provided to assessment authorities. The assessment authority will decide if the revised parameters are suitable.

4 Stormwater treatment nodes

MUSIC is a useful and widely used pollutant modelling tool. However, it should not be the only consideration when designing stormwater treatment solutions.

Treatment solutions should be designed not only to improve water quality but also to provide multiple benefits to the community and the environment.

Living Waterways (Water by Design) provides a framework for designing these systems in a way that balances water quality objectives with environmental, social and economic outcomes.

When selecting treatment devices, consider the guidance provided in *Living Waterways (Water by Design)* and use these principles to guide design and subsequently the modelling parameters. Also refer to the *Concept Design Guidelines for Water Sensitive Urban Design (Water by Design)*, *Water Sensitive Urban Design Technical Guidelines for South East Queensland (Water by Design)*, *Bioretention Technical Design Guidelines (Water by Design)* and *Wetland Technical Design Guidelines (Water by Design)*.

Refer to the information in the following section when establishing the treatment nodes you have chosen for your integrated design.

4.1 General notes

The following notes apply to all MUSIC models developed to support development applications:

4.1.1 Drainage links

Drainage links allow nodes to be connected in MUSIC. Links convey the applicable water from one node to another in line with the chosen model time step.

There are two types of links available in MUSIC:

- Primary drainage link.
- Secondary drainage link.

The following explains the use of both the primary and secondary drainage links. The *MUSIC User Manual (eWater)* describes the parameters for links between nodes.

PRIMARY DRAINAGE LINK

Primary drainage links are the predominant type of link used in MUSIC and suffice for most modelling applications.

Primary drainage links may be connected from:

- Source node to treatment.
- Source node to junction node.
- Source node to receiving node.
- Treatment node to treatment node.
- Treatment node to junction node.

The routing and/or translation functions (double click on the drainage link to bring up "Properties") can be used to adjust the timing and magnitude of flow arriving at a downstream node. The default setting of "no translation or routing" is a conservative approach for assessing treatment performance. In this instance, the model assumes that flows and associated pollutants from all parts of a catchment arrive at a treatment node at the same time. This means that MUSIC may overestimate the overflow volume.

For small catchments, where the time of concentration is not significantly longer than the modelling time step (i.e. 6 min), it is not recommended to use routing in the model.

Primary drainage links can be customised to select which components of the flow they convey. For example, a primary node connecting a bioretention system to a junction node will by default convey the low flow bypass, the high flow bypass, the pipe outflows and the weir overflows to the downstream node. By double clicking on the primary drainage link, the user can edit which of these components of the flow the link conveys. For most simple modelling applications the default settings should be used. Any deviation from the default setting must be justified.

The primary drainage link does have one major limitation. It cannot be used to split the different components of the flow leaving a node. The secondary drainage link overcomes this problem.

SECONDARY DRAINAGE LINK

The secondary drainage link increases flexibility when modelling.

Secondary drainage links are installed alongside primary drainage links to allow different components of the flow to be conveyed downstream separately. Secondary drainage links depart from the same node as their associated primary drainage link but must discharge to a different downstream node. Figure 9 demonstrates a simple model including a secondary drainage link. In Figure 9, the primary drainage link routes the standard bioretention outflow components (low flow bypass, high flow bypass, piped outflow and weir overflow) downstream. The secondary drainage link conveys downstream the water that has exfiltrated from the base of the bioretention system into the surrounding soil.

Note that when implementing a secondary drainage link, if the user assigns to the secondary drainage link a component of the flow that would by default be assigned to the associated primary drainage link, that outflow component will be automatically turned off in the primary drainage link.

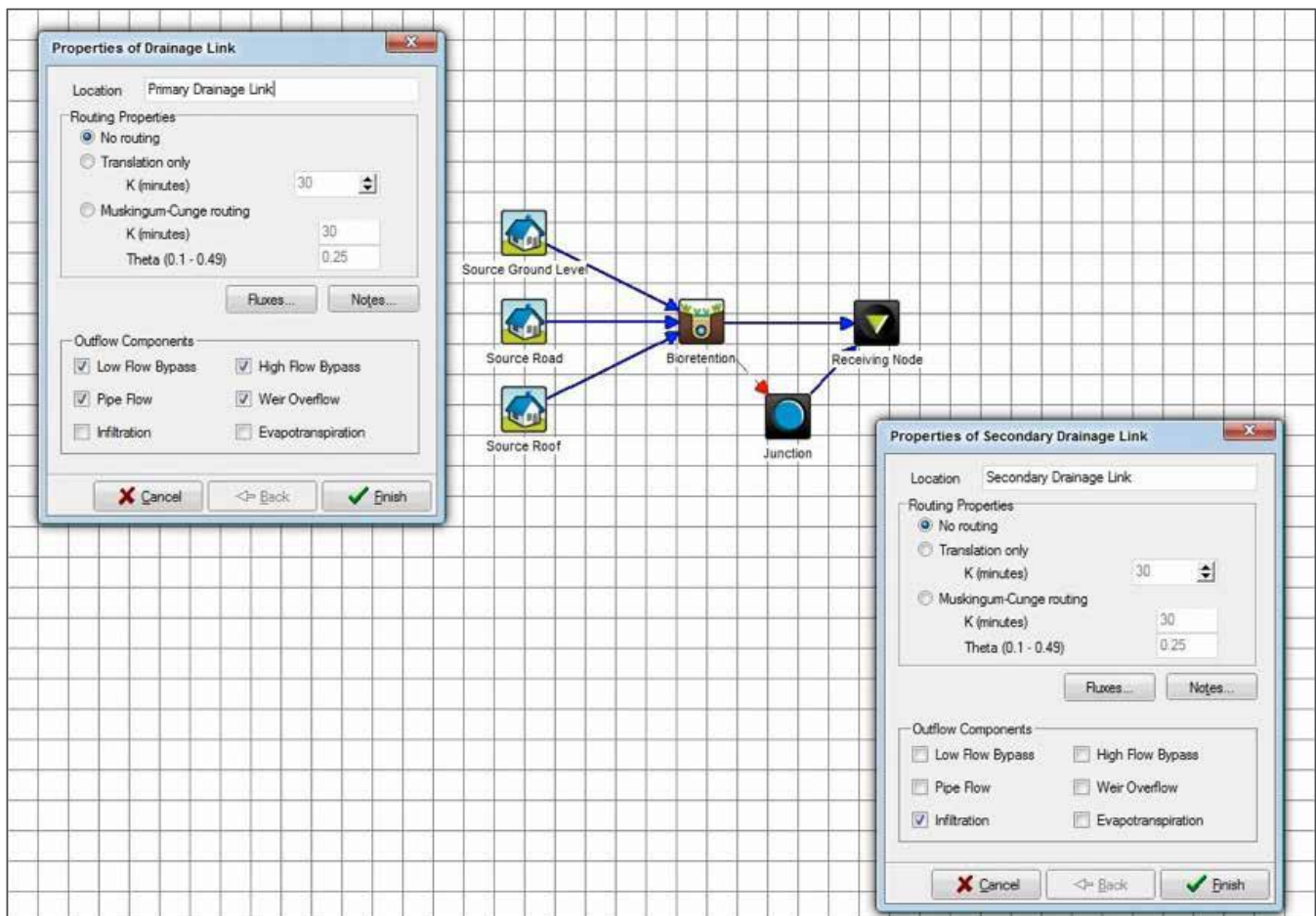


Figure 9 Secondary drainage link.

4.1.2 Baseflow

In the physical world, catchment baseflow is rarely collected in stormwater pipes and conveyed to treatment measures. However, in MUSIC, all baseflow generated by source nodes is conveyed to the downstream node by default.

Directing baseflow to treatment nodes slightly overestimates the effectiveness of the treatment train because it assumes more water is treated than would occur in reality. However, in urban catchments, baseflow represents only about 2% of the overall water balance. Thus, the overestimation is negligible and can generally be disregarded.

4.1.3 Exfiltration

Exfiltration of water from stormwater treatment systems can replenish groundwater and may form an important part of a treatment train aimed at meeting hydrologic management objectives.

The 2010 version of the *MUSIC Modelling Guidelines* prohibited exfiltration from the base of treatment nodes because MUSIC by default assumes that all exfiltrated flows are lost from the model. In the process, the model treats all pollution associated with these flows as having been removed and therefore overestimates treatment performance.

In contemporary versions of MUSIC, the secondary drainage link can be used to convey infiltrated flows downstream within models. Therefore, it is now considered appropriate to include exfiltration from treatment nodes in MUSIC, provided that:

- The exfiltration rate is justified conservatively based on both in-situ subsoil (as opposed to topsoil) testing and the subsoil type.
- The proponent demonstrates that either (a) in-situ soils will not be compacted during earthworks, or (b) that the exfiltration rate modelled is suitably discounted to take into account compaction by construction activity.
- Appropriate secondary drainage links are used to route infiltrated flows and pollution downstream from the treatment node.

Refer to Figure 9 for a simple example of a secondary drainage link used to route exfiltrated water downstream.

4.1.4 Hydrologic routing

The efficiency with which water moves within a treatment system is a function of the system's shape. Systems with low length–width ratios (e.g. ponds) have high potential for turbulence and short-circuiting; systems with high length–width ratios (e.g. swales) have an approximation of plug flow. This is simulated in MUSIC by the number of 'continuously stirred tank reactors' (CSTRs).

In MUSIC, several different shapes representing the surface component of the system are available for modelling. Click on the 'More' button at the bottom of the relevant treatment node parameter dialog box to access this feature. To select the most appropriate value, click on the button with the three small dots (next to the CSTR cells entry box). A new dialog box will open allowing the user to select the CSTR configuration that most closely reflects the design (See Figure 10).

Users are encouraged to keep the default parameters for most applications. Where proper calibration or research has been performed, then values may be changed.

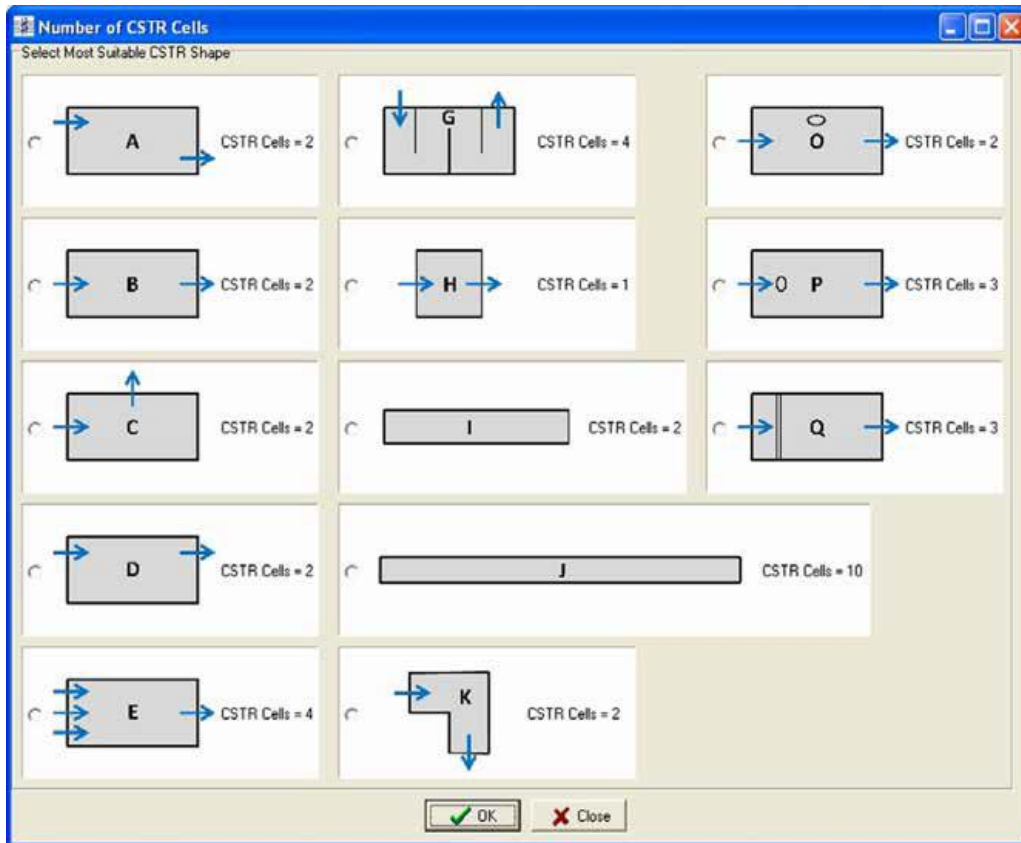


Figure 10 Example of CSTR cells.

4.1.5 Advanced treatment node properties

MUSIC contain a variety of advanced parameters within each treatment node (e.g. the first order decay model ($k-C^*$ model) under the 'More' button on a treatment node). Do not change these parameters unless recommended within a particular section of this guideline or a relevant justification has been provided to and appointed by the relevant assessment authority.

Two examples of situations where it is appropriate to change the advanced parameters include:

- Selecting suitable shape factors to represent the hydrologic routing within a treatment measure in advanced modelling scenarios (refer to Section 4.1.4).
- Setting the k and C^* values for total nitrogen in the constructed wetland treatment node as specified in Section 4.3.

4.1.6 Receiving environments

In most circumstances, stormwater is to be treated before it discharges to receiving environments (such as lakes, natural wetlands, waterways and groundwater) and these should not be modelled as treatment nodes.

4.2 Rainwater tanks

Rainwater tanks are a useful way of managing stormwater. They are mandatory in some local government areas in Queensland. Check with the local council for requirements. In areas where they are not compulsory, they can still be incorporated into the development design and MUSIC model, however, the development application must demonstrate how the development will ensure the tanks will be installed by each new homeowner. The following section explains how to incorporate them into the model.

4.2.1 Rainwater tank modelling parameters

Use the rainwater tank node for simulating water balance within tanks and estimating pollution reduction through sedimentation and reuse. Rainwater tank parameters are summarised in Table 12 with further details provided below.

NOTE: Modelling rainwater tanks for peak flow mitigation and onsite detention

MUSIC is not commonly used for modelling the effectiveness of rainwater tanks for peak flow mitigation or for onsite detention volume assessments. No guidance on this topic is provided in this guideline. If using MUSIC for this purpose, appropriate justification must be provided.

Table 12 Rainwater tank modelling parameters.

Inlet properties	
High flow bypass (m ³ /s)	100
Low flow bypass (m ³ /s)	0
Storage properties	
Volume below overflow pipe (kL)	User defined (must be greater than or equal to five times the maximum daily demand).
Depth above overflow (m)	User defined (0.2 m).
Surface area (m ²)	User defined.
Outlet properties	
Overflow pipe diameter (mm)	User defined (90 mm x $\sqrt{\text{no. tanks}}$).
Reuse parameters	
Annual demand (kL/d)	User defined irrigation demand (see Sections 4.2.2, 4.2.3 and 4.2.4) with "Potential Evapotranspiration — Rain" option selected.
Daily demand (kL/d)	User defined indoor demand (see Sections 4.2.2, 4.2.3 and 4.2.4).
Monthly distribution of annual demand (kL/yr)	0
User defined time series	Not used.

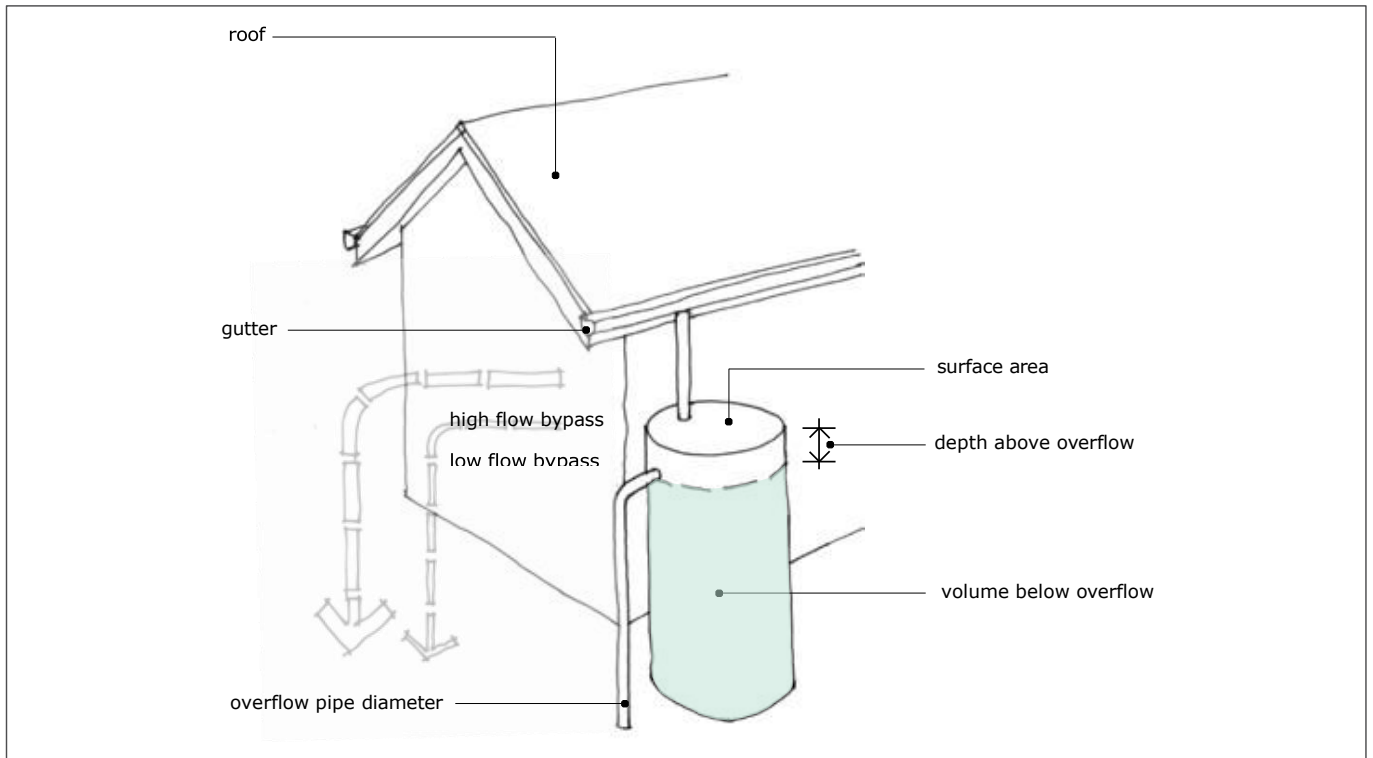


Figure 11 Rainwater tank parameters.

EXAMPLE: INCORPORATING RAINWATER TANKS INTO MUSIC

The following example models a detached dwelling with a 5 kL tank and 50% of the roof area draining to it. The road and verge at the front of the property is also included in this model (as would be required when modelling most reconfiguration of lot applications). The model would be set up by splitting the four separate surface types (road, ground level, proportion of roof draining to the rainwater tank and proportion of roof bypassing the rainwater tank), as shown in Figure 12 (i.e. the "split surface approach"). Figure 8 demonstrates how these split surface types relate to a residential allotment.

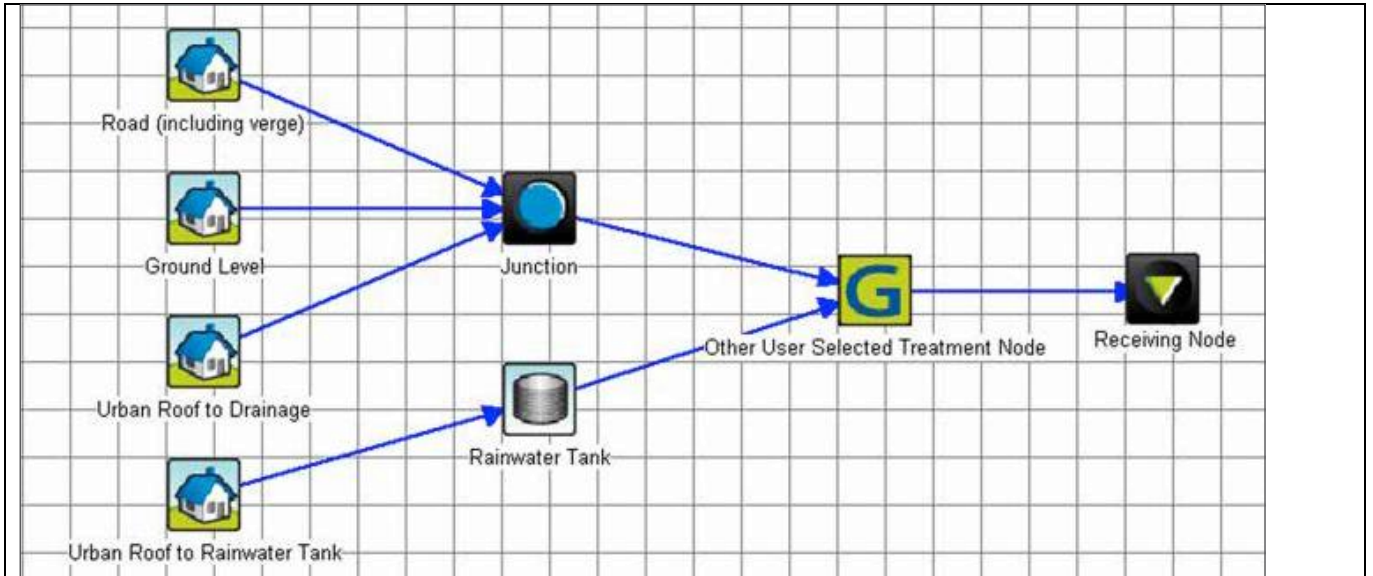


Figure 12 Example of incorporating rainwater tanks in a split surface residential MUSIC model.

4.2.2 Residential tank demands

Use the information in Table 13 and Table 14 for modelling tanks unless the assessment authority has an alternative preferred approach.

Different areas will vary in demographics so occupancy rates and rainwater tank demands should be agreed upon with the assessment authority before development applications are lodged, even if using the data in these tables.

If alternative data is used, the stormwater management plan must clearly specify and justify adopted parameters. Care needs to be taken when selecting appropriate demands. For example, if the demand for tank water is overestimated, downstream treatment systems will potentially be undersized.

Table 13 Residential occupancy rates.

Development type	Size	Occupancy (people per dwelling)		
		Permanent residential ^{1,2}		Holiday accommodation ³
		Average	Peak ⁴	Average ⁵
Detached dwelling	1 bedroom	1.6	2	0.8
	2 bedrooms	1.9	4	1.1
	3 bedrooms	2.5	6	1.3
	>3 bedrooms	3.4	8	1.9
	Overall mixed	2.8	6.7	1.5
Townhouse	Studio/1 bedroom	1.2	2	0.8
	2 bedrooms	1.6	4	1.1
	3 bedrooms	2.3	6	1.3
	>3 bedrooms	3.3	8	1.9
	Overall mixed	2	5.4	1.2
Unit	Studio/1 bedroom	1.2	2	0.8
	2 bedrooms	1.2	2	0.8

	3 bedrooms	2.2	6	1.3
	Overall mixed	1.7	4	0.8
Resort	1 bedroom		2	0.8
	2 bedrooms		4	1.1
Hotel/motel	Standard room		2	0.8
	Family room		4	1.1

¹ Residential data is based on ABS census data from the 2006 Census of Population and Housing.

² Residential development with stable permanent population and relatively few visitors or transients.

³ Tourist/holiday accommodation with transient populations.

⁴ Assumes a peak occupancy of two people per bedroom.

⁵ Assumes between 45% and 65% of rooms occupied on average (Tourism Queensland, 2008) and that the average number of people per room is between 35% and 40% of peak occupancy.

Table 14 Residential rainwater tank demands.

Use	Litres per person per day ¹
Non-potable uses	
Toilet	25
Washing machine	33
Irrigation	40
Potable uses²	
Shower	44
Dishwasher	2
Tap	19
Bathtub	1
Other	
Leak	7

¹ Figures are based on *South East Queensland Residential End Use Study: Final Report* (Beal & Stewart, 2011) and the Queensland Competition Authority's advice of the average household water use of 160 kL of water a year (equivalent to 2.5 people using 169 litres each per day).

² Potable uses require water to be at an appropriate standard (refer to the *Australian Drinking Water Guidelines*).

4.2.3 Open space irrigation demands

There is a range of approaches for estimating irrigation water demands. In the absence of project-specific information, use an annual irrigation application rate (outlined in Table 15).

Table 15 Open space irrigation demands.

Category	Description	Best practice irrigation ¹ (ML/Ha/year)
Elite	State/national competition (generally associated with stadiums).	4-9
Regional	State/regional/first grade playing surface.	2.5-5
Local	Local sports fields.	1.5-3.5

Passive	Neighbourhood parks, passive reserves, lawn areas.	02.5
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¹ Data based on Sydney Water (2011) *Best practice guidelines for holistic open space turf management in Sydney* (as applicable to warm season turf grasses) and verified against metered data for 43 parks in the Moreton Bay region.

MUSIC includes an option to apply irrigation only when rainfall is less than the daily evapotranspiration value (PET-rain). Use this selection when applying outdoor demands (as shown in Figure 13).

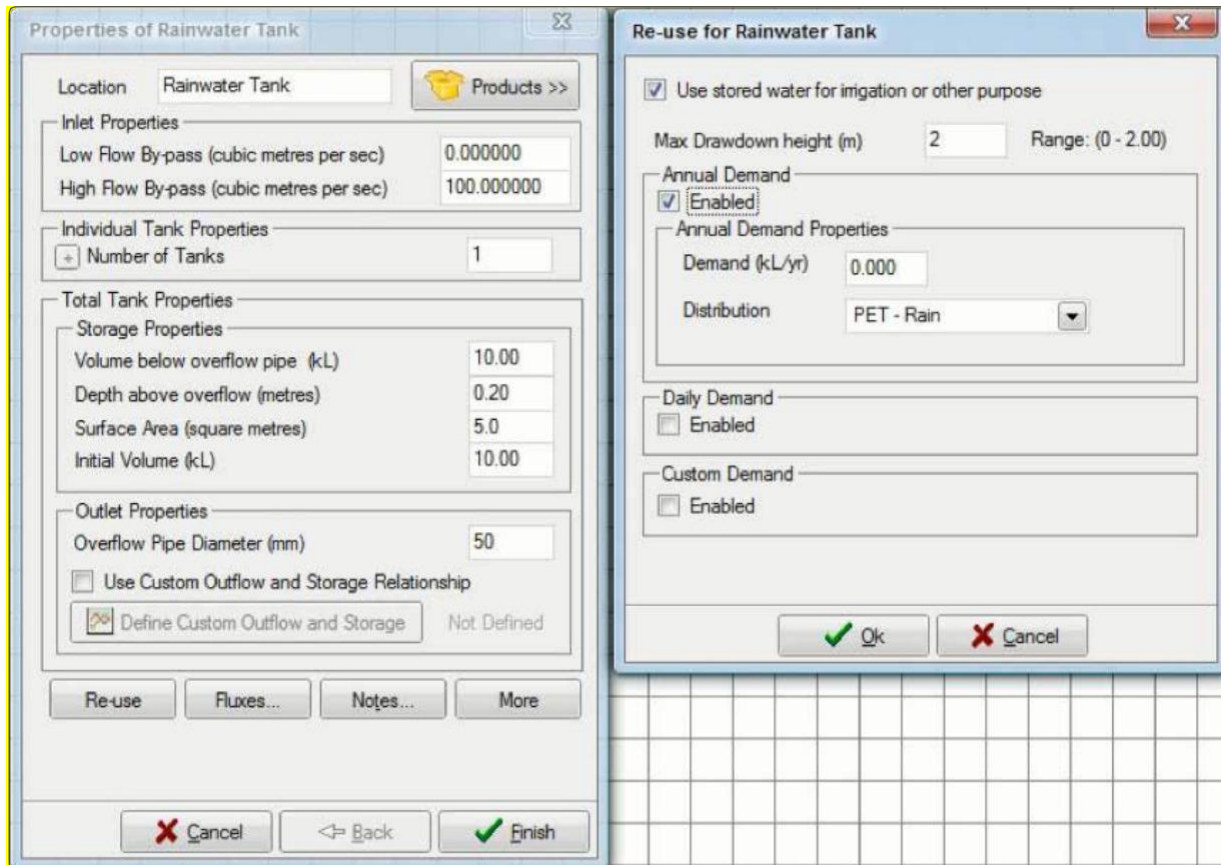


Figure 13 Rainwater tank inputs.

4.2.4 Commercial and industrial demands

For other land uses such as schools, hospitals, residential care facilities and short-term accommodation, refer to the *SEQ Water and Sewerage Planning Guidelines* (Allconnex Water, Queensland Urban Utilities and Unitywater, 2012) or the relevant local government standard for appropriate equivalent person and equivalent tenement values.

4.2.5 Rainwater tanks volume

In modelling rainwater tanks for development applications, refer to local government guidelines. If none exist, provide evidence in the development application to demonstrate how the installation of rainwater tanks will be enforced and guaranteed.

The tank volume modelled is the volume that is operating to retain runoff from the roof. This is not the total internal volume of the tank, but the total volume minus the volume below the invert of the overflow pipe and above the trickle top-up volume (these two volumes do not contribute to active storage). The trickle top-up volume can be up to a suggested maximum of 1,000 L and is configured in MUSIC via the 'Maximum Drawdown Height'.

The storage volume quoted by most tank manufacturers and suppliers is generally the active storage volume. In effect, most tank suppliers and manufactures already subtract the volume below the invert of the overflow pipe and above the trickle top up volume when quoting tank volumes. As a result, the total volume used in modelling can for most applications be the volume quoted by the manufacturer or supplier.

4.2.6 Lumped versus individual tanks

When modelling a catchment with more than one tank (and where the ratio of roof area to tank volume and reuse demand is relatively constant), the roof areas in a catchment can be lumped together, as can the tank nodes.

When lumping rainwater tanks in this way, the tank node size is scaled up to reflect the combined volumes of the individual tanks. When scaling up the dimensions of the tank, the depth in the tank should remain constant (i.e. the depth of one tank is used in the lumped tank), and the surface area increased to make up the required volume. The diameter of the overflow pipe from the tank should be equivalent to the diameter of the overflow pipe of a single tank multiplied by the square root of the number of tanks.

WORKED EXAMPLE: TANKS

Consider a greenfield site being developed as a low-density residential estate with:

- 20 lots at 550 m² with roof areas of 250 m².
- Ground level 30% impervious areas with the remainder lawn and garden beds.
- Three-bedroom detached dwellings.

5 kL above ground tanks will be provided on each lot. 50% of the roof areas will be connected to the tanks. The remaining roof areas will discharge to the drainage system and be treated by a downstream bioretention system. Overflows from the tanks will also be drained to the bioretention system to maximise onsite treatment.

Rainwater will be used for household non-potable water uses, including toilet flushing, laundry uses and garden irrigation.

Using the data provided in Table 13 and Table 14 **Error! Reference source not found.**, the following calculations are undertaken:

Water use – outdoor

- Outdoor use (per person) = 40 L/day (irrigation).
- Outdoor use (per dwelling) = 40 L/day x 2.5 people/dwelling = 100 L/day.

Water use – indoor

- Indoor use (per person) = 25 L/day (toilet) + 33 L/day (washing machine) = 58 L/day.
- Indoor use (per dwelling) = 58 L/day x 2.5 people/dwelling = 145 L/day.

Lumped tank parameters

- Catchment Area = 125 m² (50% of the roof area) X 20 (lots) = 2,500 m² = 0.25 Ha.
- Tank Volume (Below Overflow Pipe) = 5 kL X 20 = 100 kL.
- Depth Above Overflow = As default (or according to tank design) = 0.2 m.
- Surface Area = 100 (volume) / 2 (height of individual tank = 2 m) = 50 m².
- Overflow Pipe Diameter = 90 mm X $\sqrt{20}$ = 402 mm.
- Annual Demand (Representing Outdoor Use) (Scaled By Daily Pet - Rain) = 100 L/day X 0.001 kL/L X 365 d/yr X 20 (lots) = 385 kL/yr.

Daily Demand (Representing Indoor Use) = 145 L/day X 0.001 kL/L X 20 (lots) = 0.290 kL/day.

NOTE: Ensuring correct units are used

One of the most common mistakes made in modelling rainwater tanks is the use of incorrect units. The annual demand, daily demand and monthly distribution of annual demand should be modelled and reported in kL/day.

4.2.7 First-flush diverters

In many rainwater tank installations, a diverter is put in place to capture the initial runoff from the roof, which may contain high amounts of leaf matter and other contaminants. Diverters capture a certain volume of runoff after which water bypasses the diverter and enters the tank. To simulate this in MUSIC, the roof source node is configured with the rainfall threshold value set to represent the first flush volume.

For example, if the volume of the first flush diverter is 20 L, and the connected roof area is 100 m², then the rainfall threshold value for the roof source node is 0.2 mm. This 0.2 mm is added to the default rainfall threshold of the roof, which is 1 mm. Therefore, the rainfall threshold value becomes 1.2 mm (i.e. only after there has been 1.2 mm of rainfall in a day will water enter the tank).

4.3 Constructed wetlands

A summary of appropriate constructed wetland parameters is presented in Table 16 with further details outlined below.

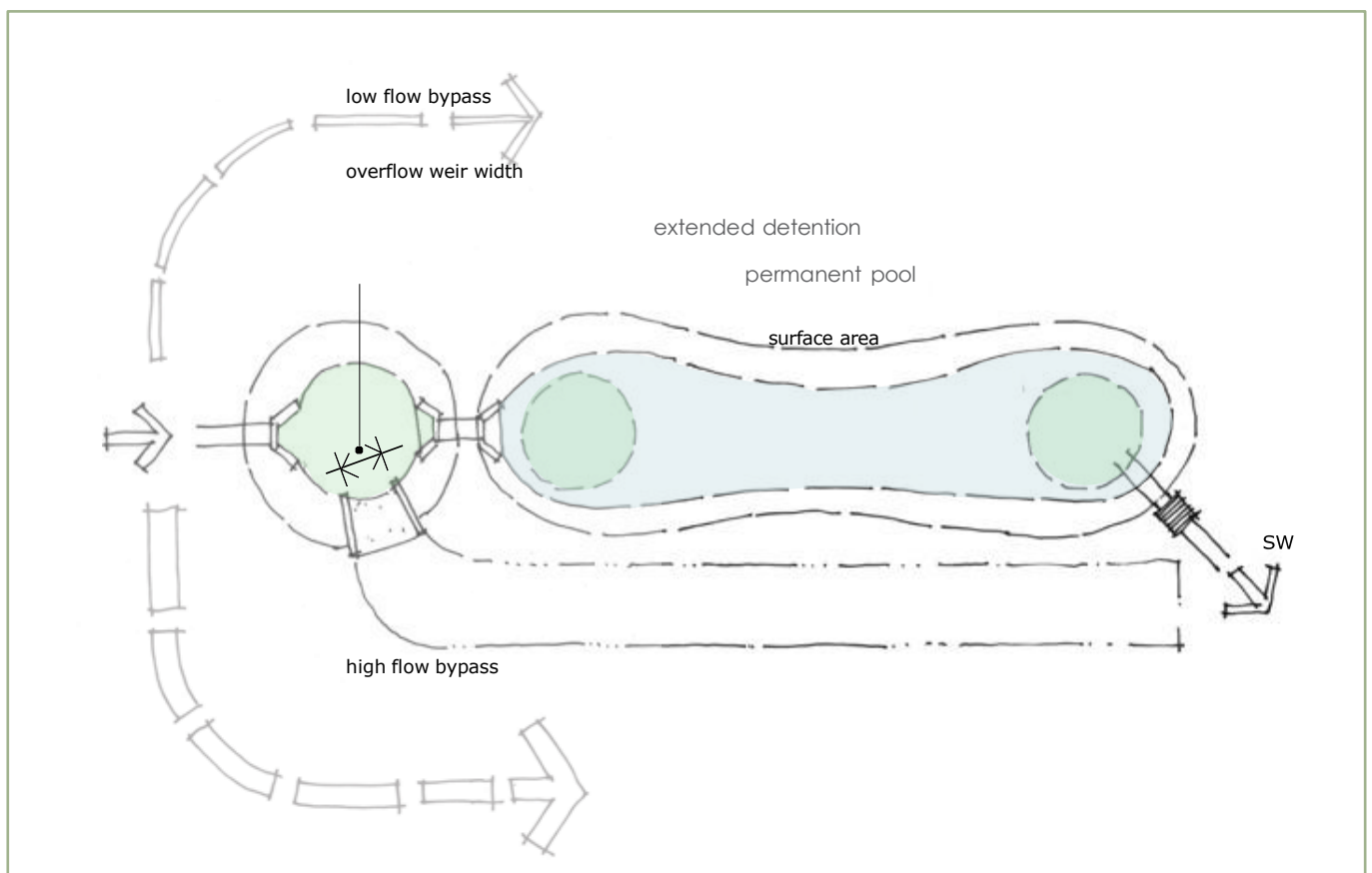
For more information on designing constructed wetlands, refer to the *Wetland Technical Design Guidelines (Water by Design)*. For further modelling advice, refer to the *MUSIC User Manual (eWater)*.

Table 16 Constructed wetland parameters input summary.

Inlet properties	
Low flow bypass (m ³ /s)	0
High flow bypass (m ³ /s)	100 or higher (see Section 4.3.1).
Inlet pond volume (m ³)	Sized to remove coarse sediment (>125 µm) during a 1-year ARI storm. Refer to the <i>Wetland Technical Design Guidelines (Water by Design)</i> for further sizing information. For initial conceptual design only, refer to Section 4.3.1 for a suitable rule of thumb.
Storage properties	
Surface area (m ²)	User defined.
Extended detention depth (m)	0.5 m maximum.
Permanent pool volume (m ³)	Generally 0.2 m to 0.3 m x surface area.
Initial volume (m ³)	Equal to permanent pool volume.
Exfiltration rate (mm/hr)	Typically 0 mm/hr.
Evaporative loss as % of PET	125
Outlet properties	
Equivalent pipe diameter (mm)	Use a user defined Storage-Discharge-Height relationship (entered under the 'More' button on the Wetland node dialog box). For preliminary sizing of

	wetlands (at the planning stage), set the equivalent pipe diameter to achieve the desired notional detention time (typically 48 hrs).
Overflow weir width (m)	Greater of surface area (m ²)/10 or weir width to convey major storm flow with 0.3 m head.
Notional detention time (hrs)	User defined (typically as close to 48 hrs as possible).
Advanced properties	
Orifice discharge coefficient	Default.
Weir coefficient	Default.
Number of CSTR cells	User defined where appropriately justified (see Section 4.1.4).
k (m/yr) and C* (mg/L) – Total suspended solids	k = Default; C* = Default (see Section 4.3.4) ¹ .
k (m/yr) and C* (mg/L) – Total phosphorus	k = Default; C* = Default (see Section 4.3.4) ¹ .
k (m/yr) and C* (mg/L) – Total nitrogen	k=200, C*= 0.75 (see Section 4.3.4) ¹ .

¹ The values adopted for the wetland node k and C* parameters for each pollutant strongly influence treatment performance for that pollutant. Wetland performance can vary from site to site depending on site characteristics and system design. Refer to Section 4.3.4 for further discussion of selecting appropriate k and C* values for wetlands.



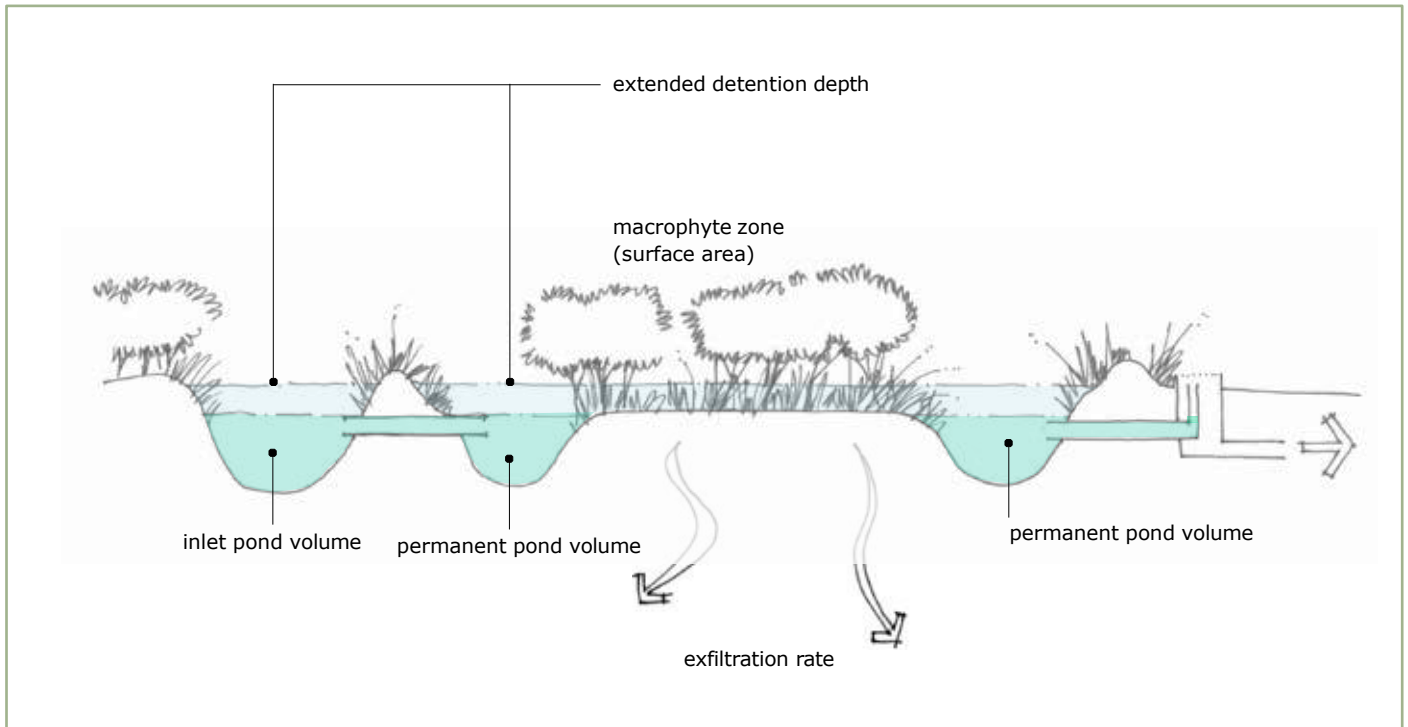


Figure 14 Constructed wetland parameters.

4.3.1 Inlet properties

All constructed wetlands are different. However, typical wetland design includes the macrophyte zone, an inlet pond and a high flow bypass. In simple terms, stormwater enters the inlet pond. The low flows are then directed to the macrophyte zone where they are treated, with the high flows bypassing via the high flow bypass.

The wetland node in MUSIC refers to both a 'low flow bypass' and a 'high flow bypass'. Users should be aware that both bypasses in MUSIC occur before the inlet pond. They do not represent the high flow bypass referred to above.

Low flow bypass (m^3/s): Unless there is a site-specific reason that low flows would be bypassed, set the low flow bypass to zero. This will result in all low flows reaching the inlet.

High flow bypass (m^3/s): Unless there is a site-specific reason that high flows would be bypassed prior to them reaching the inlet pond, set the high flow bypass to a high value (i.e. $100 \text{ m}^3/\text{s}$ or higher).

Inlet pond volume (m^3): MUSIC is not considered suitable for sizing wetland inlet ponds. Refer to the *Wetland Technical Design Guidelines (Water by Design)* for the recommended sizing method. Once the inlet pond area and volume are defined, the volume can be entered into MUSIC.

For initial conceptual design only, the inlet pond volume may be estimated as 5% of the macrophyte zone treatment area, multiplied by a depth of 1m (if the inlet pond is $<500 \text{ m}^2$) or 1.5m (if the inlet pond is $\geq 500 \text{ m}^2$).

When modelling an inlet pond with extended detention that receives 'feedback' from the macrophyte zone (i.e. water levels in the inlet pond are controlled by the macrophyte zone outlet), the extended detention volume located above the inlet pond can be included in the extended detention volume of the macrophyte zone.

4.3.2 Storage properties for macrophyte zone

Surface area (m²): The 'surface area' specified in the wetland node relates to the macrophyte zone of the wetland. There are two methods for defining the surface area:

1. Equal surface area method (preferred) – set the surface area equal to the normal water level (i.e. assume that the extended detention has vertical sides). This is the simplest approach and a more conservative estimate of the extended detention storage.
2. Average surface area method – average the surface areas of the top of the permanent pool (i.e. the 'normal water level') and the top of the extended detention (i.e. the 'top water level'). This method accounts for the battered edges typically used in wetlands. It is noted that this approach results in an overestimation of the surface area of the permanent pool and hence the evaporation rate and drawdown between rainfall events.

Extended detention depth (m): Set the extended detention depth to 0.35-0.5 m (or lower to reflect actual design parameters). Deeper extended detention depths increase the risk of plant failure due to stress from prolonged periods of excessively deep water. The default value of 1.0 m for the extended detention depth is not acceptable.

Permanent pool volume (m³): Calculate the average depth from the bathymetry or use an average depth of 0.2-0.3 m. MUSIC assumes the permanent pool volume is a constant depth, whereas constructed wetlands generally have a range of depths, including ephemeral areas (i.e. no permanent pool).

Initial volume (m³): The initial volume should be equal to the permanent pool volume. This will ensure that model runs begin with the wetland full of water. Specifying a volume less than the permanent pool volume will lead MUSIC to overestimate treatment performance.

Exfiltration rate (mm/hr): The exfiltration rate should generally be set to zero as constructed wetlands are typically lined with impermeable material. Where a wetland is expected to exfiltrate water, a non-zero value may be entered. In this scenario, the exfiltrated water must be retained in the model using a secondary drainage link (see Sections 4.1.1 and 4.1.3).

Evaporative loss as % of PET: Set to 125.

4.3.3 Outlet properties

Equivalent pipe diameter (mm): Set the equivalent pipe diameter so that the notional detention time is above 48 hours. The notional detention time of the wetland is equal to the extended detention volume (surface area multiplied by the extended detention depth), divided by the flow rate through a circular hole equal to the pipe diameter, with a head equal to the extended detention depth.

In reality, wetland outlets are rarely configured as a single orifice and thus the discharge relationship is different to that simulated in MUSIC. Additionally, the actual time taken for the wetland to draw down from the top of extended detention to the permanent pool level is greater than the notional detention time. The difference between actual drawdown and notional detention time can be explained by the fact that as the water level decreases from the top of extended detention towards the permanent pool level, the head of water also decreases and therefore the discharge rate decreases.

To account for this effect in MUSIC, a user-defined stage-discharge relationship can be specified. This allows the user to construct specific outflow characteristics consistent with their outflow design by importing a text file into MUSIC. The text file can be generated using spreadsheet software. Further guidance on creating stage-discharge files is provided in the *MUSIC Help*.

Overflow weir width (m): The length of the overflow weir controls the discharge rate when the water level in the wetland exceeds the top of extended detention. An undersized overflow weir results in water backing up, effectively adding more extended detention. To avoid this, as a starting point set the

overflow weir length as the greater of either the surface area (m²) divided by 10 m or the weir width to convey the major storm flow with 0.3 m of head.

Notional detention time (hrs): The notional detention time is a product of the surface area, extended detention depth and equivalent pipe diameter. Refer to 'equivalent pipe diameter' above for further guidance on setting the notional detention time.

4.3.4 Advanced properties

Where appropriate justification can be made, select 'Advanced Properties' by clicking on the 'More' button.

CSTR cells: Refer to Section 4.1.4 for information on CSTR cells and hydrologic routing within wetlands.

k (m/yr) and C* (mg/L): The k and C* values adopted for each pollutant strongly influence wetland treatment performance for that pollutant. There have been relatively few Australian studies into the treatment effectiveness of stormwater wetlands. The default k and C* values for wetlands presented in MUSIC are derived from monitoring data from the Hampton Park wetland in Melbourne (eWater, Appendix G) presented in Fletcher *et al.* (2004).

Further information on the treatment performance of constructed wetlands in Australia is available in DesignFlow (2016), Roberts *et al.* (2018), Payne *et al.* (2015), Parker (2010), Manganka (2013) and Manganka *et al.* (2015), with the latter three studies all based on the same wetland system at Coomera Waters in Queensland.

From consideration of the above sources:

- Total suspended solids – k and C* must be left as default.
- Total phosphorus – k and C* must be left as default.
- Total nitrogen – adopt k = 200 m/y and C* = 0.75 mg/L.

4.3.5 Reuse

The reuse demand profile for the permanent pool of a wetland is project-specific. Reuse is only possible from a wetland in MUSIC if a permanent pool volume is set within the node. Refer to Section 4.3.2 for further guidance.

4.4 Swales

A summary of appropriate swale parameters is presented in Table 17 with further details outlined below.

For further information on designing swales, refer to the *Water Sensitive Urban Design Technical Design Guidelines for South East Queensland* (Water by Design). For further modelling advice, refer to the *MUSIC User Manual* (eWater).

Table 17 Swale parameters.

INLET PROPERTIES	
Low flow bypass (m ³ /s)	0
STORAGE PROPERTIES	
Length (m)*	User defined.
Bed slope (%)	Maximum 4%.
Base width (m) ¹	User defined.
Top width (m)	User defined.
Depth (m)	User defined.

Vegetation height (m)	User defined (consider vegetation species being used).
Exfiltration rate (mm/hr)	0

¹ If the length/width ratio is low, consider lowering the CSTR and k values to account for reduced treatment effectiveness.

Swale configuration (e.g. inflow and discharge location) influences how swales should be modelled:

- OPTION A:** If a swale receives distributed lateral inflow along its length and the whole length of the swale discharges at a single point (as shown in 'Option A' of Figure 15), then the swale length should be modelled in MUSIC as its actual length. The upstream end of the catchment is well treated while the downstream end of the catchment is not treated as well. As a result the overall performance is identical to the swale modelled as a series of smaller swales (Option B). In this scenario, MUSIC should be set up using a single source node (or multiple nodes if splitting the catchment into surface types) and single swale node.
- OPTION B:** If the swale is segmented, and each segment accepts stormwater at its upstream end (as opposed to continuously along its length) and discharges at its downstream end (as shown in 'Option B' of Figure 15), the swale should be modelled in MUSIC as either a single aggregated swale (by summing the total catchment areas and total swale lengths or multiple swale segments as per Option A) or as multiple short segments, each with its own discharge point. Either option will give the same output in MUSIC.
- OPTION C:** If the swale accepts point source discharges at given locations but each segment of the swale flows into the next segment of the swale with a single outlet point at the downstream end (as shown in 'Option C' of Figure 15), the upstream part of the swale is well treated, and the downstream part is not treated well. The swale should be modelled as a series of swale nodes, each receiving inflows from the upstream swale segment and local catchment inflows, with swales modelled separately.

The following issues should also be considered when modelling swales:

- The total length of swale should account for conveyance capacity and safety limitations selected in accordance with the *Water Sensitive Urban Design Technical Design Guidelines for South East Queensland (Water by Design)*. Proponents must ensure that the system being modelled can be constructed.
- If the longitudinal grade of the swale is 5% or greater, the system is primarily for conveyance and will not provide suitable treatment of stormwater. These swales should not be included in the MUSIC model as treatment nodes.
- The height of vegetation in the model depends on the landscape treatment. Turf has a vegetation height of 50 mm. Native grasses and sedges typically have a vegetation height of 300 mm or more, however advice should be sought from a landscape architect or ecologist.
- The exfiltration rate should generally be set to zero. A non-zero rate may be adopted if justified through in-situ soil testing. If a non-zero value is adopted, the exfiltrated water must be retained in the model using a secondary drainage link (see Section 4.1.1 and 4.1.3).

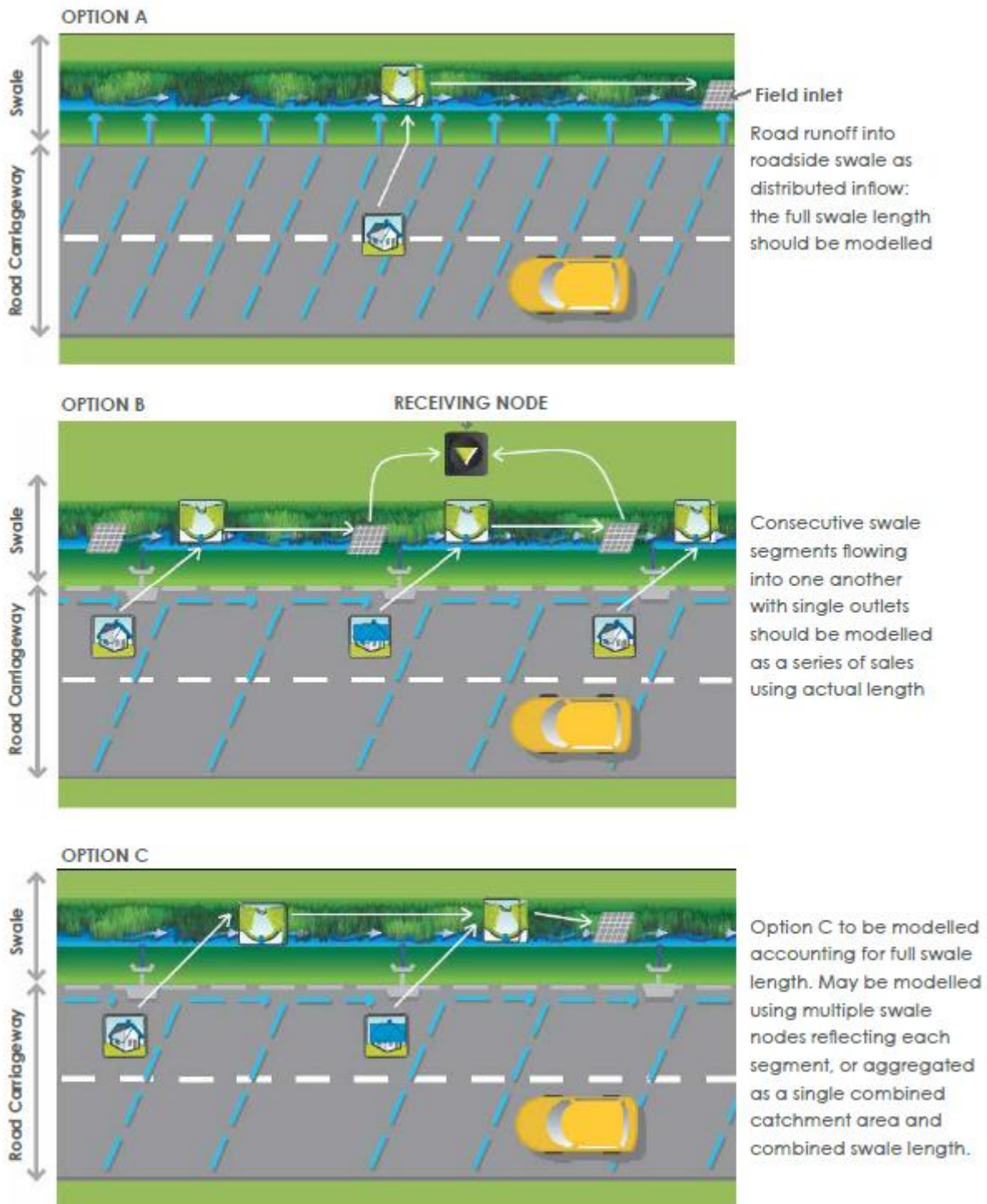


FIGURE 4.7 Typical localised and distributed inflow arrangements to swale

Figure 15 Typical localised and distributed inflow arrangements to swale.

4.5 Bioretention systems

A summary of appropriate bioretention parameters is presented in Table 18 with further details outlined below.

For more information on designing bioretention systems, refer to the *Bioretention Technical Design Guidelines* (Water by Design). For further modelling advice, refer to the *MUSIC User Manual* (eWater).

Table 18 Bioretention parameters.

Inlet properties	
Low flow bypass (m ³ /s)	User defined.
High flow bypass (m ³ /s)	User defined.
Storage properties	
Extended detention depth (m)	0.3 m
Surface area (m ²)	User defined (see Section 4.5.2).
Filter media properties	
Filter area (m ²)	User defined.
Unlined filter media perimeter (m)	User defined.
Saturated hydraulic conductivity (mm/hr)	200 mm/hr (but also run 50 mm/hr for sensitivity and present results).
Filter depth (m)	0.4 m to 1.0 m (typically 0.5-0.6 m).
Total nitrogen content in filter media (mg/kg)	User defined (in most instances use 400 mg/kg, see Section 4.5.3).
Orthophosphate content in filter media (mg/kg)	User defined (in most instances use 30 mg/kg, see Section 4.5.3)
Infiltration properties	
Exfiltration rate	User defined.
Lining properties	
Is the base lined?	User defined.
Vegetation properties	
Plant selection	User defined.
Outlet properties	
Overflow weir width (m)	Typically greater than or equal to surface area (m ²)/10.
Underdrain present	Typically yes.
Submerged zone with carbon present	User defined.
Depth (of submerged zone)	User defined.

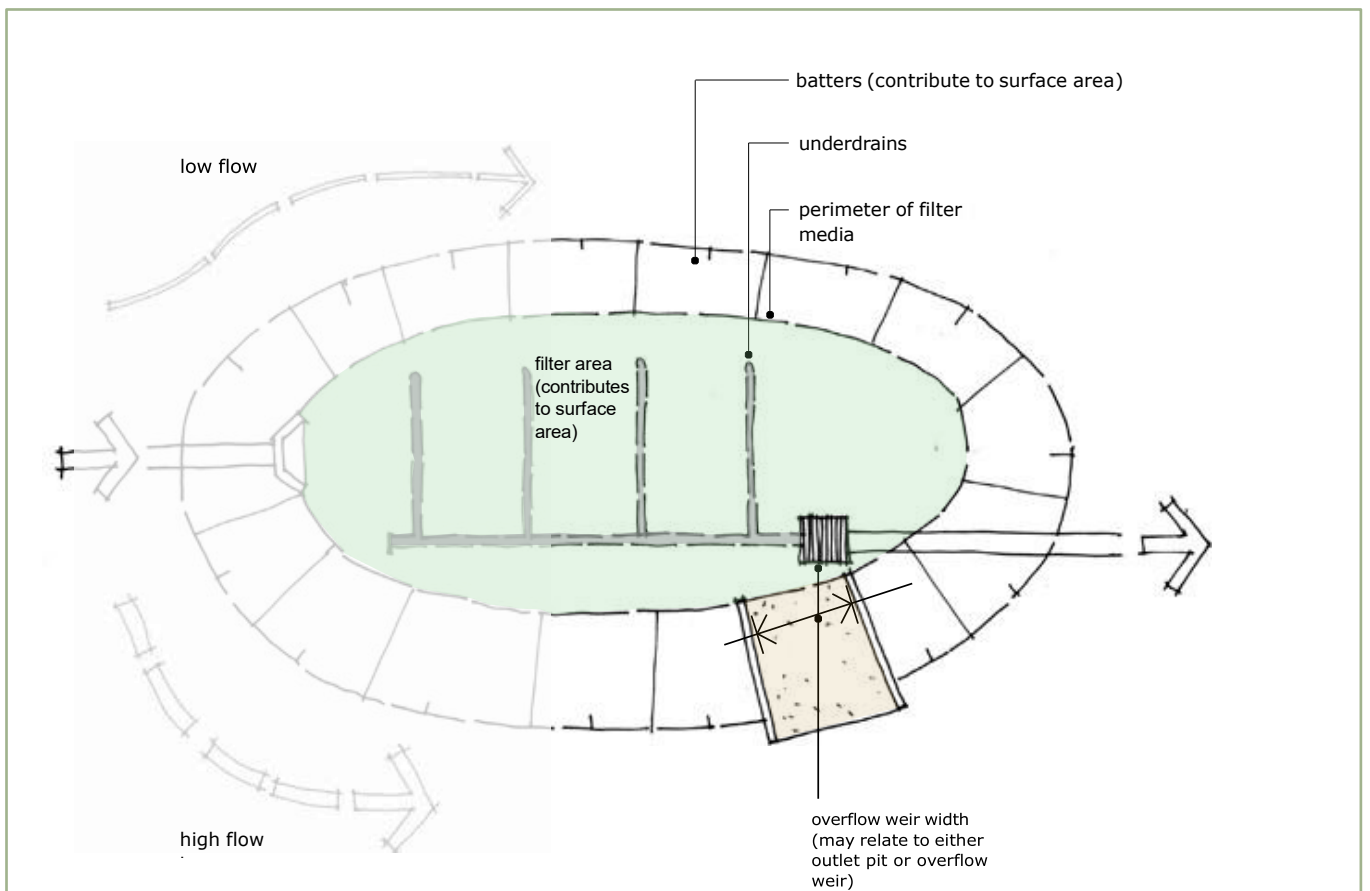
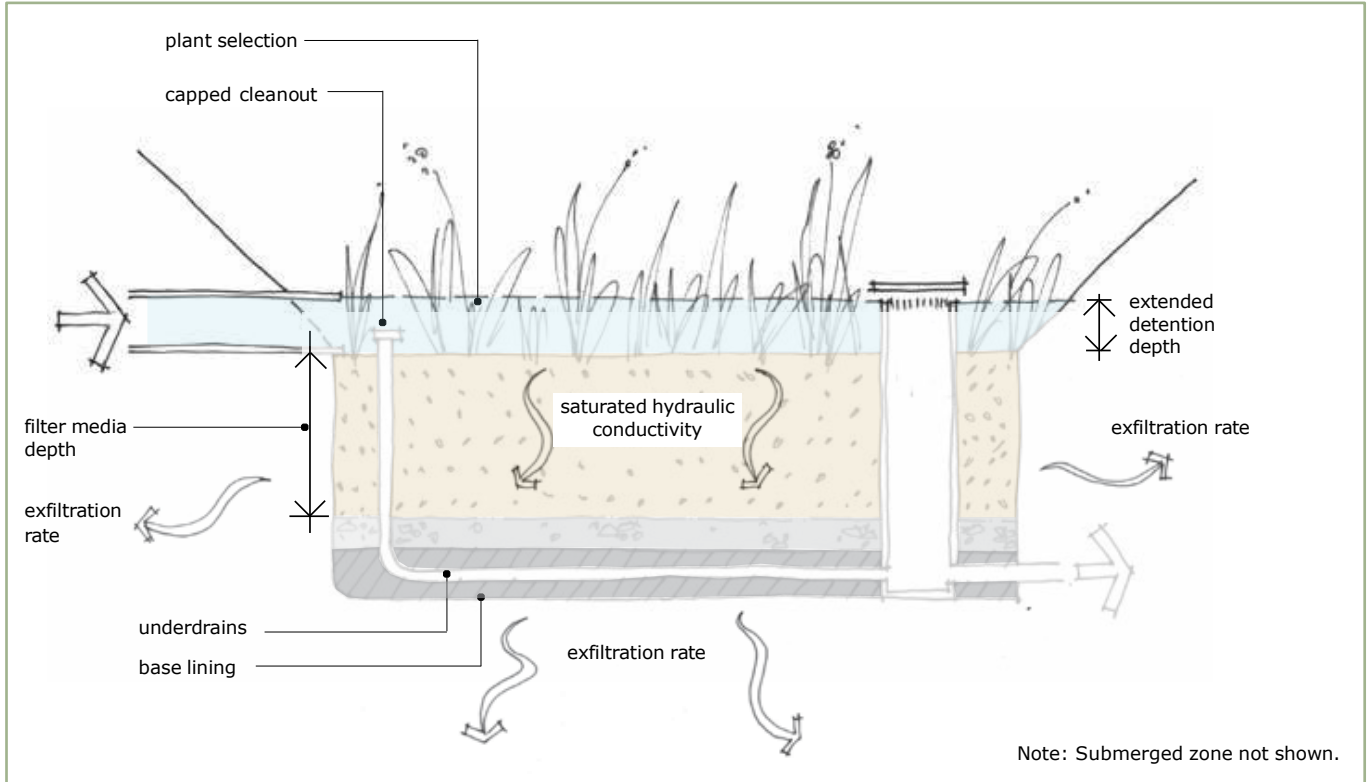


Figure 16 Bioretention system parameters.

4.5.1 Inlet properties

Low flow bypass (m^3/s): There are no standard recommendations for the low flow bypass as the inputs are dependent on individual design scenarios.

High flow bypass (m^3/s): There are no standard recommendations for the high flow bypass as the inputs are dependent on individual design scenarios. The high flow bypass should be sized to avoid scouring flows in the bioretention basin.

4.5.2 Storage properties

Surface area (m^2): The surface area parameter in MUSIC represents the area water can pond above the filter media. There are two accepted methods for defining the surface area:

1. Equal surface area method (preferred) – this method assumes that the surface area is equal to the filter area and that the extended detention storage has vertical sides. For systems with a trapezoidal-shaped extended detention storage this is a conservative estimate of the extended detention storage.
2. Median surface area method – many bioretention systems do not have vertical sides around the extended detention area. In this case, a more accurate estimate of the median surface area can be calculated based on the median depth of ponding in the extended detention area. Note that the median depth of ponding will often be less than half the extended detention depth. Calculation of the median depth of ponding requires analyses to be undertaken outside of MUSIC. The complexity of this analysis and its marginal impact on treatment sizing (especially for large systems) are the reasons this method is not preferred.

Note that bioretention systems that have an extended detention surface area substantially larger than the filter media area experience conditions which may reduce the lifespan of the system and are strongly discouraged. Systems designed in this way operate similarly to a bathtub, whereby large volumes of stormwater are captured and squeezed through a small filter media area (like a plughole).

There are significant risks associated with designing systems in this manner, including overloading the filter media with pollutants or filter media blockages. Blockages reduce hydraulic conductivity and place stress on vegetation which is likely to result in plant mortality or a change in plant composition from the intended design. Where there is no alternative approach, the filter area must not be less than 50% of the total surface area of the extended detention area.

NOTE: Co-locating bioretention and flood detention basins

When a bioretention system is incorporated into the base of a flood detention basin, the volume of the detention basin (i.e. the volume available in the basin above the top of the extended detention depth) is not to be included in the model for water quality assessment. Flood storage is not creditable as extended detention.

4.5.3 Filter and media properties

Unlined filter media perimeter (m): If the exfiltration rate is to be set to a value other than zero, set the unlined filter media perimeter to either:

- The actual unlined perimeter (if the perimeter is unlined and the perimeter is known).
- Four times the square root of the surface area (if the perimeter is unlined but the perimeter is not known).
- 0.01 m (if the perimeter of the system is lined).

Refer to Sections 4.1.1, 4.1.3 and 4.5.4 for further information.

Saturated hydraulic conductivity (mm/hr): Bioretention systems are generally installed with filter media in accordance with either the *Specifications for Bioretention Filter Media* (Water by Design) or Appendix C

of the *Adoption Guidelines for Stormwater Biofiltration Systems* (Cooperative Research Centre for Water Sensitive Cities, 2015). If installed with filter media consistent with one of these specifications, bioretention systems should be modelled with a hydraulic conductivity of 200 mm/hr.

Compliance with water quality objectives is only required for the actual long-term expected hydraulic conductivity (i.e. 200 mm/hr).

Filter depth (m²): The minimum bioretention filter depth recommended in the *Bioretention Technical Design Guidelines* (Water by Design) is 0.6 m. The filter depth depends on the available depth based on the inlet and outlet levels and the species of plants being used. Do not model the depth of the drainage layer, intermediate layer or submerged zone as part of the filter media depth.

Total nitrogen content in the filter media (mg/kg): Bioretention performance is sensitive to the amount of nitrogen in the filter media. Adopt the larger of 400 mg/kg or the actual value of total nitrogen in the filter media as established through testing. In most instances, the actual value of total nitrogen in the filter media will be less than 400 mg/kg.

The rationale for this recommendation is:

- In Queensland, the stormwater design objectives were developed using a value of 400 mg/kg. Modelling using this value returns treatment performance consistent with the basis on which the objectives were derived.
- Filter media suppliers can readily supply compliant material with a total nitrogen content of less than 400 mg/kg. Performance modelled using this value is therefore generally conservative.
- 400 mg/kg is well above what is typically provided by filter media suppliers, so even if modelling a bioretention system in a location without a regular supplier of filter media, this value is unlikely to be exceeded in a one-off filter media product.
- The only known study on how the total nitrogen content of filter media changes over the long term (Kavehei *et al.*, 2021) shows total nitrogen content increasing with time. Adopting 400 mg/kg (when freshly supplied filter media likely contain levels lower than 400 mg/kg) increases the chance that modelled performance represents long-term performance.

Orthophosphate content of filter media (mg/kg): Bioretention performance is sensitive to the amount of orthophosphate in the filter media. Adopt the larger of 30 mg/kg or the actual value of orthophosphate in the filter media as established through testing. In most instances, the actual value of orthophosphate in the filter media will be less than 30 mg/kg.

The rationale for this recommendation is similar to that described above for total nitrogen. The only known study on how orthophosphate content of filter media changes over the long term (Johnson & Hunt, 2019) also shows phosphorus content (not specifically orthophosphate) increasing with time.

4.5.4 Infiltration properties

Exfiltration rate (mm/hr): The exfiltration rate should generally be set to zero. A non-zero rate may be adopted if justified through in-situ soil testing. If a non-zero value is adopted, the exfiltrated water must be retained in the model using a secondary drainage link (see Sections 4.1.1 and 4.1.3).

NOTE: Exfiltration scenarios – relationships to other parameters

The exfiltration parameter is used to represent exfiltration from the base and sides of bioretention systems. This is set in conjunction with the unlined filter media perimeter and specifying whether or not the base of the system is lined.

If an unlined filter media perimeter is set in MUSIC and the base is set to be unlined, then exfiltration will occur in accordance with whatever exfiltration rate is set by the user. In this case, exfiltration will occur from the base and sides of the filter media according to the algorithms for side exfiltration and the

exfiltration rate for the base. Exfiltration will also occur from the sides of the extended detention area to represent loss from the batters.

If the exfiltration rate is set to 0 mm/hr, it does not matter whether an unlined filter media perimeter is set or the base is lined in MUSIC because MUSIC will not calculate any exfiltration. In this case the only loss calculated by MUSIC will be evapotranspiration from the filter media. However, for modelling clarity, it is recommended that where the entire system perimeter is lined with impermeable material, the unlined filter media perimeter should be set to 0.01 m.

If the base is lined in MUSIC but the perimeter is unlined, exfiltration can still occur from the sides, but none will be lost through the base or submerged zone. This means that moisture can be retained in a submerged zone with loss from the sides.

If the base is unlined in MUSIC and the perimeter is lined (i.e. set at 0.01 m), exfiltration will occur from the base at the exfiltration rate set by the user. This type of exfiltration is encouraged as it helps to recharge groundwater and will assist in meeting hydrologic management objectives.

Table 19 summarises the above information and provides a quick reference guide on which parameters apply to different bioretention exfiltration scenarios. This table can be used to help designers understand which parameters need to be considered for different exfiltration scenarios and can also be used to assess whether modelling aligns with design plans.

Table 19 Application of parameters to different bioretention exfiltration scenarios.

Exfiltration scenario	Unlined filter media perimeter (m)	Is the base lined (Y/N)	Exfiltration rate (mm/hr)
No exfiltration.	0.01	Y ¹	0
Exfiltration from base, sides and batters.	User defined.	N	User defined ² .
Exfiltration from sides and batters only.	User defined.	Y	User defined ² .
Exfiltration from the base only.	0.01 ¹	N	User defined ² .

¹ If an exfiltration rate of 0 mm/hr is set these parameters become redundant but should be set as noted to avoid confusion.

² See Sections 4.1.1 and 4.1.3 for discussion on applying exfiltration rates.

4.5.5 Lining properties

Is the base of the bioretention system lined? Whether the base of the system is lined or not only influences the model if the exfiltration rate is set to a value other than zero. Select yes or no depending on whether or not your bioretention system is to be lined. For further information, see the discussion on exfiltration rates and modelling using the secondary drainage link in Sections 4.1.1 and 4.1.3.

4.5.6 Vegetation properties

Plant types have a significant impact on nutrient load reduction. Root morphology and associated physiochemical processes are key factors in the variation in performance between species (Read *et al.* 2008). Select the relevant option in MUSIC in accordance with the following:

- **Vegetated with effective nutrient removal species:** Use when at least 50% of the plant cover in the bioretention system will be either (a) plants listed in Table 19 of the *Bioretention Technical Design Guidelines* (Water by Design 2026) or (b) plants that meet the functional attributes for bioretention

plants as described in Section 3.6 of the *Bioretention Technical Design Guidelines* (Water by Design 2026)

- **Vegetated with ineffective nutrient removal species:** Use when less than 50% of the plant cover in the bioretention system will be plants from either of the categories listed above.
- **Unvegetated:** Use when the system does not contain plants.

4.5.7 Infiltration and outlet properties

Overflow weir width (m): The length of the overflow weir controls the discharge rate when the water level in the bioretention system exceeds the top of the extended detention. An undersized overflow weir results in water backing up, effectively adding additional extended detention. To avoid this, it is recommended that as a starting point, the overflow weir length is set as the surface area (m²) divided by 10 m.

Underdrain present: Bioretention systems are generally configured with a collection system at their base. This usually takes the form of underdrainage pipes, but can also include specially configured outlet pits. Where a collection system is located at the base of a bioretention system, select 'Yes'. Where a collection system is not located at the base of the system, select 'No'. Note that if 'No' is selected, the system must be configured with exfiltration into the surrounding soils. This will require consideration of the appropriate lining (Sections 4.5.4 and 4.5.5) and exfiltration parameters (Section 4.1.3), as well as the use of the secondary drainage link (see Section 4.1.1).

Submerged zone with carbon present (depth in m): Where a submerged zone with carbon is present below the underdrain, select 'Yes'. Otherwise select 'No'.

4.5.8 Hydrologic routing

Refer to Section 4.1.4 for guidance on hydrologic routing. The conceptual design must be developed to illustrate why a certain option is selected. If the conceptual design is not available, use the default value.

4.5.9 Bioretention in series

When bioretention systems are designed in series, only the stormwater that overtops the first bioretention system (either via the overflow pit or weir) should enter the second system. This requires a separate drainage system to keep the treated and untreated stormwater separate between the systems.

In earlier versions of MUSIC, pollutant reductions through the filter media of a bioretention system were based on empirical equations to estimate the performance of the system. These equations were based on observed relationships derived from monitoring data and assumed an individual bioretention system that is accepting untreated stormwater. Modelling bioretention systems in series in earlier versions of MUSIC without a bypass results in an overestimation of the treatment performance of the series of bioretention systems. This is because MUSIC assumes the downstream system is receiving untreated stormwater and, therefore will assume the same level of pollutant reductions as for untreated stormwater.

In more recent versions of MUSIC, the performance of the system is less dependent on inflow concentrations and hydraulic loading is properly accounted for. However, use the prescribed methodology below to ensure good modelling practice.

To properly model bioretention in series, include a low flow bypass in the downstream bioretention node to bypass treated flows from the upstream bioretention. Set the bypass at the maximum discharge rate of the upstream bioretention (approximated by multiplying the filter media area by hydraulic conductivity). This will ensure untreated overflows from upstream enter the downstream system and treated flows are bypassed. Some untreated stormwater will also bypass, but this volume is small in the context of the total stormwater volume. Alternatively, a secondary drainage link can be used to separate treated and untreated flows.

WORKED EXAMPLE: MODELLING BIORETENTION IN SERIES

Assume a bioretention system of 150 m² is required for a catchment to meet best practice objectives.

Figure 17 shows a MUSIC model containing two bioretention systems, each with a 75 m² filter media area (total 150 m²). The first bioretention is modelled according to the parameters described in these guidelines. The treated outflow (low flows) from the first system bypass directly to the receiving node using a low flow bypass on the second bioretention.

The saturated hydraulic conductivity of the first bioretention system is 200 mm/hr (equating to 200 L/m²/hr, or 0.055 m³/m²/s) and the area is 75 m², equating to a filtered flow rate of about 4.2 L/s or 0.004 m³/s. This flow rate (0.004 m³/s) is then entered as the 'Low Flow By-Pass' in the second bioretention node (as shown in Figure 17).

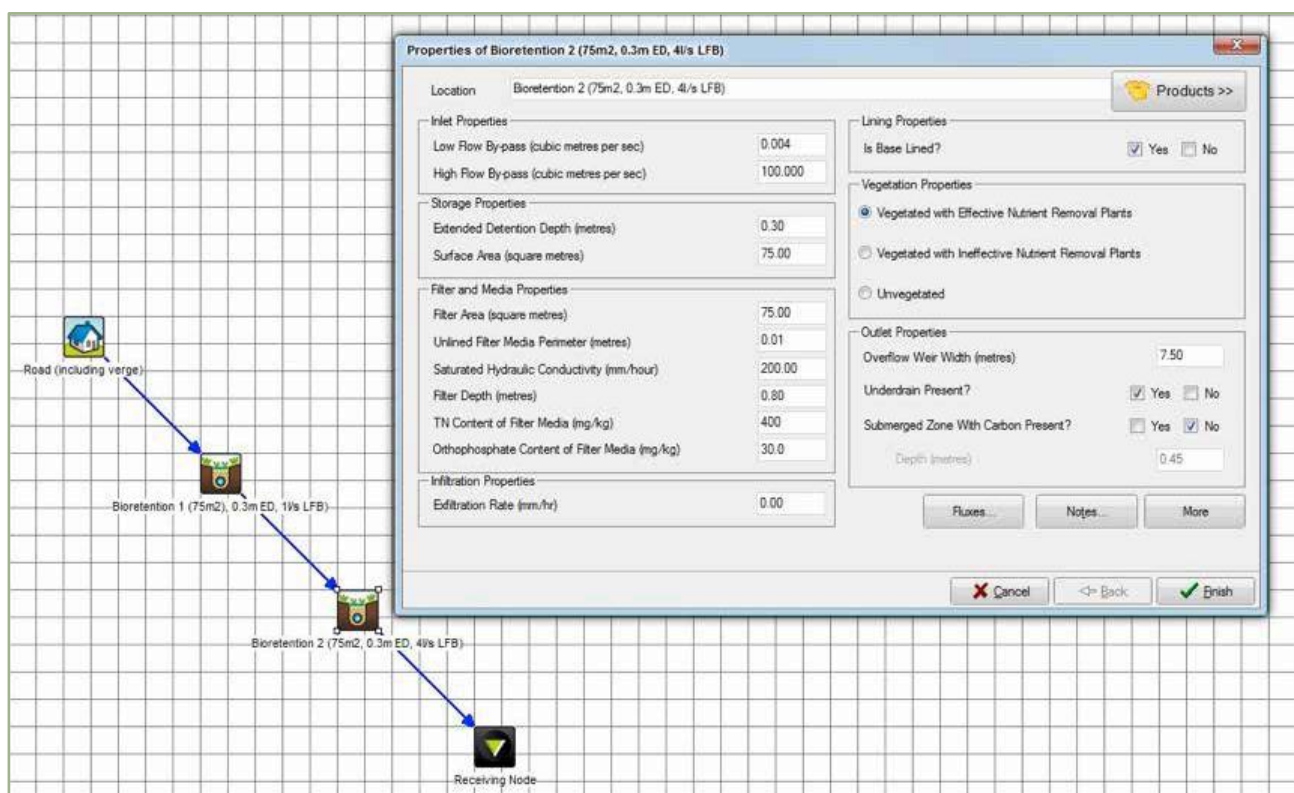


Figure 17 Modelling bioretention in series.

Where smaller bioretention systems (such as street tree pods) drain into larger (precinct) bioretention systems and the systems are directly connected (i.e. the treated outflow from the smaller system flows directly into the larger one via a piped connection), the above low flow bypass method should still be used (as shown in Figure 18). However, if there are additional untreated catchment flows entering the larger bioretention (as shown in Figure 19), then the low flow bypass method is not required.

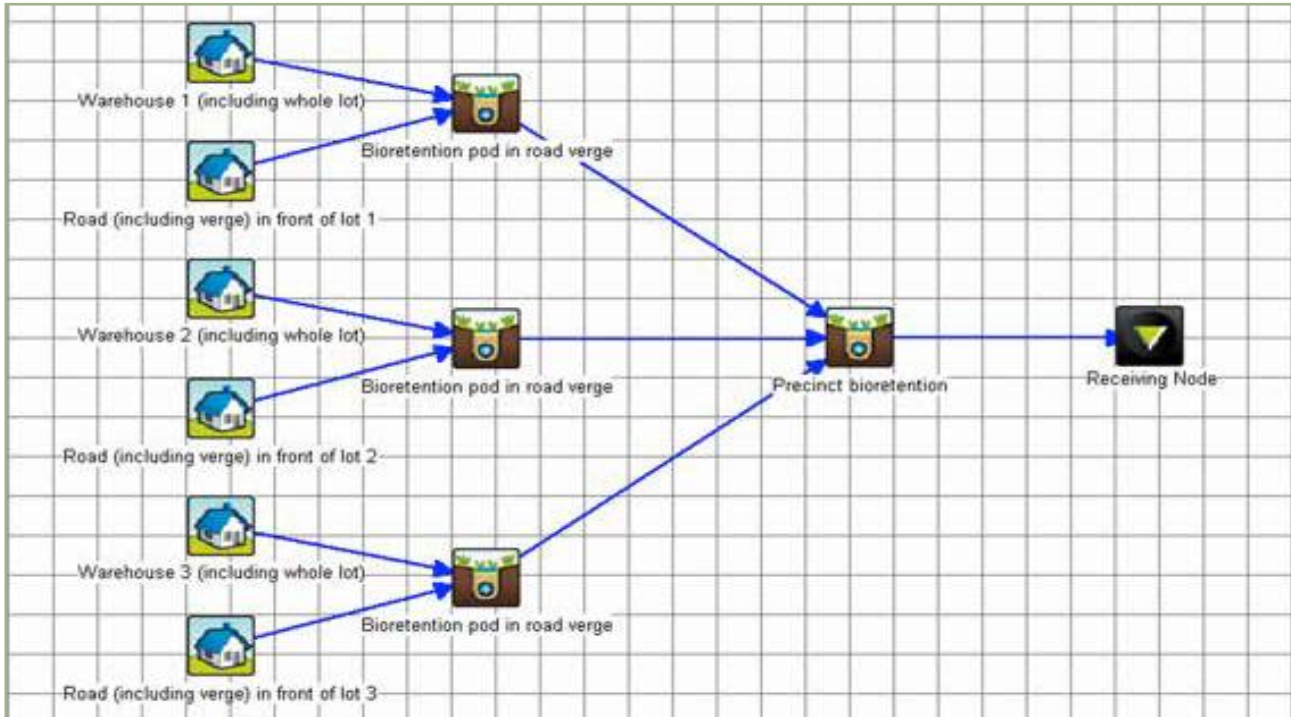


Figure 18 Directly connected bioretention systems.

Underdrainage from upstream systems bypass the downstream system by setting an appropriate low flow bypass on the downstream system.

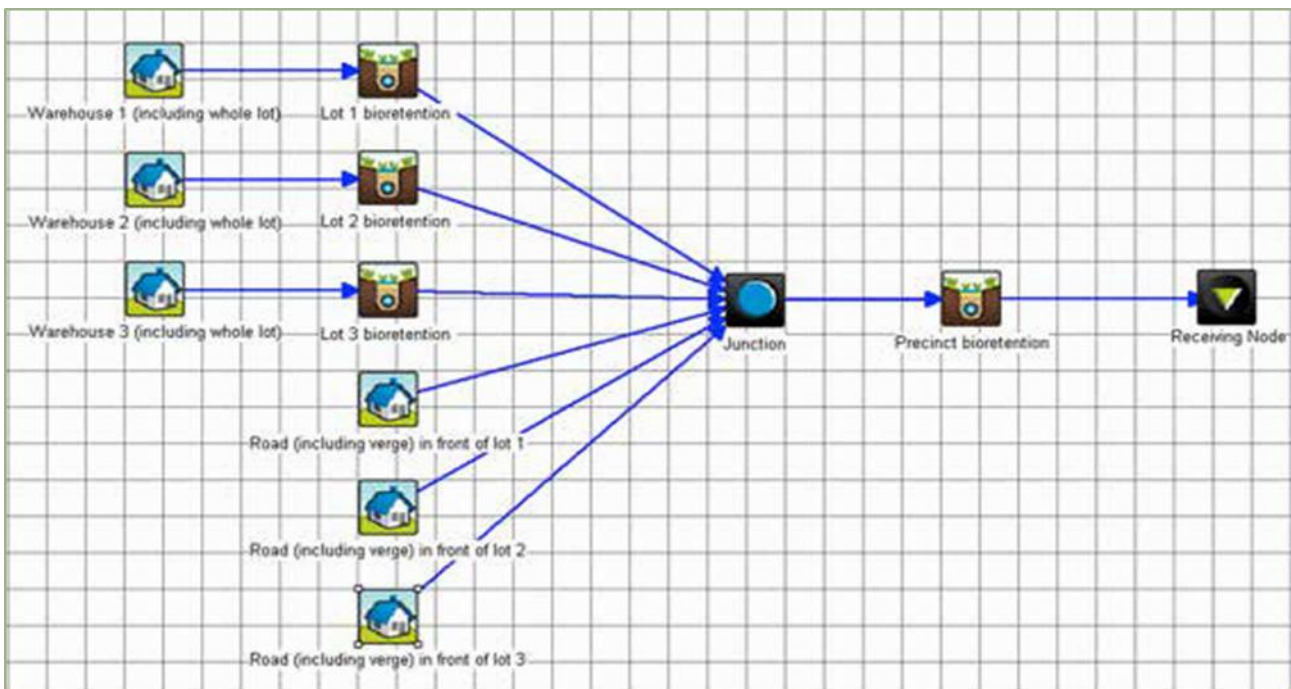


Figure 19 Bioretention in series with extra catchment area. No low flow bypass is set on the downstream system.

4.6 Bioretention swales

The difference between a normal swale and a bioretention swale is that the latter has filter media and underdrainage (much like a bioretention system). Bioretention swales must be modelled as a bioretention system with zero extended detention followed by a swale with a low flow bypass set to the infiltration rate of the filter media area. The appropriate MUSIC layout is shown in Figure 20 and the calculation provided below. Provide a copy of calculations to the assessment authority.

To model pollutant reductions from bioretention swales, separate the treatment system into its various components:

- Batter slopes or buffers – this only applies where inflows reach the base of the swale through lateral inflow over a vegetated flow path (e.g. roadside swale). For further guidance on setting up the buffer node refer to Section 4.7.
- Bioretention filter media components (refer to Section 4.5).
- Surface swale components. For further guidance on setting up the swale node refer to Section 4.4.

The majority of the treatment node parameters should be set in accordance with the advice provided in the buffer (Section 4.7), bioretention system (Section 4.5) and swale (Section 4.4) sections of this guideline.

The only two exceptions to this are that:

- The bioretention node component should be modelled with no extended detention depth. This is because for most rainfall events, minimal ponding occurs above the surface of bioretention swales.
- The low flow bypass for the swale node should be established using the following equation:

$$\text{Low flow bypass} = \frac{\text{Filter media surface area (m}^2\text{)} \times \text{hydraulic conductivity of the filter media (mm/hr)}}{3600 \times 1000}$$

Where:

$$\text{Filter media surface area (m}^2\text{)} = \text{Filter media length (m)} \times \text{filter media width (m)}$$

If the swale is designed so that an ordinary swale (without a bioretention filter) discharges to a bioretention trench at the end of the swale, then the order of the bioretention filter node and the swale node shown in Figure 20 should be reversed and the low flow bypass for the swale set to 0.



Figure 20 Standard bioretention swale model.

4.7 Buffers

The buffer node is described in the *MUSIC Help*. Buffer nodes are generally located upstream of other stormwater treatment nodes.

The exfiltration rate should generally be set to zero (see Section 4.1.3). A non-zero rate may be adopted if justified through in-situ soil testing. If a value other than zero is adopted, the exfiltrated water must be retained in the model using a secondary drainage link (see Section 4.1.1). Buffers are only appropriate for simulating situations where flow is dispersed (sheet flow). If vegetation accepts concentrated flows or

pipe flows, then using the buffer node in the MUSIC model is not appropriate (as minimal stormwater treatment will occur).

There may be an opportunity to model buffers as modified swale treatment nodes, however they must be clearly designed as a swale with flow dispersal across the full width of the vegetated area.

Care needs to be taken in setting up and assessing MUSIC models to ensure that source nodes can actually drain to the buffer node.

The treatment processes in a buffer strip are modelled by a set of simple transfer functions derived from a review of worldwide literature. The transfer functions cannot be adjusted in the buffer strip node.

4.8 Proprietary and custom products

Proprietary and custom products such as gross pollutant traps (GPTs), trash racks and proprietary nutrient removal devices can be modelled in MUSIC.

4.8.1 Demonstrating performance

Where pollutant reductions for GPTs and other proprietary products are reported, this data must be justified. Unless required otherwise by the assessment authority, reported performance shall be in accordance with Stormwater Australia's *Stormwater Quality Improvement Device Evaluation Protocol*.

The treatment node selected for use must accurately reflect the treatment performance indicated by the relevant assessment protocol.

NOTE: Sensitivity to high flow bypass value

Proprietary products generally operate with a high flow bypass. It is important to enter the correct high flow bypass rate for the proposed unit into the gross pollutant node in MUSIC so that no pollutant reductions are attributed to bypassed flows.

4.8.2 Other considerations

In addition to treatment performance, it is prudent to consider a range of other factors when specifying GPTs and proprietary treatment devices.

Storage volumes

Device storage volumes must be large enough to store collected pollutants between maintenance cycles. Supporting calculations should be provided.

Lifecycle and maintenance costs

GPT and proprietary treatment device lifecycle and maintenance costs can be variable compared to both other proprietary devices and other treatment types, such as bioretention systems and constructed wetlands. Assessment authorities should require an assessment of both lifecycle and maintenance costs before implementing proprietary treatment devices.

A pragmatic manner to complete such an assessment is to compare the lifecycle and maintenance costs of the GPT or proprietary treatment device with that of a bioretention system sized to achieve equivalent treatment performance.

Proprietary device costs can be obtained from manufacturers' quotes, while bioretention maintenance costs can be obtained from a variety of sources, including the following (adjusting suitably for inflation as these resources are now dated):

- *A Business Case for Best Practice Stormwater Management (Water by Design)*.
- *The Guide to the Cost of Maintaining Bioretention Systems (Water by Design)*.

- *Water Sensitive Urban Design Lifecycle Costing Data* (Melbourne Water, 2013).

NOTE: Ongoing data collection

At the time of writing, Water by Design is undertaking a project to collate and analyse WSUD maintenance cost data. When completed, the outcomes of this project may assist with lifecycle and maintenance costing for bioretention systems.

Installing devices as modelled

Proprietary and custom treatment devices installed must match those modelled. The device modelled must be shown on stormwater reporting and detailed design plans, along with a note that the device cannot be substituted for an alternative unless the applicant can demonstrate to the assessment authority that the proposed alternative is equivalent or better to that shown on the design plans.

Equivalent or better means at a minimum:

- Equal or greater treatment performance for all pollutant types modelled using an accurate high flow bypass.
- Equal or lesser maintenance costs.

4.9 Sediment basins

The *MUSIC User Manual* (eWater) describes the parameters for the sediment basin node.

Sediment basins are frequently used in construction phase erosion and sediment control to minimise and capture sediment-laden runoff and as pre-treatment for other treatment measures such as wetlands (e.g. an inlet pond). They are sized according to the design storm discharge and the target particle size (generally 0.125 mm).

NOTE: Construction phase sediment basins

This section does not cover construction phase sediment basins, as MUSIC is generally not suitable for modelling the pollutant removal capacity of this type of basin. Refer to *Best Practice Erosion & Sediment Control* (IECA, 2008) for guidance.

The performance of sediment basins is often simulated using the inlet pond within the wetland node. Examples of when sediment basins may be modelled independently include:

- Where information about sediment basin outflows needs to be obtained independently from macrophyte zone outflows.
- When providing pre-treatment to bioretention basins or other treatment systems.
- When splitting sediment basin outflows between different downstream nodes.

NOTE: Coarse sediment forebays

Coarse sediment forebays are a relatively small, shallow feature sometimes included at the inlet of bioretention systems. They are designed to reduce the amount of coarse sediment entering bioretention systems. They are not specifically designed to remove total suspended solids and the extent of any removal will be dependent on how much coarse sediment has accumulated in the forebay since it was last maintained. It is therefore recommended that coarse sediment forebays are not credited with total suspended solids removal (i.e. forebays should not be modelled as sediment basins in MUSIC).

When modelling a sediment basin upstream of a wetland or bioretention system where there is no flow restriction between the sediment basin and the downstream treatment measure for the design flow (usually \leq 3-month ARI), the notional detention time in the sediment basin node should be set to a short period (e.g. one hour). When the sediment basin is upstream of a wetland or bioretention system and there is a flow restriction, the notional detention time should be as designed (8-10 hours is usually recommended for a centralised basin).

Sediment basin surface area should be calculated in the same manner as for wetlands (see Section 4.3.1).

4.10 Infiltration systems

The *MUSIC User Manual* (eWater) describes the parameters for the infiltration node.

Infiltration is an important aspect of urban stormwater management, particularly for recharge of groundwater and compliance with frequent flow management objectives. Stormwater must be treated before infiltration (e.g. infiltration from an unlined bioretention system or swale as both provide treatment prior to infiltration).

Subsoils should be considered when planning infiltration systems (e.g. dispersive or sodic soils).

When modelling infiltration systems within a model to be used for demonstrating compliance with water quality objectives, the exfiltrated water must be retained in the model using a secondary drainage link (see Sections 4.1.1 and 4.1.3).

4.11 Porous pavements

A summary of recommended porous pavement parameters is presented in Table 20 with further details below. Porous paving allows runoff to drain through or between paving and infiltrate the underlying media. It can provide some degree of stormwater treatment, but more importantly, it increases the pervious area of the developed catchment and promotes infiltration.

In MUSIC, any unvegetated filtration system with filter media must be modelled using the media filtration node. This applies to the modelling of porous paving. Care should be taken in setting up the node to only represent the filtration zone and not the underlying drainage layer.

The drainage layer is usually imported coarse material with little or no treatment capacity. Removal of particulates and some dissolved pollutants is achieved through filtration and adsorption onto soil particles in the treatment zone or filter media (typically a base of coarse sand, loamy sand or other mix of finer material). The porous pavement and associated drainage layer and filter media must be free draining (i.e. does not hold water after rainfall).

This requires the design and associated reporting (e.g. stormwater management plan) to illustrate:

- That the porous pavement incorporates an underdrainage system (slotted pipe or similar) which freely drains to downstream drainage systems.
- That the in-situ soils have a suitably high saturated hydraulic conductivity to accept treated flows from the base of the porous pavement (i.e. in-situ permeability is greater than porous pavement filter media permeability). If it cannot be illustrated that the system is free draining, then the porous pavement cannot be modelled in MUSIC.

Table 20 Media filtration node parameters to represent porous pavements.

Inlet properties	
Low flow bypass (m ³ /s)	User defined.
High flow bypass (m ³ /s)	User defined.

Storage properties	
Extended detention depth (m)	Set to 0 m unless there is a specific design intent to allow frequent ponding above the paving.
Surface area (m ²)	User defined.
Exfiltration rate (mm/hr) ¹	0
Filtration properties	
Filter area (m ²)	User defined (must equal surface area where extended detention depth = 0).
Filter depth (m)	0.4 m to 0.6 m (dependent on depth of treatment zone).
Filter median particle diameter (mm)	1 mm (or less, dependent on the filtration media).
Saturated hydraulic conductivity (mm/hr)	Equivalent to the media used (suggest 360 mm/hr for sand).
Depth below underdrain pipe (% of filter depth)	0
Outlet properties	
Overflow weir width (m)	Equal to the length of the system.

¹ Note: Care should be taken when using porous pavement where dispersive subsoils are present as they may erode underground and undermine infrastructure.

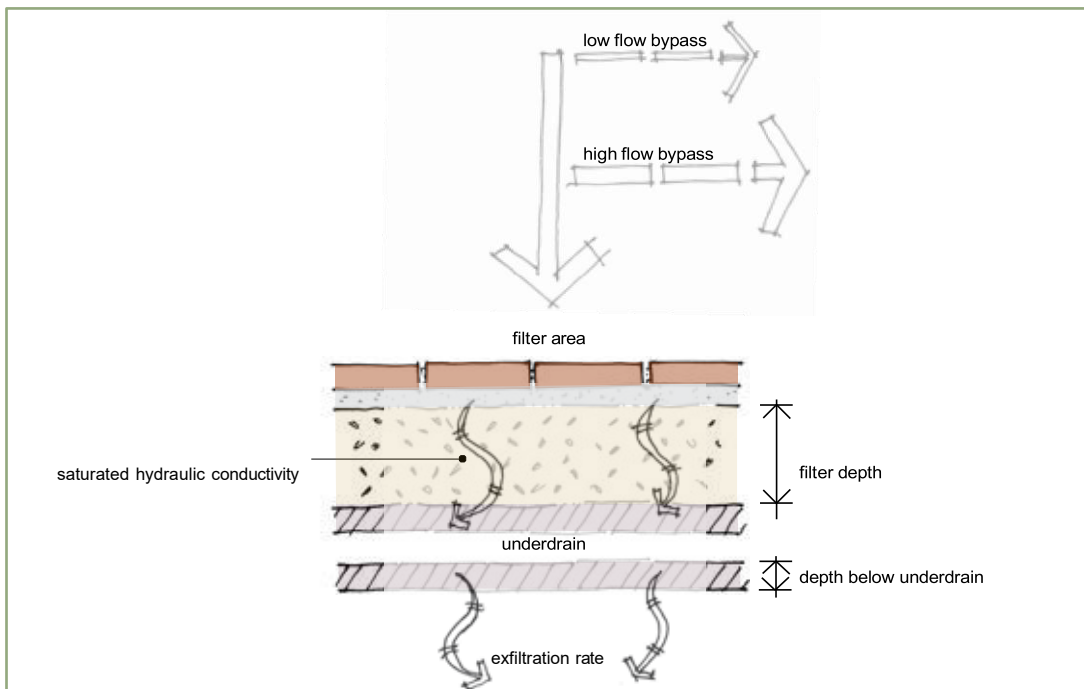


Figure 21 Porous pavement parameters.

The catchment draining to the porous pavement should be separated into two or more nodes. One node should represent the surface flow to the porous area of the paving and the other should represent the direct rainfall on the hard surface of the paving.

For the source node representing the porous pavement area, adopt a 100% impervious fraction for that source node.

The reason the treatment area is modelled for porous pavement is because generally these treatment systems do not have a large external catchment like wetlands or bioretention systems. The runoff from

the actual area of the pavement can represent a significant portion of total flow that is treated and therefore has an influence on treatment outcomes.

Figure 22 demonstrates how porous pavement should be set up in MUSIC.

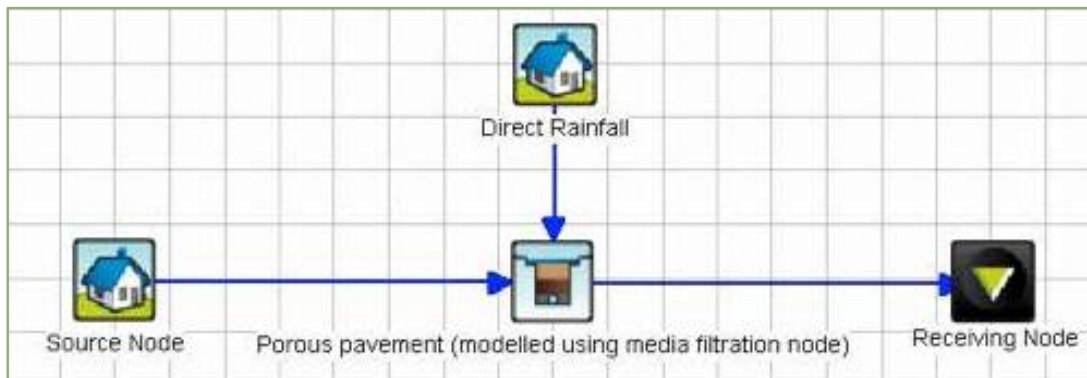


Figure 22 Example of porous pavement application in MUSIC.

Music node: Model porous pavement using the media filtration node with the parameters shown in Table 14.

Extended detention depth (m): Set extended detention depth to zero unless there is a specific design intent to allow frequent ponding above the pavement.

Filter area (m²): Set the opening area or void ratio of the porous pavement (not the total surface area) as the filter area. This should be estimated from the product specifications.

Filter depth (m): Set the filter depth to represent the total depth of the treatment zone or filter media. Do not model the depth of the drainage layer or intermediate layers (if used) as part of the filter media.

Saturated hydraulic conductivity (mm/hr): The saturated hydraulic conductivity should be determined as representative of the smallest median aggregate (D50) in the porous pavement treatment zone or filter media (base and/or subbase layers). This value should be factored by 0.5 to allow reduced permeability during the pavement lifecycle. Saturated hydraulic conductivity testing will need to be supplied to justify the value used.

Exfiltration rate (mm/hr): It is preferable to drain the filtered runoff away from the pavement subgrade. In the model, assume that there is zero depth below the system and that the exfiltration rate loss is 0 mm/hr (see Section 4.1.3 for discussion on exfiltration). A non-zero rate may be adopted if justified through in-situ soil testing and it can be demonstrated that the pavement subgrade will not be negatively affected. If a non-zero value is adopted, the exfiltrated water must be retained in the model using a secondary drainage link (see Section 4.1.1).

4.12 Water wise street trees

Water wise street trees come in many configurations. They can assist with the management of water quality while providing additional benefits to tree health, amenity and cooling.

This section primarily provides guidance on how to model the basic water wise street tree described in the *Water Wise Street Trees Concept Design Catalogue* (Water by Design). This style of water wise street tree is characterised by a circular, square or rectangular opening in the kerb which connects to a buried perforated pipe. Water conveyed through the pipe infiltrates into the soil surrounding the tree, with excess flow discharged back to the kerb via further pipes. Figure 23 and Figure 24 show a constructed example and design sketch of this type of water wise street tree.



Figure 23 Basic water wise street tree in a residential area.

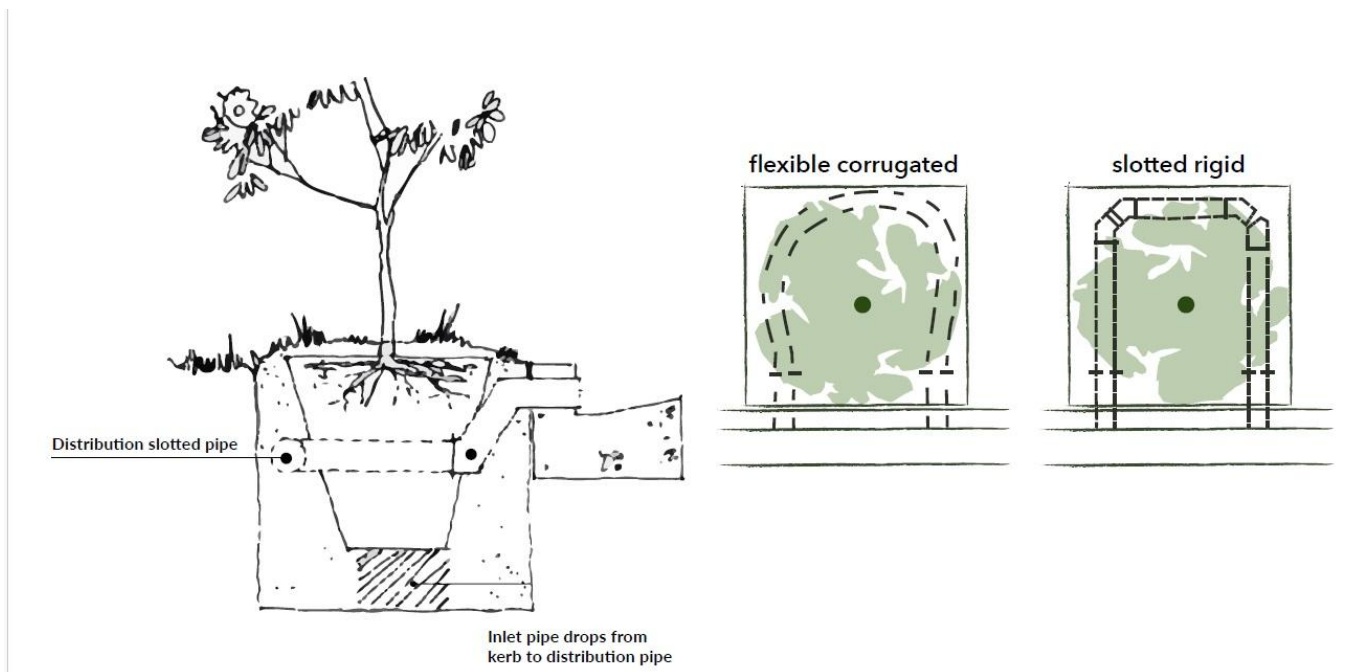


Figure 24 Design of basic water wise street tree.

The performance of water wise street trees should be modelled using the bioretention node. A summary of the appropriate parameters for modelling the basic water wise street tree is provided in Table 21 with additional detail provided in the sections below.

NOTE: Ongoing development of this treatment technology

Water wise street tree technology is undergoing further development and research. Guidance may be updated in subsequent versions of this document. Furthermore, guidance provided herein is based upon a first principles adaptation of bioretention modelling practices to water wise street trees. Little field validation of modelled results has occurred. Results should be treated with care.

Table 21 Water wise street tree parameters.

Inlet properties	
Low flow bypass (m ³ /s)	0 m ³ /s.
High flow bypass (m ³ /s)	100 m ³ /s (unless secondary routing defined).
Storage properties	
Surface area (m ²)	Same as filter area.
Extended detention depth (m)	Specify a very high value. The value of the filter area (in metres rather than square metres) is recommended as a starting point.
Filter media properties	
Filter area (m ²)	User defined.
Unlined filter media perimeter (m)	User defined.
Saturated hydraulic conductivity (mm/hr)	Typically 50 – 100 mm/hr.
Filter depth (m)	0.6 – 1.2 m.
Total nitrogen content of filter media (mg/kg)	User defined (if unknown, use 400 mg/kg).
Orthophosphate content in filter media (mg/kg)	User defined (if unknown, use 30 mg/kg).
Lining properties	
Is the base lined?	Typically unlined.
Vegetation properties	Effective nutrient removal plants should be specified.
Infiltration and outlet properties	
Overflow weir width (m)	Typically greater than or equal to the value of the filter area (in metres rather than square metres).
Exfiltration rate (mm/hr)	0 mm/h or based on in-situ testing (in which case, model using the secondary drainage link as described in Section 4.1.1).
Underdrain present	No.
Submerged zone with carbon present	No.

4.12.1 Inlet properties

Low flow bypass (m³/s): If the water wise street tree inlet is set slightly above the invert of the gutter (to manage sediment buildup) then a low flow bypass will need to be calculated. Otherwise low flow bypass can be set to zero.

High flow bypass (m³/s): The high flow bypass rate of the water wise street tree is dependent upon a number of factors including the capacity of water to infiltrate from the distribution pipe into the growing media, the capacity of the distribution pipe itself and the capacity of the inlet. The high flow bypass value should therefore be set as the lesser of:

- The infiltration capacity of the distribution pipe.
- The maximum capacity of the distribution pipe.
- The maximum inflow capacity of the inlet.

Note: Inlet design should be matched to the contributing catchment, which should in turn be matched to soil moisture capacity and tree health requirements.

NOTE: Sensitivity of treatment performance to inflow volumes

Water wise street tree treatment performance is strongly related to the volume of stormwater entering the system. Underestimating the low flow bypass or overestimating the high flow bypass will result in the model overestimating treatment performance.

NOTE: Inlet efficiency

The basic water wise street tree inlet design is generally not 100% efficient at capturing stormwater. Even between the low flow and high flow bypass rates, not all water enters the inlet. This phenomenon is not easily modelled in MUSIC. It can be done using the generic node (similar flow splitting described in Section 4.13), but the process is convoluted, particularly if multiple treatment systems are present in the model. Users should note that the above guidance regarding low flow and high flow bypasses will thus likely overestimate treatment performance, particularly for systems with low-efficiency inlets such as the basic water wise street tree.

4.12.2 Storage properties

Surface area (m²): The surface area should be the same as the filter area.

Extended detention depth (m): The extended detention depth is the depth of ponding on the surface of the water wise street tree. Where a subsurface distribution pipe is used, this value must be set to zero.

4.12.3 Filter media properties

Filter area (m²): For the basic water wise street tree, adopt a filter media area equivalent to the area 300 mm either side of the distribution pipe (see Figure 25). For types of water wise street trees where water is applied to the surface of the tree pit, the filter area is the area that is subject to ponding (usually the dimensions of the tree pit).

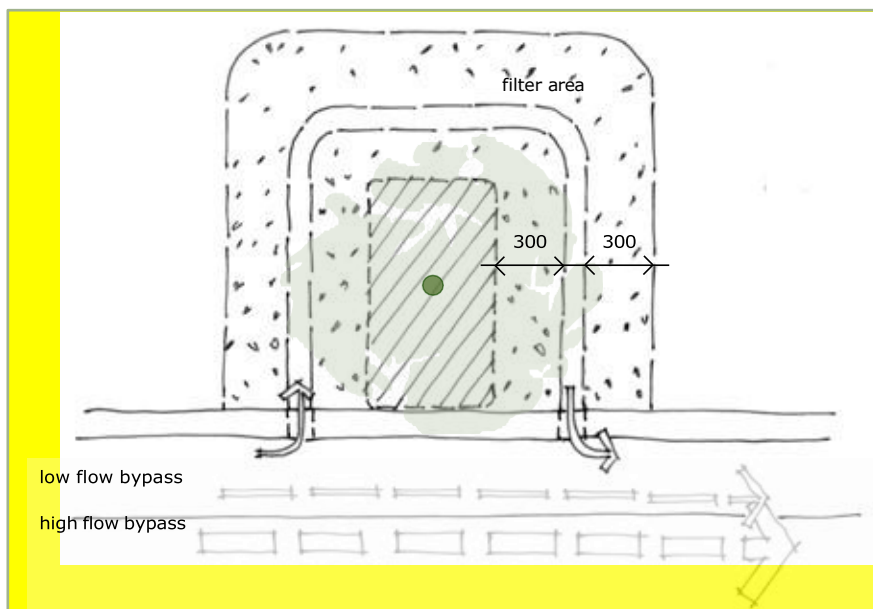


Figure 25 Water wise street tree filter media area.

Unlined filter media perimeter (m): The unlined filter media perimeter shall be the lesser of:

- The length of the perimeter of the garden bed that is unlined. Where a perimeter of the garden bed is not defined, adopt the perimeter of the interface between the growing media and the in-situ soil.
- The length of the perimeter of the filter media area that is unlined.

Saturated hydraulic conductivity (mm/hr): Soils used in water wise street tree pits typically have a lower hydraulic conductivity than bioretention systems. Saturated hydraulic conductivity is likely to be between 50 and 100 mm/hr.

Filter depth (m): The filter depth should be calculated as the depth of the growing media in the garden bed (up to a maximum of 1 m) minus the depth of the invert of the distribution pipe below the surface of the growing media.

Total nitrogen content in filter media (mg/kg): The performance of treatment systems modelled using the bioretention node in MUSIC is sensitive to the value of total nitrogen in the filter (growing) media. Where total nitrogen content in the growing media is unknown, a value of 400 mg/kg should be used. Where the total nitrogen content in the growing media is known, the higher of the known value and 400 mg/kg should be used.

Orthophosphate content in filter media (mg/kg): The performance of treatment systems modelled using the bioretention node in MUSIC is sensitive to the value of orthophosphate in the filter (growing) media. Where the orthophosphate content in the growing media is unknown, a value of 30 mg/kg should be used. Where the orthophosphate content in the growing media is known, the higher of the known value and 30 mg/kg should be used.

4.12.4 Lining properties

Is the base lined? In most instances, water wise street trees will have an unlined base. Therefore, when modelling most water wise street trees, select 'No'. However, if the base is lined select 'Yes'.

4.12.5 Vegetation properties

Vegetation type:

- **Vegetated with effective nutrient removal plants:** Contains plants that are either (a) listed as core functional species in the *Bioretention Technical Design Guidelines (Water by Design)* or (b) compliant with the functional requirements for plants as described in the *Bioretention Technical Design Guidelines (Water by Design)*.
- **Vegetated with ineffective nutrient removal plants:** Contains plants that do not meet the above criteria.
- **Unvegetated:** Does not contain plants.

4.12.6 Infiltration and outlet properties

Overflow weir width (m): In the bioretention node, the length of the overflow weir controls the discharge rate when the water level exceeds the top of the extended detention. Modelling with an undersized overflow weir results in water backing up, causing the model to behave as if the extended detention depth is greater than specified. As an overflow weir is not present in water wise street trees, it may appear sensible to adopt a value of 0 m. This, however, will cause the model to overestimate treatment performance. To avoid this, it is recommended that a very high value be specified for the overflow weir length. As a starting point, use the value of the filter area (in metres rather than square metres).

Exfiltration rate (mm/hr): The exfiltration rate is the rate at which water moves from the soil within the water wise street tree garden bed and into the surrounding and underlying in-situ soil. It is not the rate at which water seeps from the distribution pipe into the garden bed soil. Water wise street trees rely on exfiltration (and evapotranspiration) to remove water from the stormwater network. The exfiltration rate must therefore be set at the rate at which water will infiltrate into the surrounding in-situ subsoil. This must consider real-world soil conditions and any compaction likely to occur during construction. If this value is unknown, a rate of 0 mm/hr should be adopted. If a value other than 0 mm/hr is adopted, a secondary drainage link must be used to retain treated exfiltrated water within the model (see Section 4.1.1).

Underdrain present: Typically water wise street trees are designed without underdrainage. If this is the case then this parameter should be set to zero.

Submerged zone with carbon present (depth in m): Submerged zones are formed in bioretention systems using an elevated underdrainage outlet and impermeable liner. Basic water wise street trees aim to infiltrate stormwater into the subsoil and typically do not contain an underdrain. In this case the street tree would not have a saturated zone. In climatic regions with extended dry periods, submerged zones or wicking storage can be utilised to improve tree health and reduce potable irrigation demand.

4.12.7 Additional notes on sediment and gross pollutant removal

The primary pollutants that basic water wise street trees are designed to treat are nitrogen and phosphorus. They are not designed to treat sediment or gross pollutants. Efforts are made in design to ensure that systems bypass coarse sediment loads and gross pollutants. Some fine sediment will enter the distribution pipe but it is not the purpose of the system to treat sediment. Other water wise street trees may be designed to treat sediment and gross pollutants, but their modelling is not described herein.

When modelling basic water wise street trees as prescribed in this guideline, MUSIC will report that the system is removing sediment and gross pollutants. If modelling individual water wise street trees, the values reported for sediment and gross pollutant removal should be ignored and treated as if they are 0%.

Modelling water wise street trees in conjunction with other treatment systems is more challenging. In this instance, the model must be built including the basic water wise street trees and other treatment systems. It should then be run to obtain the removal rates for flow, total nitrogen and total phosphorous. The model should then be adjusted to remove the water wise street trees and re-run to obtain pollutant removal rates for total suspended solids and gross pollutants.

4.13 Generic nodes

The *MUSIC User Manual* (eWater) describes the parameters that can be defined for the generic node.

This node requires the user to specify the pollutant reduction rates (under 'Transfer Functions'). As these rates are different for each device, you must properly demonstrate the capacity of the system to remove pollution in the development application. The development application must include information that clearly demonstrates:

- The proposed treatment measure operates in a manner that cannot be represented using one of the other MUSIC treatment nodes.
- The proposed reduction efficiencies are justified by rigorous scientific testing and results are published in a credible engineering/scientific journal.
- The modelled pollutant reduction efficiency reflects the published figures.

Splitting flows using the generic node

A common and accepted use of generic nodes is to represent a flow split where low flows are directed to one downstream treatment node (e.g. a wetland) and high flows are directed to another (e.g. a swale representing a bypass channel). One generic node can only generate one of the split streams (e.g. it can only model either the low flow or the high flow stream). To model multiple streams in the same model (i.e. to ensure the total combined low flows and high flows are modelled), replicate the nodes upstream of the generic node.

Set one generic node to allow all low flows up to the maximum treatable flow to pass through. Flows above the threshold are removed from the model at this point. The mirrored catchment using the second generic node (with an identical configuration upstream of the node) is then set to only pass the high flows (high flow minus the low flows).

WORKED EXAMPLE: FLOW SPLITTING

This example demonstrates how to set up a wetland model which uses two generic treatment nodes to split the maximum treatable flow rate from flow that is bypassed to the high flow bypass channel. The advantage of splitting the flows in this example is that the model takes account of the pollutant removal capacity of the high flow bypass channel which is modelled using the swale node.

Figure 26 shows a system that has a maximum treatable flow rate of 2 m³/s. The overall MUSIC layout is shown as well as the configuration of each generic node. All flows up to the treatable flow pass through the treatment node using a 1:1 transformation. Any flows above 2 m³/s stay at 2 m³/s (i.e. when the inflow is 3 m³/s, the flows that pass through the system are still a maximum of 2 m³/s and the extra 1 m³/s is removed from the model). For the high flow generic node (i.e. flows greater than 2 m³/s), when the inflow is less than or equal to 2 m³/s, no flow is passed. Flows above 2 m³/s pass through on a 1:1 line (remembering to subtract 2 m³/s). The combined flow downstream of the two generic nodes should be equal to the inflow to one of the generic nodes.

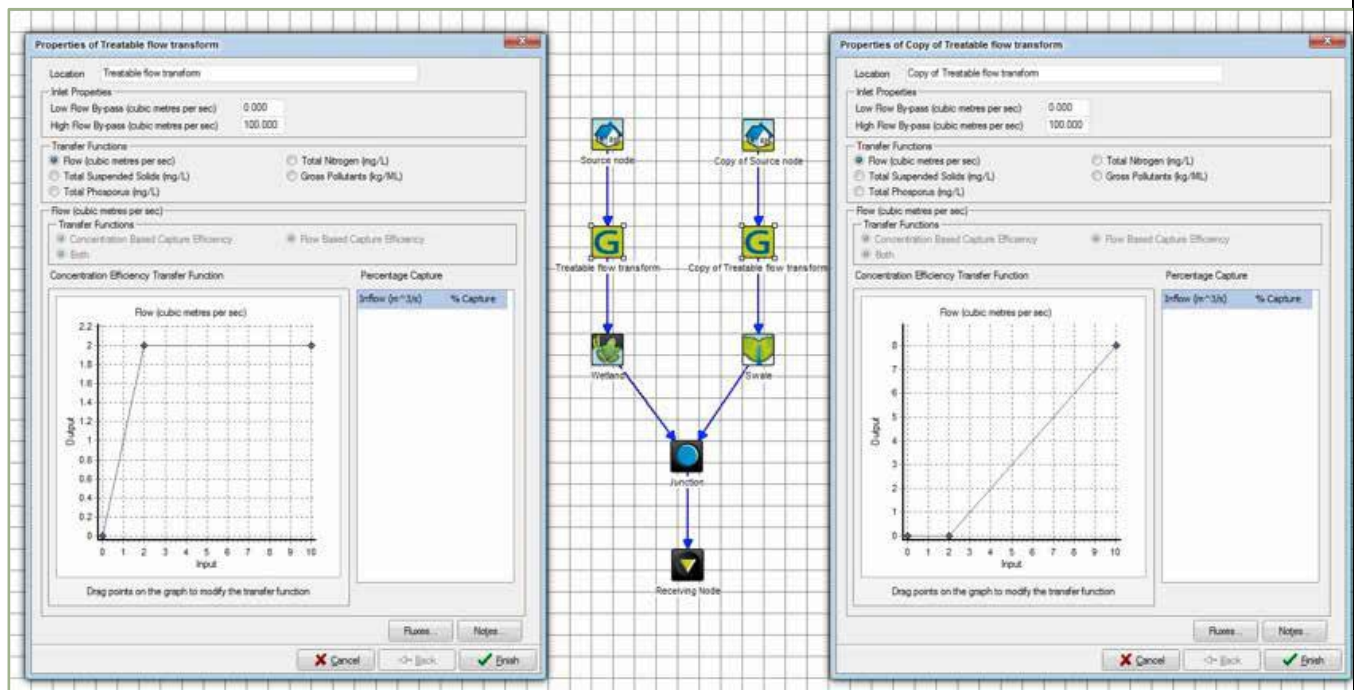


Figure 26 MUSIC generic node configuration for flow splitting.

NOTE: Assessing treatment train effectiveness in split models

When there is a flow split in the model, care needs to be taken when assessing the treatment train effectiveness. In the above example, the catchment area above the generic nodes has been doubled, so at the receiving node the treatment train calculation of input flows and loads will also be doubled. The treatment train effectiveness should therefore be calculated manually using the inputs from the actual (not doubled) catchment area (i.e. the actual load-based reduction should be calculated by taking the source load and subtracting the load reductions in each of the split streams).

4.14 Stormwater harvesting

Stormwater harvesting refers to the capture, treatment, storage and reuse of runoff from any impervious areas in a catchment. Detailed information on designing stormwater harvesting systems can be found in

the draft *Stormwater Harvesting Guidelines for South East Queensland (Water by Design)*. This section details how stormwater harvesting systems should be modelled in MUSIC.

Stormwater can be stored in tanks (above- and below-ground), wet and dry ponds and aquifers. Above- and below-ground enclosed storages can be modelled using the rainwater tank node. Open above-ground storages should be modelled with the pond node to account for evaporation losses from the storage.

Storages are generally designed so only treated flows enter the storage. The untreated flow from upstream should bypass the storage. To model this, use either the generic node flow split (refer to Section 4.13 for details on how to split flows) or set a high flow bypass on the storage to ensure untreated flows from upstream also bypass the storage. The chosen option will be dependent on what happens to the flow downstream of the storage. Usually, the storage is the last point in a treatment train. If so, the high flow bypass option is appropriate.

The size of storage and the yield are sensitive to the modelling time step when the volume of the storage is relatively small compared to the demand. However, using the six-minute time step for modelling (as recommended in Section 3.2) will avoid this issue. Note also that if the tank volume is less than four or five times the average daily demand, MUSIC may overestimate the yield.

For residential and irrigation demands, refer to Section 4.2.2 and Section 4.2.3. Commercial and industrial demands may be project-specific. Refer to Section 4.2.4.

5 Life cycle cost assessment

Life cycle costing is described in the *Australian Standard AS/NZS 4536:1999 Life cycle costing – An application guide* as a process to determine the sum of all expenses associated with a product or project, including acquisition, installation, operation, maintenance, refurbishment, discarding and disposal costs. Life cycle costing is one element in a decision-making process and can assist in determining the relative merits of one treatment train over another.

Living Waterways (Water by Design) sets out some information requirements (refer to 'Living Local Economies' section) on life cycle costs and maintenance.

MUSIC has a life cycle costing function embedded within each of the treatment nodes (right-click on treatment node and select 'Life Cycle Costings'). The receiving node allows calculation of the total life cycle costs of all the elements in a treatment train and an equivalent annual payment (once the model has been run, right-click on the receiving node and select 'Life Cycle Costings').

An outline of the information required for using the life cycle costing function in MUSIC is detailed below. To set the individual costing elements of each treatment device, MUSIC provides expected, upper, and lower cost estimates to choose from. The expected cost estimate should be selected unless justification for other cost estimates is provided. For more details, consult the life cycle costing chapter in the *MUSIC User Manual* (eWater).

5.1 Global costing properties

Real discount rate (%): Up-to-date figures for the real discount rate to use should be sourced from experienced local stormwater asset managers or the Queensland Competition Authority (QCA). The rate used can significantly affect life cycle costing results. The sensitivity analysis, which is automatically undertaken in the costing module, should be reviewed. The current default in MUSIC is 5.5% (based on 2005 data).

Annual inflation rate (%): Current inflation rate figures should be sourced from experienced local stormwater asset managers or the QCA. The current MUSIC default inflation rate is 2%; however the Reserve Bank of Australia uses a long-term annual inflation rate of about 2.5%.

Base year for costing: The base year for costing determines the year the costings are reported in. This is generally the year the development application is submitted.

Span of analysis (years): The span of analysis is relevant when assessing the life cycle cost of the treatment train, rather than the cost of an individual element. The span of analysis should be set to reflect the longest expected life cycle of all the elements in the treatment train and is typically set at 50 years.

5.2 Individual node costing properties

MUSIC costing data was obtained through surveys across the public and private sectors. This data is scaled according to the inflation rate to the current year of analysis. While the data is now dated, it may still be of use to compare the costs associated with different treatment strategies. Life cycle costing should be provided for each individual node (with a caveat noting the source of the data).

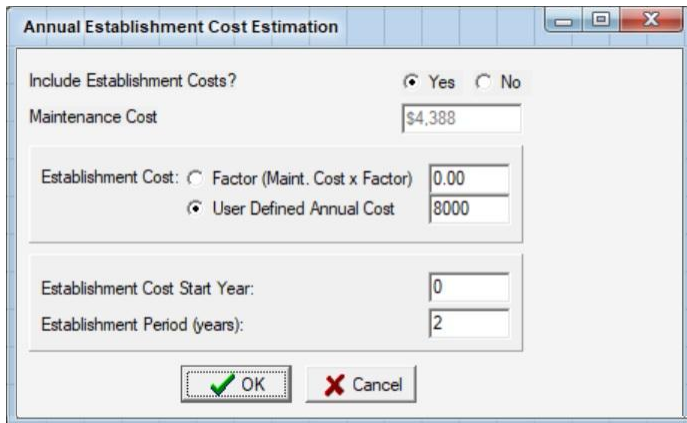
In most cases, the default costing properties can be used for acquisition cost, annual maintenance cost, annualised renewal/adaption cost and decommissioning cost. Where costing data for particular elements are known, they should be used to replace the default costing values provided in MUSIC.

For more up-to-date information refer to:

- *The Guide to the Cost of Maintaining Bioretention Systems* (Water by Design).
- *The Off-site Stormwater Quality Solutions Discussion Paper* (Water by Design).
- *Water Sensitive Urban Design Lifecycle Costing Data* (Melbourne Water, 2013).

In MUSIC, an allowance is made for establishment costs (right-click on treatment node, select 'Life Cycle Costing' > 'This Node' > 'Annual Establishment Costs'). These costs can be important when constructing vegetated treatment systems and allowances should be made where these costs are known. If the costs of establishment (including routine inspections, weeding, watering, plant replacement, etc.) are known, enter the costs directly into the establishment cost manual entry dialog box (as shown in Figure 27). Where the establishment costs are not known, set the establishment cost at twice the maintenance cost using the same dialog box (see Figure 28).

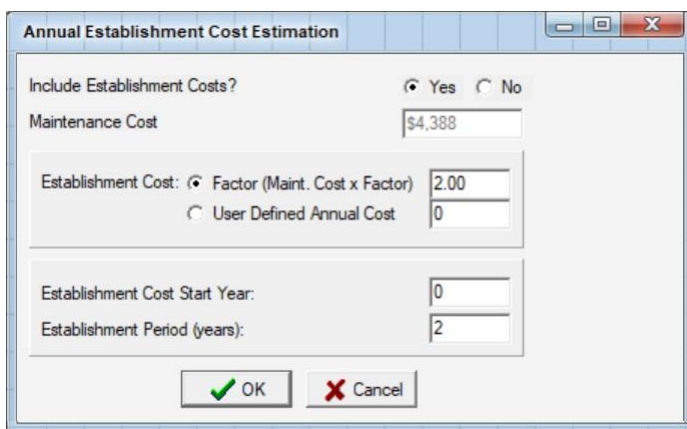
Once all costs are defined, the results can then be obtained and reported for either an individual node or the entire treatment train. Further reporting requirements are provided in Section 6.4.



The dialog box 'Annual Establishment Cost Estimation' contains the following fields and controls:

- 'Include Establishment Costs?' with radio buttons for 'Yes' (selected) and 'No'.
- 'Maintenance Cost' text box containing '\$4,388'.
- 'Establishment Cost:' section with two radio buttons: 'Factor (Maint. Cost x Factor)' (0.00) and 'User Defined Annual Cost' (8000, selected).
- 'Establishment Cost Start Year:' text box containing '0'.
- 'Establishment Period (years):' text box containing '2'.
- 'OK' and 'Cancel' buttons at the bottom.

Figure 27 User defined establishment cost entry.



The dialog box 'Annual Establishment Cost Estimation' contains the following fields and controls:

- 'Include Establishment Costs?' with radio buttons for 'Yes' (selected) and 'No'.
- 'Maintenance Cost' text box containing '\$4,388'.
- 'Establishment Cost:' section with two radio buttons: 'Factor (Maint. Cost x Factor)' (2.00, selected) and 'User Defined Annual Cost' (0).
- 'Establishment Cost Start Year:' text box containing '0'.
- 'Establishment Period (years):' text box containing '2'.
- 'OK' and 'Cancel' buttons at the bottom.

Figure 28 Maintenance factor establishment cost entry.

6 Results

MUSIC offers a number of options for generating and interrogating outputs from models. Only the outputs required for proving compliance with the stormwater quality management objectives are described here. For more information refer to the *MUSIC User Manual* (eWater).

6.1 Load analysis

The *MUSIC User Manual* (eWater) describes the statistics functions. Statistics are useful to obtain a numerical summary of the inputs and outputs of various nodes.

To demonstrate compliance with the stormwater quality management objectives, use the 'Mean Annual Loads' and 'Treatment Train Effectiveness' statistic functions (as shown in Figure 29).

The 'Mean Annual Loads' function reports the inputs, outputs and percentage reduction of flows (ML/yr), total suspended solids (kg/yr), total phosphorous (kg/yr) and total nitrogen (kg/yr) across a single node.

In comparison, the 'Treatment Train Effectiveness' function reports the inputs, outputs and percentage reductions across the node being interrogated and all upstream nodes.

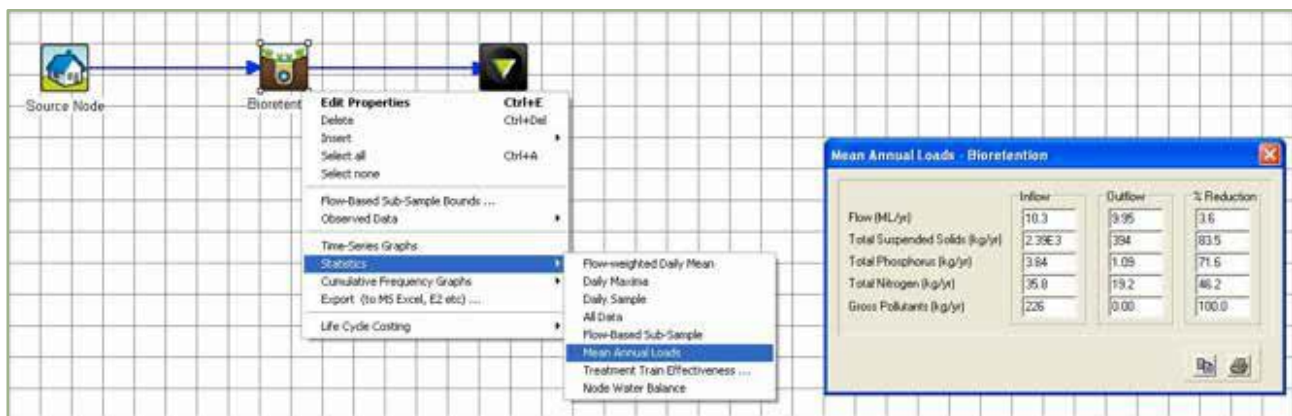


Figure 29 Example 'Mean Annual Loads' results.

NOTE: Models using the generic treatment node to adjust flows

For models that include a generic node which adjusts inflow–outflow at a point in the model (i.e. removes or adds flow or pollutants), the 'Treatment Train Effectiveness' reporting shows differences in annual pollutant loads due to this reduction or increase in flow, as well as any actual treatment within upstream nodes. In these cases, calculate the mean annual loads by comparing the pollutant load generated at the source nodes to the pollutant load arriving at the receiving node. Refer to Section 4.13 for further discussion of generic nodes.

6.2 Pollutant concentration analysis

In some instances, assessment authorities may require pollutant concentrations to be assessed. When interrogating the pollutant concentration results in MUSIC, remove any time steps with zero flow from the analysis. To do this, set the 'Lower Flow Threshold' in the 'Flow-based Sub-sample Bounds' dialog box to zero by right-clicking on the treatment, junction or receiving node once the model has run (as shown in Figure 30). The statistical analysis then only counts time steps in which outflows greater than zero occur. Refer to Section 2.1 of *Developing Design Objectives for SEQ* (Water by Design), for further information on concentration-based objectives.

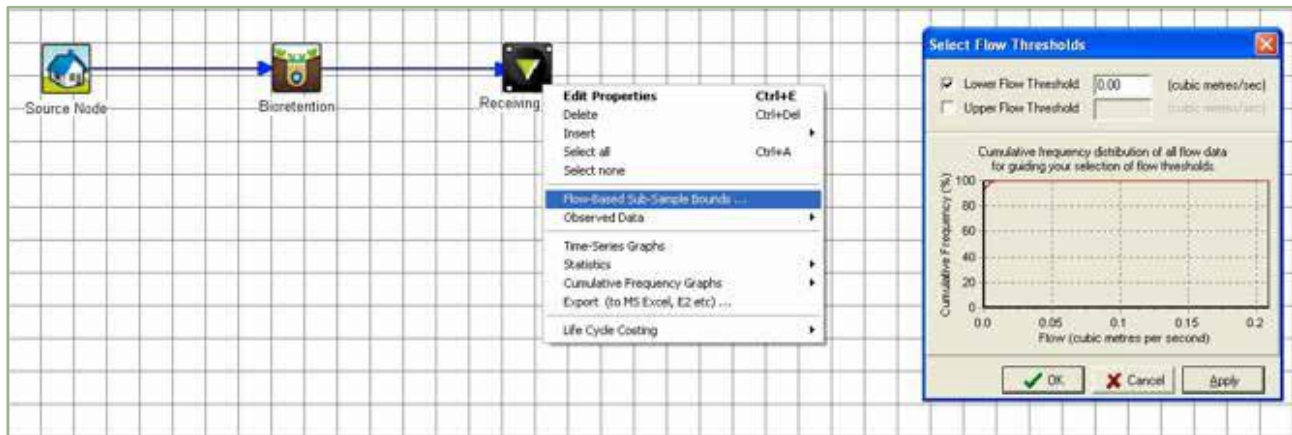


Figure 30 Setting the Lower Flow Threshold for pollutant concentration analysis.

6.3 Total permissible loads analysis

As described in Section 2.1, total permissible loads style objectives offer an alternative to pollutant load reduction targets that may be desirable when undertaking modelling of low impact developments, or where the assessment authority wishes to set objectives closely related to the environmental needs of receiving waterways. Section 2.1 describes how to obtain results from MUSIC for total permissible loads style objectives.

6.4 Life cycle costing

Life cycle costing information in MUSIC can be extracted when setting up the life cycle costing properties at each node. While these costs are indicative, they can be of assistance to asset managers in planning maintenance resources and expenditure for future contributed assets.

To extract this information, first establish the individual node costing elements and run the MUSIC model. Then select the 'Results' button on the life cycle costing entry dialog as shown in Figure 31. While some of the individual costing elements are shown in this entry dialog, the results screen (Figure 32) summarises the costings and accounts for any renewal adaption period to present total costs.

For each node, costing results should be extracted from the results screen (as shown in Figure 32). These details should be provided to the assessment authority.

Life Cycle Costing Definition for Bioretention

All cost estimates are based on functions derived from costing data that were collected from around Australia in 2003-04. The cost estimates displayed are inflated to the base costing year defined in the costing properties for this MUSIC project.

For more detail of the nature and origin of each of the algorithms used, specific caveats and explanation of the R-squared and p values associated with each algorithm, refer to the Life Cycle Costing chapter of the MUSIC User Manual.

Life Cycle (yrs)	50
Total Acquisition Cost (\$)	\$19,991
Typical Annual Maintenance Cost (\$)	\$3,523
Annual Establishment Cost (\$)	\$7,047
Annualized Renewal/Adaptation Cost (\$)	\$431
Renewal/Adaptation Period (yrs)	25
Decommissioning Cost (\$)	\$8,614

Notes...

Figure 31 Life cycle costing entry.

Bioretention - Life Cycle Cost Results

Summary | Relative Distribution | Temporal Distribution | Sensitivity to Real Discount Rate

Costing Inputs					
Life Cycle (yrs)	50	Renewal/Adaptation Cost	\$10,204	Real Discount Rate (%)	5.50
Acquisition Cost	\$17,154	Renewal Period (yrs)	25	Annual Inflation Rate (%)	2.00
Annual Maintenance Cost	\$3,392	Decommissioning Cost	\$8,161	Base Year for Costing	2014
Annual Establishment Cost	\$10,177	Establishment Period (yrs)	2		


Costing Results		
	Life Cycle Cost of Bioretention (\$2014)	\$97,448
	Equivalent Annual Payment Cost of the Asset (\$2014/annum)	\$1,949
	Equivalent Annual Payment per m3/s maximum flow reduction	invalid
	Equivalent Annual Payment/ML flow reduction/annum	\$6,594.16
	Equivalent Annual Payment/kg Total Suspended Solids/annum	\$2.12
	Equivalent Annual Payment/kg Total Phosphorus/annum	\$1,116.41
	Equivalent Annual Payment/kg Total Nitrogen/annum	\$267.07
	Equivalent Annual Payment/kg Gross Pollutant/annum	\$11.51

Figure 32 Example life cycle costing results.

7 Lodgement, reporting and assessment

This section provides information to assist with the lodgement, reporting and assessment of MUSIC models associated with development applications.

7.1 Lodgement requirements

Where a MUSIC model is created to support a development application, the assessment authority may request that the MUSIC model is submitted at the same time as the development application.

The reporting of the modelling methodologies and assumptions should always accompany a MUSIC model submitted for assessment. Depending on the scale and/or complexity of the modelling undertaken and the specific requirements of the assessment authority, the reporting of modelling methodologies and assumptions may:

- Form part of an integrated water management or total water cycle management plan.
- Form part of a stormwater management plan.
- Be a standalone MUSIC modelling report.
- Consist of standalone completed copies of the reporting tables outlined in this guideline.

Appendix C of this guideline provides a set of reporting tables. Prior to lodging a development application, the proponent should check with the assessment authority what level of reporting is required for each application. In all cases, completed copies of the reporting tables provided in Appendix C should form part of any MUSIC reporting requirements to allow rapid assessment. The assessment authority may require information in addition to that outlined in this guideline.

MUSIC reporting should also be accompanied by plans which demonstrate that proposed treatment strategies can be readily constructed and maintained within the area allocated on the proposed site and that treatment measures will be free draining. This will require some detailed information (e.g. invert levels) to be lodged at the planning stage and proponents should be aware that some assessment authorities may require the lodgement of fully detailed plans as part of planning applications.

For further guidance on conceptual and detailed design, refer to the *Water by Design Concept Design Guidelines for Water Sensitive Urban Design*, *Water Sensitive Urban Design Technical Design Guidelines for South East Queensland*, *Bioretention Technical Design Guidelines* and *Wetland Technical Design Guidelines*.

For further guidance on stormwater reporting, proponents should also refer to local and state policies and guidelines.

7.2 Reporting requirements

7.2.1 Introduction

The introduction should contain at least:

- A description of the site location (including lot and plan number/s and latitude and longitude).
- A reference to relevant documents (e.g. conceptual or detailed design drawings, site plans, etc.)
- An outline of the stormwater management objectives.

7.2.2 Site and drainage characteristics

The following site and drainage information must be presented:

- The current and proposed land use of the development site.

- Sub catchments for the developed scenario demonstrating how drainage on the site is to be managed (i.e. flow directions). This should include a description of both the existing contours or topography and how future drainage is to be configured (including final site topography as a result of any earthworks).
- The location of proposed treatment measures modelled in MUSIC.
- The location of the site discharge point/s.
- Evidence that the modelled total catchment area is equal to that shown on site plans and catchment layouts.

7.2.3 Stormwater management strategy

Describe the site opportunities and constraints for stormwater controls (e.g. if steep topography prevents the use of devices such as swales). This section should include a description of the stormwater management options selected for the site during the operational phase of the development.

A brief explanation should demonstrate that the proposed stormwater management measures:

- Are appropriate for the specific site and development scale.
- Have adequate area for implementation (including all associated requirements such as batters, high flow bypass, maintenance access, etc.) and are appropriately placed within the development.
- Will be free draining.
- Are hydraulically sound (by safely conveying the design events) and their detention times are appropriate for the performance required.
- Have appropriate maintenance access.

Further guidance on how to address these details is provided in the *Water by Design Water Sensitive Urban Design Technical Design Guidelines for South East Queensland*, *Bioretention Technical Design Guidelines* and *Wetland Technical Design Guidelines*.

7.2.4 MUSIC modelling summary

Summarise the modelling methodology, including information on modelling parameters and assumptions. Include information on the meteorological data, time step, source nodes and treatment nodes consistent with the guidelines. Where the modelling approach varies from the approach outlined in this guideline, justify the use of alternative values. Review the MUSIC assessment checklists provided in this guideline when preparing the report to ensure all matters have been suitably addressed.

Appendix C provides the recommended format and the minimum information required for presenting the model inputs.

Where other treatment nodes are used, report all parameters adopted. Reporting is required to include justification of all parameters used (as stated in the relevant sections of these guidelines).

7.2.5 Performance reporting

Appendix C provides a table for reporting the performance of the proposed treatment train (Table 62). This should be lodged with all development applications and accompanied by a statement confirming modelling and performance. This statement should be provided in addition to the information outlined in Table 62.

Sample statement:

"I _____ hereby state that the proposed stormwater treatment strategy is: feasible; can be accommodated within the proposed development layout with free draining treatment measures; achieves the stormwater management objectives of ____%TSS, ____%TP, ____%TN; and has been modelled as described in this report."

7.2.6 Life cycle costs

When lodging development applications, provide the life cycle costing analysis results from MUSIC to the assessment authority using Table 63. Reporting is to include individual costing elements (acquisition cost, annual maintenance cost, etc.), total life cycle cost, analysis period and any assumptions or details on user-defined costs.

For development applications, include total acquisition costs, establishment costs and maintenance costs as undiscounted costs.

Applicants should also provide an interpretation of the maintenance and renewal costs to show that the proposed treatment measures will not impose an unmanageable maintenance burden on the asset manager. Where multiple treatment options are considered as concept designs, present life cycle costing information for each scenario and discuss the preferred option. The preferred option may not always be the one that has the lowest construction and maintenance costs (e.g. where there is a desire to provide additional high-value structures for amenity, such as boardwalks through a wetland).

The design may also have other beneficial outcomes such as enhancing community interaction with the natural environment. Refer to the 'Living Local Economies' section of *Living Waterways* (Water by Design) for ideas on how to weigh up and present a variety of beneficial outcomes that a design may have.

7.2.7 AUDITING TOOLS

MUSIC Link is an auditing tool developed by eWater to assist assessment authorities in reviewing MUSIC models. MUSIC Link highlights any discrepancies between models and pre-defined local parameters.

Where the relevant assessment authority has subscribed to MUSIC Link, development proponents should use the auditor to self-assess their models against local parameters prior to lodging a development application. This will allow the proponent to understand whether any aspect of their modelling is inconsistent with local parameters and, if necessary, amend modelling practice or provide suitable justification for using alternative parameters when lodging development applications.

7.3 MUSIC assessment checklist

Appendix D provides assessment tables to assist assessment officers in reviewing the major components of a MUSIC model. Proponents may also find these tables useful as a means to cross-check their reporting tables and as a pre-lodgement check to confirm the modelling approach with the assessment authority.

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APPENDIX A: Regional climatic and rainfall-runoff parameters

A1 South East Queensland

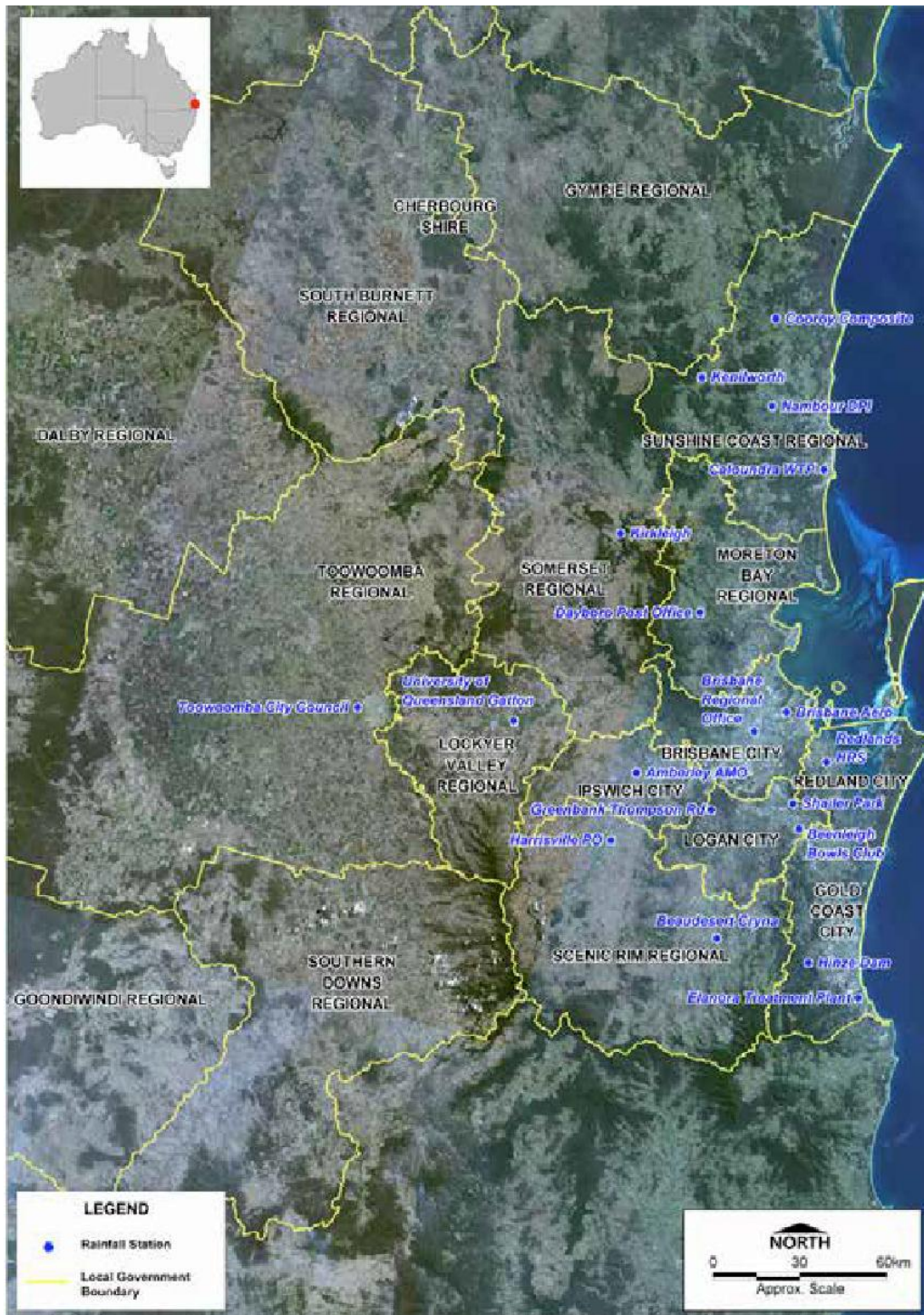


Figure 33 Rainfall station locations across South East Queensland (BMT WBM, 2009).

Table 22 Rainfall data and modelling periods for regions within South East Queensland.

Council	Station ID	Station name	Climate period for MUSIC	Mean annual rainfall over period (mm)	Mean PET (mm) ¹											
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Brisbane City Council (east)	40223	Brisbane Aero	1/1/1980 – 31/12/1989	1149	193	151	150	109	75	63	65	84	112	148	175	199
Brisbane City Council (west)	40659	Greenbank Thompson Rd	1/1/1980 – 31/12/1989	784	181	139	137	102	72	62	63	81	108	138	159	184
Brisbane City Council (central)	40214	Brisbane Regional Office	1/1/1980 – 31/12/1989	1178	188	146	146	107	74	63	65	84	111	144	171	192
Moreton Bay City Council	40063	Dayboro Post Office	1/1/1980 – 31/12/1989	1256	189	145	147	109	77	67	68	86	112	146	166	188
Gold Coast City Council (north)	40406	Beenleigh Bowls Club	1/1/1990 – 31/12/1999	1152	192	151	147	106	73	61	62	79	108	147	170	195
Gold Coast City Council (south)	40609	Elanora Treatment Plant	1/1/1989 – 31/12/1998	1436	160	134	133	101	72	57	58	72	95	132	145	163
Gold Coast City Council (central)	40584	Hinze Dam	1/1/1976 – 31/12/1985	1371	176	143	137	140	72	59	60	75	102	141	158	180
Ipswich City Council (east)	40659	Greenbank Thompson Rd	1/1/1980 – 31/12/1989	784	181	139	137	102	72	62	63	81	108	138	159	184
Ipswich City Council (west)	40004	Amberley AMO	1/1/1990 – 31/12/1999	781	172	133	131	101	73	63	64	82	106	136	153	178
Sunshine Coast Regional Council (north)	40059	Cooroy Composite	1/1/1973 – 31/12/1983	1600	198	159	161	121	89	76	77	93	118	162	182	193
Sunshine Coast Regional Council (east)	40496	Caloundra WTP	1/1/1997 – 31/12/2006	1348	198	155	160	121	86	73	74	91	118	160	180	201
Sunshine Coast Regional Council (west)	40106	Kenilworth	1/1/1988 – 31/12/1997	1075	195	158	160	119	87	76	77	92	117	161	179	190

Sunshine Coast Regional Council (central)	40282	Nambour DPI	1/1/1989 – 31/12/1998	1527	204	166	169	125	89	76	78	93	121	168	187	199
Lockyer Valley Regional Council	40082	University of Queensland Gatton	1/1/1980 – 31/12/1989	756	179	138	140	104	74	63	66	82	108	142	160	181
Logan City Council (east)	40715	Shailer Park	1/1/1990 – 31/12/1999	1119	195	153	149	107	74	61	63	80	110	148	173	199
Logan City Council (west)	40659	Greenbank Thompson Rd	1/1/1980 – 31/12/1989	784	181	139	137	102	72	62	63	81	108	138	159	184
Redland City Council	40265	Redlands HRS	1/1/1997 – 31/12/2006	1088	202	160	156	111	75	62	64	81	112	155	181	209
Scenic Rim Regional Council (east)	40014	Beaudesert Cryna	1/1/1968 – 31/12/1977	829	175	138	136	101	70	60	61	77	104	138	156	176
Scenic Rim Regional Council (west)	40094	Harrisville PO	1/1/1997 – 31/12/2006	579	176	136	134	101	71	62	63	80	106	138	155	180
Somerset Regional Council	40318	Kirkleigh	1/1/1980 – 31/12/1989	910	189	149	151	112	80	70	71	87	114	153	170	186
Toowoomba Regional Council	41467	Toowoomba City Council	1/1/1961 – 31/12/1970	898	173	133	137	100	74	63	66	81	104	139	158	173

¹ Source for PET values: Climate Atlas of Australia

Table 22 shows the rainfall stations and modelling periods to be used for South East Queensland. This data has been compiled from existing local government MUSIC modelling guidelines and assessment of additional rainfall data. The rainfall stations and modelling periods have been selected as they most closely characterise the mean annual rainfall for the surrounding region and have a minimal amount of missing and/or accumulated data. Table 22 also provides the monthly mean potential evapotranspiration data to be used for each location.

Note that the Toowoomba station specified should not be used any further west than the urban areas surrounding Clifton, Toowoomba and Crows Nest.

Table 23 Recommended MUSIC rainfall-runoff parameters for South East Queensland.

Parameter ^{1, 2}	Land use			
	Urban residential	Commercial and industrial	Rural residential	Forest
Rainfall threshold (mm)	1	1	1	1
Soil storage capacity (mm) ³	500	18	98	120
Initial storage (% capacity)	10	10	10	10
Field capacity (mm)	200	80	80	80
Infiltration capacity coefficient a	211	243	84	200
Infiltration capacity exponent b	5.0	0.6	3.3	1.0
Initial depth (mm)	50	50	50	50
Daily recharge rate (%)	28	0	100	25
Daily baseflow rate (%)	27	31	22	3
Daily deep seepage rate (%)	0	0	0	0

¹ Source: Data derived from the calibration of data from Brisbane City Council's Stormwater Monitoring Program (BMT WBM, 2005).

² The pervious area and soil parameters can significantly affect model results when modelling an area with <10% impervious areas, such as rural residential development. In the absence of calibrated values specific to the location being modelled, the values in the table above are provided as a guide.

³ MUSIC will warn that the normal range is between 10 and 400 mm. 500 mm is generally appropriate in SEQ.

A2 Whitsunday Region

Table 24 Rainfall data and modelling periods for locations within the Whitsunday region.

Station ID	Station name	Climate period for MUSIC	Mean annual rainfall over period (mm)	Mean PET (mm) ¹											
				JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
33247	Proserpine Airport	1992 – 2001	1388	191	164	187	139	113	97	99	116	139	184	200	192
33257	Bowen Airport	1990 – 1999	893	196	170	193	142	115	100	101	119	144	188	206	198
33013	Collinsville Airport	1986 – 1995	702	184	158	178	132	107	93	94	111	134	177	193	187

¹ Source for PET values: Climate Atlas of Australia

Table 24 shows the rainfall stations and modelling periods to be used for the Whitsunday Regional Council area. The rainfall stations and modelling periods have been selected as they most closely characterise the mean annual rainfall for the surrounding region and have a minimal amount of missing and/or accumulated data. Table 24 also provides the monthly mean potential evapotranspiration data to be used for each location.

Table 25 Rainfall-runoff parameters.

MUSIC parameter ¹	
Rainfall threshold (mm)	1
Soil capacity (mm)	100
Initial storage (% capacity)	30
Field capacity (mm)	100
Infiltration capacity coefficient a	200
Infiltration capacity exponent b	1
Initial depth (mm)	10
Daily recharge rate (%)	4
Daily baseflow rate (%)	2
Deep seepage (%)	0.4

¹ Source: Mackay MUSIC Modelling Guidelines (DesignFlow and Mackay Regional Council, 2008) with soil capacity adjusted for Whitsunday region (based on the calibration of rainfall and flow gauge data from the Gregory River flow gauge station (Gregory River at Lower Gregory, Station No 122004A, Lat: 20°18'01.6"S, Long: 148°32'54.2"E, Catchment area: 47 km², Data period: 2004 – 2013).

A3 Mackay Region

Rainfall data, PET data and rainfall-runoff parameters for the Mackay Regional should be in accordance with the Mackay MUSIC Modelling Guidelines (DesignFlow and Mackay Regional Council, 2008)

A4 Other major centres

This appendix provides recommended climatic data to be used in other major centres not addressed by the previous appendices.

Table 26 Rainfall data and modelling periods for other major centres not addressed previously.

Location	Rainfall station name (ID)	PET station name (ID)	Climate period for MUSIC
Cairns	Simmonds Creek at Kamma Pine Road (111009A)	Hambledon Mill CSR (31028)	2001-2010
Townsville	Black River at Bruce Highway (117002A)	Townsville Aero (32040)	2011-2020
Rockhampton	Dairy Creek at Old Railway (130364B)	Rockhampton Aero (39083)	2013-2022
Gladstone	Calliope River at Castlehope (132001A)	Gladstone Radar (39123)	2012-2021
Bundaberg	Gregory River at Leasons (137103A)	Bundaberg Aero (39128)	2013-2022
Hervey Bay	Mary River at Home Park (138014A)	Bundaberg Aero (39128)	2010-2019
Gympie	Mary River at Fishermans Pocket (138007A)	Gympie (40093)	2010-2019

Table 26 shows the rainfall stations and modelling periods to be used for each of seven major centres. Climatic templates for each centre are available for download from www.waterbydesign.com.au/music-climate-templates

Table 27 Rainfall-runoff parameters.

MUSIC parameter	
Rainfall threshold (mm)	1
Soil capacity (mm)	100
Initial storage (% capacity)	30
Field capacity (mm)	100
Infiltration capacity coefficient a	200
Infiltration capacity exponent b	1
Initial depth (mm)	10
Daily recharge rate (%)	4
Daily baseflow rate (%)	2
Deep seepage (%)	0.4

¹ Source: As per the Whitsunday Region (refer to Table 25)

APPENDIX B: Source node parameter summaries

B1 Residential urban source node summary

Table 28 Typical breakdown of surface types and impervious fraction for split and lumped residential urban source nodes^{1,2}

Development type	Split catchment approach						Lumped catchment approach	
	Road reserve		Roof		Ground level		Impervious fraction	
	Breakdown of surface types (%)	Impervious fraction (%)	Breakdown of surface types (%)	Impervious fraction (%)	Breakdown of surface types (%)	Impervious fraction (%)	Range (%)	Preferred (%)
Residential – 10 dwellings/ha	25	60	25 (based on 250 m ² roof area)	100	50	15	40 – 55	45
Residential – 15 dwellings/ha	25	60	32.5 (based on 215 m ² roof area)	100	42.5	20	50 – 60	55
Residential – 40 dwellings/ha	30	70	35	100	35	30	60 – 70	65
Residential – 80 dwellings/ha	32.5	80	35	100	32.5	50	70 – 95	85

¹ To be used for conceptual design and broad planning only. Development applications require measurement of areas from development plans.

² Extracted from Table 6, Table 8 and Table 9.

Table 29 Rainfall-runoff parameters for residential urban source nodes.

Parameter ¹	Urban residential
Rainfall threshold (mm)	
Soil storage capacity (mm)	
Initial storage (% capacity)	
Field capacity (mm)	
Infiltration capacity coefficient a	
Infiltration capacity exponent b	
Initial depth (mm)	
Daily recharge rate (%)	
Daily baseflow rate (%)	
Daily deep seepage rate (%)	

¹ Insert relevant regional data from Appendix A.

Table 30 Pollutant export parameters for residential urban source nodes (log₁₀ values) ¹.

Modelling approach	Flow type	Pollutant source	TSS log ¹⁰ values		TP log ¹⁰ values		TN log ¹⁰ values	
			Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Lumped	Baseflow	Urban lumped	1.00	0.34	-0.97	0.31	0.31	0.20
	Stormflow		2.18	0.39	-0.47	0.32	0.32	0.23
Split	Baseflow	Roof	N/A	N/A	N/A	N/A	N/A	N/A
		Road reserve	1.00	0.34	-0.97	0.31	0.20	0.20
		Ground level	1.00	0.34	-0.97	0.31	0.20	0.20
	Stormflow	Roof	1.30	0.39	-0.89	0.31	0.26	0.23
		Road reserve	2.43	0.39	-0.30	0.31	0.26	0.23
		Ground level	2.18	0.39	-0.47	0.31	0.26	0.23

¹ Extracted from Table 10 and Table 11.

B.2 Rural residential urban source node summary

Table 31 Typical impervious fraction for lumped rural residential urban source nodes^{1,2}.

Development land use or surface type	Impervious fraction (%)	
	Range (%)	Preferred (%)
Rural uses		
Rural residential (> 0.4 ha lots)	5-20	10
Rural residential (< 0.4 ha lots)	10-25	20
Rural	0-5	2
Public zones		
Public open space	5-50	20
Car parks	70-95	90
Library, sporting, depots	50-90	70
Schools and university	50-80	70

¹ To be used for conceptual design and broad planning only. Development applications require measurement of areas from development plans.

² (extracted from Table 9).

Table 32 Rainfall-runoff parameters for lumped rural residential urban source nodes¹.

PARAMETER	RURAL RESIDENTIAL
Rainfall threshold (mm)	
Soil storage capacity (mm)	
Initial storage (% capacity)	
Field capacity (mm)	
Infiltration capacity coefficient a	
Infiltration capacity exponent b	
Initial depth (mm)	
Daily recharge rate (%)	
Daily baseflow rate (%)	
Daily deep seepage rate (%)	

¹ Insert relevant regional data from Appendix A.

Table 33 Pollutant export parameters for lumped rural residential urban source nodes (log10 values)¹.

Flow type	TSS log ¹⁰ values		TP log ¹⁰ values		TN log ¹⁰ values	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Baseflow	0.53	0.24	-1.54	0.38	-0.52	0.39
Stormflow	2.26	0.51	-0.56	0.28	0.32	0.30

¹ Extracted from Table 10.

B.3 Industrial urban source node summary

Table 34 Typical breakdown of surface types and impervious fraction for split and lumped industrial urban source nodes^{1,2}.

Development type	Split catchment approach						Lumped catchment approach	
	Road reserve		Roof		Ground level		Impervious fraction	
	Breakdown of surface types (%)	Impervious fraction (%)	Breakdown of surface types (%)	Impervious fraction (%)	Breakdown of surface types (%)	Impervious fraction (%)	Range (%)	Preferred (%)
Typical industrial (warehouse, manufacturing, workshop, etc.).	30	75	50	100	20	60	70-95	90

¹ To be used for conceptual design and broad planning only. Development applications require measurement of areas from development plans.

² Extracted from Table 6, Table 8 and Table 9.

Table 35 Rainfall-runoff parameters for split and lumped industrial urban source nodes¹.

Parameter	Industrial
Rainfall threshold (mm)	
Soil storage capacity (mm)	
Initial storage (% capacity)	
Field capacity (mm)	
Infiltration capacity coefficient a	
Infiltration capacity exponent b	
Initial depth (mm)	
Daily recharge rate (%)	
Daily baseflow rate (%)	
Daily deep seepage rate (%)	

¹ Insert relevant regional data from Appendix A.

Table 36 Pollutant export parameters for industrial urban source nodes (log₁₀ values)¹.

Modelling approach	Flow type	Pollutant source	TSS log ₁₀ values		TP log ₁₀ values		TN log ₁₀ values	
			Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Lumped	Baseflow	Industrial lumped	0.78	0.45	-1.11	0.48	0.14	0.20
	Stormflow		1.92	0.44	-0.59	0.36	0.25	0.32
Split	Baseflow	Roof	N/A	N/A	N/A	N/A	N/A	N/A
		Road reserve	0.78	0.45	-1.11	0.48	0.14	0.20
		Ground level	0.78	0.45	-1.11	0.48	0.14	0.20
	Stormflow	Roof	1.30	0.44	-0.89	0.36	0.25	0.32
		Road reserve	2.43	0.44	-0.30	0.36	0.25	0.32
		Ground level	1.92	0.44	-0.59	0.36	0.25	0.32

¹ Extracted from Table 10 and Table 11.

B.4 Commercial urban source node summary

Table 37 Typical breakdown of surface types and impervious fraction for split and lumped commercial urban source nodes^{1,2}.

Development type	Split						Lumped	
	Road reserve		Roof		Ground level		Impervious fraction	
	Breakdown of surface types (%)	Impervious fraction (%)	Breakdown of surface types (%)	Impervious fraction (%)	Breakdown of surface types (%)	Impervious fraction (%)	Range (%)	Preferred (%)
Business or town centre, offices and bulky goods.	30	75	50	100	20	80	70-95	90
Garden and landscape suppliers.							30-60	50

¹ To be used for conceptual design and broad planning only. Development applications require measurement of areas from development plans.

² Extracted from Table 6, Table 8 and Table 9.

Table 38 Rainfall-runoff parameters for lumped commercial urban source nodes¹.

Parameter	Commercial
Rainfall threshold (mm)	
Soil storage capacity (mm)	
Initial storage (% capacity)	
Field capacity (mm)	
Infiltration capacity coefficient a	
Infiltration capacity exponent b	
Initial depth (mm)	
Daily recharge rate (%)	
Daily baseflow rate (%)	
Daily deep seepage rate (%)	

¹ Insert relevant regional data from Appendix A.

Table 39 Pollutant export parameters for commercial urban sources nodes (log₁₀ values)¹.

Modelling approach	Flow type	Pollutant source	TSS log ₁₀ values		TP log ₁₀ values		TN log ₁₀ values	
			Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Lumped	Baseflow	Commercial lumped	0.78	0.39	-0.60	0.50	0.32	0.30
	Stormflow		2.16	0.38	-0.39	0.34	0.37	0.34
Split	Baseflow	Roof	N/A	N/A	N/A	N/A	N/A	N/A
		Road reserve	0.78	0.39	-0.60	0.50	0.32	0.30
		Ground level	0.78	0.39	-0.60	0.50	0.32	0.30
	Stormflow	Roof	1.30	0.38	-0.89	0.34	0.37	0.34
		Road reserve	2.43	0.38	-0.30	0.34	0.37	0.34
		Ground level	2.16	0.38	-0.39	0.34	0.37	0.34

¹ Extracted from Table 10 and Table 11.

B.5 Forest source node summary

Table 40 Typical impervious fraction for lumped forest source nodes¹.

Development land use or surface type	Impervious fraction (%)	
	Range	Preferred
Forest or conservation	0-5	0

¹ Extracted from Table 9.

Table 41 Rainfall-runoff parameters for lumped forest source nodes¹.

Parameter	Commercial
Rainfall threshold (mm)	
Soil storage capacity (mm)	
Initial storage (% capacity)	
Field capacity (mm)	
Infiltration capacity coefficient a	
Infiltration capacity exponent b	
Initial depth (mm)	
Daily recharge rate (%)	
Daily baseflow rate (%)	
Daily deep seepage rate (%)	

¹ Insert relevant regional data from Appendix A.

Table 42 Pollutant export parameters for lumped forest source nodes (log¹⁰ values)¹.

Flow type	TSS log ¹⁰ values		TP log ¹⁰ values		TN log ¹⁰ values	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Baseflow	0.51	0.28	-1.79	0.28	-0.59	0.22
Stormflow	1.90	0.20	-1.10	0.22	0.075	0.24

¹ Extracted from Table 10.

B.6 Agricultural source node summary

Table 43 Typical impervious fraction for lumped agricultural source nodes¹.

Development land use or surface type	Impervious fraction (%)	
	Range	Preferred
Rural	0-5	2

¹ Extracted from Table 9.

Table 44 Rainfall-runoff parameters for lumped agricultural source nodes¹.

Parameter	Commercial
Rainfall threshold (mm)	
Soil storage capacity (mm)	
Initial storage (% capacity)	
Field capacity (mm)	
Infiltration capacity coefficient a	
Infiltration capacity exponent b	
Initial depth (mm)	
Daily recharge rate (%)	
Daily baseflow rate (%)	
Daily deep seepage rate (%)	

¹ Insert relevant regional data from Appendix A.

Table 45 Pollutant export parameters for lumped agricultural source nodes (log₁₀ values)¹.

Flow type	TSS log ₁₀ values		TP log ₁₀ values		TN log ₁₀ values	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Baseflow	1.00	0.13	-1.155	0.13	-0.155	0.13
Stormflow	2.477	0.31	-0.495	0.30	0.29	0.26

¹ Extracted from Table 10.

APPENDIX C: Reporting tables

Prior to lodging checklists, designers should cross-check their work against the assessment tables in Appendix D. By doing so, designers can gain a better understanding of how their designs are likely to be assessed and thereby reduce the likelihood of information requests. Benefits of avoiding information requests include reduced design and assessment costs and timeframes.

Editable, electronic versions of these checklists are available from www.waterbydesign.com.au.

Table 46 Meteorological and rainfall-runoff data reporting table.

Input	Data used in modelling
Rainfall station	Station name and number.
Time step	Six-minute time step required.
Modelling period	Period modelled and total number of modelled years.
Mean annual rainfall (mm)	
Evapotranspiration (mm)	
Rainfall-runoff parameters	Note which land use parameters were used (e.g. 'residential'). Any deviation from the information recommended in these guidelines requires justification using Table 49.
Pollutant export parameters	Note which land use parameters were used (e.g. 'residential'). Any deviation from the information recommended in these guidelines requires justification using Table 50 and Table 51.

Table 47 Catchment definition reporting table.

Catchment ID	Area (ha)	Land use	Total impervious (%)
1 (reference to catchment plan).	Total area of sub catchment.	Residential, commercial, industrial, etc.	Total impervious portion of catchment as measured off development plans.
2 (etc.).			
TOTAL			

Table 48 Catchment split reporting table.

Catchment ID	Area (ha)	Land use	Total impervious (%)
1 (reference to catchment plan).	Area of surface type.	Roof to tank.	Impervious portion of each surface type or lumped land use as measured off development plans.
	Area of surface type.	Roof to ground.	
	Area of surface type.	Road reserve.	
	Area of lumped land use.	Ground level or lumped.	
2 (etc.).	Area of surface type.	Roof to tank.	Impervious portion of each surface type or lumped land use as measured off development plans.
	Area of surface type.	Roof to ground.	
	Area of surface type.	Road reserve.	
	Area of lumped land use.	Ground level or lumped.	
TOTAL			

Table 49 Rainfall-runoff parameter reporting table¹.

Parameter	Source node 1	Source node 2 (etc.)
Land use		
Rainfall threshold (mm)		
Soil storage capacity (mm)		
Initial storage (% capacity)		
Field capacity (mm)		
Infiltration capacity coefficient a		
Infiltration capacity exponent b		
Initial depth (mm)		
Daily recharge rate (%)		
Daily baseflow rate (%)		
Daily deep seepage rate (%)		

¹ This table only to be used where there has been any deviation from the parameters recommended in these guidelines.

Table 50 Pollutant export parameter reporting table – split catchment approach¹.

Catchment ID	Land use	Flow type	Split catchment land use					
			TSS log ¹⁰ values		TP log ¹⁰ values		TN log ¹⁰ values	
			Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
1 (reference to catchment plan).		Baseflow						
		Stormflow						
		Baseflow						
		Stormflow						
		Baseflow						
		Stormflow						
2 (etc.).		Baseflow						
		Stormflow						
		Baseflow						
		Stormflow						
		Baseflow						
		Stormflow						

¹ This table only to be used where there has been any deviation from the parameters recommended in these guidelines.

Table 51 Pollutant export parameter reporting table – lumped catchment approach¹.

Catchment ID	Land use	Flow type	Lumped catchment land use					
			TSS log ¹⁰ values		TP log ¹⁰ values		TN log ¹⁰ values	
			Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
1 (reference to catchment plan).		Baseflow						
		Stormflow						
2 (etc.).		Baseflow						
		Stormflow						

¹ This table only to be used where there has been any deviation from the parameters recommended in these guidelines.

Table 52 Rainwater tank node reporting table.

Rainwater tanks (Section 4.2)		
Catchment ID	Treatment node 1	Treatment node 2 (etc.)
Volume below overflow pipe (kL). If greater than one tank, specify number of tanks, volume per tank and total volume (e.g. 10 tanks x 5 kL = 50 kL).		
Depth above overflow (m).		
If tanks are lumped, is depth below overflow the same as a single tank and overflow pipe scaled accordingly (Section 4.2.6)?		
Surface area (m ²). For lumped tanks the surface area must be adjusted in accordance with Section 4.2.6.		
Overflow pipe diameter (mm). For lumped tanks this must be equivalent to the diameter of the overflow pipe of a single tank multiplied by the square root of the number of tanks (Section 4.2.6).		
Stored water used for irrigation and other purposes? (Y/N)		
PET.		
PET - Rain.		
Indoor connections (e.g. toilet, laundry, etc.).		
Indoor demand (kL/day).		
Outdoor demand (kL/day).		
Daily demand (kL/day).		
Monthly distribution of annual demand (kL/day).		
Confirmation that k and C* remain default? (Y/N).		

Table 53 Wetland node reporting table.

Constructed wetlands (Section 4.3)		
Catchment ID	Treatment node 1	Treatment node 2 (etc.)
Inlet pond volume (m ³). (Cannot be sized in MUSIC).		
Macrophyte zone surface area (m ²).		
Has the surface area been calculated appropriately (Section 4.3.2)? (Y/N).		
Extended detention depth (m) (Section 4.3.2). This must be less than or equal to 0.5 m.		
Permanent pool volume (m ³).		
Exfiltration rate (mm/hr) (Section 4.3.2).		
If an exfiltration rate greater than zero has been used, has the secondary drainage link been used to return the exfiltrated flows to the model (Section 4.1.1)? (Y/N or N/A).		
Evaporative loss as % of PET.		
Equivalent pipe diameter (m). Should be set so that notional detention time is as close to 48 hours as possible. Where appropriate, Storage-Discharge-Height table to be attached. Refer to Section 4.3.3 for advice on accounting for user defined stage-discharge relationship.		
Overflow weir width (m).		
Notional detention time (hrs). Should be as close to 48 hours as possible.		
Number of CSTR cells.		
Confirmation that k and C* for TSS and TP remain default? (Y/N).		
Confirmation that k and C* for TN have been adjusted to K = 200 and C* = 0.75? (Y/N).		

Table 54 Swale node reporting table.

Swales (Section 4.4) and surface component of bioretention swales (Section 4.6)¹		
Catchment ID	Treatment node 1	Treatment node 2 (etc.)
Low flow bypass (m ³ /s). The calculation should be provided by the applicant separately.		
Length (m). Length must account for conveyance capacity and safety limitations selected in accordance with the <i>Water Sensitive Urban Design Technical Design Guidelines for South East Queensland (Water by Design)</i> .		
Bed slope (%) (maximum 4%).		
Base width (m).		
Top width (m).		
Depth (m).		
Vegetation height (m). Must reflect landscape design.		
Exfiltration rate (mm/hr) (Section 4.4).		
If an exfiltration rate greater than zero has been used, has the secondary drainage link been used to return the exfiltrated flows to the model (Section 4.1.1)? (Y/N or N/A).		
If the swale accepts point source discharges at given locations, is it split into separate lengths? (Y/N or N/A).		
Confirmation that k and C* remain default? (Y/N).		
Additional items for bioretention swales (Section 4.6)		
Is the swale node located in the model downstream of bioretention swale surface component? (Y/N).		
Is the low flow bypass of the swale node set to the infiltration rate of the bioretention filter media? (Y/N).		

¹ For bioretention filter component use Table 55.

Table 55 Bioretention node reporting table.

Bioretention (Section 4.5)		
Catchment ID	Treatment node 1	Treatment node 2 (etc.)
Surface area (m ²).		
Has the filter area been calculated appropriately? (Y/N or N/A).		
Extended detention depth (m).		
Filter area (m ²).		
Unlined filter media perimeter (m).		
Saturated hydraulic conductivity (mm/hour).		
Filter depth (m).		
Total nitrogen content of filter media (%).		
Orthophosphate content of filter media (mg/kg).		
Is the base lined? (Y/N).		
Effectiveness of plant total nitrogen removal? (effective/ineffective/unvegetated).		
Overflow weir width (m).		
Exfiltration rate (mm/hr).		
If an exfiltration rate greater than zero has been used, has the secondary drainage link been used to return the exfiltrated flows to the model (Section 4.1.1)? (Y/N or N/A).		
If exfiltration rate has been used, is the exfiltration rate justified? (Y/N or N/A).		
Underdrain present? (Y/N).		
Submerged zone with carbon present? (Y/N).		
Depth of submerged zone (m).		
Confirmation that k and C* remain default? (Y/N).		
If bioretention systems are modelled in series, is there a low flow bypass modelled in the downstream bioretention system/s? (Y/ N, N/A) (NOTE: Separate drainage systems are required if a low flow bypass is modelled).		

Table 56 Buffer node reporting table.

Buffers (Section 4.7)		
Catchment ID	Treatment node 1	Treatment node 2 (etc.)
Does the treatment node reflect the vegetated area receiving sheet flow only? (Y/N).		
IF 'NO' TO THE ABOVE, THIS NODE CANNOT BE USED.		
Percentage of upstream area (% as shown on the development plans)?		
Buffer area (% of impervious area as shown on the development plans)?		
Is the exfiltration rate set to zero?		
If an exfiltration rate greater than zero has been used, has the secondary drainage link been used to return the exfiltrated flows to the model (Section 4.1.1)? (Y/N or N/A).		

Table 57 Proprietary and custom products (including gross pollutant traps) node reporting table.

Proprietary and custom products (Section 4.8)		
Catchment ID	Treatment node 1	Treatment node 2 (etc.)
Are the proposed pollutant reduction efficiencies verified against SQIDEP (or other locally endorsed verification process)?		
Does the data provided include performance results under dry weather flows (to account for potential pollutant leeching)? (Y/N). Copies of the supporting data must be lodged with the development application.		
Is the assumed high flow bypass rate consistent with manufacturer specifications? (Y/N). Provide copies of relevant specifications with development application.		
IF 'NO' TO ANY OF THE ABOVE, THE PROPOSED POLLUTANT REDUCTION RATES CANNOT BE RELIED UPON AS BEING REASONABLE ASSUMPTIONS OF PRODUCT PERFORMANCE.		
Storage volume of GPT? (m ³).		
Expected maintenance frequency (months).		
Is the storage volume large enough to contain all sediments and gross pollutants received by unit between maintenance events? (Y/N).		

Table 58 Sediment basin node reporting table.

Sediment basin (Section 4.9)		
Catchment ID	Treatment node 1	Treatment node 2 (etc.)
Surface area (m ²).		
Has the surface area been calculated appropriately (Section 4.3.2)? (Y/N).		
Extended detention depth (m).		
Permanent pool volume (m ³).		
Exfiltration rate (mm/hr).		
If an exfiltration rate greater than zero has been used, has the secondary drainage link been used to return the exfiltrated flows to the model (Section 4.1.1)? (Y/N or N/A).		
Evaporative loss as % of PET.		
Equivalent pipe diameter (m). Where appropriate, refer to Section 4.3.3 for advice on accounting for user defined stage-discharge relationship.		
Overflow weir width (m).		
Notional detention time (hrs). This should be set to account for potential flow restriction.		
Number of CSTR cells.		
Confirmation that k and C* remain default? (Y/N).		

Table 59 Infiltration node reporting table.

Infiltration system (Section 4.10)		
Catchment ID	Treatment node 1	Treatment node 2 (etc.)
Is the exfiltration rate justified (Section 4.1.1)? (Y/N).		
Can the hydraulic conductivity of the in-situ soils be guaranteed even after earthworks? (Y/N).		
IF 'NO' TO ANY OF THE ABOVE, THIS NODE CANNOT BE USED.		
Pond surface area (m ²).		
Extended detention depth (m).		
Filter area (m ²).		
Unlined filter media perimeter (m).		
Depth of infiltration media (m).		
Exfiltration rate (mm/hr).		
Has the secondary drainage link been used to return the exfiltrated flows to the model (Section 4.1.1)? (Y/N or N/A). If the secondary drainage link is not used, WQOs must be achieved prior to stormwater entering an infiltration system.		
Overflow weir width (m).		

Evaporative loss as % of PET.		
Confirmation that k and C* remain default? (Y/N).		

Table 60 Porous pavement node reporting table.

Porous pavements (Section 4.11)		
Catchment ID	Treatment node 1	Treatment node 2 (etc.)
Is direct rainfall modelled as a separate source node with a 100% impervious fraction? (Y/N).		
Is the biofilter filter area set to represent the opening area or void ratio of the porous pavement (i.e. not the total surface area)? (Y/N). This should be estimated from the product specifications.		
Is the extended detention depth set to 0 m?		
Is the filter depth set to represent the treatment depth only (i.e. does not include the depth of the drainage layer)? (Y/N).		
Media filtration node parameters (when modelling porous pavement)		
Extended detention depth (m).		
Surface area (m ²).		
Exfiltration rate (mm/hr).		
If an exfiltration rate greater than zero has been used, has the secondary drainage link been used to return the exfiltrated flows to the model (Section 4.1.1)? (Y/N or N/A).		
Filter area (m ²).		
Filter depth (m).		
Filter media particle diameter (mm).		
Saturated hydraulic conductivity (mm/hr).		
Depth below underdrain (% of filter depth).		
Have the k and C* values been retained as default values or otherwise justified? (Y/N).		
Is the filter media particle diameter and saturated hydraulic conductivity consistent with manufacturer specifications? (Y/N).		

Table 61 Water wise street tree reporting table¹.

Water wise street trees (Section 4.12)		
Catchment ID	Treatment node 1	Treatment node 2 (etc.)
Surface area (m ²).		
Extended detention depth (m).		
Has the filter area been calculated appropriately? (Y/N or N/A).		
Filter area (m ²).		
Unlined filter media perimeter (m).		
Saturated hydraulic conductivity (mm/hour).		
Filter depth (m).		
Total nitrogen content of filter media (%).		
Orthophosphate content of filter media (mg/kg).		
Is the base lined? (Y/N).		
Effectiveness of plant total nitrogen removal? (effective/ineffective/ unvegetated).		
Overflow weir width (m).		
Exfiltration rate (mm/hr).		
If an exfiltration rate greater than zero has been used, has the secondary drainage link been used to return the exfiltrated flows to the model (Section 4.1.1)? (Y/N or N/A).		
If exfiltration rate has been used, is the exfiltration rate justified? (Y/N or N/A).		
Confirmation that underdrain is not present (Y/N).		
Confirmation that submerged zone with carbon is not present (Y/N).		
Confirmation that k and C* remain default (Y/N).		
If water wise street trees are modelled in series, is there a low flow bypass modelled in the downstream system/s? (Y/N or N/A) (NOTE: Separate drainage systems are required if a low flow bypass is modelled).		

¹ NOTE: Model water wise street trees using the bioretention node (in accordance with Section 4.12).

Table 62 Stormwater quality modelling results reporting table.

Catchment ID	Pollutant	Inflows (kg/yr)	Outflows (kg/yr)	Reduction (kg/yr)	Reduction achieved (%)	Water quality objective (%)
1	TSS					
	TP					
	TN					
2 (etc.)	TSS					
	TP					
	TN					
TOTAL	TSS					
	TP					
	TN					

Table 63 Life cycle cost reporting table.

Global properties			
Real discount rate (%)			
Annual inflation rate (%)			
Base year for costing			
Costing element	Treatment 1	Treatment 2 (etc.)	Total
Acquisition cost (\$)			
Annual maintenance cost (\$)			
Annual establishment cost (\$)			
Establishment period (yrs)			
Renewal/adaption cost (\$)			
Renewal/adaption period (yrs)			
Decommissioning cost (\$)			

APPENDIX D: Assessment checklists

Table 64 General application information.

Application information	
Site or Project Name	DA No.
Lot and Plan No.	
Location	

Table 65 Climate and time step assessment checklist¹.

Climate and time step (check reporting Table 46)	Y	N	Comments/issues to follow up
Has the correct rainfall station been used?			
Has a six-minute time step been used for assessment against stormwater quality management objectives?			
Has the correct modelling period been selected?			
Has the correct potential evapotranspiration been selected?			

¹ Refer to Section 3.1, Section 3.2 and Appendix A.

Table 66 Catchment and source node assessment checklist¹.

Climate and time step (check reporting Table 47)	Y	N	Comments/issues to follow up
Do the source node areas reported reflect the catchment areas shown on the plan?			
Does the total area reported reflect the total catchment shown on the development plan?			
Does the land use reported reflect the proposed land use?			
Is the total imperviousness percentage for each land type appropriate (for development applications this must be measured directly from plans)?			

¹ Refer to Section 3.3.

Table 67 Catchment split assessment checklist.

Catchment split (check reporting Table 48)	Y	N	Comments/issues to follow up
Has a 'split catchment' approach been used?			

Does the area of each land use/surface type reported reflect the areas shown on the plan?			
Does the total area reported reflect the total catchment shown on the development plan?			
Do the land uses or surface types reported reflect the proposed development (i.e. have correct source nodes been used)?			
Is the impervious fraction for each land use or surface type appropriate? (NOTE: for development applications this must be measured direct from plan; otherwise refer Section 3.3.3.)			
For split catchment modelling where rainwater tanks are proposed as treatment nodes, is the percentage of connected roof area appropriate (Section 4.2)?			

Table 68 Rainfall and runoff assessment checklist¹.

Rainfall-runoff and pollutant export parameter (check reporting Table 49 and either Table 50 or Table 51, depending on the modelling approach)	Y	N	Comments/issues to follow up
Have the correct rainfall-runoff parameters been used?			
Have appropriate pollutant export parameters been used?			
Has stochastic generation been used for all pollutants?			

¹ Refer to Section 3.3 and Appendix A.

Table 69 All treatment nodes assessment checklist.

All treatment nodes	Y	N	Comments/issues to follow up
Will treatment nodes modelled be free draining? Compare the total depth of the treatment measures modelled against development plan levels.			
Have any receiving environments been modelled as treatment systems? These include natural waterways, natural wetlands, naturalised channel systems, environmental buffers, freshwater and brackish lake and pond systems (existing or constructed). Stormwater must be treated before it discharges to these systems.			

Table 70 Rainwater tank nodes assessment checklist¹.

Rainwater tanks (check reporting Table 52)	Y	N	Comments/issues to follow up
Has the volume below the overflow pipe (kL) been calculated appropriately?			
Has the depth above the overflow pipe been calculated appropriately?			
If tanks are lumped, is the depth below overflow pipe the same as a single tank and the overflow pipe scaled accordingly (Section 4.2.6)?			
Has the total tank surface area been calculated appropriately? For lumped tanks refer to Section 4.2.6.			
Has the overflow pipe diameter been calculated appropriately? For lumped tanks this must be equivalent to the diameter of the overflow pipe of a single tank multiplied by the square root of the number of tanks (Section 4.2.6).			
Has stormwater reuse been calculated appropriately? PET. PET - Rain.			
Have appropriate indoor connections been selected?			
Has the indoor demand been calculated appropriately?			
Has the outdoor demand been calculated appropriately?			
Has the daily demand been calculated appropriately?			
Has the monthly distribution of annual demand been calculated appropriately?			
Have k and C* been retained as default values?			

¹ Refer to Section 4.2.

Table 71 Wetland node assessment checklist¹.

Wetlands (check reporting Table 53)	Y	N	Comments/issues to follow up
Has the inlet pond volume been sized appropriately to capture coarse sediment?			
Has the macrophyte zone surface area been calculated appropriately?			
Is the extended detention depth less than or equal to 0.5 m?			
Has the permanent pool volume been calculated appropriately?			
Is the exfiltration rate set to 0 mm/hr?			
If an exfiltration rate greater than zero has been used, has the secondary drainage link been used to return the exfiltrated flows to the model (Section 4.1.1)?			
Has the evaporative loss as % of PET been set to 125% or less?			
Has the equivalent pipe diameter been set so that the notional detention time is about 48 hours?			
Has the overflow weir width been calculated appropriately?			
Is the notional detention time (hrs) approximately 48 hours?			
Are the number of CSTRs appropriate for the shape of the system?			
Have k and C* been retained as default values for all parameters except total nitrogen (which has been adjusted to reflect Section 4.3.4)?			

¹ Refer to Section 4.3.

Table 72 Swale node assessment checklist¹.

Swales (check reporting Table 54)	Y	N	Comments/issues to follow up
Is the length equivalent to the length shown on the development plans and does it account for conveyance capacity and safety limitations selected in accordance with the <i>Water Sensitive Urban Design Technical Design Guidelines for South East Queensland (Water by Design)</i> ?			
Is the bed slope less than or equal to 4%?			
Are the base width, top width and depth equivalent to the length shown on the development plans?			
Is the set vegetation height appropriate for the selected species (Section 4.4)?			
Is the exfiltration rate set to 0 mm/hr?			
If an exfiltration rate greater than zero has been used, has the secondary drainage link been used to return the exfiltrated flows to the model (Section 4.1.1)?			
If the swale accepts point source discharge at given locations, is it split into separate lengths?			
Have k and C* been retained as default values?			
Bioretention swales			
Is the swale node located in the model downstream of the bioretention swale surface component?			
Is the low flow bypass of the swale node set to the infiltration rate of the filter?			

¹ Refer to Section 4.4.

Table 73 Bioretention and bioretention swale nodes assessment checklist¹.

Bioretention and bioretention swale filter components (check reporting Table 54 and Table 55)	Y	N	Comments/issues to follow up
Has the filter surface area been calculated appropriately?			
Is the extended detention depth consistent with the depth shown on the development plans and between 0-0.3 m?			
Is the filter media area consistent with the area shown on the development plans?			
Has an appropriate unlined filter media perimeter been set?			
Has an appropriate saturated hydraulic conductivity been set?			
Is the filter media depth modelled equivalent to the depth of media shown on the plans? This depth should not include the intermediate layer, drainage layers, or submerged zone.			
Is the total nitrogen content in the filter media set to either 400 mg/kg or another suitably justified value?			
Is the orthophosphate content in the filter media set to 30 mg/kg or another suitably justified value?			
Is the base lined?			
Has the system been modelled to reflect the nutrient removal properties of the plants to be used on site?			
Is the overflow weir width appropriate?			
Is the exfiltration rate set to zero?			
If an exfiltration rate greater than zero has been used, has the secondary drainage link been used to return the exfiltrated flows to the model (Section 4.1.1)?			
If an exfiltration rate greater than zero has been used, is the exfiltration rate justified?			
Has the system been modelled with underdrains present?			
Is a submerged zone with carbon present?			
Is the depth of submerged zone consistent with plans?			
If bioretention systems are modelled in series, is there a low flow bypass modelled in the downstream bioretention system/s? (NOTE: Separate drainage systems are required if a low flow bypass is modelled).			
Have k and C* been retained as default values?			

Bioretention swale component only

(check Table 54)

Has an extended detention depth of 0 m been used?			
Has the low flow bypass been calculated? The calculation should be provided by the applicant separately.			

¹ Refer to Section 4.5.

Table 74 Buffer node assessment checklist¹.

Buffers (check reporting Table 56)	Y	N	Comments/issues to follow up
Does the treatment node reflect the vegetated area receiving sheet flow only?			
Is the percentage of upstream area buffered consistent with catchment plans?			
Does the buffer area accurately reflect the percentage impervious area as shown on the development plans?			
Is the exfiltration rate set to zero?			
If an exfiltration rate greater than zero has been used, has the secondary drainage link been used to return the exfiltrated flows to the model (Section 4.1.1)?			

¹ Refer to Section 4.7.

Table 75 Proprietary and custom products (including gross pollutant traps) node assessment checklist¹.

Proprietary and custom products (check reporting Table 57)	Y	N	Comments/issues to follow up
Are the proposed pollutant reduction efficiencies verified against SQIDEP (or other locally endorsed verification method (Section 4.8)?			
Does the data provided include performance results under dry weather flows (to account for potential pollutant leaching)?			
Is the assumed high flow bypass rate consistent with manufacturer specifications?			
IF 'NO' TO ANY OF THE ABOVE, THE PROPOSED POLLUTANT REDUCTION RATES CANNOT BE RELIED UPON AS BEING REASONABLE ASSUMPTIONS OF PRODUCT PERFORMANCE.			
Is the storage volume modelled consistent with the proposed unit?			
Is the expected maintenance frequency a reasonable assumption?			

Is the storage volume large enough to contain all sediments and gross pollutants received by unit between maintenance events?			
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¹ Refer to Section 4.8.

Table 76 Sediment basin node assessment checklist¹.

Sediment basins (check reporting Table 58)	Y	N	Comments/issues to follow up
Has the surface area been calculated appropriately (Section 4.3.2)?			
Is the extended detention depth consistent with the development plans?			
Is the permanent pool volume consistent with the development plans?			
Is the exfiltration rate set to 0 mm/hr?			
If an exfiltration rate greater than zero has been used, has the secondary drainage link been used to return the exfiltrated flows to the model (Section 4.1.1)?			
Is the evaporative loss as % of PET reasonable?			
Has the equivalent pipe diameter been set appropriately? (Where appropriate, refer to Section 4.3.3 for advice on accounting for user-defined stage-discharge relationship.)			
Is the overflow weir width consistent with the development plans?			
Is the notional detention time set to account for potential flow restriction?			
Are the number of CSTRs appropriate for the shape of the system?			
Have the k and C* values been retained as default values?			

¹ Refer to Section 4.9.

Table 77 Infiltration node assessment checklist¹.

Infiltration (check reporting Table 59)	Y	N	Comments/issues to follow up
Is the exfiltration rate justified?			
Has the secondary drainage link been used to return the exfiltrated flows to the model (Section 4.1.1)? If the secondary drainage link is not used, WQOs must be achieved prior to stormwater entering an infiltration system.			
Can the hydraulic conductivity of the in-situ soils be guaranteed even during earthworks?			
IF 'NO' TO ANY OF THE ABOVE, THIS NODE CANNOT BE USED.			
Is the pond surface area consistent with the plans?			
Is the extended detention depth consistent with the plans?			
Is the filter area consistent with the plans?			
Is the unlined filter media perimeter appropriate?			
Is the depth of infiltration media consistent with the plans?			
Is the exfiltration rate justified?			
Is the overflow weir width consistent with the plans?			
Is the evaporative loss as % of PET reasonable?			
Have the k and C* values been retained as default values?			

¹ Refer to Section 4.10.

Table 78 Porous pavement node assessment checklist¹.

Porous pavements ¹ (check reporting Table 60)	Y	N	Comments/issues to follow up
Has the applicant answered 'YES' to all questions in the reporting table?			

¹ Refer to Section 4.11.

² NOTE: Check all other parameters for the porous pavement using Table 60.

Table 79 Water wise street tree assessment checklist¹.

Water wise street tree ¹ (check reporting Table 61)	Y	N	Comments/issues to follow up
Has the filter surface area been calculated appropriately?			
Has the extended detention depth been set to 0 m (or otherwise appropriately justified)?			
Is the filter media area consistent with the area shown on the development plans?			
Has an appropriate unlined filter media perimeter been set?			
Has an appropriate saturated hydraulic conductivity been set? (NOTE: Typically between 50 and 100 mm/hr for water wise street trees.)			
Is the filter media depth modelled equivalent to the depth of media shown on the plans?			
Is the total nitrogen content in the filter media set to either 400 mg/kg or another suitably justified value?			
Is the orthophosphate content in the filter media set to 30 mg/kg or another suitably justified value?			
Is the base lined?			
Has the system been modelled to reflect the nutrient removal properties of the plants to be used on site?			
Is the overflow weir width appropriate?			
Is the exfiltration rate set to zero?			
If an exfiltration rate greater than zero has been used, has the secondary drainage link been used to return the exfiltrated flows to the model (Section 4.1.1)?			
If an exfiltration rate greater than zero has been used, is the exfiltration rate justified?			
Has the system been modelled without underdrains present?			
Has the system been modelled without a submerged zone with carbon present?			
If water wise street trees are modelled in series, is there a low flow bypass modelled in the downstream system/s? (NOTE: Separate drainage systems are required if a low flow bypass is modelled.)			
Have k and C* been retained as default values?			

¹ Refer to Section 4.12.

² NOTE: Model water wise street trees using the bioretention node in accordance with Section 4.12.

Table 80 Overall approval assessment checklist.

Design objectives (check reporting Table 62)	Y	N	Comments/issues to follow up
Have all water quality objectives been met?			
Is the MUSIC model approved?			