WSUD 07

InSite Water Management Tool

Stormwater management for small-scale development

ENGINEERING METHODS

January 2020

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Disclaimer

1 Introduction

This engineering methods report provides detail of the technical basis, including relevant formulae, behind the Water Sensitive SA InSite Water Management Tool (Insite Water), and aims to provide transparency regarding the design and function of the Tool.

This report will help users of Insite Water to understand the rigor of the analysis and clarity over assumptions within InSite Water when assessing performance of the proposed water efficiency, water sensitive urban design (WSUD) and flood control elements of a development against the design criteria pre-set within the Tool.

Please read this document in conjunction with the Water Sensitive SA *InSite Water Management Tool user manual – stormwater management for small-scale development* which takes the user step-by-step through the input fields and application of the InSite Water Tool.

As part of a suite of resources (refer to Figure 1), this engineering methods report has been created to support development applications, serving as an ancillary technical document with respect to water conservation and efficiency, and stormwater runoff flow, volume and quality management.

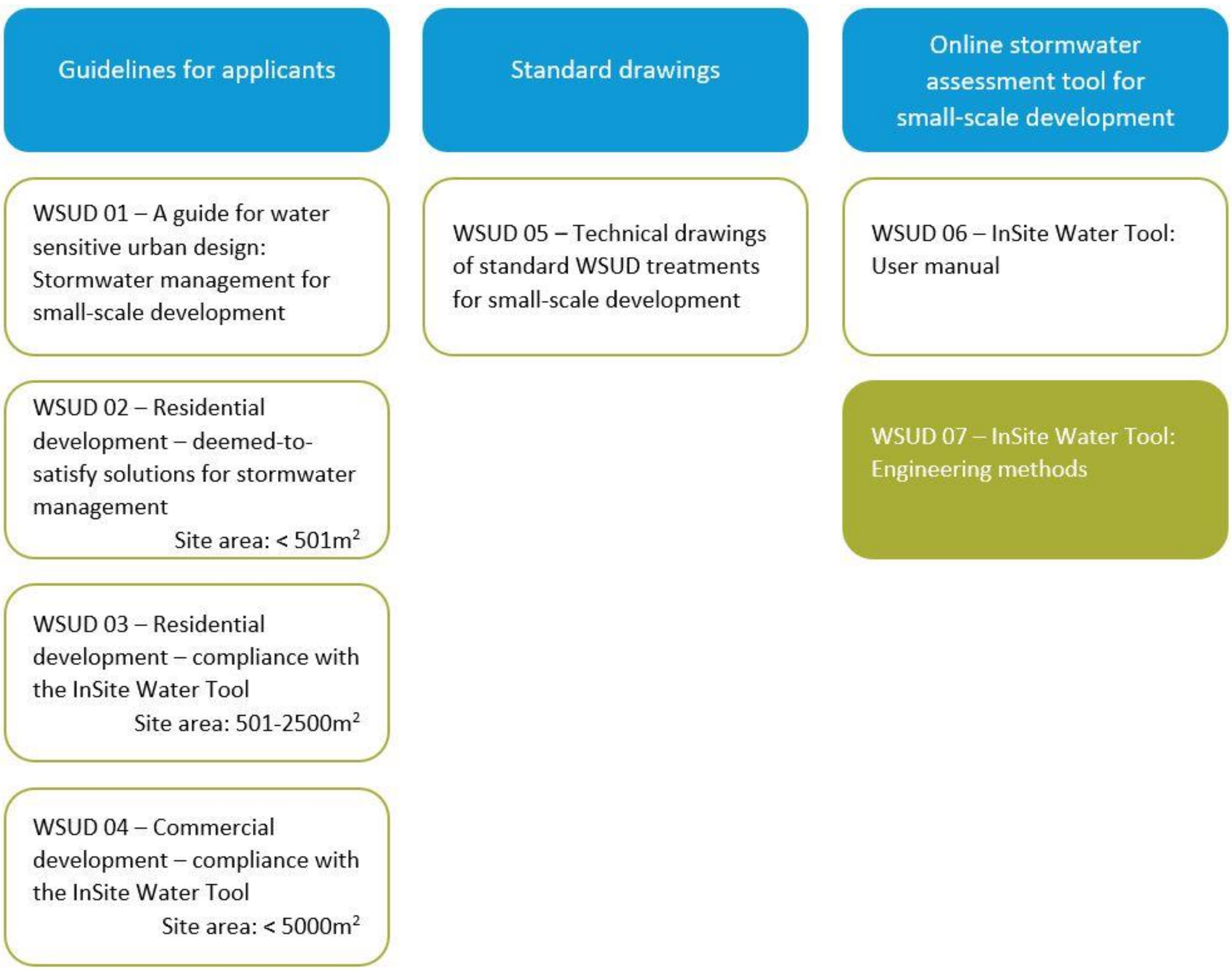

Figure 1: Water sensitive urban design resources for development applicants

2 Overview of approach

Each of the four sections of this document addresses one of the InSite Water Tool performance targets separately: VOLUME, QUALITY, FLOW and EFFICIENCY. Achievement of all four performance targets is required for any small-scale development to receive an overall certificate of compliance within the InSite Water Tool.

The analysis for the Tool is based upon equations provided within *Melbourne Water's Water Sensitive Urban Design (WSUD) Engineering Procedures* (CSIRO Publishing 2005), the Melbourne Water STORM tool, the new *Australian Rainfall and Runoff Guide* (AR&R 2016) as well as Australian stormwater industry best practices such as the retention sizing work from John Argue and the Natural and Built Environments Research Centre, University of South Australia. See Figure 2 for an overview of the methodology for the Tool.

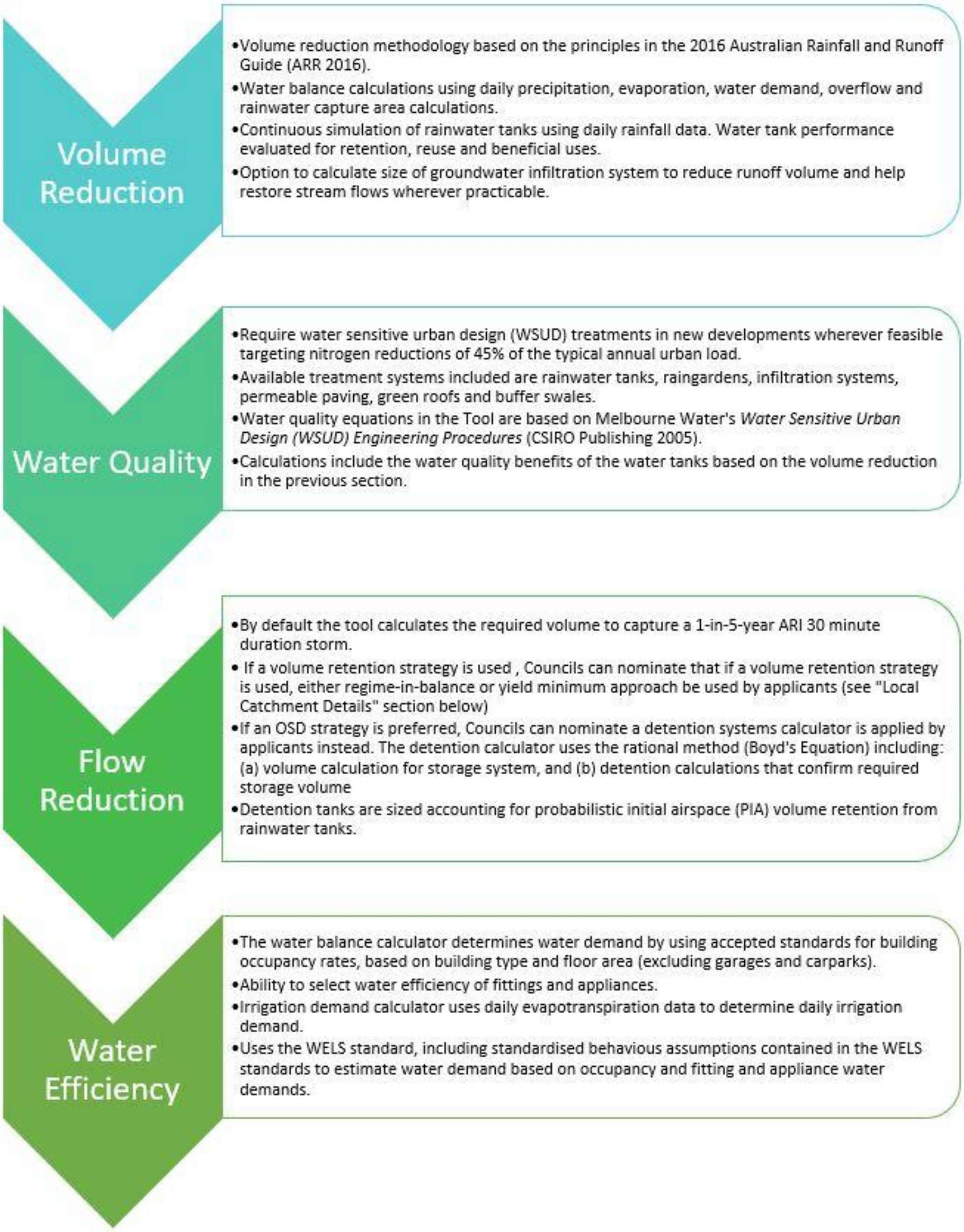

Figure 2: InSite Water Tool for stormwater management methodology high-level outline

Given the different calculation methods for each performance objective outlined in Figure 2, a range of different rainfall and design storms have been applied within the InSite Water Tool as indicated in Table 1.

Table 1: Summary of rainfall data and design storms used in InSite Water

Performance objective	AEP	Rainfall data period	Time step	Design storm
Volume reduction	n/a Continuous simulation model	20 years of daily rainfall data	Daily water balance	n/a Continuous simulation model
Water quality	n/a Continuous simulation model	10 years of rainfall data	6 mins	n/a Continuous simulation model
Flow reduction	20% (residential) 5% (commercial)	Event based (rational method) using 2016 Australian Rainfall and Runoff (ARR) IFD data	Event based (rational method)	30 minutes
Water efficiency	n/a Continuous simulation model	20 years of daily rainfall data	Daily water balance	n/a Continuous simulation model

3 Volume

A large portion of this section of the Tool is centred upon volume retention and reducing directly connected impervious areas, with such features fundamental to calculate stormwater quality.

Volume reduction is calculated using continuous simulation of the site's water balance. The simulation runs 20 years of daily rainfall and evaporation data.

The data is from the Bureau of Meteorology, and it is taken from the local Council's forecast area (See Figure 3 below).

Continuous simulation Data loaded automatically based on the user selected local Council.

See the Bureau of Meteorology's South Australia Forecast Area Map for more information about forecast areas.

The tool divides areas into forecast zones to simplify the load on the web server, and forecast zones are deliberately designed to match local climate and rainfall patterns. The forecast zones have been set up by the Bureau of Meteorology as a close match to both average rainfall zones and to Council boundaries.

Disclaimer: Sensitivity analysis shows that there is little difference to the outcomes of the tool from the minor variations of weather and rainfall within the forecast zones. The purpose of the tool is for benchmarking designs against standards, Council approvals and schematic design of stormwater. For engineering detailed design and hydrological flood modelling, we recommend using more powerful desktop specialist hydrological modelling software such as EPA SWIMM or MUSIC.

Figure 3: South Australia Forecast Area Map. Source: Commonwealth of Australia 2017, Bureau of Meteorology – http://www.bom.gov.au/sa/forecasts/map.shtml

Table 2: Additional details on volume reduction continuous simulation algorithms

Item	Methodology
Approach to volume reduction	Volume reduction is based on volume runoff for all impervious areas. This is based on a predetermined (see flow reduction section) or user selected storm intensity and duration. Volume reduction is set as a percentage of total impervious area runoff volume retained by the water tank and any infiltration devices. The volume reduction targets is that annual average volume should be the same as the pre development level. An allowance of 10% over pre-development levels is allowed to account for uncertainties. In addition, Councils can nominate a higher target for individual applications if the local drainage system warrants it. These would correspond to: 60% – Best Practice (redevelopment sites in constrained catchments); and 90% – Excellent practice (for sites near high value streams and in areas with little or no additional capacity left in the stormwater system). Volume retention targets are based on the new *Australian Rainfall and Runoff Guide* (ARR) (Engineers Australia 2016) and the *Urban stormwater best practice environmental management guidelines* (BPEM, CSIRO Publishing 1999)
Continuous simulation of rainwater tanks	Continuous simulation picks up the variables of roof area connected, tank size, drawdown (water use), overflow and first flush. The simulation will run over a period of 20 years of daily rainfall data. The formula used is The model uses water balance equations to calculate the reliabilities and water savings as described below. $R_t = D_t$; if $I_t + S_{(t-1)} \geq D_t$ (1) $R_t = I_t + S_{(t-1)}$; if $I_t + S_{(t-1)} < D_t$ (2) Here D_t is the daily water demand in m^3 for each day; $S_{(t-1)}$ is the final storage in the tank (m^3) for the previous day; R_t is the release from the rainwater tank for each day (m^3) and I_t is the inflows into the rainwater tank from the roof catchment each day (m^3). The spill from the rainwater tank (SP_t) is also necessary to calculate the current day storage in the rainwater tank based on equations (3) and (4): $SP_t = I_t + S_{(t-1)} - D_t - SMAX$; if $I_t + S_{(t-1)} - D_t > SMAX$ (3) $SP_t = 0$; if $I_t + S_{(t-1)} - D_t \leq SMAX$ (4) Here SMAX is the design storage capacity of the tank (m^3). The final storage for each day (S_t) is calculated using (5) and (6): $S_t = SMAX$; if $SP_t > 0$ (5) $S_t = S_{(t-1)} + It – R_t$; if $SP_t = 0$ (6) The adopted definition of reliability is the ratio of days where the RWH system can supply the intended demand without mains top-up against the total number of days simulated in the modelling, and the water savings is the total amount of harvested water used in a year on average. The volume reduction is the total amount of water used. The overflow is the amount that overflows divided by the volume that falls on the collection area.
Water balance	Water demand is calculated using a standard set of behaviours and with the water demand of user chosen fittings. Default water efficient fittings have been selected for good outcomes, however, these can be adjusted. For example, the water demand of a toilet will be: number of occupants x water use per flush x usage (1 full flush : 4 half flushes per person) The water savings are calculated by comparing a benchmark building with industry standard fittings compared to modelled fittings. For example, the standard toilet is a three star toilet (minimum requirement of the plumbing code of Australia). Water savings are achieved if the user selects a four or five star WELS rated toilet (www.waterrating.gov.au). This is the same methodology as used by other water efficiency tools such as Green Star (www.gbca.org.au) and BESS (www.bess.net.au) See below EFFICIENCY section for more detail on the default WELS ratings.

Item	Methodology
Irrigation demand	The water balance calculator also has an irrigation calculator to calculate seasonal irrigation demand based on rainfall and evaporation data, the efficiency of the watering system used and the area of irrigation required. It is important that irrigation demand is worked out accurately using daily weather data, as watering hooked up to rainwater tanks will greatly alter the water balance of a water tank. The irrigation methodology is as outlined by irrigation average monthly values, which are in turn based on demand requirements as determined by Efficient irrigation: A reference manual for turf and landscape (Connellan 2002) Note: If there is supply available via a purple pipe scheme, demand will be assumed to always be met by that alternative supply, however if the supply is via a rainwater retention tank, then the model will only assume irrigation demand is met by the tank if the tank has sufficient storage.

Algorithm notes: Occupancy profile

Occupancy is required to work out the building's water demand as part of the volume and efficiency calculations.

InSite Water uses the relevant Building Type to calculate average Occupancy Profile.
Estimated Building Occupancy = Maximum Peak Occupancy x Occupancy Hours Profile x Building Size.

- Maximum occupancy can be found in BCA Volume 1, Table D1.13 'Area per Person According to Use'

Occupancy Profile is the average % of people using the building at any one time (occupancy hours profile) as defined within the BCA Section J.

Table 3: Building Class of Australia occupancy profiles.

BCA Class	Building type	Average occupancy profile (based on a Building Peak Occupancy = 1)
Class 1	Individual dwellings	1
Class 2	Apartments	0.9
Class 3	Hotel or other residential building	0.6
Class 4	Penthouse or dwelling in a non-residential building	0.9
Class 5	Office	0.4
Class 6	Shop, restaurant or retail	0.3
Class 7	Industrial or storage	0.4
Class 8	Industrial laboratory or process building	0.4
Class 9	Public buildings	0.5
Class 9A	Healthcare	0.8
Class 9B	School or childcare	0.3
Class 9C	Aged care building	0.6
	Maximum occupancy – 100% occupied 24/7	2

4 Flow

Discussion of the flow reduction strategy and the 2016 ARR standard

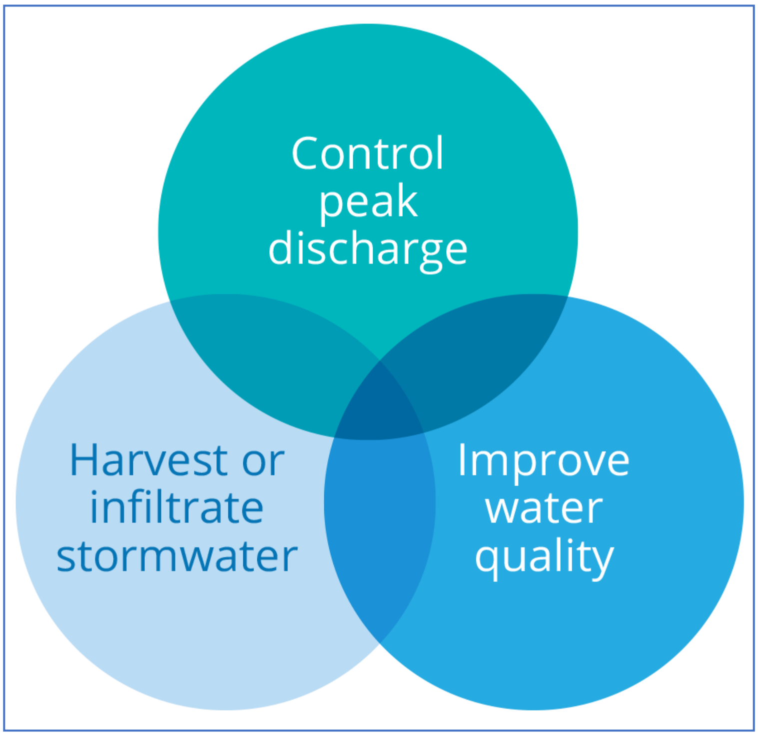

Figure 4 Potential overlapping volume management design objectives (ARR 2016 figure 9.4.1.)

In 2016, Engineers Australia released the new ARR 2016 guide – a guide to flood estimation. ARR is the main standard used by civil engineers and hydrologists in Australia for design of stormwater infrastructure. This is the first major update of this standard since 1987, and it is a step change in how stormwater infrastructure is designed. In the last 30 years, stormwater approaches have evolved significantly, and the 2016 ARR guide introduces multiple objectives as well as flood mitigation (e.g. resilience, WSUD, liveability, sustainability and affordability) and the perspective of other disciplines such as aquatic ecology and landscape design[1].

Strategic use of water efficiency, rainwater, stormwater infiltration and wastewater recycling at multiple scales can supplement the performance of centralised water supply and drainage systems to provide more sustainable and affordable outcomes (ARR 2016). These integrated strategies reduce the requirement to transport water, stormwater and wastewater across regions with associated reductions in costs of extension, renewal and operation of infrastructure. In particular, the concept of volume management has been emphasised (ARR 2016, Book 9, Ch. 4). The historical practice of designing urban stormwater systems has focused on peak flows, stormwater detention, and conveyance in hydraulically efficient pipes and channels. It is now recognised that volume of stormwater runoff, urban amenity and water quality treatment also need to be managed.

The ARR 2016 guide discourages the use of stormwater detention to limit flow rates in favour of volume management (which in the InSite Water Tool is called Flow Retention), except in clear cases where existing local street level pipe infrastructure needs protection in the face of increased imperviousness through ongoing urban redevelopment.

Typically, this is achieved through design and installation of volume management and water treatment devices, such as rainwater retention tanks, rainwater infiltration systems, and unlined biological treatment devices such as raingardens, tree pits and bioswales.

The design of volume management and stormwater treatment trains must include objectives that are relevant to the site, the surrounding catchment and receiving waterways. An adequate number of facilities are required to be built and maintained in catchments to ensure that stored, harvested or infiltrated

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[1] Engineers Australia (2016) *Australian Rainfall and Runoff: A guide to flood estimation*, Book 9, Chapter 3 Philosophy of urban stormwater management. Viewed online on 20/12/2016 at http://book.arr.org.au.s3-website-ap-southeast-2.amazonaws.com/

stormwater will significantly reduce peak discharges at catchment outlets, or where existing downstream infrastructure is overwhelmed by redevelopment.

Table 4: Further details on FLOW algorithms

Item	Methodology
IFD – Intensity Frequency Duration	Intensity Frequency Duration data is from the 2016 IFD located at http://www.bom.gov.au/water/designRainfalls/ IFD data has been collected for each Council. The data is automatically entered by the site for when the user selects their Council location. The 2016 IFDs provided here because they are: based on a more extensive data base (than the 1987 IFDs), with more than 30 years of additional rainfall data and data from extra rainfall stations; more accurate estimates, combining contemporary statistical analysis and techniques with an expanded rainfall database; and better estimates of the 2% and 1% annual exceedance probability IFDs than the interim 2013 IFDs or the old 1987 IFDs. Note: The new BoM IFD data uses AEP, which replaces ARI. AEP and ARI are both a measure of the rarity of a rainfall event: Average Recurrence Interval (ARI) is defined as: "The average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration." It is implicit in this definition that the periods between exceedances are generally random. Annual exceedance probability (AEP) is defined as: "The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year." The translation equation is: AEP = 1 – exp(-1/ARI) There is also the terminology Exceedances per Year or EY, which aligns directly with ARI. E.g. a 5-Year ARI = a 0.2 EY For the tool, we have mostly used the more widely understood ARI terminology. In the equations in the tool we have used the following translation: 1 in5-year storm equates to a 18.13% AEP or 0.2 EY 1 in 20-year ARI corresponds to a 5% AEP 1 in 100-year ARI corresponds with a 1% AEP.[2]. Further discussion of stormwater terminology can be found in Book 1; Chapter 2; Section 2.2 Terminology of ARR 2016 http://arr.ga.gov.au/arr-guideline
Approach to flow reduction	Flow reduction is based on applying the rational method for the site. Please note there are many rational method variations for sizing detention and drainage infrastructure, so our calculator may occasionally give different sizing estimates to other software or proprietary spreadsheets. Our method is based on industry standard techniques and procedures as outlined in the ARR (Engineers Australia 2016). The tool is set by Default to use 'RETENTION', but it can also be set to calculate 'DETENTION' labelled OSD in the tool. See below for further discussion of these two methodologies. See 'Retention Calculator' and 'Detention Calculator' sections below for more detail on equations and parameters used in the tool.

[2] New ARR probability terminology, Engineers Australia's National Committee on Water Engineering http://arr.ga.gov.au/__data/assets/pdf_file/0006/40398/New-ARR-Probability-Terminology_final.pdf

Item	Methodology
Antecedent conditions	The applies a nominal Probable Initial Available Storage (PIAS) to water retention tanks as 33%. The tool does not calculate PIAS directly, it is assumed, for the purposes of this modelling, that for storms with an ARI of 5 years and greater the water tank will have one-third of the capacity available for stormwater detention. This assumption is supported by detailed analysis by Coombes and Barry (2008) that utilises continuous simulation (using PURRS modelling[3] software) and virtual storage volumes to determine a PIAS. PIAS is the likely headspace available in a rainwater tank prior to a storm event of a given ARI[3]. The Coombes and Barry analysis shows the likely PIAS with irrigation to be two-thirds of the volume. The InSite Water Tool has taken the more conservative and industry standard value of one-third as it is less likely that irrigation will be required in medium and high-density developments.
Reporting	This tool is intended for preliminary sizing by building designers, and then for further checking by a qualified stormwater professional. The tool cannot account for basic user errors such as expecting water to flow up hill (not checking site relative levels). However, the tool does include aa report generation function that provides tool inputs and outputs to facilitate easier checking by Council and stormwater professionals of on-site designs.
Additional detailed drainage design Items	Future upgrades may include additional separate tools that would be useful for stormwater design professionals such as pit and pipe sizing tools, orifice sizing and specification generations. These would be in a separate 'qualified engineer / hydrologist only' section of the website to avoid confusing non-qualified users.
Climate change	This report has not modelled climate change impacts, other than adopting the latest IFD curves from ARR, however, future upgrades of this project can propose ways that climate change adaptation measures can be built as a function of the tool's methodology.

Retention calculator – Stormwater Volume Management

This tool has used guidance for the use of infiltration trenches and infiltration wells. The methodology is complex, and it is outlined in *WSUD: Basic procedures for "source control" of stormwater – a handbook for Australian practice*[4]. Further guidance is also outlined in the Water Sensitive SA publication, *A guide for water sensitive urban design: Stormwater management for small-scale development*.

An extract from the *ARR 2019 Book 9 Chapter 4 Guideline*[5] is as follows:

> *There is considerable legacy terminology used to describe these facilities including detention (or retarding), retention, extended detention or slow release. These terms are a derivative of outlet structures and different operational strategies that change the behaviour of stormwater storages.*
>
> *Stormwater storages designed in accordance with 'detention' practices include those where runoff is temporarily stored and simultaneously released via an outlet structure. This process typically lowers peak discharge and attenuates the hydrograph so that the average time of*

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[3] Coombes PJ and Barry ME (2008) *Determination of available storage in rainwater tanks prior to storm events*. Water Down Under 2008

[4] Argue JR (2004/2013) *WSUD: Basic procedures for "source control" of stormwater – a handbook for Australian practice*. Urban Water Resources Centre, University of South Australia.

[5] *ARR Book 9 Chapter 4* Published online (June 2019) at http://www.arr-software.org/pdfs/ARR_190514_Book9.pdf

release is delayed. The storage volume and capacity of the outlet must be determined by catchment wide modelling to achieve target outflow peak discharges at the catchment outlet.

Stormwater storages designed in accordance with 'retention' practices provide sufficient storage in the volume management facility to contain additional runoff from urban development. The volume of stored stormwater is then drawn down by infiltration, harvesting or slow release. Typical hydrographs of flows from a rural catchment and subsequent urban development of the catchment are presented in the Figure below. Inflow and outflow hydrographs which apply to a volume management facility used in a typical retention strategy, are shown below.

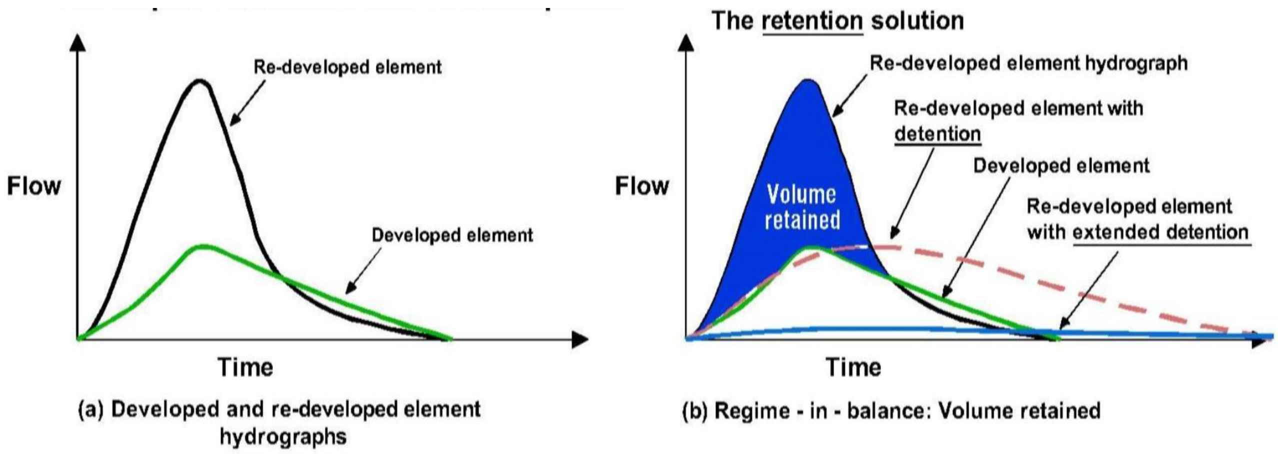

Figure 5 Hydrographs of retention methodology vs detention methodology with developed catchment with 'redevelopment'[6]

Detention calculator

Increase in stormwater runoff may be attributed to changes in land use for urban development. Building hard, impervious, surfaces such as roofs, paving and site drainage increases the volume and speed of stormwater runoff. Such surfaces also reduce the permeability of the site and thus the capacity of stormwater to soak into the ground.

Given limitations with respect to the capacity of existing stormwater drainage systems, a requirement to install on-site stormwater detention or retention is warranted to ensure that stormwater runoff does not increase flooding on the premises or further downstream.

Providing onsite stormwater detention delivers temporary storage of stormwater runoff which allows for control of volume and runoff rate, ensuring that there is limited overload to the receiving system. Location, size and subsequent impact of the development are all factors that InSite Water aims to take into consideration when determining the required size of storage and rate of discharge.

InSite Water currently uses Boyd's Equation as it was found to give a conservative but reliable estimation of OSD volume, when tested alongside four other methods, including the Modified Rational Method, Swinburn Method, Basha Method (1994) and Aron and Kibler Method. The outputs of modelling OSD requirements

[6] *Use of WSUD 'source control' practices to manage floodwaters in urbanising landscapes: developed and ultra-developed catchments* Authors: John R Argue* and David Pezzaniti**
*Adjunct Professor of Water Engineering
**Senior Research Engineer Centre for Water Management & Reuse, University of South Australia

using Boyds formula with a range of storm durations is shown in the calculation report generated by InSite Water. The outputs of modelling Boyds formula with a range of storm durations is shown in the calculation report generated by InSite Water.

Boyds equation:

$S_{max} = V_1 (1 - Q_p / L_p)$

Where

S_{max} = Maximum Volume of Storage (m^3)

V_1 = Volume of inflow (m^3)

L_p = Peak discharge of inflow hydrograph (m^3 / sec)

Q_p = Peak discharge of outflow hydrograph (m^3 / sec)

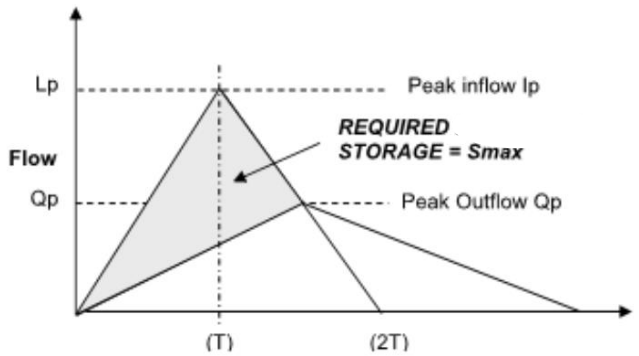

Figure 6: Diagram outlining Boyds Equation hydrograph

Site Analysis and Calculating Permissible Site Discharge (PSD)

The following component serves as a summary of the Detention Calculator section. It provides a conservative detention tank size estimated for preliminary design purposes only (represented by the figure denoted in m^3 as 'Preliminary Detention Tank Size Estimate'). The figure takes into consideration total detention from earlier input categories including 'Rainwater Tanks and Recycled Water Connections' with respect to rainwater tank allowance and freeboard, as well as, the post development total impervious area as earlier indicated under the 'Stormwater Quality' section.

Note: With respect to OSD methodology, the calculations are based on a standard modified rational method adopted from the Australian Rainfall and Runoff Guidelines (2001).

Runoff Coefficient – Pre and Post Development Details

The tool automatically specifies pre and post development details to determine respective runoff coefficients. This is particularly required for post development consideration which is linked to specifying the site's storage size requirement.

The base case (pre-development) assumes no existing OSD or rainwater tank storage, and that all impervious areas are directly connected to the Council stormwater drainage system.

Table 5: Runoff coefficient and AEP/ ARI data requirements that are required to be obtained from the local drainage authority to determine respective results.

<table>
<tr><th>Input category</th><th>Details</th></tr>
<tr><td>Base Case (Pre-Development) Design Storm</td><td>The base case pre-development design storm is 30 minutes.
Refer to Critical Storm Duration Tc (Catchment) defined in Table 6 for an explanation of why this design storm has been chosen.</td></tr>
<tr><td>Post Development Detention Requirement (Site Storage Requirement)</td><td>The detention storage requirement is calculated using Boyds Equation and standard Rational Method PSD calculations.
Non-residential developments will require marginally larger storage volumes than residential to meet the more stringent requirements for Commercial and Industrial drainage.
- The runoff coefficient is designed to align with the FLOW Performance objective in the WSSA Guide WSUD 01 | A guide for water sensitive urban design: Stormwater management for small-scale development:
- Guideline objective 2.1: Stormwater flow management performance measure – residential development
• Post development peak rate of runoff from the development site for the critical design storm shall not exceed that from the pre-development site from a 5-year ARI (0.2 EY / 18.13% AEP) storm event.
• This option is automatically loaded if in the ‘New development type’ drop-down menu ‘Non-residential development’ <u>is not</u> selected.
- Guidelines objective 2.2: Stormwater flow management performance measure – commercial, industrial and institutional development
• Post development peak rate of runoff from the development site for the critical design storm shall not exceed that from the pre-development site from a 20 year ARI (5% AEP) storm event.
• This option automatically loaded if in the ‘New development type’ drop-down menu ‘Non-residential development’ <u>is</u> selected.</td></tr>
<tr><td>Base Case (Pre-Development) Fraction Impervious (Ratio)</td><td>Pre-development fraction impervious is selected by the user based on the existing site details:
<table><tr><th>Type</th><th>Fraction impervious</th></tr><tr><td>Undeveloped (greenfield)</td><td>0.2</td></tr><tr><td>Residential site area > 750m² per dwelling</td><td>0.4</td></tr><tr><td>Residential site area, 501m² - 750m² per dwelling</td><td>0.5</td></tr><tr><td>Residential site area, 350m² - 500m² per dwelling</td><td>0.6</td></tr><tr><td>Residential site area < 350m² per dwelling</td><td>0.7</td></tr><tr><td>Commercial (including car parks)</td><td>0.9</td></tr><tr><td>Industrial</td><td>0.8</td></tr></table></td></tr>
<tr><td>Base Case (Post-Development) Fraction Impervious (Ratio)</td><td>Base Case Post development fraction impervious (ratio) default values:
<table><tr><th>Type</th><th>Fraction impervious</th></tr><tr><td>Residential</td><td>0.4</td></tr><tr><td>Commercial (including car parks)</td><td>0.9</td></tr><tr><td>Industrial</td><td>0.8</td></tr></table></td></tr>
</table>

	Notes: (i) Local drainage systems are designed to cater for a certain fraction imperviousness, typically in a range 0.2 to 0.5 for residential areas. (ii) Runoff coefficient is then calculated based on the rational method equations in the ARR 1987 guide. Note: no detailed guidance on the Rational Method is provided in ARR 2016. (iii) the actual Post-Development Runoff Coefficient is based upon on the total impervious areas entered into the tool.

Other detention tank design details

Default values have been provided and calculated in order to determine the rainfall intensity at the catchment area and at the site specified in millimetres per hour (mm/h). The rainfall intensity values are used to indicate and specify the 'Peak Post Development Flow', 'Runoff Volume' and 'Stored Volume' that is momentary contained within the detention tanks during storm events and is gradually discharged over time (as specified in section Detention Calculator – Site Storage Requirement (SSR)).

Table 6: Default detention tank design details that may be adjusted based upon sourcing valid and reputable independent data.

Input category	Unit	Details
Permissible Site Discharge (PSD)	L/sec	Based on previous inputs, the rational method is used to calculate the maximum allowable discharge leaving the site in litres per second (L/sec). This value has been calculated given by the earlier inputs provided. PSD Permissible site discharge is calculated to provide the peak flow rates of the development with varying fraction impervious F_{imp} (pre-development). Q = C I A / 360 (m3/S) or Q = C I A / 0.36 (l/s) Where: Q = peak flow rate (l/s) C_{10} = runoff coefficient for a 1-in-10-year storm. I = rainfall intensity from BoM IFD data (mm/h) A = site area (hectares) and $C_{10} = F_{imp}*0.9+(1-F_{imp})*C_{10}(1hour)$ For more details see the Australian Rainfall and Runoff Guide (2016) http://arr.ga.gov.au/arr-guideline PSD uses 10% AEP (~ 1 in 10-year ARI) that can then be adjusted with an intensity factor to other storm intensities
Critical Storm Duration Tc (Catchment)	mins	Default data is 30 minutes. A time of concentration of 30 minutes (best practice) has been selected based on industry consultation and workshops. This is opposed to a time of concentration of 5 minutes (standard industry practice). The 30-minute Tc equates to the critical infrastructure the detention performance objective is applied to protect – being Council pipes within about 3.6km of the site, assuming water is flowing at 2m/s.

Input category	Unit	Details
		Further discussion on-site time of concentration is included in Section 5 – of the WSSA Detention Scenario analysis report (unpublished) [7].
Rainfall Depth (mm) for Critical Storm Duration Tc (Catchment)	mm	Default values are provided based on the local area that was provided when inputting generic Project Detail specifications. If adjusting the default data provided, enter Intensity-Frequency-Duration (IFD) data (rainfall depth in millimetres) for a duration of concentration closest to the 'Critical Storm Duration'. Data is available from the Bureau of Meteorology. **Note:** The rainfall depth should match a storm with: A 20% AEP (~1 in 5-year ARI) for residential developments A 5% AEP (1 in 20-year ARI) for commercial developments. Within the tool the 20% AEP rainfall depth is converted to other storms using standard ARR 1987 rational method methodology. The tool applies a 1 in 5-year or a 1 in 20-year ARI depending on the type of project selected on the first page. This is according to our agreed performance objective 2 in section 1.2 of the InSite Water GUIDE.
Site Time of Concentration Tc (Site)	mins	Default data is 10 minutes. The duration in which it takes water to flow through the site.
Rainfall Depth Tc (Site)	mm	Intensity-Frequency-Duration (IFD) data (rainfall depth in mm) for a 10-minute duration storm with a 10% AEP (~ 1 in 10-year ARI) for the Council area that was earlier specified. This is converted to 1 in 5 years mathematically using standard rational method calculations. This factor is then used in the Boyd's equation formulas.
Tank based detention		The tool provides an option of traditional dedicated tank-based detention with a portion of the tank being nominated as 'headspace' above a leaky orifice. The tool will include a simplified 'orifice calculator' to make sizing an orifice for a desired maximum flow rate easier. The tool will recognise tank-based detention as meeting the entire requirements of the design, or as an offset to an additional underground detention if required.

[7] Water Sensitive SA and Organica Engineering (2017) *Online stormwater assessment tool for small-scale infill development: Milestone 1 Report A comparison of Council engineering requirements, current best practice stormwater management and practitioner needs in the greater Adelaide Region*. Unpublished but available on request from Water Sensitive SA.

Detention Calculator – Site Storage Requirement (SSR)

IFD rainfall depth data (rainfall depth in mm) for a storm with the duration as shown and a 10% AEP (~1 in 10 year ARI) for your Council. Site specific data is available from the Bureau of Meteorology

Storm Duration (mins)	Enter Rainfall depth (mm)	Peak post development flow (l/s)	Runoff volume (m3)	Stored Volume (m3)
5	9	10.71	4.28	2.92
10	11.79	7.02	5.62	2.9
15	14.39	5.71	6.85	2.77
30	19.14	3.8	9.12	0.96
60	24.29	2.41	11.57	0
120	30.42	1.51	14.5	0

Figure 7: Site storage requirement results influencing the preliminary detention Tank Size Estimate whereby Rainfall Depth figures may be altered dependent on the storm. This is not shown to the end user, but the results are available in the detailed calculation report.

5 Quality

The water quality section is based on established methodologies developed by Melbourne Water. We can provide a quite simple user interface, at the same time undertaking very advanced stormwater quality analysis based on continuous simulation of standard water treatment items. This approach of simplifying the interface while retaining back end engineering rigour has been used successfully in Victoria for over a decade in the STORM tool, which is widely used to size water treatment installations on private redevelopment sites.

On the basis of treating the site as a post-development, InSite Water will calculate the stormwater quality rating for both:

- The rainwater tanks, independently, with respect to the entire site coverage; followed by,
- An overall stormwater quality assessment for the entire site, incorporating the additional WSUD features specified.

Overall results specify the total impervious area of the site, alongside the total nitrogen and suspended solids reduced as runoff to respective waterways due to the WSUD features that have been incorporated within the development.

A robust framework representing best practice standards and objectives are set out in the *South Australia Water Sensitive Urban Design Policy* (Department of Environment, Water and Natural Resources, 2013) for reduction in total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN) loads for post-construction phase developments. indicates the objectives that align with state-wide performance targets representative of best practice. The outputs produced by InSite Water rare cognisant of such objectives and targets. Alternatively, if the site is larger the 5000m^2, the MUSIC software package can be used to demonstrate compliance[8].

Table 7: Methodology for pollutant removal calculations.

Item	Methodology
Approach to water quality	Water quality is based on the targets outlined in *Urban stormwater: Best practice environmental management guidelines* (CSIRO 1999. Electronic edition published by CSIRO PUBLISHING, 2006). These are the same targets that are referenced in the SA WSUD policy (Water sensitive urban design – Creating more liveable and water sensitive cities in South Australia, DEWNR). The final tool will adopt the following pollution reduction targets: • Suspended solids (SS) – 80% retention of the typical urban annual load. • Total phosphorus (TP) – 60% retention of the typical urban annual load. • Total nitrogen (TN) – 45% retention of the typical urban annual load. • Litter – 90% retention of typical urban annual load. These targets have been set within state policy within *Water sensitive urban design: Creating more liveable and water sensitive cities in South Australia* (SA WSUD Policy). The policy is underpinned by the B Myers, et. al. (2011), *Interim water sensitive urban design targets for Greater Adelaide*, Goyder Institute for Water Research Technical Report Series No. 11/7. This report represents the most recent assessment of performance-based stormwater runoff quality measures for Greater Adelaide. The pollution reduction targets may be refined over time as further catchment-based data and information becomes available.

[8] MUSIC is a commercial software package produced by eWater https://ewater.org.au

Item	Methodology
	Subsequent work by Rouse K, et al (2016) *New modelling capability to target stormwater interventions that support seagrass health along Adelaide's coast*, Goyder Institute for Water Research Technical Report Series No. 16/9, Adelaide, South Australia, places increasing importance on the role of sediment in the degradation of coastal sea grass habitats.
Water Quality Calculation Methodology	Water quality calculations are very similar to the Melbourne Water STORM tool. The storm tool can be viewed online at https://storm.melbournewater.com.au/ The storm methodologies are useful as they are designed for web-based toolkits. For advanced pollution abatement modelling, desktop software such as MUSIC should be used. These are established methodologies used for nearly ten years in Victoria for on-site systems. STORM methodologies, and this toolkit are based on the *WSUD engineering procedures: Stormwater: Stormwater* (Melbourne Water 2005, Kindle Edition available at https://www.amazon.com.au/dp/B004Z4OS7I/ref=rdr_kindle_ext_tmb)
Inputs and outputs	Users are asked to input the following for each impermeable area on the site: • Impermeable area name; • Impermeable area size (m^2); • Treatment Type (e.g. raingarden, infiltration) • Treatment size The calculator then returns the % reduction in Nitrogen achieved by the various treatments. Phosphorus, Litter and Total Suspended Solids may be calculated in future upgrades.
Water Tank pollutant removal	The calculator also calculates the water quality performance of the water tank by subtracting the pollutants contained in the retained tank water.
Best practice benchmark score	A 'STORMWATER' score is also given as a target. The target is to remove 45% of nitrogen, which achieves 100 'STORMWATER' points. Nitrogen is difficult to remove because it is soluble in water, and generally requires tertiary treatment to reduce its levels in stormwater runoff, or nitrogen can be reduced proportional to the percentage of stormwater runoff re-used via rainwater tanks or infiltration systems. Nitrogen is a good proxy for removal of other pollutants as it is generally the most difficult pollutant to remove. If the total nitrogen reduction target is achieved, it is deemed to be a good indicator that other pollutant targets have been achieved.
Limitations	This tool cannot model larger catchments (above 0.5 hectares use the MUSIC software). The pollution reduction targets may be refined over time as further catchment-based data and information becomes available. The inclusion of proprietary water treatment systems for water treatment is being investigated, but are not currently able to be included as a WSUD treatment measure in the tool.

Stormwater quality score calculation details

The stormwater quality score is determined using lookup tables of treatments, as a percentage of the entered impervious areas. Treatments can be any size between 0% and 8% of the size of the impervious area.

The tool uses a lookup function to draw on pre-modelled treatment area curves. The treatment lookup algorithm is as follows:

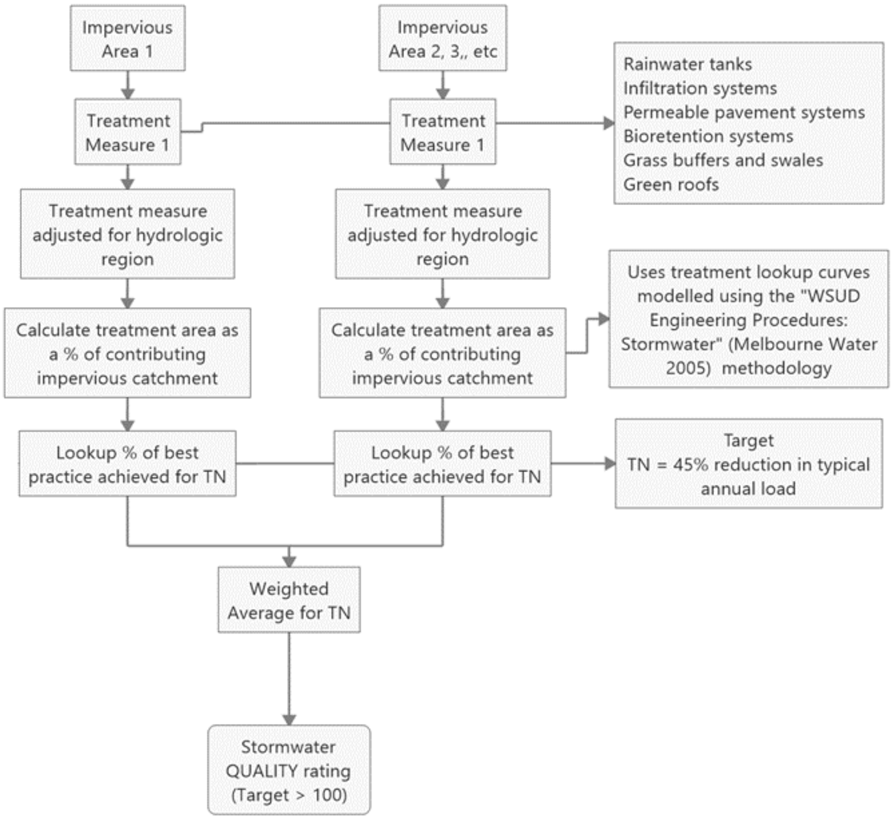

Figure 8: Stormwater quality determination algorithm

If more than one impervious area and treatment area is entered, the calculator determines the overall stormwater QUALITY rating for the site based on the weighted average of the ratings for each treatment measure.

The weighted average is determined by multiplying the individual contributing impervious areas for each treatment measure by the individual lookup curve score for each treatment measure. The sum of these values for all of the treatment measures is then divided by the sum of the impervious areas.

The score for rainwater tanks is determined by reducing the total nitrogen by the amount of stormwater diverted from stormwater by the water tanks. For example, if the rainwater tanks divert 45% of stormwater from the stormwater drainage system, then the nitrogen pollution will be reduced by 45%.

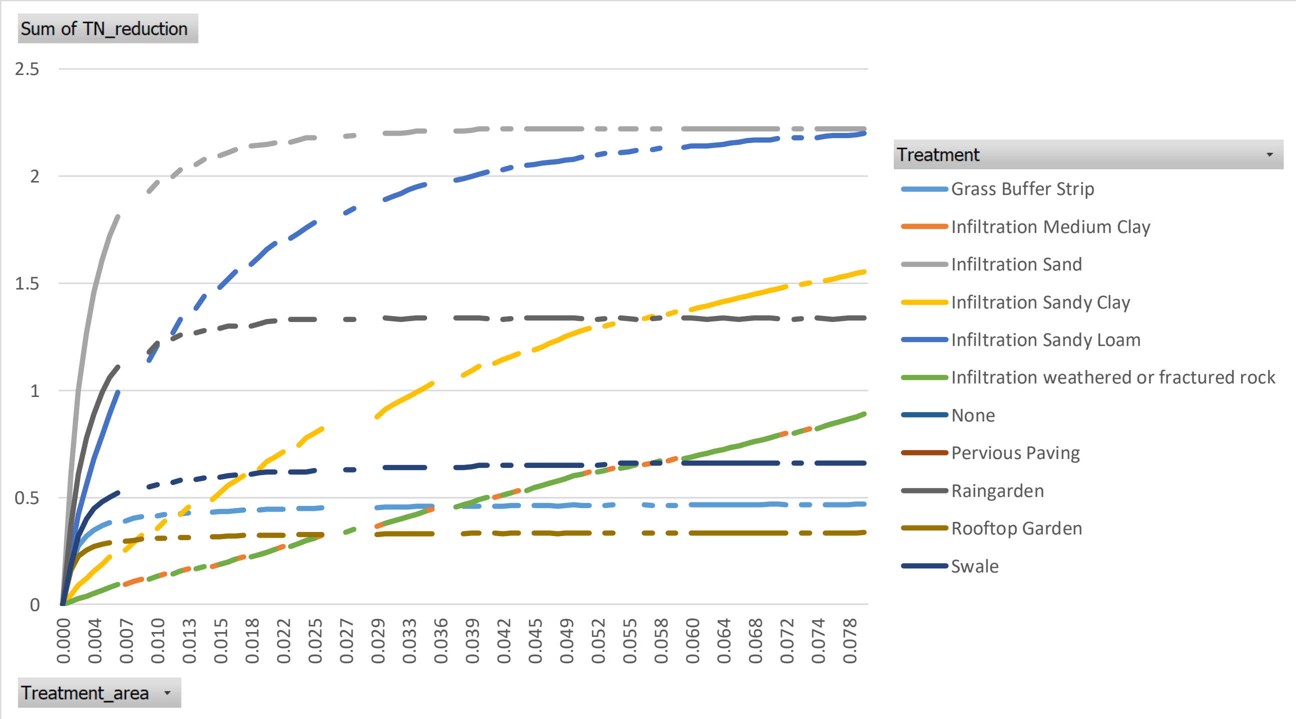

Figure 9: Total nitrogen treatment response curves for the various treatment types. The Y Axis is the % nitrogen reduction divided by the 45% target, and the X-Axis is the treatment size as a % of the impervious area.

Sites must achieve an equivalent score of 100 to pass this category indicating that the total nitrogen reduction is greater than 45% of the typical annual load received by waterways and thus complies with the Best Practice Performance Objectives. The calculator rates the performance of treatment measures by calculating the performance of treatment measures relative to the percentage of pollutant reduction targets that have been achieved by the treatment measures.

The percentage nitrogen reduction is converted into a STORMWATER QUALITY score using the equation

STORMWATER SCORE = (TN reduction % / 45) x 100

OR

TN reduction % = STORMWATER SCORE x (45 / 100)

For example, using this equation a STORMWATER SCORE of 80 would equate to a 36% reduction in Nitrogen runoff. The water quality calculations are limited to sites where impervious areas are over 40% so this tool is not suitable for low density developments.

6 Efficiency

In order to maximise water efficiency and support volume reduction it is encouraged for developments to incorporate water efficient appliances. The Water Efficiency Labelling and Standards (WELS) scheme is an Australian Federal system established to rate appliances based on their water efficiency and assigning a relevant WELS rating (WELS Star rating) label to certain products. The scheme supports consumers to select water efficient products, conserving water supply and reducing water bills.

Table 8: Water efficient appliances and fixtures – WELS Rating and associated water savings against industry benchmark, performance criteria and best practice

Typical fixture	Minimum requirements (used in the Tool)	Best practice
Basins	4 Star WELS	6 Star WELS
Kitchen taps	4 Star WELS	6 Star WELS
Toilets	4 Star WELS	6 Star WELS
Showerheads	3 Star WELS (with flow between 7.5–9 litres/minute)	3 Star WELS (with flow between 4.5 – 6.0 litres/minute)
Urinals	4 Star WELS	6 Star WELS or waterless
Dishwashers	3 Star WELS	6 Star WELS
Washing machines	3 Star WELS	6 Star WELS
Baths	Medium sized contemporary bath	Small square tub/combined shower

Once completed the Water Efficiency, Rainwater Tanks and Recycled Water Connections sections of the Tool, a Total Water Saving value; expressed in kilolitres (kL) and as a percentage (%) of potable water saved from the use of water efficient appliances and fixtures, the installation of rainwater tanks, and recycled water connections, is automatically calculated.

Table 9: Water saving percentages to be satisfied in order to meet or exceed minimum performance target.

Potable water saving (%)	Classification
25%	Minimum target
>25%	Best practice

The water saving target has been set using extensive experience in Victoria with the BESS tool and in NSW with the BASIX tool on what a household can reasonably achieve using good design principles. Usually about 10% of savings are provided by efficient fittings and an additional 15% of savings are provided by the water tank. This will vary based on the specific building design. Higher targets are technically feasible but they tend to require more complex and expensive equipment such as greywater or blackwater recycling. A building that is not connected to a potable water source is deemed to comply with water saving targets.

Water use is calculated using the general formula:

- Water use = times per day an occupant uses fixture x water use per use of fixture x number of occupants.

The calculator works out both the benchmark water use and the modelled water use simultaneously and compares the difference to work out the water efficiency savings %.

To get the total water saving, the calculator also includes the modelled water savings from the water tank (see VOLUME section).

Occupant usage and behaviour assumptions have been drawn from the Water Efficiency Labelling Scheme (WELS) Australian Standard 6400:2016 Water efficient products — Rating and labelling[9].

The InSite Water Tool can also accommodate an alternative water source. Where recycled water is provided to a property, it is assumed that the supply will be adequate to meet the connected non-potable uses. If both a water tank and a third pipe water supply are used, then the calculator will assume that the water in the water tank will be used first, and then the backup supply will be from the recycled water.

Extensive calibrations of the efficiency part of the tool have demonstrated that the Target can be readily achieved using a combination of water efficiency and rainwater harvesting. The target can also be achieved with EITHER only stringent efficiency OR only a water tank, though this approach is harder. A balanced approach of a water tank (or a third pipe alternative water supply), plus efficient fittings is recommended to meet this target

7 Quality control and calibration

Organica Engineering has calibrated and checked the approach in the InSite Water Tool using spreadsheet-based equations and analysis to avoid generating website coding errors. Organica Engineering has also compared the Tool results with the results generated by the more established EPA stormwater management model (SWMM). EPA SWMM is a dynamic rainfall-runoff model suitable for simulation of runoff primarily from urban areas. Five models were established to test each of three Scenarios:(i) 1 allotment into 2
(ii) 2 allotments into 5
(iii) Commercial development of approximately 5,000 m^2.

This range of models has been used to evaluate different site storage, infiltration and combination effects in order to evaluate and compare the calculations as outlined in a separate Milestone 1 report[10]. Each pipe size, storage curve, catchment parameter, invert height, etc. was specified within the SWMM model, giving rise to many possible combinations and permutations.

For further information please refer to: *Water Sensitive SA and Organica Engineering (2017) Online stormwater assessment tool for small-scale infill development: Milestone 1 Report: A comparison of Council engineering requirements, current best practice stormwater management and practitioner needs in the greater Adelaide Region*. Unpublished but available on request from Water Sensitive SA.

[9] WELS Standards http://www.waterrating.gov.au/about/standards

Glossary of common stormwater design terms

<table>
<tr><th>Term</th><th>Definition</th></tr>
<tr><td>AEP</td><td>

Annual exceedance probability is defined as: The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year. With ARI expressed in years, the relationship is: AEP = 1 – exp (-1/ARI). Further discussion of stormwater terminology can be found in Book 1; Chapter 2; Section 2.2 Terminology of ARR 2016 http://arr.ga.gov.au/arr-guideline.

The diagram below shows which terminology should be used with the coloured in number boxes.

Australian Rainfall and Runoff terminology

<table>
<tr><th>Frequency Descriptor</th><th>EY</th><th>AEP (%)</th><th>AEP (1 in x)</th><th>ARI</th><th>Uses in Engineering Design</th></tr>
<tr><td rowspan="6">Very frequent</td><td>12</td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>99.75</td><td>1.002</td><td>0.17</td><td rowspan="5">Water sensitive urban design</td></tr>
<tr><td>4</td><td>98.17</td><td>1.02</td><td>0.25</td></tr>
<tr><td>3</td><td>95.02</td><td>1.05</td><td>0.33</td></tr>
<tr><td>2</td><td>86.47</td><td>1.16</td><td>0.50</td></tr>
<tr><td>1</td><td>63.2</td><td>1.58</td><td>1.00</td></tr>
<tr><td rowspan="5">Frequent</td><td>0.69</td><td>50.00</td><td>2</td><td>1.44</td><td rowspan="5">Stormwater/pit and pipe design</td></tr>
<tr><td>0.5</td><td>39.35</td><td>2.54</td><td>2.00</td></tr>
<tr><td>0.22</td><td>20.00</td><td>5</td><td>4.48</td></tr>
<tr><td>0.2</td><td>18.13</td><td>5.52</td><td>5.00</td></tr>
<tr><td>0.11</td><td>10.00</td><td>10.00</td><td>9.49</td></tr>
<tr><td rowspan="3">Infrequent</td><td>0.05</td><td>5.00</td><td>20</td><td>20.0</td><td rowspan="7">Floodplain management and waterway design</td></tr>
<tr><td>0.02</td><td>2.00</td><td>50</td><td>50.0</td></tr>
<tr><td>0.01</td><td>1.00</td><td>100</td><td>100</td></tr>
<tr><td rowspan="4">Rare</td><td>0.005</td><td>0.50</td><td>200</td><td>200</td></tr>
<tr><td>0.002</td><td>0.20</td><td>500</td><td>500</td></tr>
<tr><td>0.001</td><td>0.10</td><td>1000</td><td>1000</td></tr>
<tr><td>0.0005</td><td>0.05</td><td>2000</td><td>2000</td></tr>
<tr><td rowspan="5">Extremely Rare</td><td>0.0002</td><td>0.02</td><td>5000</td><td>5000</td><td rowspan="6">Design of high-consequence infrastructure (eg major dams)</td></tr>
<tr><td></td><td></td><td rowspan="4">↓</td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>Extreme</td><td></td><td></td><td>PMP</td><td></td></tr>
</table>

Diagram sourced online from the Bureau of Meteorology
http://www.bom.gov.au/water/designRainfalls/ifd/ifd-faq.shtml

</td></tr>
<tr><td>ARI</td><td>Average recurrence interval is defined as: The average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration. The ARR 2016 discourages the use of ARI, however as it is still commonly used in the stormwater industry this guide provides both ARI and the equivalent AEP / EY value.</td></tr>
<tr><td>ARR 2016
ARR 2019</td><td>Australian Rainfall and Runoff (Engineers Australia 2016, published at http://arr.ga.gov.au) is a national guideline document, data and software suite that is the default national standard for the estimation of design flood characteristics in Australia. Note an updated version was published in March 2019.</td></tr>
<tr><td>Deemed-to-satisfy</td><td>A simplified checklist approach to achieving compliance targets (as opposed to a custom designed or software modelled approach).</td></tr>
<tr><td>Detention storage</td><td>The component of a rainwater tank used to store water harvested from rooftops (rainwater) or stormwater runoff from hard surfaces “detained” in a tank for a limited period. Stormwater detention tanks are intended to remain empty, except during periods of rainfall and for a short time thereafter. Unlike retention rainwater storages, the distinguishing feature of a stormwater detention tank is that it is specially fitted with a valve to slowly release water over time.</td></tr>
</table>

Term	Definition
EY	**Exceedances per year** is the number of times an event is likely to occur or be exceeded within any given year.
Infill growth	Growth occurring through densification of existing developed areas.
InSite Water	An integrated water cycle management design toolkit focused on Council approvals for infill growth www.insitewater.com.au
OSD	**On site detention** A common practice of slowing down stormwater release rates into stormwater drains by using a detention tank with a known outflow rate.
PMP	**Probable maximum precipitation** The greatest depth of precipitation for a given duration meteorologically possible for a given size storm area at a particular location at a particular time of year, with no allowance made for long-time climatic trends (World Meteorological Organization).
Rainwater	Rainfall collected from the roofs of buildings.
Rainwater tank	A water tank that is used to collect and store rainwater runoff, typically from rooftops via rain gutters.
Retention storage	The component of a rainwater tank used to store water harvested from rooftops (rainwater). The water retained is used inside the home (e.g. toilets, laundry or hot water services) or for reticulated irrigation OR The component of stormwater runoff from hard surfaces (stormwater) retained in infiltration systems to provide passive irrigation to the surrounding soils, rather than simply discharging to the drainage system.
Soil site classification	Soils site classification is according to *Australian Standard AS 2870/2011 – Residential slabs and footings*[10] Site classifications and movement are based on soil reactivity **Class A** (0-10mm) Stable, non-reactive. Most sand and rock sites. Little or no ground movement likely as a result of moisture changes. **Class S** (10-20mm) Slightly reactive clay sites. May experience slight ground movement as a result of moisture changes. **Class M / M-D** (20-40mm) Moderately reactive clay or silt sites. May experience moderate ground movement as a result of soil conditions and moisture changes. **Class H1 / H1-D** (40-60mm) Highly reactive clay sites. May experience a high amount of ground movement as a result of soil conditions and moisture changes. **Class H2 / H2-D** (60-75mm) Highly reactive clay sites. May experience very high ground movement as a result of soil conditions and moisture changes. **Class E / E-D** (75mm+) Extremely reactive sites. May experience extreme amounts of ground movement as a result of soil conditions and moisture changes. **Class P** (this is approximately 70% of building sites in Australia) Problem sites. Sites may be classified as 'Class P' as a result of mine subsidence, landslip, collapse activity or coastal erosion (e.g. dunes), soft soils with a lack of suitable bearing, cut and/or filled sites, or creep areas. Ground movement as a result of moisture changes may be very severe. If you are building on a Class P site you will need to consult a structural engineer. The '**D**' inclusion (i.e. M-D, H1-D, H2-D or E-D) The 'D' in these classifications refers to 'deep' movements in soil due to deep variances in moisture. These classifications are mostly found in dry areas.
Stormwater	Rainfall that runs off all urban surfaces such as roofs, pavements, car parks, roads, gardens and vegetated open space.
WELS	Australian Water Efficiency Labelling Standards scheme.
WSUD	**Water sensitive urban design** Design principles that aim to reduce the impact of interactions between the urban built form and the urban water cycle including surface water, potable water, groundwater, urban and roof runoff, wastewater and stormwater.

[10] *AS 2870-2011 – Residential slabs and footings* available from SAI Global https://infostore.saiglobal.com/