Urban stormwater—Queensland best practice environmental management guidelines 2009

Technical Note: Derivation of Design Objectives

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1 Introduction

This Technical Note describes technical studies undertaken to derive stormwater management design objectives for the operational phase of development as described in Chapter 2 of the "Urban stormwater–best practice environmental management guidelines 2009" (Queensland EPA 2009). The stormwater management design objectives are intended for application within urban developments throughout Queensland and focus on stormwater management requirements for the protection of waterway health. Other stormwater management design objectives relating to drainage and flooding are not covered here but are nonetheless still important and intended to apply in concert with the design objectives for waterway health described herein.

The stormwater management design objectives for waterway health have been derived using the methods employed in "WSUD: Developing Design Objectives for Water Sensitive Developments in South East Queensland - Version 2, 8th November 2007" (SEQ HWP 2007). The HWP work included extensive testing of the proposed WSUD design objectives on a broad range of urban developments to assess feasibility in terms of cost and ease of compliance. The findings from the SEQ HWP work suggests the stormwater management design objectives described in Chapter 2 of the "Urban stormwater–best practice environmental management guidelines 2009–" (Queensland EPA 2009) will be applicable to most urban developments in Queensland.

2 Stormwater Quality Management Design Objectives

The urban stormwater quality management design objectives for Queensland as described in Chapter 2 of the "Urban stormwater–best practice environmental management guidelines 2009" (Queensland EPA 2009) adopt a pollutant load reduction approach. This is consistent with the approach employed in other parts of Australia and as recommended in Australian Runoff Quality (Engineers Australia 2005, p1-7) and ANZECC (2000, p 3.3.2). A discussion on the benefits of adopting a load reduction approach as compared to a discharge concentration approach is provided in (SEQ HWP 2007, Ch 2.1).

2.1 Stormwater Quality Management Design Objective

The load reduction targets for Queensland were derived from predictive computer modeling using MUSIC (Model for Urban Stormwater Improvement Conceptualisation) as detailed in Appendix A. The load reduction targets are based on achievable load reductions from current "best practice" stormwater management infrastructure operating in Queensland climatic and pollutant export conditions. "Best Practice" in this instance refers to stormwater management infrastructure designed and constructed to [1]contemporary design standards and sized to operate at the technology's reasonable limit of economic performance as defined by the "point of diminishing return" on treatment performance curves derived from the predictive modeling (refer to Appendix A).

Currently, bioretention treatment systems employing surface vegetation and soil filtration are widely considered to be the most efficient stormwater treatment technology for reducing loads of typical urban stormwater pollutants, namely: suspended sediments; particulate and soluble nutrients; metals and hydrocarbons. If gross pollutants (>5mm diameter) are present, or are likely to be present, then a "treatment train" approach is typically required with a gross pollutant capture device placed at the head (i.e. upstream) of other downstream treatment devices.

To ensure the best possible stormwater treatment outcome is achieved, the load reduction targets for Queensland have been established from the predicted performance of bioretention treatment sized at the technologies "point of diminishing return". For all regions of Queensland, this was found (refer to Appendix A) to be bioretention treatment area equivalent to 1.5% of the contributing catchment area (e.g. a 10ha residential or industrial development would require a 0.15ha bioretention treatment area to comply with the local areas load reduction targets).

2.1.1 Targets

The load reduction targets for Queensland are outlined in Table 2.1 with the regions within which the targets apply shown on Figure 2.1.

2.1.2 Application

Applicable to all urban development, excluding development that is less than 25% impervious and that complies with the frequent flow management design objective (refer Section 3.1).

[1] Contemporary design standards for stormwater management infrastructure can be found in the most recent revision of WSUD Technical Design Guidelines in SEQ (SEQ HWP) or a locally relevant equivalent.

2.1.3 Compliance

To ensure practical compliance with the load reduction targets in Table 2.1, quantitative model testing was undertaken to confirm that other stormwater treatment technologies (i.e. other than bioretention) can also be used to comply with the targets. This testing, which included stormwater treatment technologies such as gross pollutant capture devices, swales and constructed stormwater wetlands, configured to form "treatment trains", showed the targets can be attained by a range of "treatment train" solutions. This allows for solution flexibility.

Compliance with the load reduction targets will typically be demonstrated using an accepted quantitative model (such as MUSIC) with all model inputs and outputs provided to the approval authority to enable review and verification of the model results.

Table 2.1 Summary of design objectives for stormwater quality management - operational (post construction) phase of development. (From Chapter 2 of the "Urban stormwater–best practice environmental management guidelines 2009")

Region	**[12]Minimum reduction in developed site pollutant loads (%)**			
	Suspended solids (TSS)	**Total phosphorus (TP)**	**Total nitrogen (TN)**	**Gross Pollutants > 5mm**
Eastern Cape York	75	60	35	90
Central and Western Cape York (north)	75	60	40	90
Central and Western Cape York (south)	80	65	40	90
Wet Tropics	80	65	40	90
Dry Tropics	80	65	40	90
Central Coast (north)	75	60	35	90
Central Coast (south)	85	70	45	90
South East Queensland	80	60	45	90
Western Districts	85	70	45	90

[2] It is expected that application of best practice designed stormwater treatment technologies configured in an appropriately sequenced 'treatment train' will exceed the design objectives presented in Table 2.1

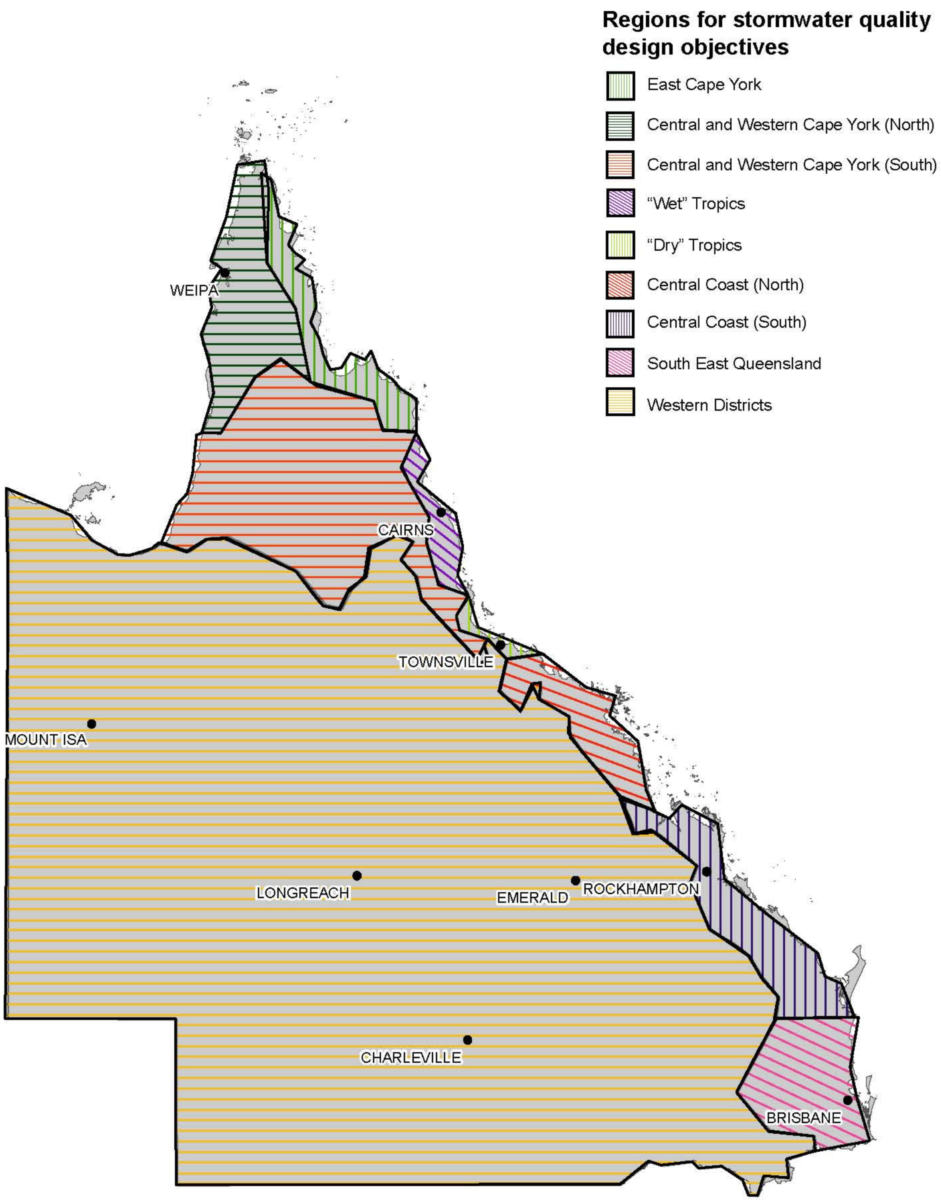

Figure 2.1 – Delineation of regions for application of operational phase stormwater quality management design objectives.

3 Water Quantity Design Objectives

Stormwater quantity management for waterway health enhancement focuses on the management of frequent urban stormwater flows that cause disturbance to aquatic habitats and aquatic ecosystem health. This is distinct from urban stormwater quantity management for flood management purposes which is concerned with the management of less frequent, more extreme stormwater flows that cause nuisance flooding and potential flood damages. The later is an important part of integrated stormwater management and should in no way be compromised in pursuit of the management of more frequent flows for waterway health enhancement.

Two stormwater quantity management design (performance) objectives have been proposed in Chapter 2 of the "Best Practice Environmental Management Guidelines - Urban Stormwater" (EPA 2008). These are:

- A Frequent Flow Management Design Objective.
- A Waterway Stability Management Design Objective.

These are discussed in more detail in the following sections.

3.1 Frequent Flow Management Design Objective

This objective aims to protect in-stream ecosystems from the significant effects of increased runoff frequency by capturing the initial portion of runoff (referred hereafter as the design runoff capture depth) from impervious areas. This approach ensures that the frequency of hydraulic disturbance to in-stream ecosystems in developed catchments is similar to fully pervious pre-developed catchment conditions.

3.1.1 Target

Numerical modeling studies (refer to Appendix B) were undertaken to define an appropriate design runoff capture depth for the Frequent Flow Management design objective based on the modeling undertaken for the objectives determined for SEQ. The design runoff capture depth was selected to provide a similar frequency of surface runoff for small rainfall events and to achieve a similar overall annual volume of runoff (AVR) to an un-developed catchment.

The resultant design objective is to capture and manage the following design runoff capture depth (mm/day) from all impervious surfaces:

- Developments with a total fraction impervious <40%: design runoff capture depth > 10mm/day
- Developments with a total fraction impervious >40%: design runoff capture depth > 15mm/day

Table 3.1 shows the result summary of annual volume of runoff (AVR) calculations which helped to determine the recommended design runoff capture depths. Results presented in this table as well as the flow duration curves in Appendix B indicate that these daily runoff capture depths do not achieve 100% replication of 3pre-development hydrology, but they do significantly reduce the frequency of surface runoff events and overall volumetric runoff coefficients. This is especially evident when comparing the AVR and flow duration curves calculated for impervious areas with no runoff capture and management.

Capturing and managing the first 20mm of surface runoff from impervious surfaces would achieve close to "pre-developed" catchment hydrology and where practical this should be pursued by development proponents.

3.1.2 Application

This objective is expected to be only applied in catchments to waterways and wetlands that are classified as High Environmental Value (HEV) systems or if the local Council intends to rehabilitate a modified system.

3.1.3 Demonstrating Compliance

The spatial distribution of the required *capture volume* (i.e. impervious area x design runoff capture depth) within an urban development may be adapted to suit individual site conditions, provided that the required *capture volume* from all impervious areas is captured before leaving the site. Implementing the required *capture volume* will reduce pollutant load, providing a synergistic benefit for water quality. Hence there may be opportunity to incorporate the required *capture volume* within stormwater quality treatment measures, potentially eliminating the need for separate additional storage to meet the frequent flow management design objective.

The Frequent Flow Management Design Objective requires that the *capture volume* be available each day. Therefore, the disposal of the captured stormwater (either by infiltration, evapotranspiration, reuse, discharge via [3]bioretention, or combinations of these) must be capable of drawing down the captured stormwater within 24 hours. In most cases it will not be possible to fully draw down the *capture volume* within 24 hours if relying only on local infiltration, evapotranspiration and/or re-use as the disposal methods. This is because the rate at which these disposal methods can draw down the *capture volume* will typically be too slow. Therefore, discharge via bioretention will be required in most situations.

High Environmental Value (HEV) waterways and wetlands, in particular ephemeral systems, may be highly vulnerable to increased baseflow conditions. It is therefore important to assess the in-stream ecology of the receiving waterway before deciding the appropriate disposal method. In particulalr, care should be taken to ensure the in-stream ecology of the receiving waterway is resilient to the extended baseflow conditions that may result from discharge via bioretention. It may be the case that certain HEV waterways that are determined to be vulnerable to an increase in baseflow may need to have urban development avoided within their catchment areas (unless it can be demonstrated that infiltration, evapotranspiration and re-use disposal methods can be employed in lieu of discharge via bioretention).

Disposal of the *capture volume* by infiltration should only be considered when local soil and groundwater conditions are suitable. Urban salinity can be a problem if excessive infiltration is attempted in areas of low infiltration or shallow groundwater table. Contamination of groundwater aquifers by poor quality stormwater runoff may also be a problem, particularly if there are existing beneficial users of the local groundwater resource (including the environment).

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[3] Disposal of the *capture volume* by discharge through a bioretention system to the receiving waterway was an acceptable solution agreed by Dr Chris Walsh (Monash University). Dr Walsh led the underlying scientific research that identified the need for this design objective to protect waterway health.

Table 3.1 Summary of design objectives for management of stormwater quantity. Frequent flow management objectives for developments with differing proportions of impervious area are shown as bold, italicised values.

Region	Rainfall Station	Modelling Period	Daily Capture and Management (mm/day)	Undeveloped (0%) AVR (ML/day)	20% Impervious AVR (ML/day)	40% Impervious AVR (ML/day)	60% Impervious AVR (ML/day)	80% Impervious AVR (ML/day)
Eastern Cape York	LOCKHART RIVER	16/6/2001 - 31/8/2006	10mm	10.2	10.5	10.9	11.2	11.5
		Five years two months	15mm	10.2	10.1	10.1	10	10
			20mm	10.2	9.84	9.48	9.12	8.76
Central and Western Cape York	WEIPA	1/1/1980 - 31/21/1989	10mm	8.35	8.65	8.95	9.25	9.55
		Ten years	15mm	8.35	8.25	8.15	8.05	7.95
			20mm	8.35	7.94	7.52	7.11	6.7
	PALMERVILLE	1/1/1990 - 31/21/1999	10mm	3.55	3.85	4.15	4.45	4.75
		Ten years	15mm	3.55	3.61	3.66	3.71	3.77
			20mm	3.55	3.41	3.28	3.14	3
"Wet" Tropics	CAIRNS	1/1/1975 - 31/12/1984	10mm	9.23	9.66	10.1	10.5	11
		Ten years	15mm	9.23	9.31	9.4	9.49	9.58
			20mm	9.23	9.05	8.87	8.69	8.52
"Dry" Tropics	TOWNSVILLE	1/1/1970- 31/21/1983	10mm	4.64	5.09	5.54	5.99	6.45
		Fourteen Years	15mm	4.64	4.86	5.08	5.31	5.53
			20mm	4.64	4.68	4.72	4.76	4.81
Central Coast North	MACKAY	1/1/1990 to 31/12/1999	10mm	6.12	6.76	7.41	8.05	8.69
		Ten Years	15mm	6.12	6.49	6.87	7.25	7.63
			20mm	6.12	6.3	6.48	6.66	6.84
Central Coast South	ROCKHAMPTON	1/1/1980 - 31/21/1989	10mm	0.85	1.38	1.91	2.44	2.98
		Ten years	15mm	0.85	1.2	1.55	1.9	2.25
			20mm	0.85	1.07	1.3	1.52	1.75
South East Queensland	NAMBOUR	1/1/1985 - 31/12 1998	10mm	4.78	5.4	6.02	6.64	7.27
		14 years	15mm	4.78	5.07	5.36	5.65	5.94
			20mm	4.78	4.84	4.9	4.96	5.02
Western Districts	MOUNT ISA	1/1/1990 - 31/21/1999	10mm	0.67	0.95	1.23	1.51	1.79
		Ten years	15mm	0.67	0.84	1	1.17	1.34
			20mm	0.67	0.76	0.86	0.95	1.05
	CHARLEVILLE	1/1/1990 - 31/21/1999	10mm	0.38	0.68	0.97	1.26	1.55
		Ten years	15mm	0.38	0.56	0.74	0.92	1.1
			20mm	0.38	0.48	0.57	0.67	0.76

3.2 Waterway Stability Management Design Objective

Urban development typically increases the duration of sediment-transporting flow in urban streams, often leading to increased rates of bed and bank erosion and damage to key benthic habitat (i.e. scouring of sand/gravel beds and displacement of larger structural habitats such as pool riffle sequences). The purpose of this design objective is therefore to limit changes in downstream sediment transport potential by attenuating flows of intermediate magnitude (i.e. up to 1 yr ARI). These events are responsible for a large proportion of total sediment movement in streams.

Details of the technical studies undertaken to develop the waterway stability management design objective for South East Queensland are provided in Appendix B and C of the "WSUD: Developing Design Objectives for Water Sensitive Developments in South East Queensland - Version 2, 8th November 2007" (SEQ HWP 2007). These same technical studies have not been undertaken for other parts of Queensland. Local Council's are therefore encouraged to undertake similar technical studies to those undertaken in SEQ to confirm the appropriateness of the SEQ waterway management design objective for their local area. In the interim, the SEQ waterway stability management design objective will apply to all parts of Queensland

3.2.1 Target

Limit the post-development peak 1 year Average Recurrence Interval (ARI) event discharge within the receiving waterway to the pre-development peak 1 year Average Recurrence Interval (ARI) event discharge.

3.2.2 Application

The Waterway Stability Design Objective is expected to be applied only within catchments contributing to un-lined waterways or if the local Council intends to decommission a lined waterway and re-instate a natural channel system.

3.2.3 Demonstrating Compliance

Appendix C in "WSUD: Developing Design Objectives for Water Sensitive Developments in South East Queensland - Version 2, 8th November 2007" (SEQ HWP 2007) describes two methods that can be used to demonstrate compliance with the Waterways Stability Management Design Objective.

Method A is a quick look-up curve derived from simplistic triangulated hydrographs (climatic region specific) and is considered suitable for application to all development scales across Queensland (despite the 10ha upper limit placed on use of Method A in SEQ). Independent testing of Method A by consultant DesignFlow (as part of a peer review of this Technical Note) showed Method A can be used for both small and large (>10ha) scale developments. The testing undertaken by Designflow showed Method A conservatively over-estimates, for all development scales, the required on-site detention storage required to comply with the design objective. If an individual developer wants to further refine the required on-site detention storage then the more detailed Method B, which involves catchment scale runoff routing modeling, can be adopted.

Local Council's with access to capable catchment hydrology and hydraulics practitioners may decide to apply Method B to selected catchments and then prescribe in local planning schemes the required on-site detention and permissible 1yr ARI site discharge to be complied with by prospective developments.

4 Summary

This technical note summarises the technical studies completed to derive state-wide WSUD design objectives as presented in Chapter 2 of the “Best Practice Environmental Management Guidelines - Urban Stormwater” (EPA 2008). The proposed design objectives were derived using the same technical methods employed for derivation of WSUD design objectives for urban developments in South East Queensland as described in “WSUD: Developing Design Objectives for Water Sensitive Developments in South East Queensland - Version 2, 8th November 2007” (SEQ HWP 2007).

The three proposed WSUD design objectives are:

- A **Stormwater Quality Design Objective**. This objective aims to protect receiving water quality by limiting the quantity of key pollutants discharged in stormwater from urban development.

- Stormwater Quantity Design Objectives being:

    - A **Frequent Flow Management Design Objective**. This objective aims to protect in-stream ecosystems from the significant effects of increased runoff frequency by capturing the initial portion of runoff from impervious areas. This approach ensures that the frequency of hydraulic disturbance to in-stream ecosystems in developed catchments is similar to predevelopment conditions.

    - A **Waterway Stability Management Design Objective**. This objective aims to prevent exacerbated in-stream erosion downstream of urban areas by controlling the magnitude and duration of sediment-transporting flows

The performance measures/targets for each of these objectives are presented in Table 4.1 and have been derived to reflect the different climatic regions throughout Queensland

Table 4.1 - Summary of WSUD Objectives

Design Objective	Performance Measure/Target
Stormwater Quality	Stormwater discharged from development areas to be treated in accordance with best practice for each climatic region (refer Table 2.1 and Figure 2.1).
Waterway Stability	Limit the post-development peak one-year Average Recurrence Interval (ARI) event discharge within the receiving waterway to the pre-development peak one-year Average Recurrence Interval (ARI) event discharge
Frequent Flow	Capture and manage the following design runoff capture depth (mm/day) from all impervious areas such that the frequency of surface runoff is the same as pre-development conditions: - Developments with a total fraction impervious <40%: Design runoff capture depth = 10mm/day - Developments with a total fraction impervious >40%: Design runoff capture depth = 15mm/day Note, Runoff capture capacity needs to be replenished within 24 hours of the runoff event.

5 References

Australian and New Zealand Environment and Conservation Council (ANZECC 2000), Australian and New Zealand Guidelines for Fresh and Marine Water Quality Australian Water Association and New Zealand Ministry for the Environment.

Engineers Australia (2005), "Australian Runoff Quality", Wong, T.H.F. (ed).

South East Queensland Healthy Waterways Partnership (SEQ HWP 2006), "WSUD Technical Design Guidelines for South East Queensland".

South East Queensland Healthy Waterways Partnership (SEQ HWP 2007), WSUD: "Developing Design Objectives for Water Sensitive Developments in South East Queensland - Version 2, 8th November 2007"

Victorian Stormwater Committee 1999, Urban Stormwater - Best Practice Environmental Management Guidelines.

Appendix A: Derivation of Water Quality Design Objectives

The derivation of "best practice" load-based reduction targets for each climatic region in Queensland used predictive modeling techniques employing continuous simulation based on a continuous period of typical climatic conditions for each area.

Australian Runoff Quality (2005, p.7-5) states that the ANZECC Guidelines propose the application of physico-chemical conceptual time series models as a means of summarising our best understanding of the pathways and transformation processes of key stressors such as TSS, TP and TN. The computer model MUSIC (Model for Urban Stormwater Improvement Conceptualisation - Version 3.01) developed by the Cooperative Research Centre for Catchment Hydrology (CRCCH) is one such conceptual model.

The MUSIC model represents our current best understanding of the transformation of rainfall to runoff (surface and baseflow) in urban environments, the generation of key stormwater pollutants (stressors) in surface flows and base flows from various land surfaces, and the removal of key pollutants (stressors) from urban stormwater runoff by contemporary best practice stormwater treatment technologies. For this reason the MUSIC model was used to derive the "best practice" load-based reduction targets for Queensland.

The MUSIC models were configured as follows:

- 1ha residential catchment and 1ha industrial catchment. The following disaggregation of surfaces (including % impervious) was employed:

  Residential

  - 0.4ha roof area (100% impervious)
  - 0.08ha ground level impervious (100% impervious)
  - 0.32ha ground level pervious (0% impervious)
  - 0.2ha road reserve (60% impervious)

  Industrial

  - 0.5ha roof area (100% impervious)
  - 0.2ha ground level impervious (100% impervious)
  - 0.1ha ground level pervious (0% impervious)
  - 0.2ha road reserve (60% impervious)

- Climatic time series at six minute time steps for each climatic region. The data used from the Bureau of Meteorology is shown below in Table A1.

Table A1: Summary of rainfall data used for each climatic region

	Rainfall station	Period of rainfall data
Eastern Cape York	LOCKHART RIVER	16/6/2001 - 31/8/2006 (Five years two months)
Central and Western Cape York (north)	WEIPA	1/1/1980 - 31/12/1989 (Ten years)
Central and Western Cape York (south)	PALMERVILLE	1/1/1990 - 31/12/1999 (Ten years)
Wet Tropics	CAIRNS	1/1/1975 - 31/12/1984 (Ten years)
Dry Tropics	TOWNSVILLE	1/1/1970- 31/12/1983 (Fourteen years)
Central Coast (north)	MACKAY	1/1/1990- 21/12/1999 (Ten years)
Central Coast (south)	ROCKHAMPTON	1/1/1980 - 31/12/1989 (Ten years)
South East Queensland	NAMBOUR	1/1/1985 - 31/12/1998 (Fourteen years)
Western Districts	MOUNT ISA CHARLEVILLE	1/1/1990 - 31/12/1999 (Ten years) 1/1/1990 - 31/12/1999 (Ten years)

- Pervious area soil moisture store parameters based on the MUSIC model default values. The MUSIC model default values are the values calibrated by the CRCCH for Brisbane. Insufficient information on the hydrology of local soils was available to allow locally specific pervious area moisture store parameters to be used. The contribution of pervious areas to urban stormwater runoff volume and pollutant loads is typically only small compared to impervious surfaces and therefore it was not deemed necessary to pursue in any further detail derivation of locally relevant soil moisture store parameters.

- The storm flow pollution generation parameters for each surface type were derived from *Gold Coast City Council's Stormwater Quality Management Guidelines*, April 2006 (GCCC 2006) as reproduced in Table A2. The baseflow pollution generation parameters were based on *Guidelines for Pollutant Export Modelling in Brisbane Version 8,* April 2006 (BCC 2006).

- Stormwater quality treatment performance parameters for bioretention derived from performance monitoring data collected from across Australia and Internationally by the CRCCH (refer to MUSIC Version 3.01 User Manual, Appendix F). Insufficient local stormwater treatment performance data was available for bioretention treatment systems to allow for specific local performance data sets to be used for the derivation of the guideline values for each climatic region.

- The following design layout for bioretention systems:
    - 0.3m extended detention;
    - 200mm/hr hydraulic conductivity; and
    - 0.8m filter media depth.
    - Surface storage (extended detention) surface area equal to underlying bioretention filter media area.

Table A3 summarises the "best practice" load reduction results obtained from the MUSIC model generated performance curves for bioretention. The actual performance curves for each region and scenario are provided following Table A3.

Table A2: Summary of storm flow mean pollutant concentration

Land Use Category	TSS Concentration Log_{10} mg/L	Source	TP Concentration Log_{10} mg/L	Source	TN Concentration Log_{10} mg/L	Source
Urban Residential						
Roads	2.43	Fletcher et al. value for TSS from roads	-0.30	Fletcher et al. value for TP from roads	0.26	BCC value for TN from residential catchment
Roofs	1.30	Fletcher et al. value for TSS from roofs	-0.89	Fletcher et al. value for TP from roofs	0.26	BCC value for TN from residential catchment
Other Impervious Areas	2.18	BCC value for TSS from residential catchment	-0.47	BCC value for TP from residential catchment	0.26	BCC value for TN from residential catchment
Other Pervious Areas	2.18	BCC value for TSS from residential catchment	-0.47	BCC value for TP from residential catchment	0.26	BCC value for TN from residential catchment
Industrial						
Roads	2.43	Fletcher et al. value for TSS from roads	-0.30	Fletcher et al. value for TP from roads	0.25	BCC value for TN from industrial catchment
Roofs	1.30	Fletcher et al. value for TSS from roofs	-0.89	Fletcher et al. value for TP from roofs	0.25	BCC value for TN from industrial catchment
Other Impervious Areas	2.43[A]	Fletcher et al. value for TSS from roads	-0.30[A]	Fletcher et al. value for TP from roads	0.25	BCC value for TN from industrial catchment
Other Pervious Areas	2.18[B]	BCC value for TSS from residential catchment	-0.47[B]	BCC value for TP from residential catchment	0.25	BCC value for TN from industrial catchment
Commercial						
Roads	2.43	Fletcher et al. value for TSS from roads	-0.30	Fletcher et al. value for TP from roads	0.37	BCC value for TN from commercial catchment
Roofs	1.30	Fletcher et al. value for TSS from roofs	-0.89	Fletcher et al. value for TP from roofs	0.37	BCC value for TN from commercial catchment
Other Impervious Areas	2.43[A]	Fletcher et al. value for TSS from roads	-0.30[A]	Fletcher et al. value for TP from roads	0.37	BCC value for TN from commercial catchment
Other Pervious Areas	2.18[B]	BCC value for TSS from residential catchment	-0.47[B]	BCC value for TP from residential catchment	0.37	BCC value for TN from commercial catchment

[A] - The TSS and TP concentrations for roads have been applied to the "other impervious areas" for industrial and commercial land uses because these areas are likely to largely comprise car parks and other heavy use areas.

[B] - It is considered appropriate to apply consistent TSS and TP concentrations to the "other pervious areas" (i.e. landscape areas, parklands) and the BCC concentrations for residential catchments are considered to be the most representative of "other pervious areas".

Table A3: Load reduction targets for Queensland

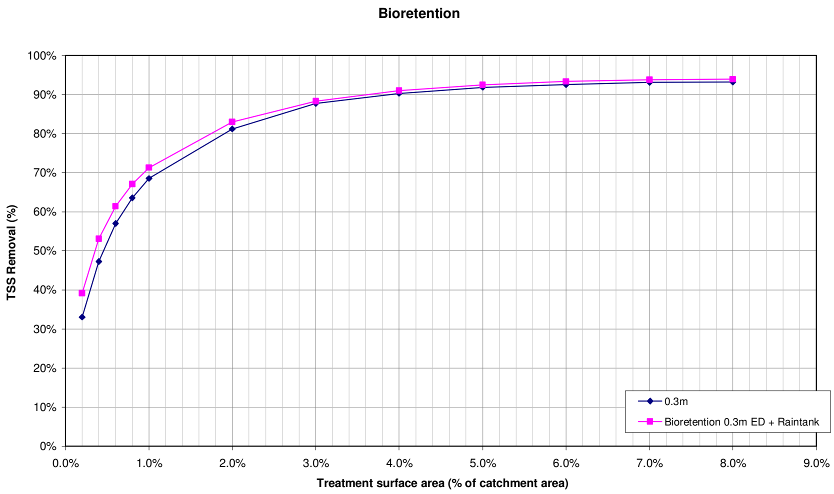
Region	Rainfall Station	% Pollutant Load Reduction								
		Bioretention @ 1.5% Residential - no rainwater tanks			*Bioretention @ 1.5%* Industrial - no rainwater tanks			*Selected Target Values*		
		TSS	**TP**	**TN**	**TSS**	**TP**	**TN**	**TSS**	**TP**	**TN**
Eastern Cape York	Lockart River	75	59	34	75	60	33	75	60	35
Central and Western Cape York (north)	Weipa	77	63	39	76	62	37	75	60	40
Central and Western Cape York (south)	Palmerville	81	65	41	80	64	39	80	65	40
Wet Tropics	Cairns	79	64	40	80	65	40	80	65	40
Dry Tropics	Townsville	81	66	42	80	66	40	80	65	40
Central Coast (north)	Mackay	77	61	37	78	62	36	76	60	35
Central Coast (south)	Rockhampton	88	72	49	86	71	46	85	70	45
*South East Queensland	Nambour	83	66	41	84	68	41	80	60	45
Western Districts	Mt Isa	85	70	45	84	69	42	85	70	45
	Charleville	90	73	49	89	73	47			

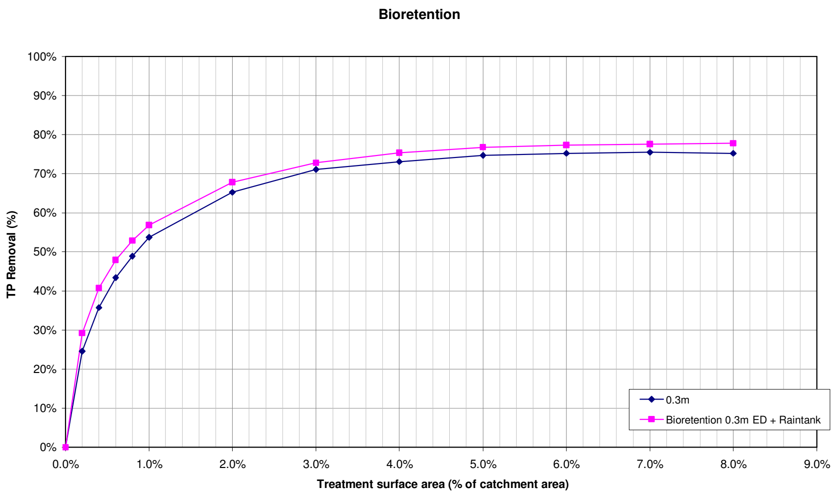
**SEQ targets selected to be consistent with SEQ HWP (2007)*

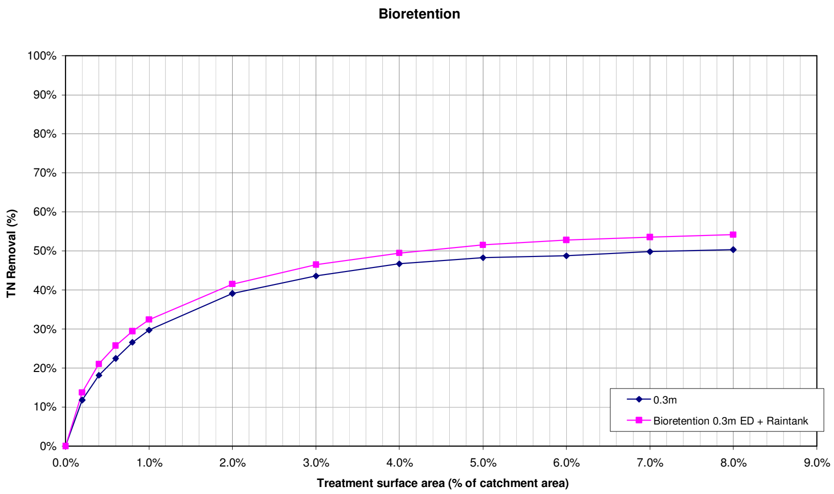
Treatment Performance curves for Queensland Climatic Regions

Eastern Cape York: Lockhart River

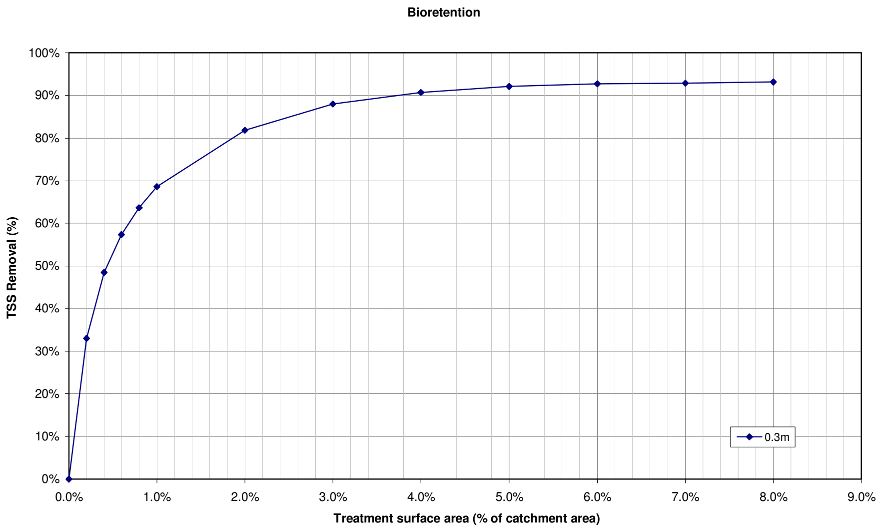
Residential

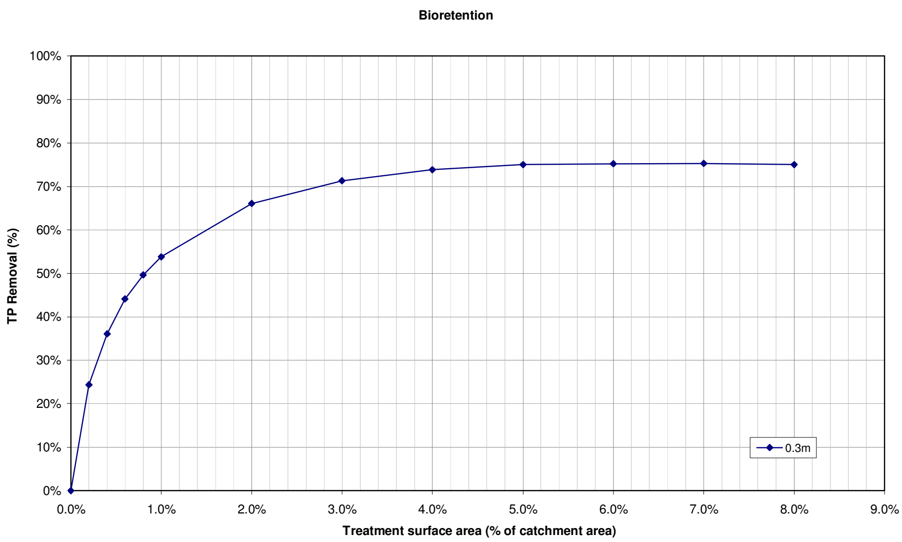


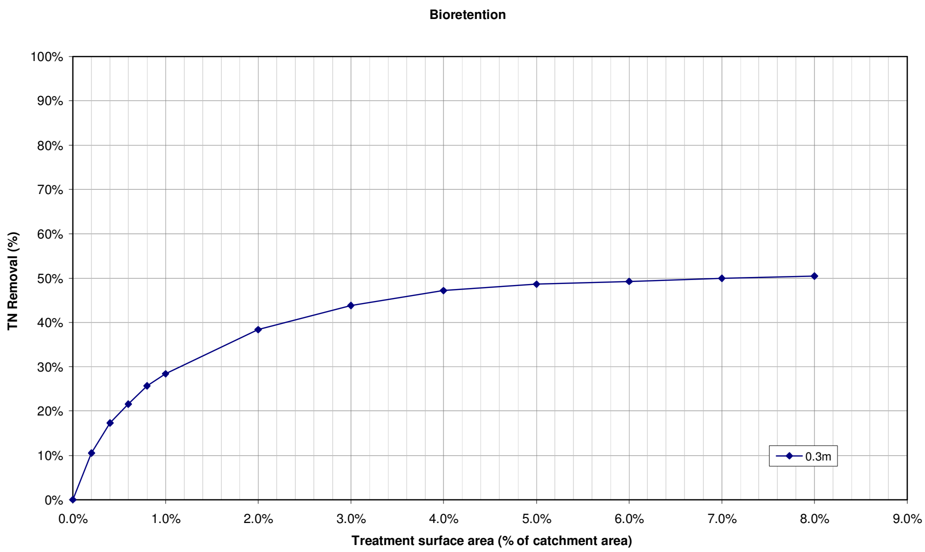




Industrial

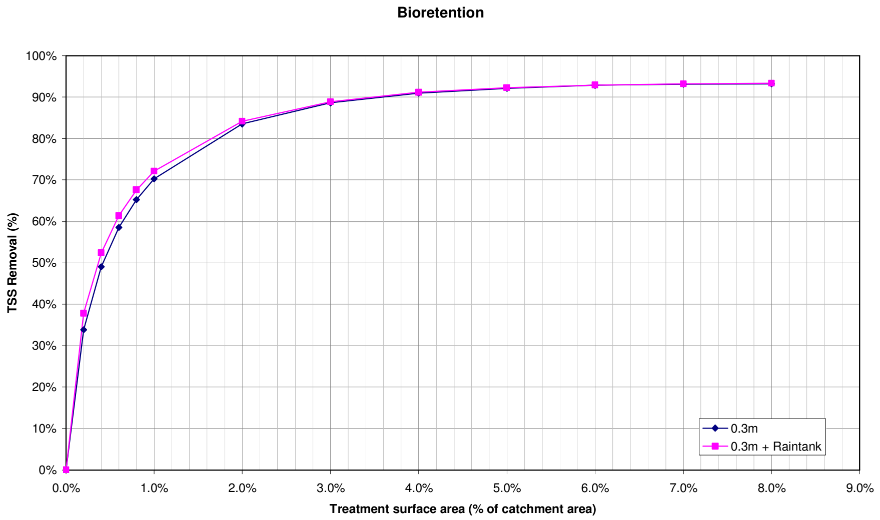

Bioretention
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
TSS Removal (%)
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m

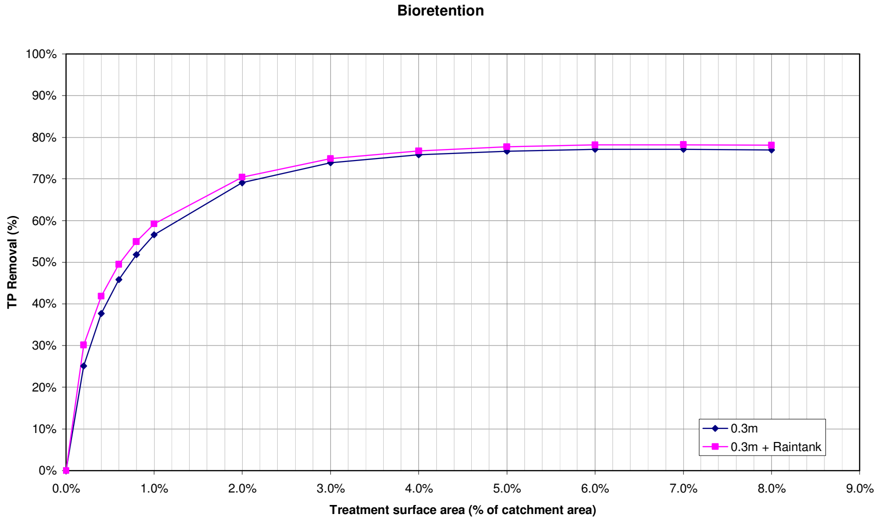

Bioretention
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
TP Removal (%)
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m

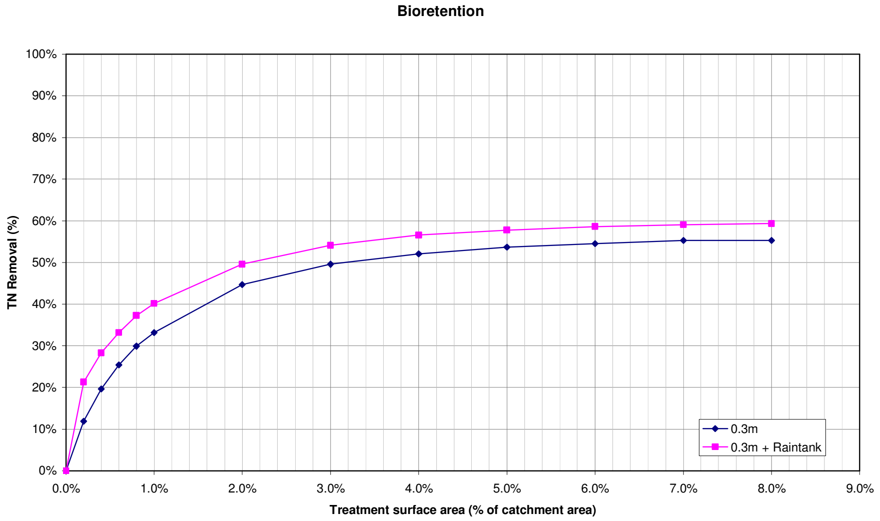

Bioretention
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
TN Removal (%)
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m

Central and Western Cape York: Weipa

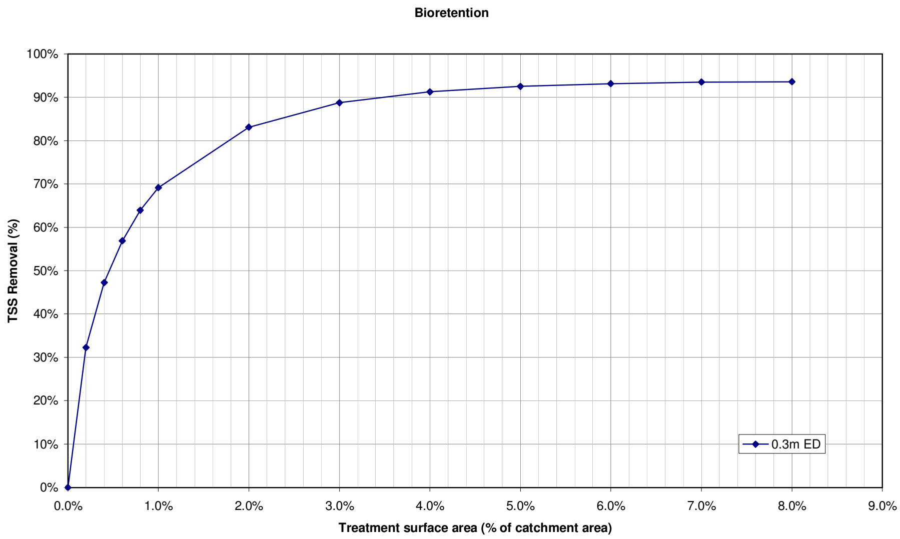
Residential

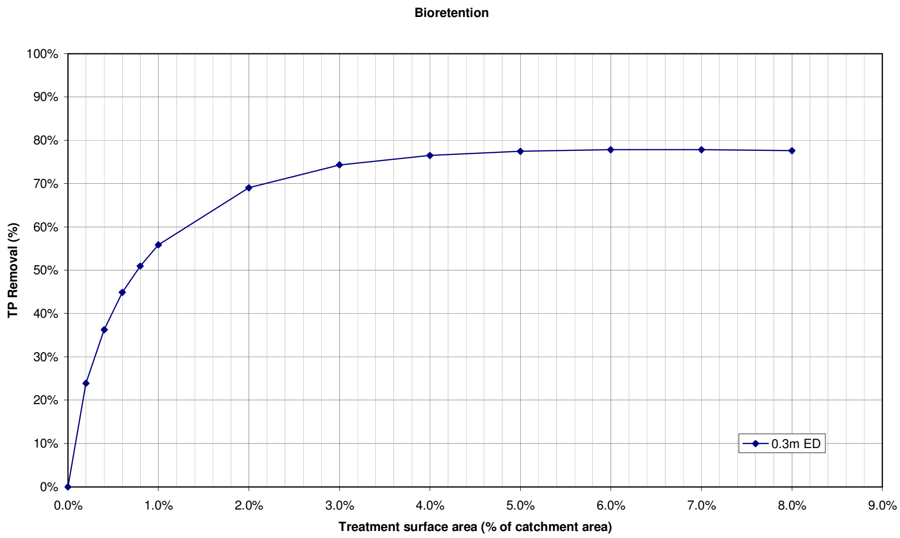


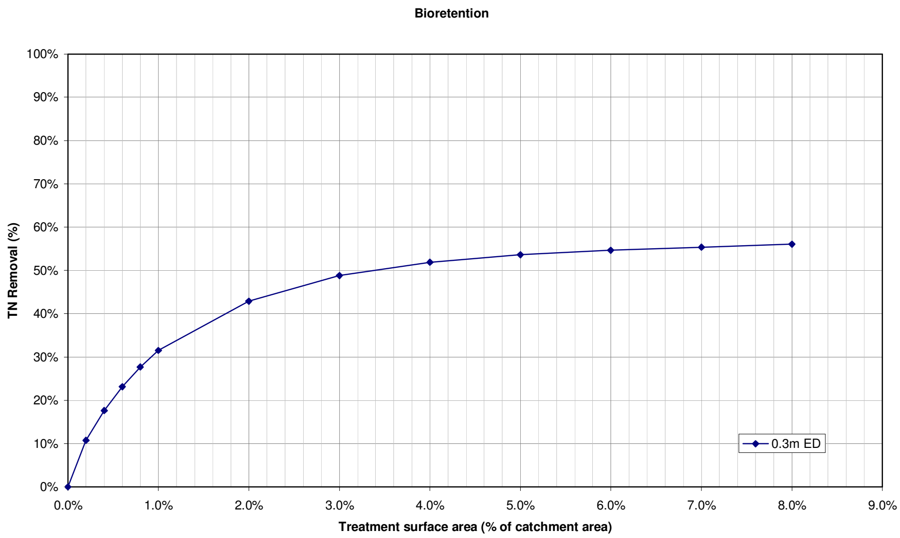




Industrial


Bioretention
TSS Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m ED

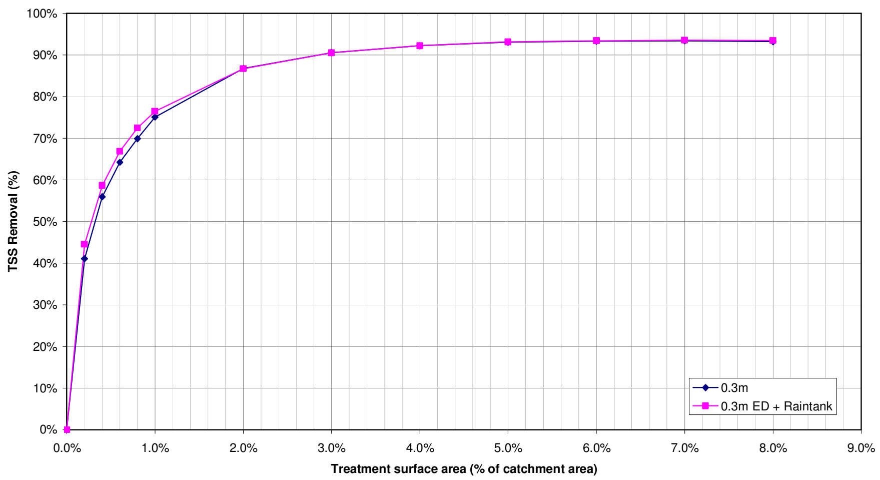

Bioretention
TP Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m ED


Bioretention
TN Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m ED

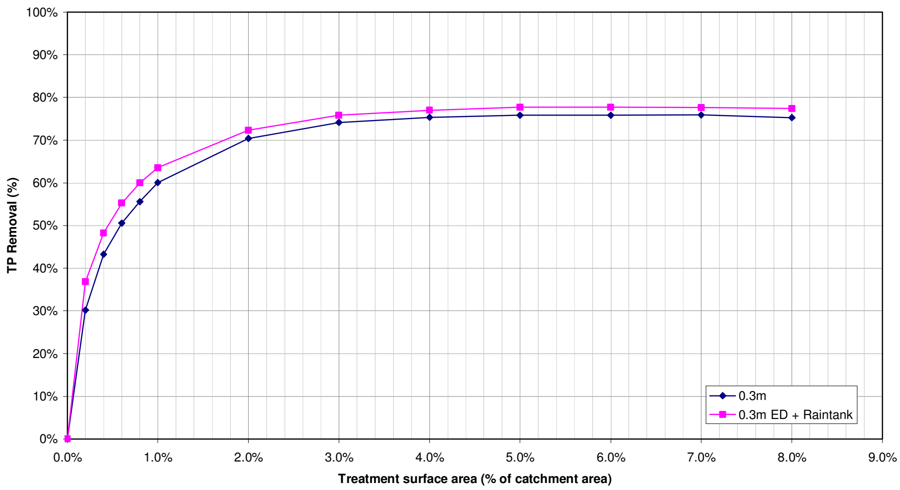
Central and Western Cape York: Palmerville

Residential

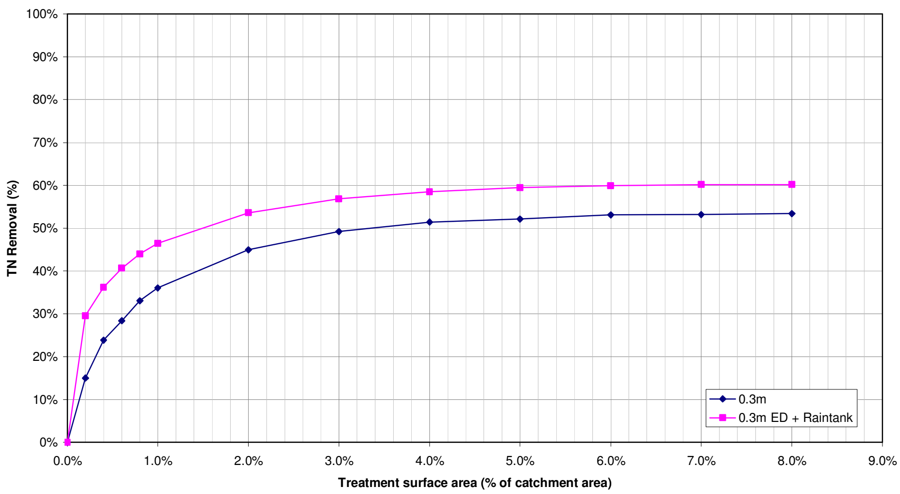
Bioretention



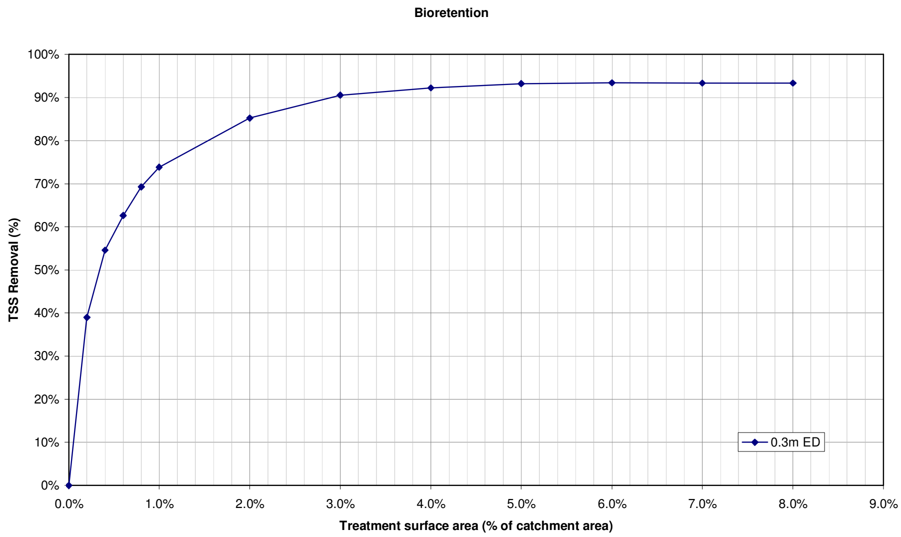
Bioretention

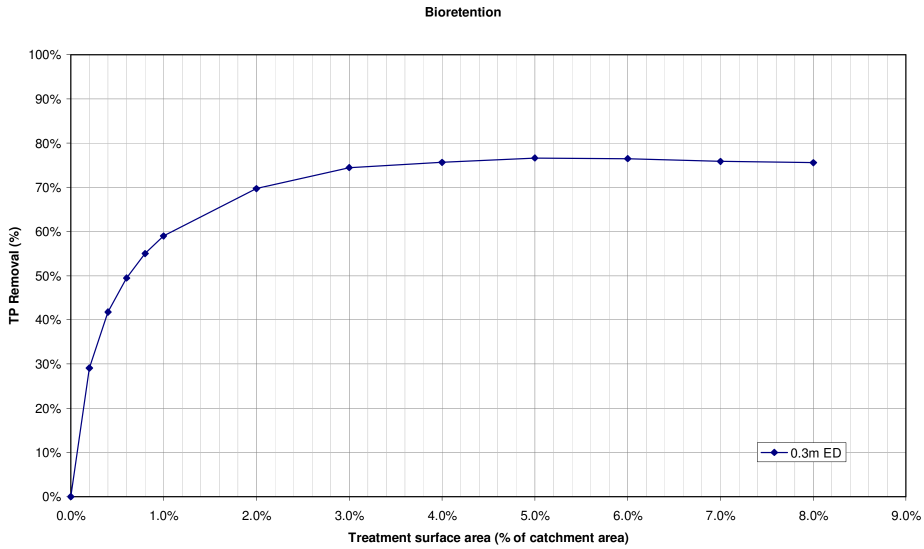


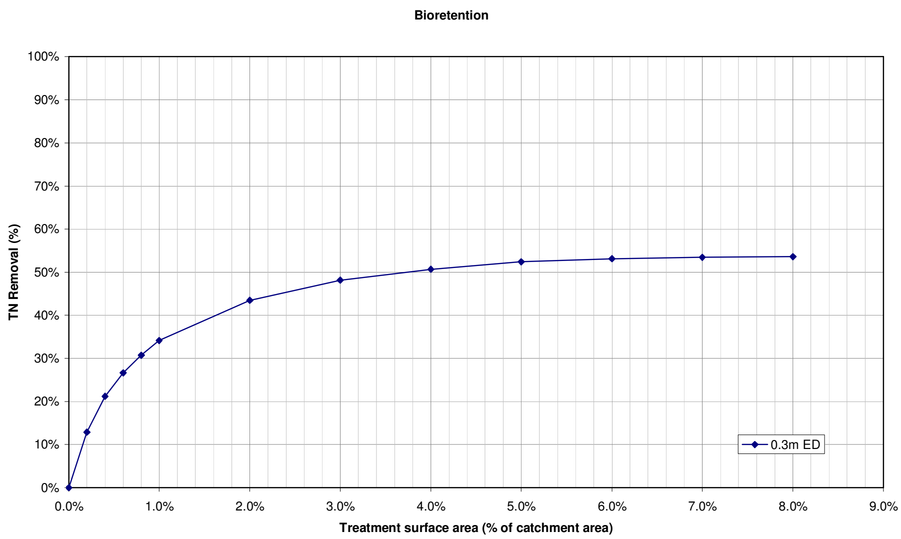
Bioretention



Industrial

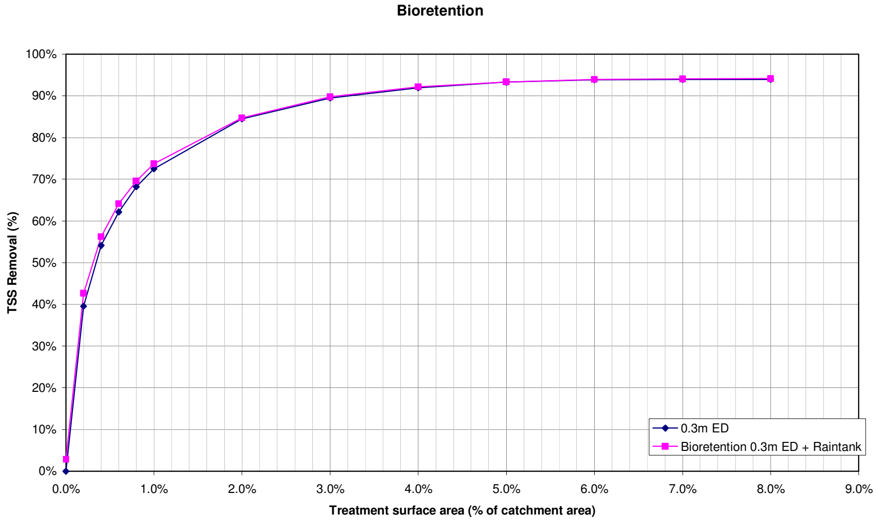

Bioretention
TSS Removal (%)
Treatment surface area (% of catchment area)
0.3m ED

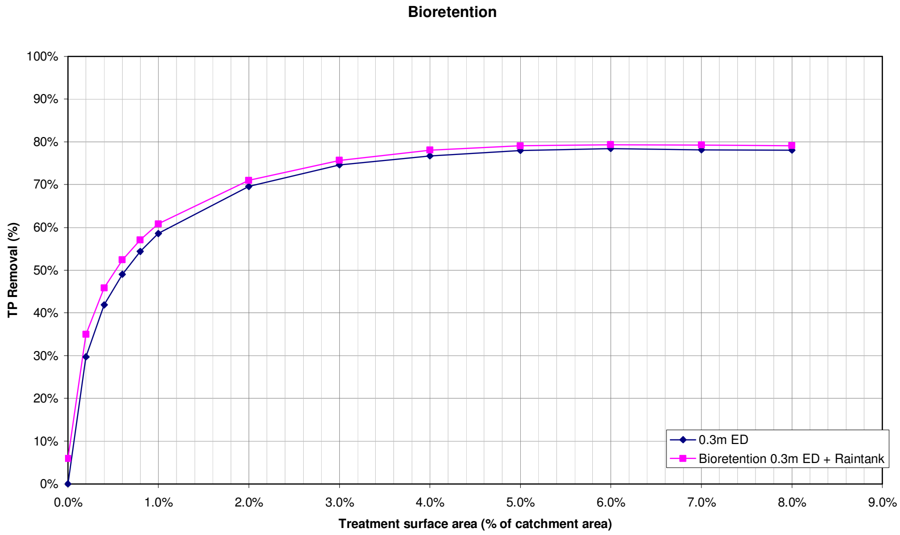

Bioretention
TP Removal (%)
Treatment surface area (% of catchment area)
0.3m ED

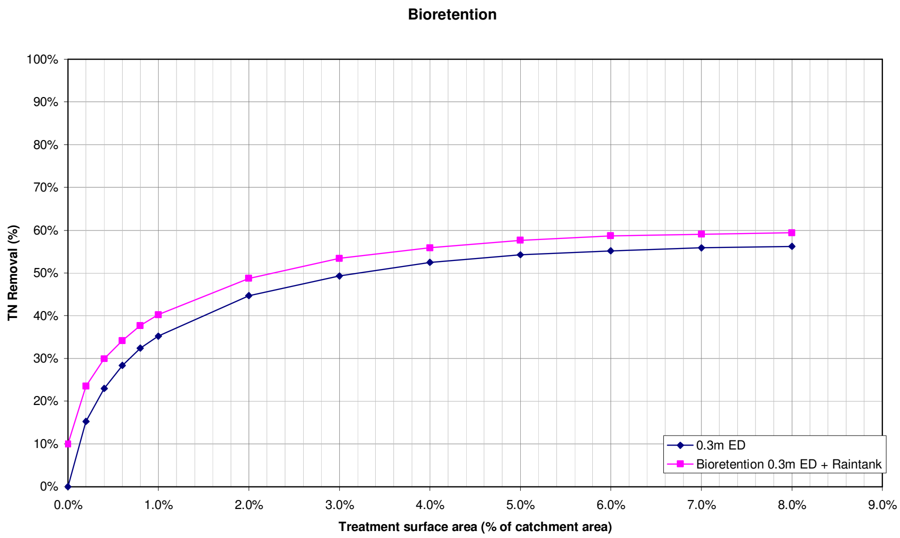

Bioretention
TN Removal (%)
Treatment surface area (% of catchment area)
0.3m ED

"Wet" Tropics: Cairns

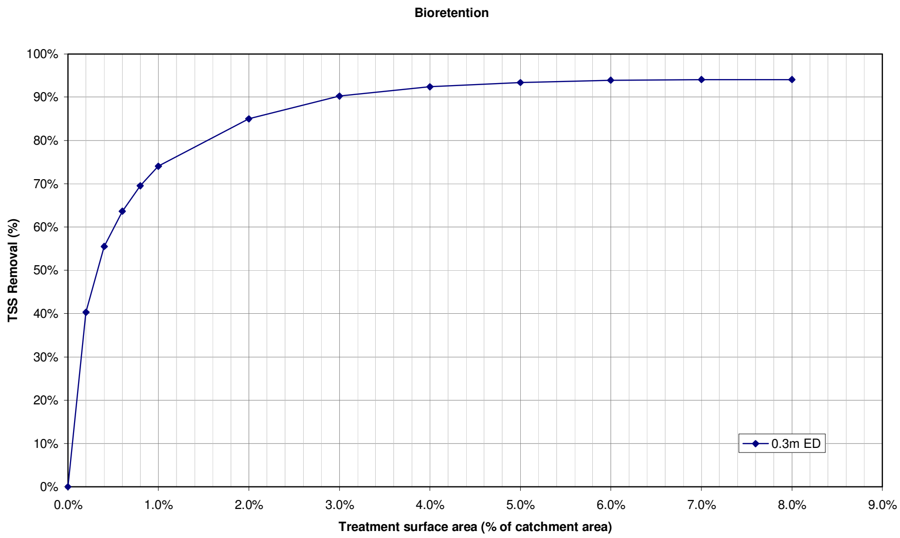
Residential

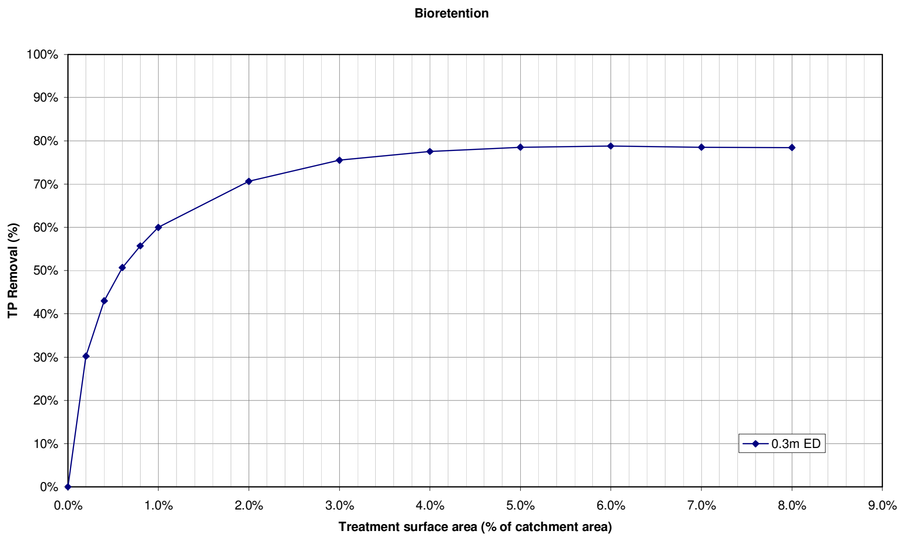






Industrial


Bioretention
TSS Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m ED


Bioretention
TP Removal (%)
100%
90%
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1.0%
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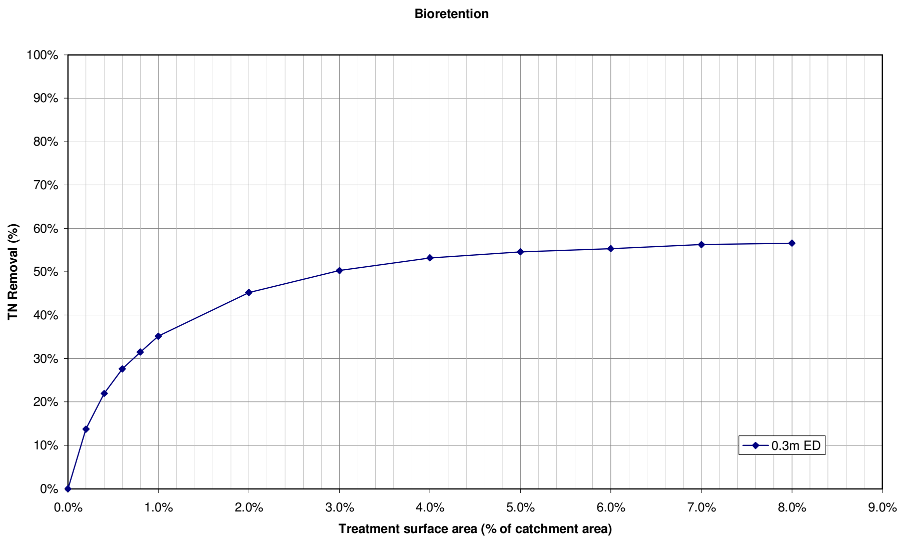
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m ED


Bioretention
TN Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
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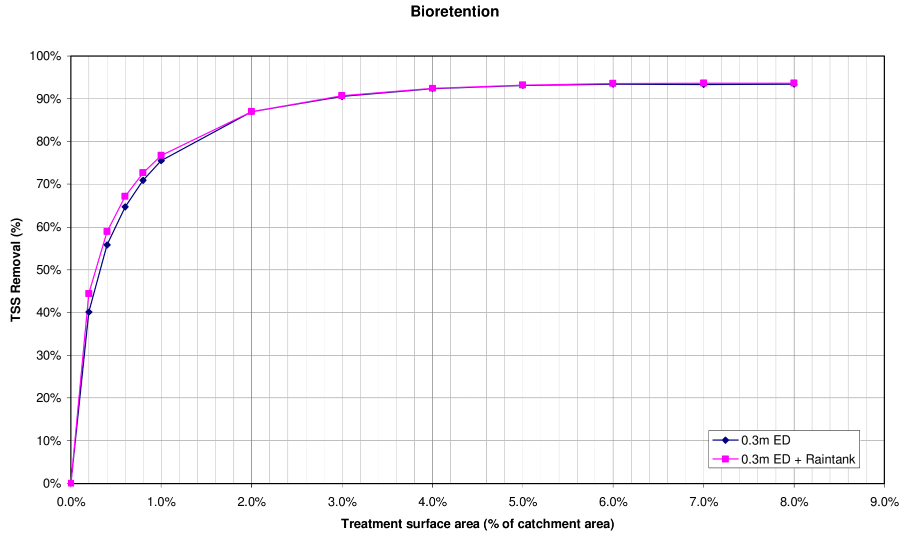
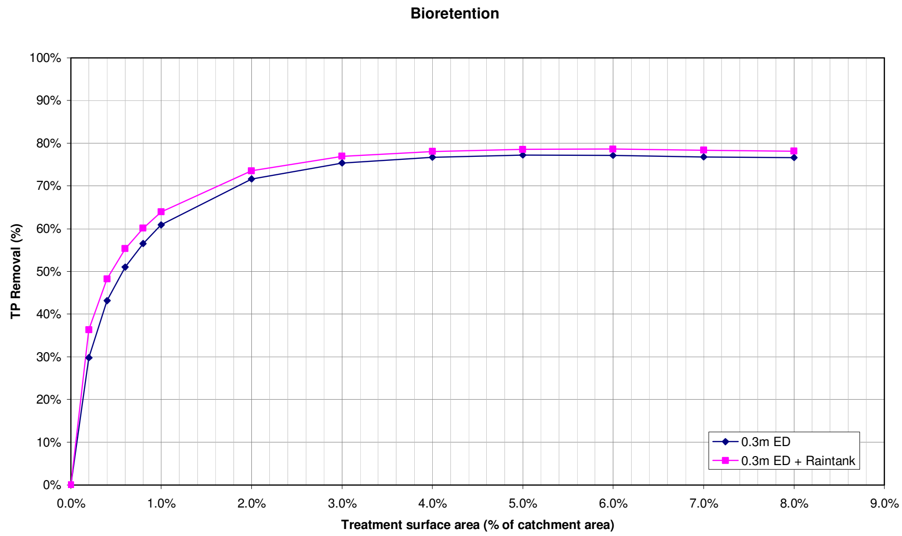
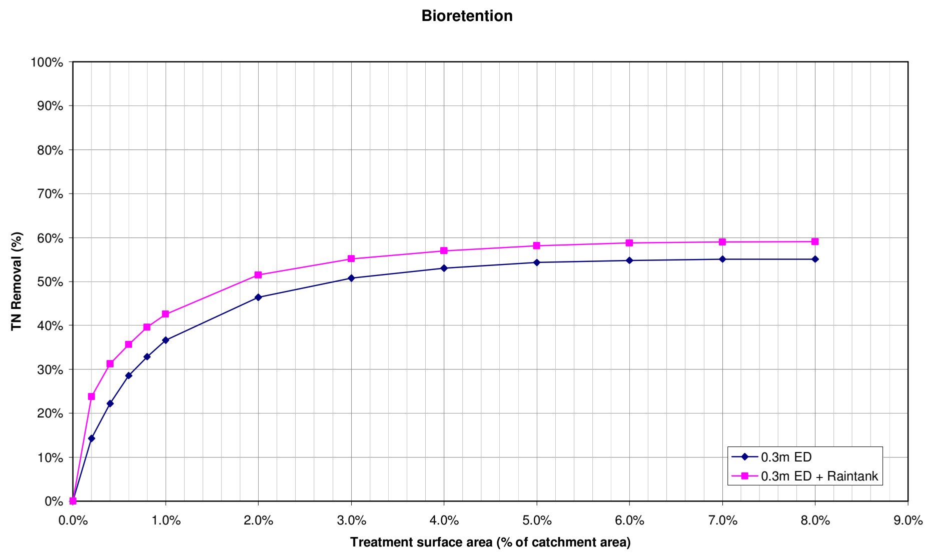
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m ED

"Dry" Tropics: Townsville

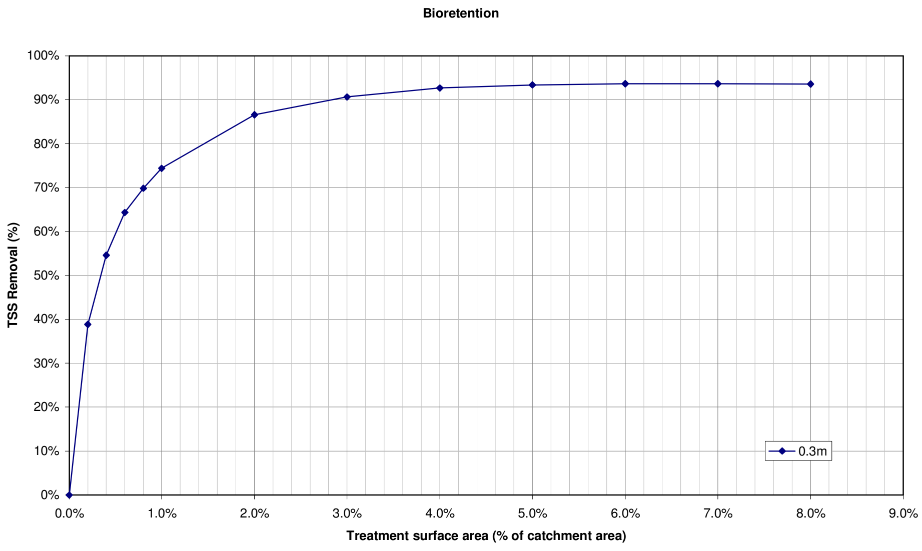
Residential







Industrial


Bioretention
TSS Removal (%)
Treatment surface area (% of catchment area)
0.3m
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
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4.0%
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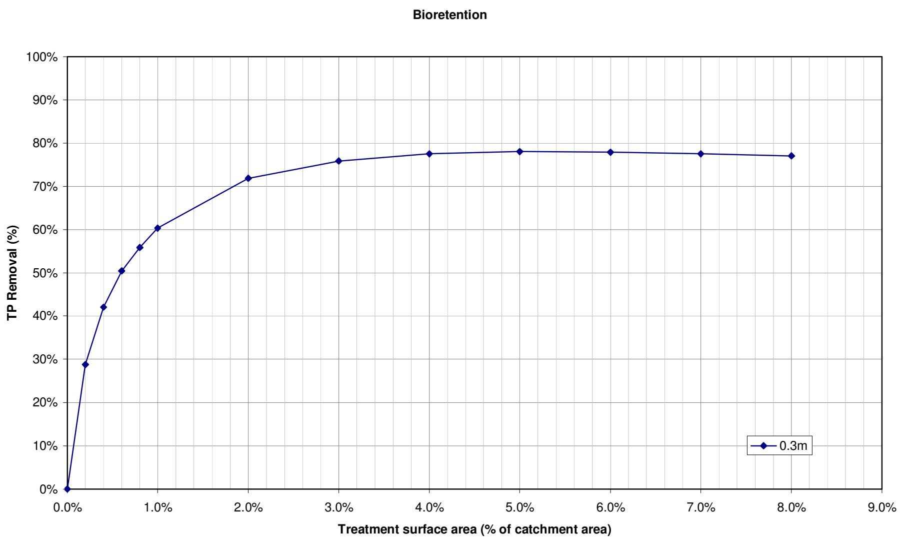
7.0%
8.0%
9.0%


Bioretention
TP Removal (%)
Treatment surface area (% of catchment area)
0.3m
100%
90%
80%
70%
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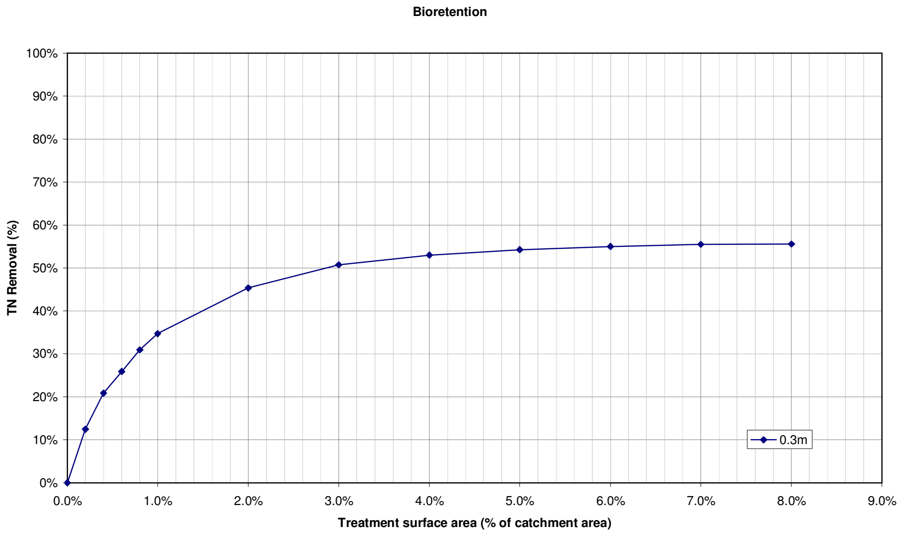
Bioretention
TN Removal (%)
Treatment surface area (% of catchment area)
0.3m
100%
90%
80%
70%
60%
50%
40%
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10%
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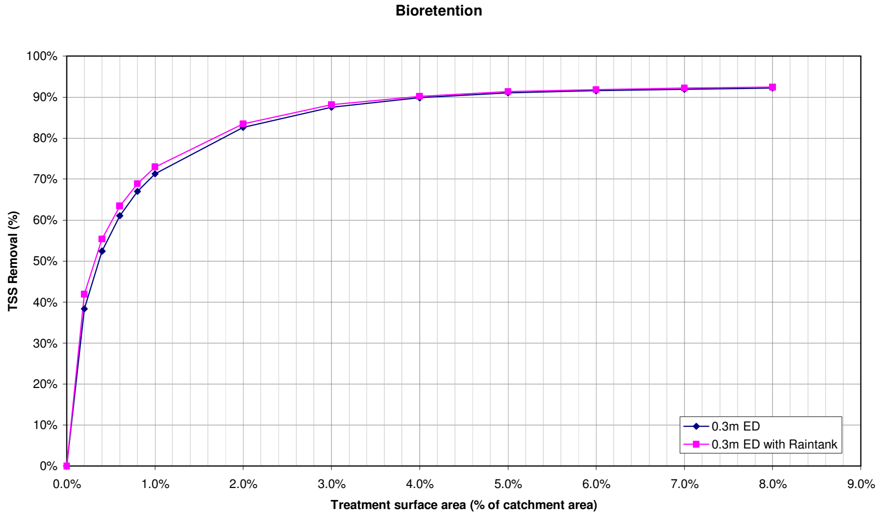
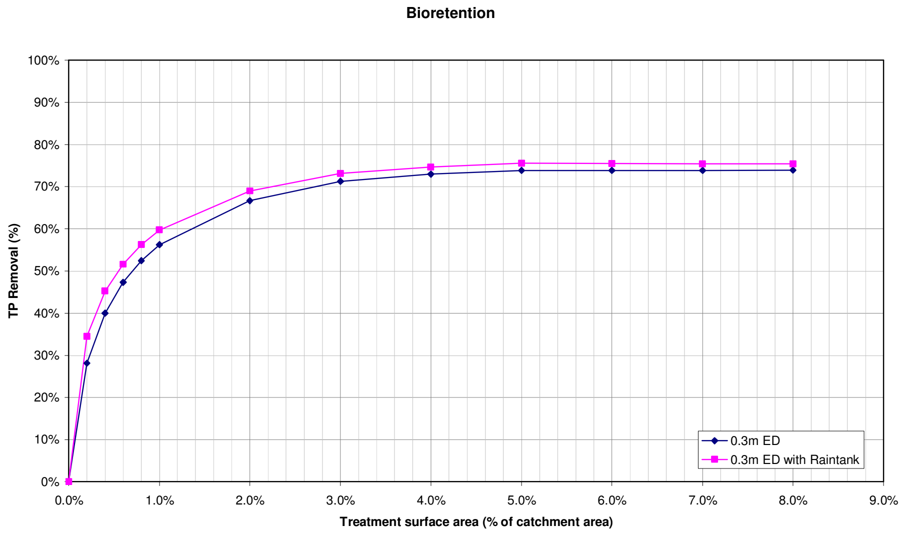
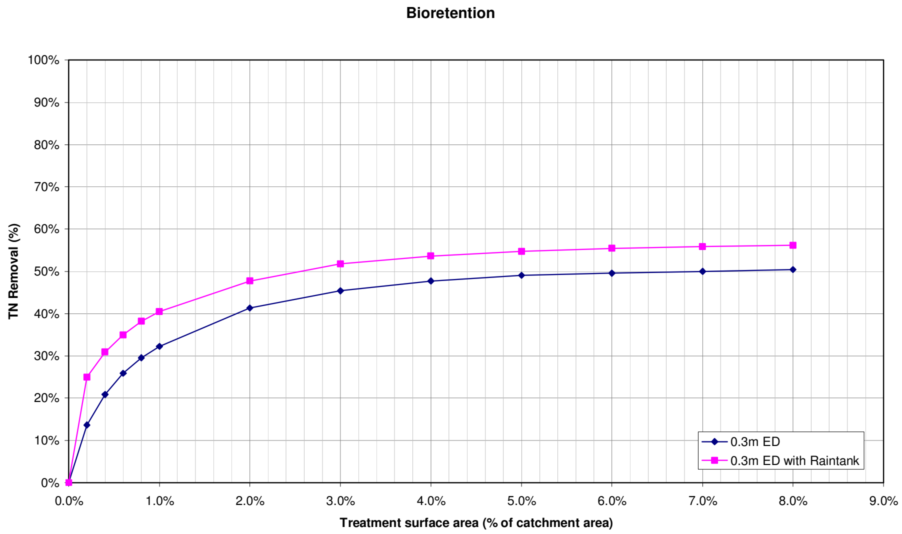
9.0%

Central Coast North: Mackay

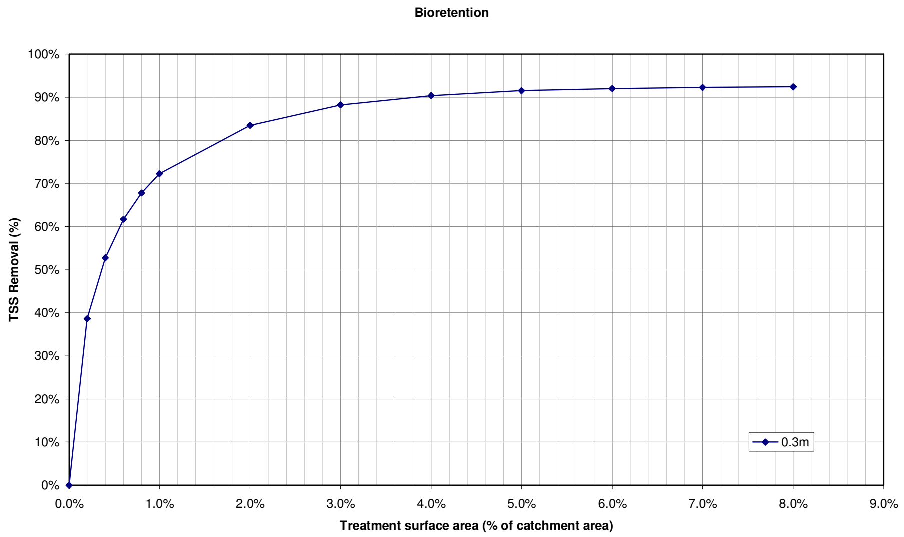
Residential

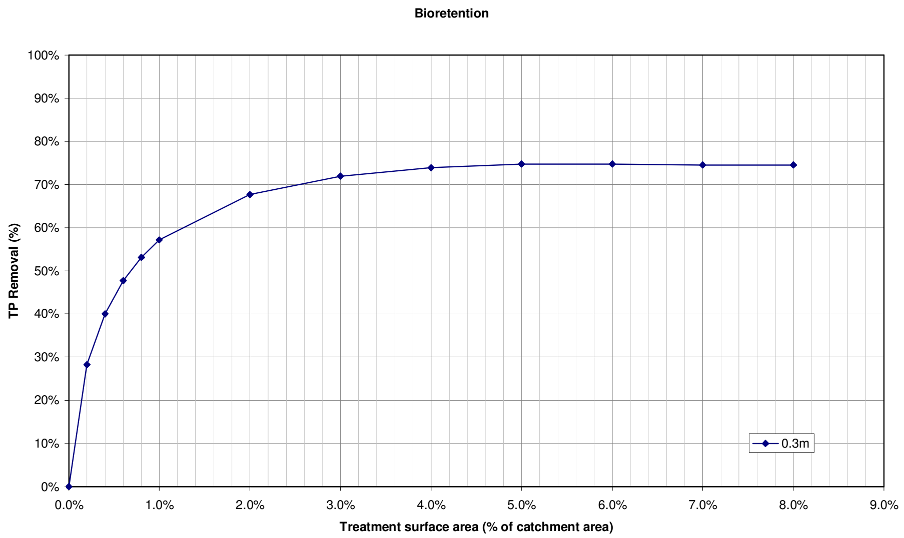


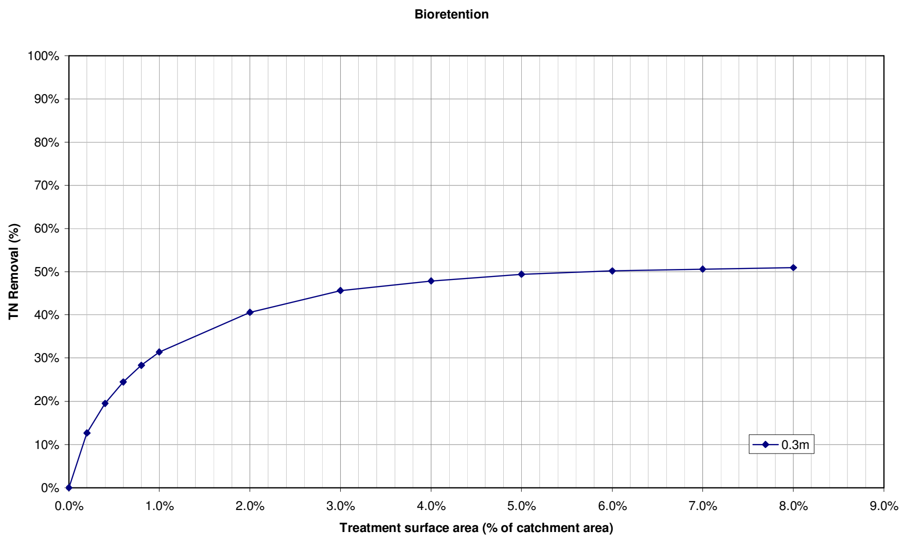




Industrial


Bioretention
TSS Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m


Bioretention
TP Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m


Bioretention
TN Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
3.0%
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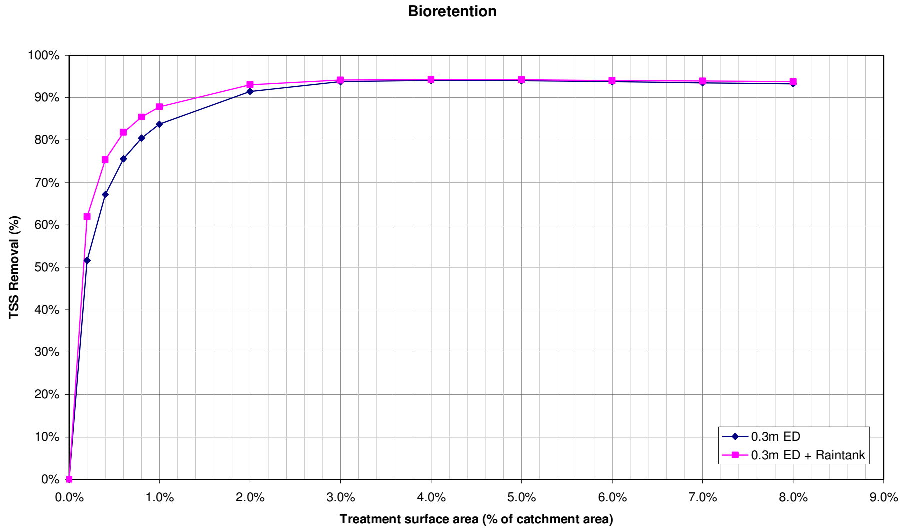
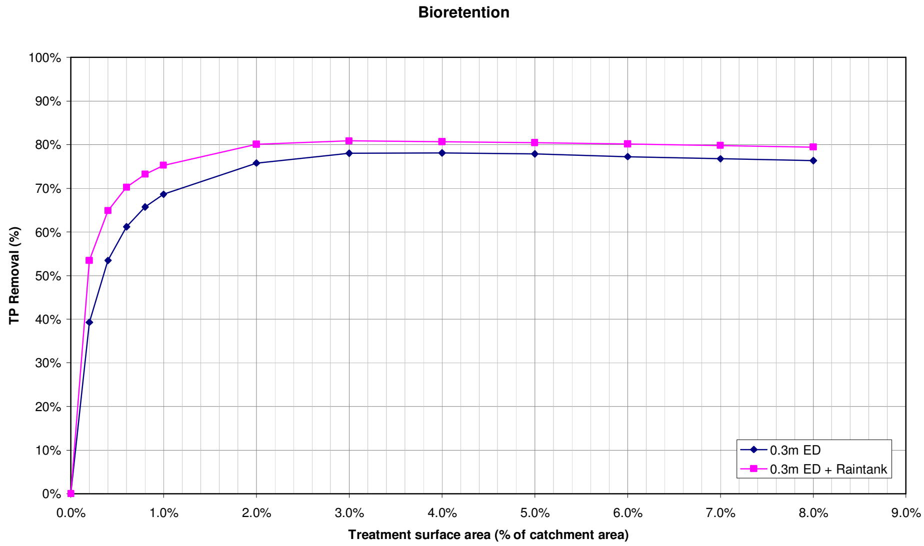
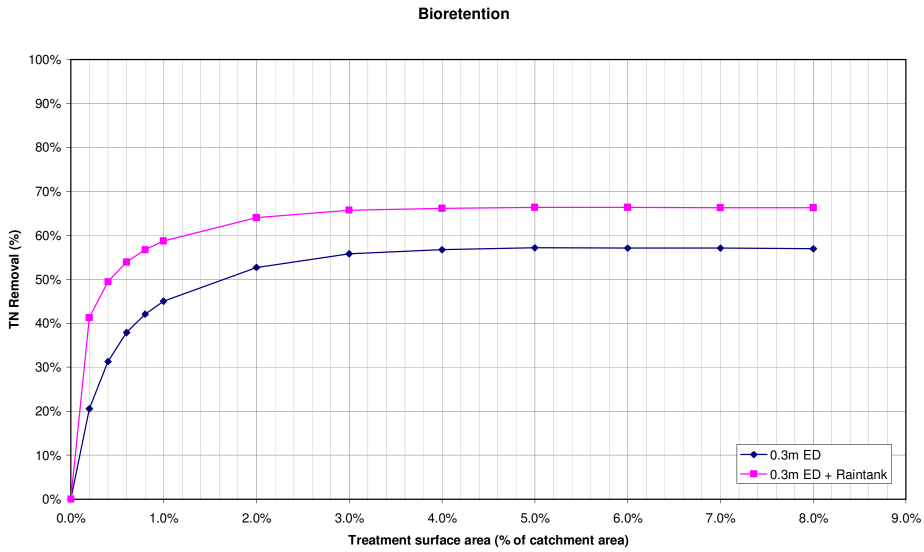
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m

Central Coast South: Rockhampton

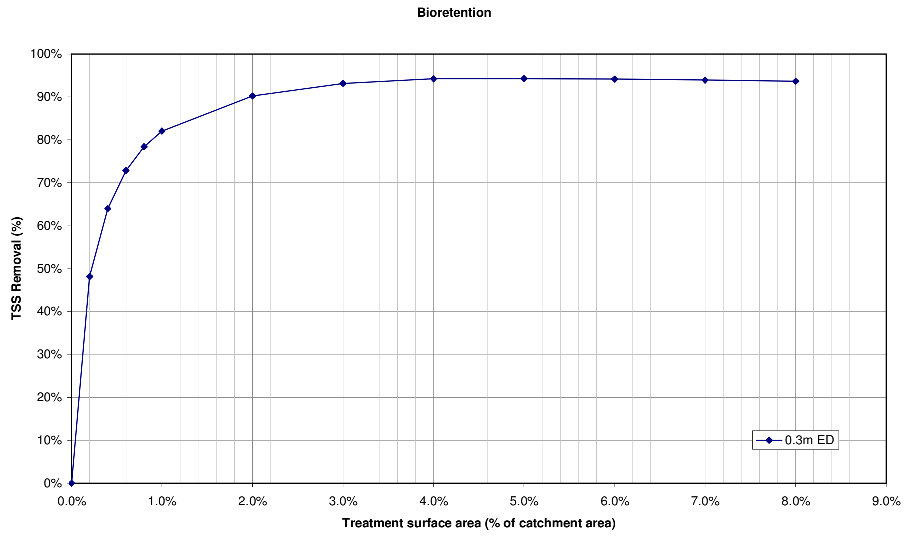
Residential

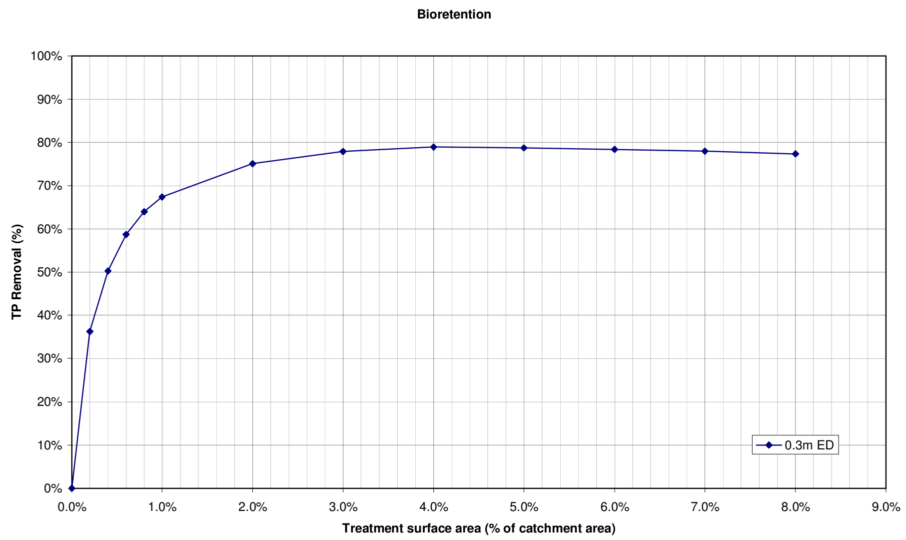


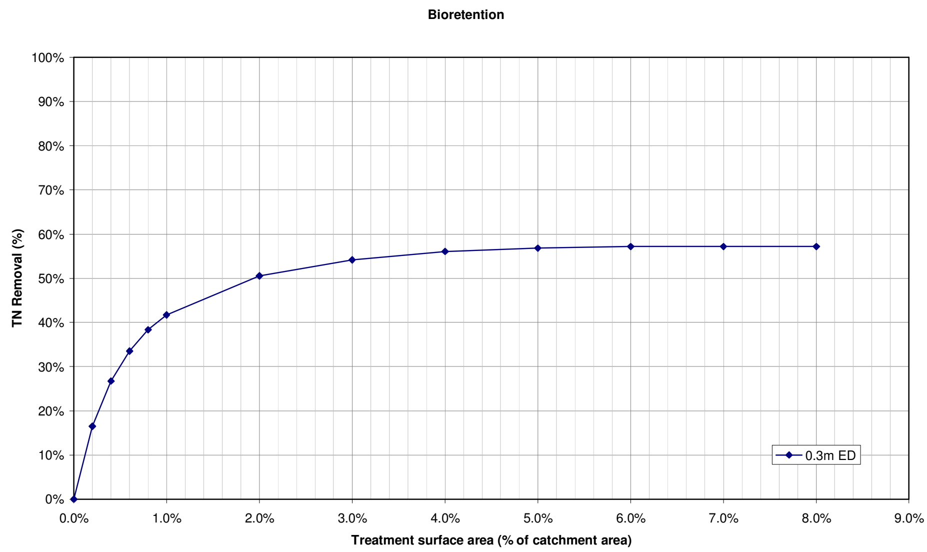




Industrial

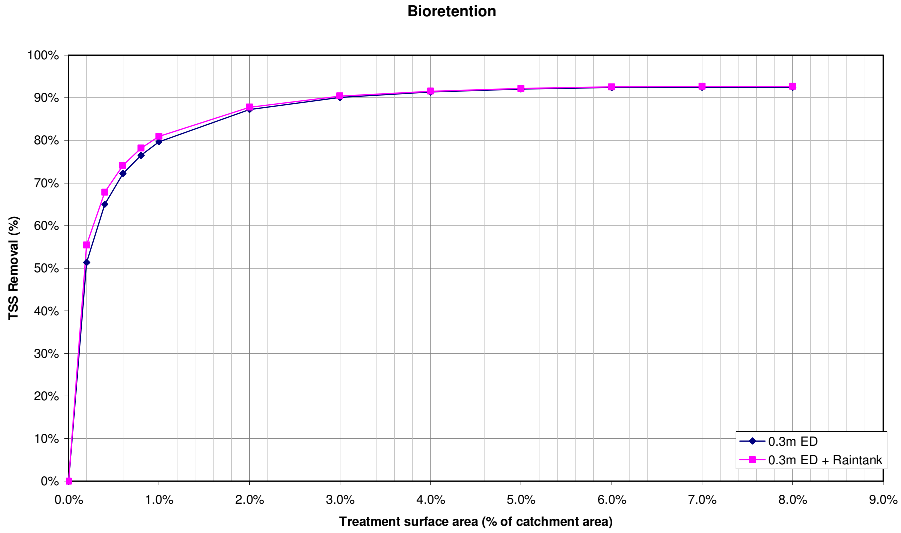

Bioretention
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
TSS Removal (%)
0.3m ED
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)

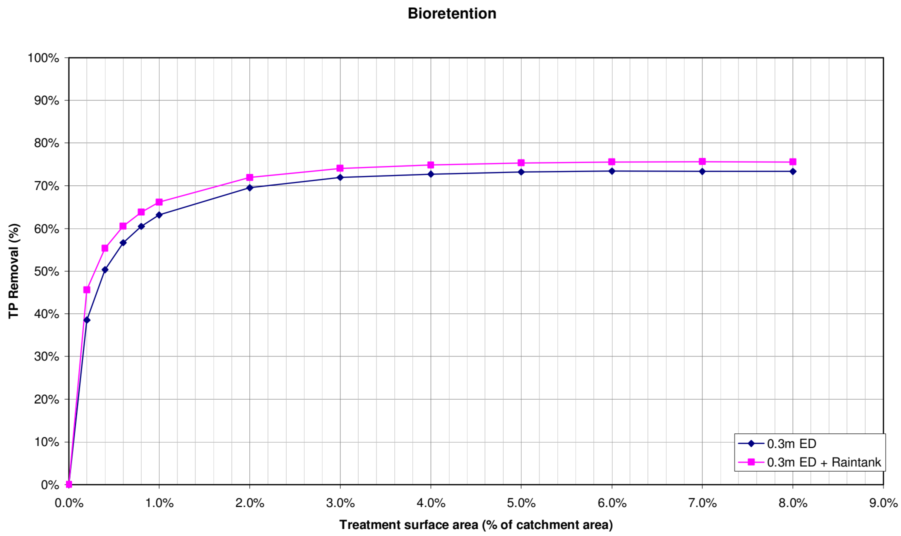

Bioretention
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
TP Removal (%)
0.3m ED
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)

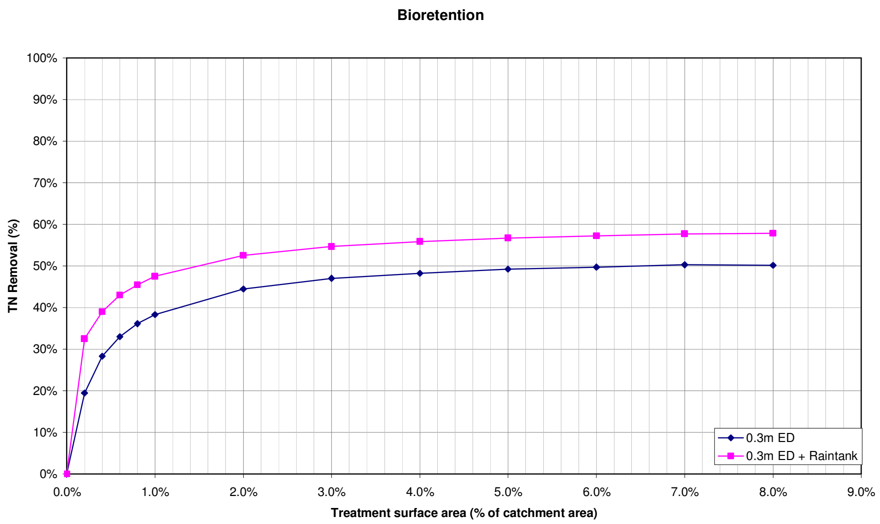

Bioretention
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
TN Removal (%)
0.3m ED
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)

South East Queensland: Nambour

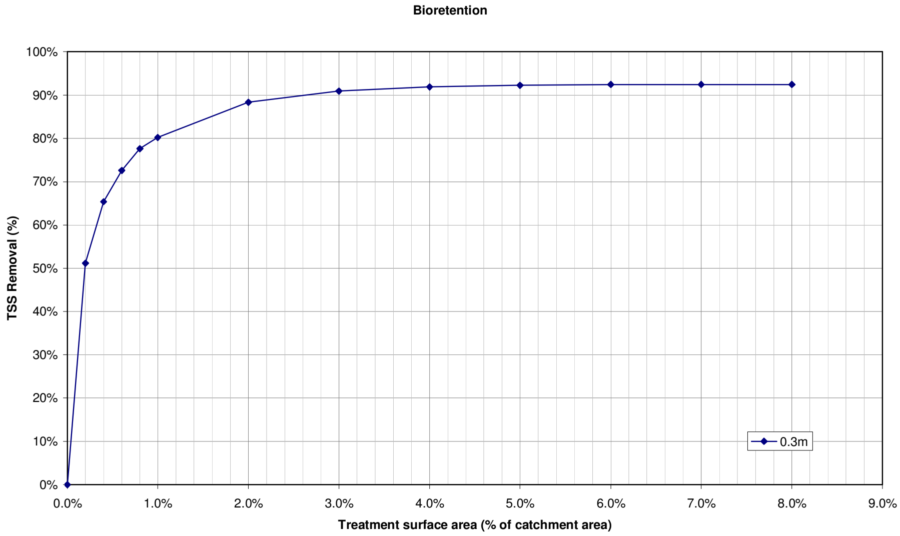
Residential

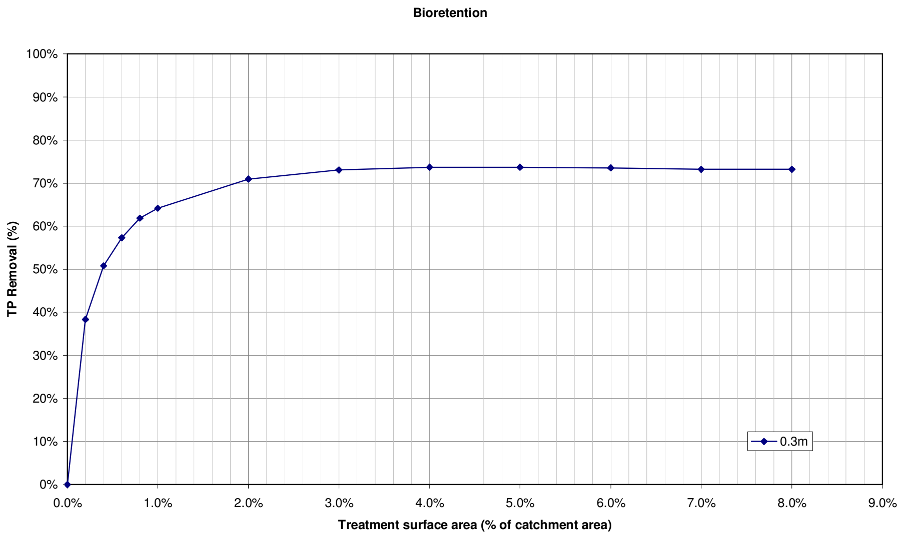


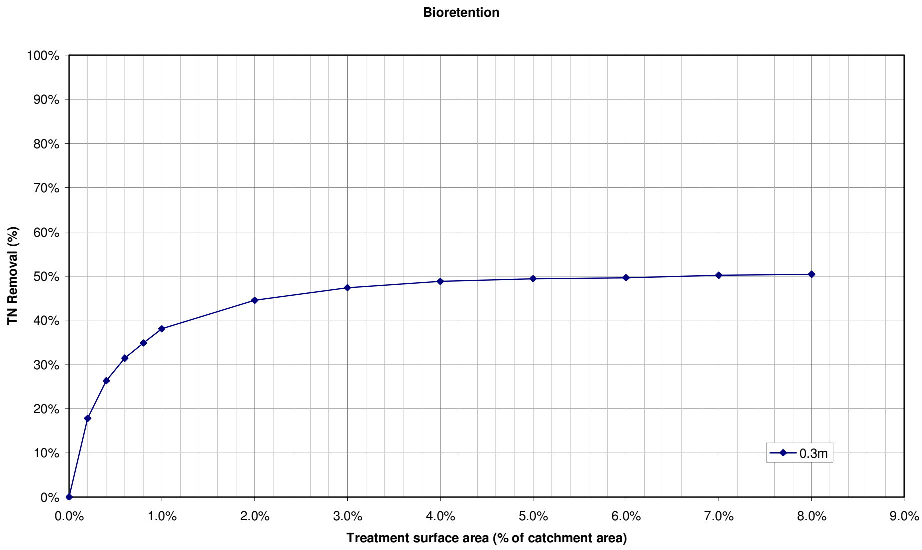




Industrial

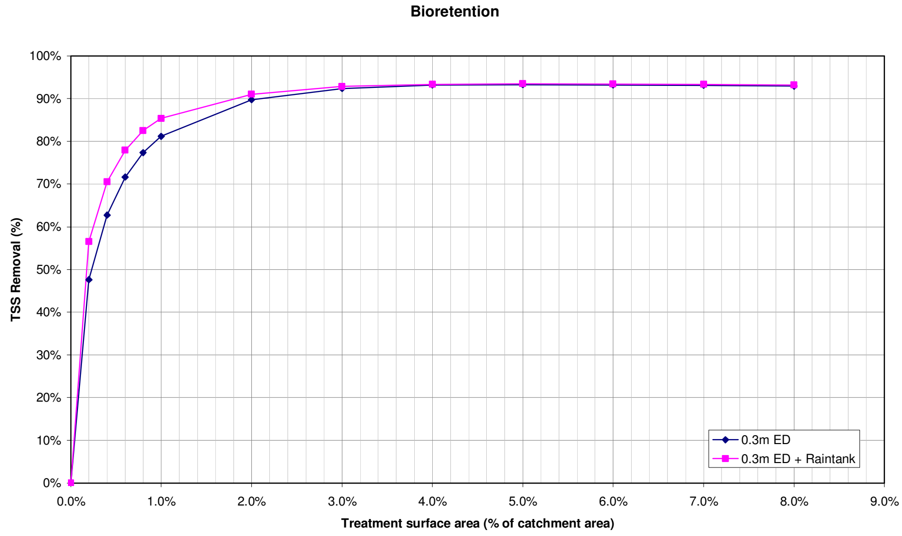

Bioretention
TSS Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m

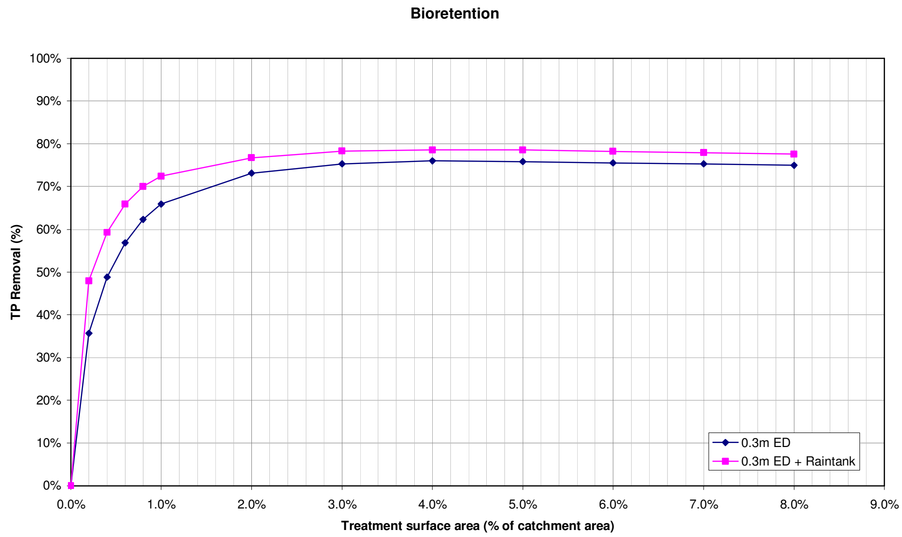

Bioretention
TP Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m

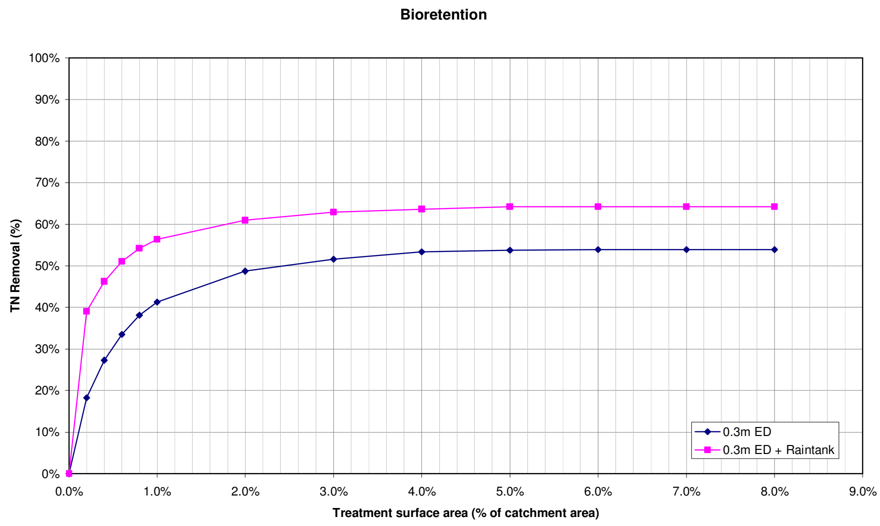

Bioretention
TN Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m

Western Districts: Mt Isa

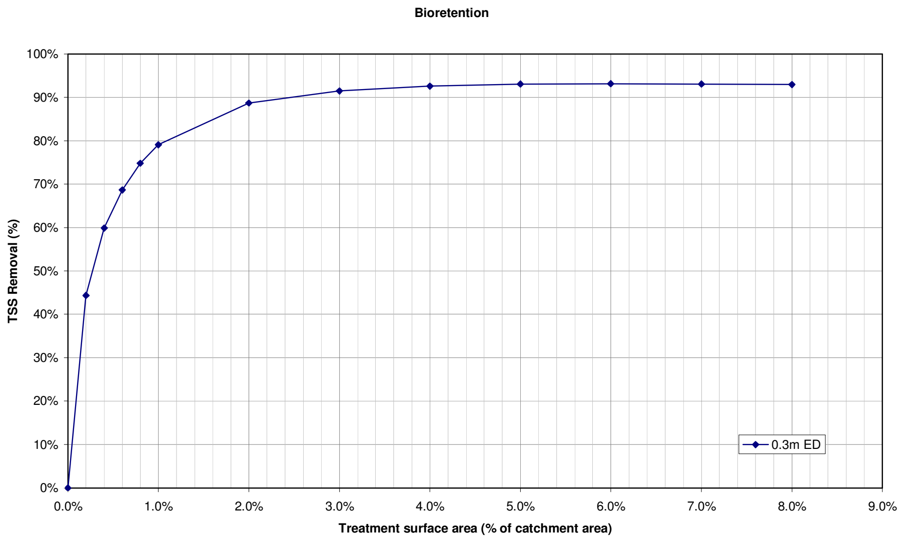
Residential

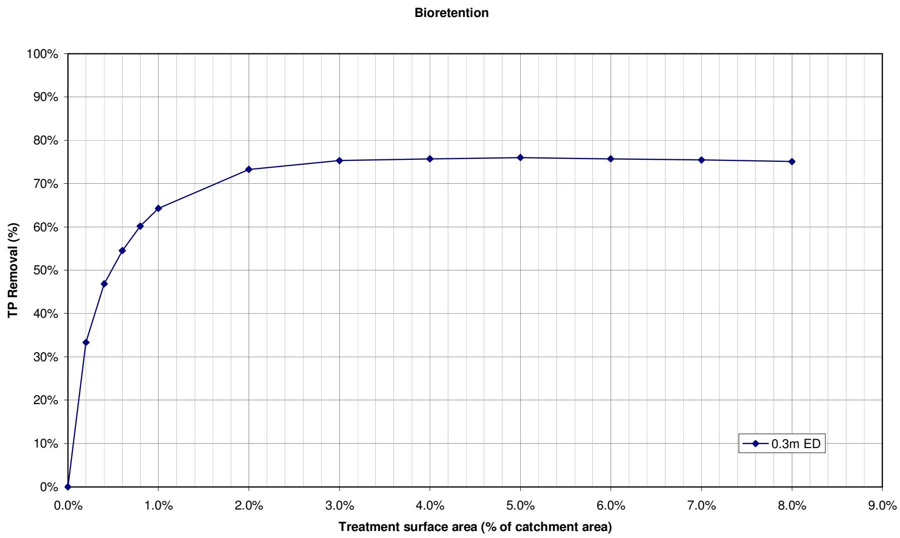


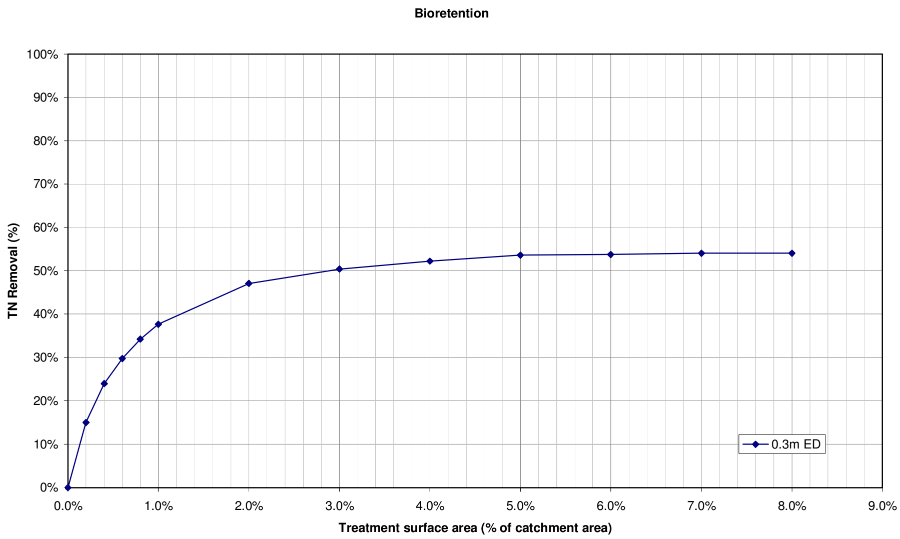




Industrial

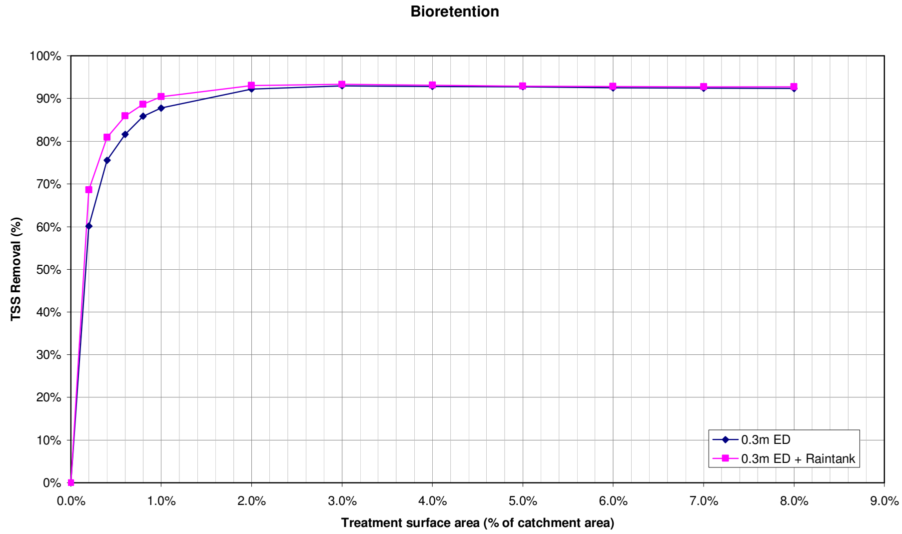

Bioretention
TSS Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m ED

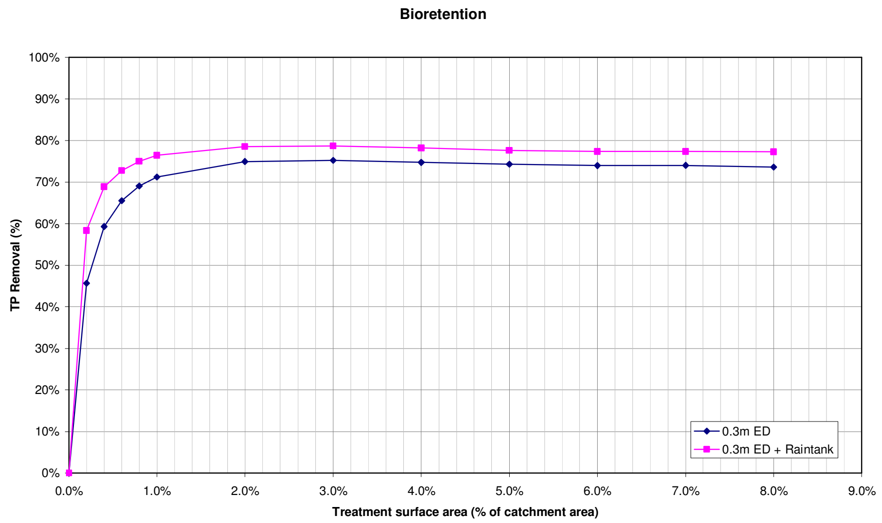

Bioretention
TP Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m ED

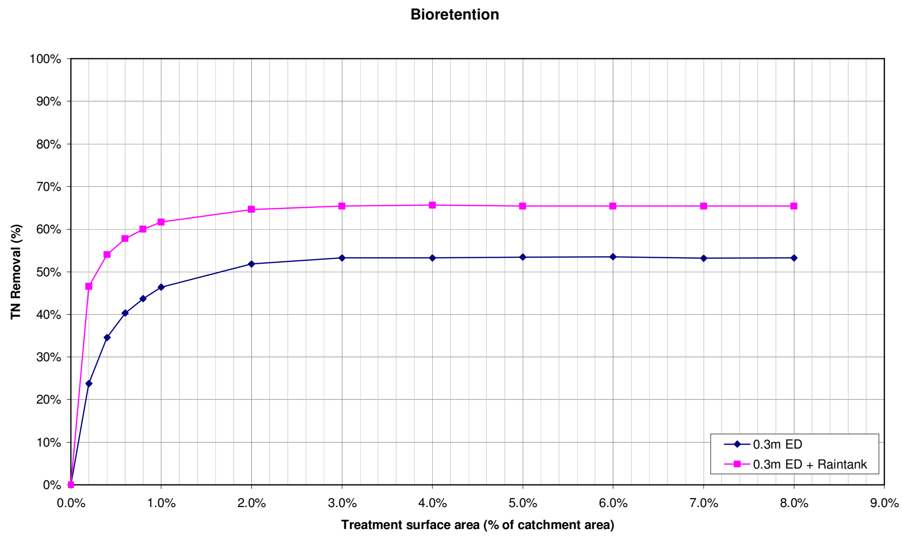

Bioretention
TN Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m ED

Western Districts: Charleville

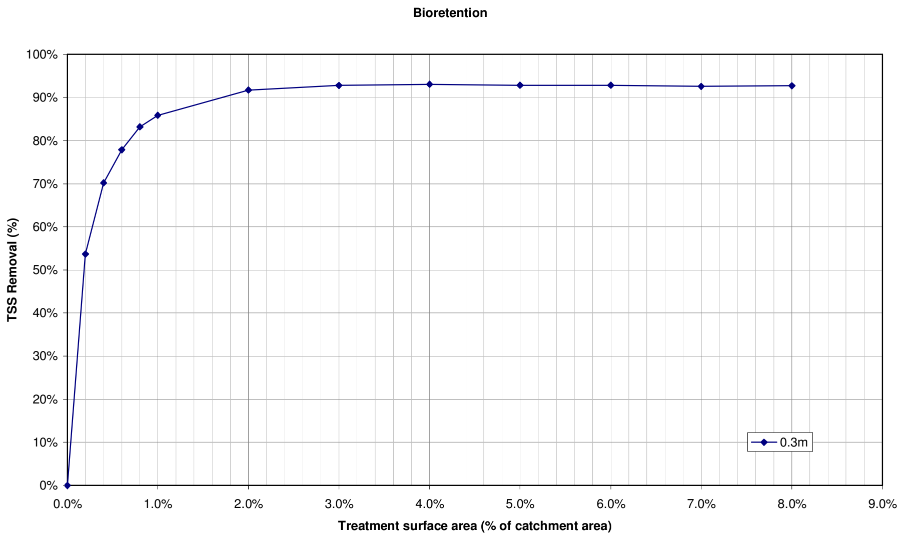
Residential

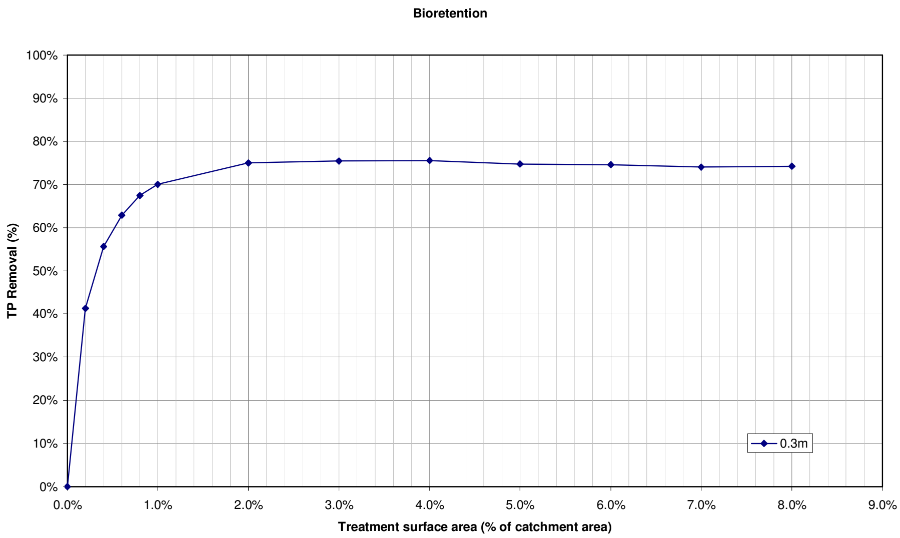


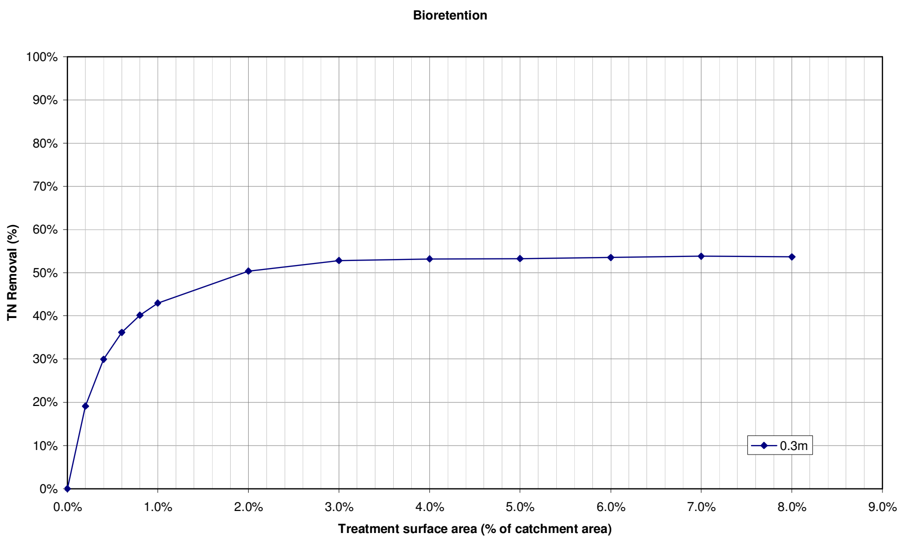


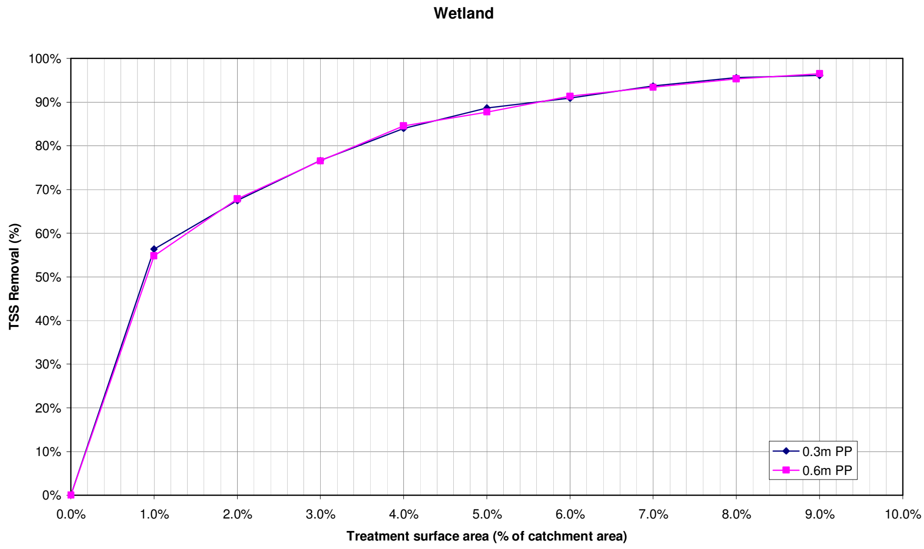


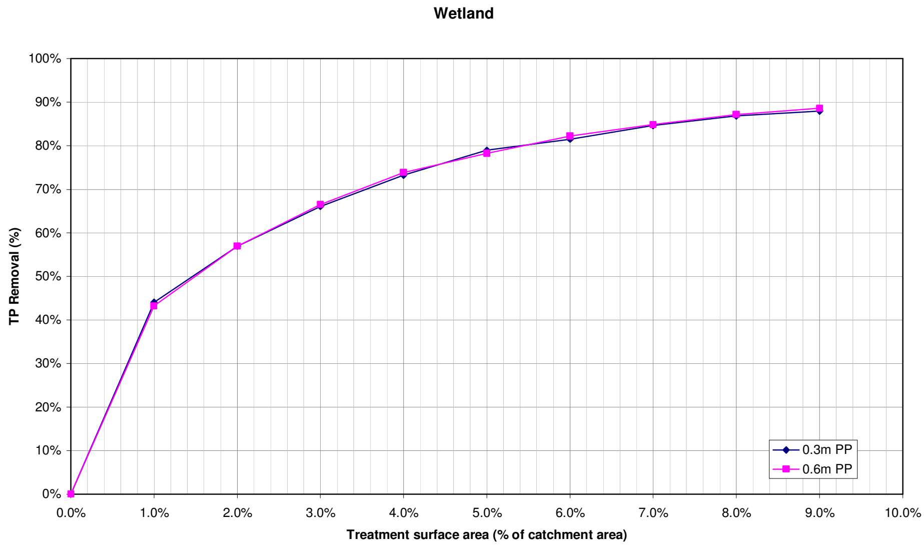
Industrial

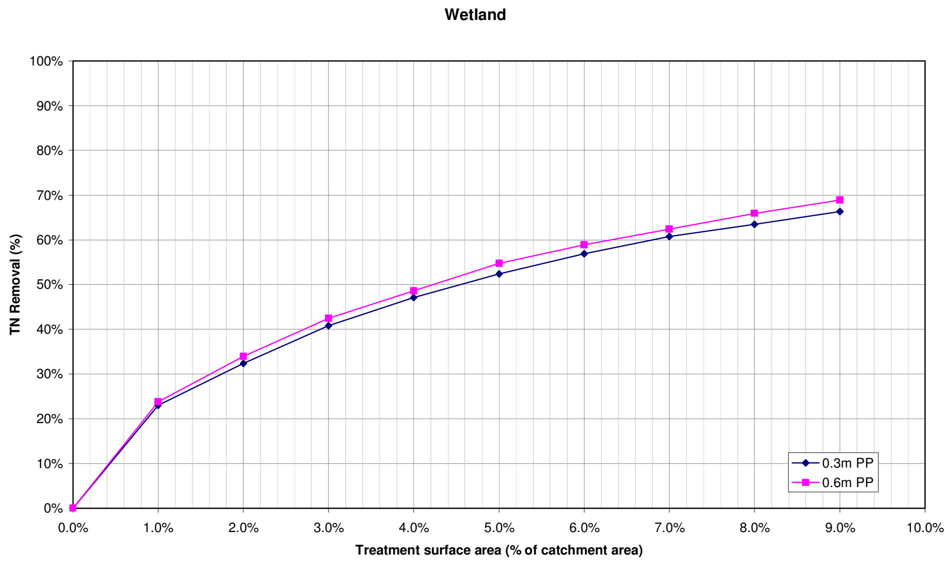

Bioretention
TSS Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m


Bioretention
TP Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m


Bioretention
TN Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)
0.3m


Wetland
TSS Removal (%)
Treatment surface area (% of catchment area)
0.3m PP
0.6m PP


Wetland
TP Removal (%)
Treatment surface area (% of catchment area)
0.3m PP
0.6m PP


Wetland
TN Removal (%)
Treatment surface area (% of catchment area)
0.3m PP
0.6m PP

Appendix B: Derivation of Water Quantity Design Objectives – frequent flow management objective

Numerical modelling studies were undertaken to establish appropriate design capture volumes to achieve the proposed frequent flow objective for Queensland. The capture volume was selected to provide a similar frequency of surface runoff form small rainfall events and to achieve a similar overall volumetric runoff coefficient to an undeveloped site.

Preliminary analysis was undertaken using MUSIC and the River Analysis Package (RAP) to determine:

- Surface runoff characteristics under "pre-development" catchment conditions
- Surface runoff characteristics under different "post-development" conditions with differing initial capture and management rates

The analysis was undertaken using 6 minute rainfall data from each climatic region. The data used from the Bureau of Meteorology is shown below.

	Rainfall station	Period of rainfall data
Eastern Cape York	LOCKHART RIVER	16/6/2001 - 31/8/2006 (Five years two months)
Central and Western Cape York (north)	WEIPA	1/1/1980 - 31/12/1989 (Ten years)
Central and Western Cape York (south)	PALMERVILLE	1/1/1990 - 31/12/1999 (Ten years)
Wet Tropics	CAIRNS	1/1/1975 - 31/12/1984 (Ten years)
Dry Tropics	TOWNSVILLE	1/1/1970- 31/12/1983 (Fourteen years)
Central Coast (north)	MACKAY	1/1/1990- 21/12/1999 (Ten years)
Central Coast (south)	ROCKHAMPTON	1/1/1980 - 31/12/1989 (Ten years)
South East Queensland	NAMBOUR	1/1/1985 - 31/12/1998 (Fourteen years)
Western Districts	MOUNT ISA CHARLEVILLE	1/1/1990 - 31/12/1999 (Ten years) 1/1/1990 - 31/12/1999 (Ten years)

The soil moisture parameters were based on the MUSIC model defaults and pollutant generation parameters were taken from Gold Coast City Council's MUSIC Guidelines.

Pre-development
The pre-developed catchment was modelled as an urban catchment with 0% impervious areas.

Post-development
The post development catchment was modelled as urban catchments with the following proportiion of impervious area:

- 20%
- 40%
- 60%
- 80%

Each of these scenarios was run with capture and management of the first 0, 5, 10, 15 and 25mm of daily runoff from impervious areas. The AVR calculations for each of these based on the different climatic regions are shown below.

Flow duration curves are also attached showing the "pre-development" condition (0% impervious), impervious runoff with no capture as well as with 5mm, 10mm, 15mm and 20mm daily runoff capture rates for each climatic region. The X-axis is the percentage of time exceeded (expressed as a proportion, not as percentage). Where the flow duration curves depart from the "pre-development" condition reveals the frequency of occurrence of surface runoff events.

The results presented in this section demonstrate that the required capture volume increases with the proportion of impervious area.

AVR Calculations for each climatic region

(a summary of these results in presented in section 3 of this report)

Eastern Cape York: Lockhart River

Total Fraction Impervious %	Daily Capture and Management mm/day	Target AVR (pre-development) ML/day	Actual AVR ML/year
20	0	10.2	11.8
	5	10.2	11
	10	10.2	10.5
	15	10.2	10.1
	20	10.2	9.84
40	0	10.2	13.5
	5	10.2	11.9
	10	10.2	10.9
	15	10.2	10.1
	20	10.2	9.48
60	0	10.2	15.1
	5	10.2	12.7
	10	10.2	11.2
	15	10.2	10
	20	10.2	9.12
80	0	10.2	16.6
	5	10.2	13.5
	10	10.2	11.5
	15	10.2	10
	20	10.2	8.76

Central and Western Cape York (north): Weipa

Total Fraction Impervious %	Daily Capture and Management mm/day	Target AVR (pre-development) ML/day	Actual AVR ML/year
20	0	8.35	9.91
	5	8.35	9.17
	10	8.35	8.65
	15	8.35	8.25
	20	8.35	7.94
40	0	8.35	11.5
	5	8.35	10
	10	8.35	8.95
	15	8.35	8.15
	20	8.35	7.52
60	0	8.35	13
	5	8.35	10.8
	10	8.35	9.25
	15	8.35	8.05
	20	8.35	7.11
80	0	8.35	14.6
	5	8.35	11.6
	10	8.35	9.55
	15	8.35	7.95
	20	8.35	6.7

Central and Western Cape York (south): Palmerville

Total Fraction Impervious %	Daily Capture and Management mm/day	Target AVR (pre-development) ML/day	Actual AVR ML/year
20	0	3.55	4.72
	5	3.55	4.2
	10	3.55	3.85
	15	3.55	3.61
	20	3.55	3.41
40	0	3.55	5.89
	5	3.55	4.84
	10	3.55	4.15
	15	3.55	3.66
	20	3.55	3.28
60	0	3.55	7.05
	5	3.55	5.48
	10	3.55	4.45
	15	3.55	3.71
	20	3.55	3.14
80	0	3.55	8.22
	5	3.55	6.12
	10	3.55	4.75
	15	3.55	3.77
	20	3.55	3

"Wet" Tropics: Cairns

Total Fraction Impervious %	Daily Capture and Management mm/day	Target AVR (pre-development) ML/day	Actual AVR ML/year
20	0	9.23	11
	5	9.23	10.2
	10	9.23	9.66
	15	9.23	9.31
	20	9.23	9.05
40	0	9.23	12.7
	5	9.23	11.1
	10	9.23	10.1
	15	9.23	9.4
	20	9.23	8.87
60	0	9.23	14.5
	5	9.23	12
	10	9.23	10.5
	15	9.23	9.49
	20	9.23	8.69
80	0	9.23	16.3
	5	9.23	12.9
	10	9.23	11
	15	9.23	9.58
	20	9.23	8.52

"Dry" Tropics: Townsville

Total Fraction Impervious %	Daily Capture and Management mm/day	Target AVR (pre-development) ML/day	Actual AVR ML/year
20	0	4.64	5.88
	5	4.64	5.4
	10	4.64	5.09
	15	4.64	4.86
	20	4.64	4.68
40	0	4.64	7.12
	5	4.64	6.16
	10	4.64	5.54
	15	4.64	5.08
	20	4.64	4.72
60	0	4.64	8.35
	5	4.64	6.92
	10	4.64	5.99
	15	4.64	5.31
	20	4.64	4.76
80	0	4.64	9.59
	5	4.64	7.69
	10	4.64	6.45
	15	4.64	5.53
	20	4.64	4.81

Central Coast (north): Mackay

Total Fraction Impervious %	Daily Capture and Management mm/day	Target AVR (pre-development) ML/day	Actual AVR ML/year
20	0	6.12	7.8
	5	6.12	7.15
	10	6.12	6.76
	15	6.12	6.49
	20	6.12	6.3
40	0	6.12	9.48
	5	6.12	8.17
	10	6.12	7.41
	15	6.12	6.87
	20	6.12	6.48
60	0	6.12	11.2
	5	6.12	9.2
	10	6.12	8.05
	15	6.12	7.25
	20	6.12	6.66
80	0	6.12	12.8
	5	6.12	10.2
	10	6.12	8.69
	15	6.12	7.63
	20	6.12	6.84

Central Coast (south): Rockhampton

Total Fraction Impervious %	Daily Capture and Management mm/day	Target AVR (pre-development) ML/day	Actual AVR ML/year
20	0	0.85	2.06
	5	0.85	1.64
	10	0.85	1.38
	15	0.85	1.2
	20	0.85	1.07
40	0	0.85	3.26
	5	0.85	2.43
	10	0.85	1.91
	15	0.85	1.55
	20	0.85	1.3
60	0	0.85	4.47
	5	0.85	3.22
	10	0.85	2.44
	15	0.85	1.9
	20	0.85	1.52
80	0	0.85	5.68
	5	0.85	4.01
	10	0.85	2.98
	15	0.85	2.25
	20	0.85	1.75

South East Queensland: Nambour

Total Fraction Impervious %	Daily Capture and Management mm/day	Target AVR (pre-development) ML/day	Actual AVR ML/year
20	0	4.78	6.64
	5	4.78	5.87
	10	4.78	5.4
	15	4.78	5.07
	20	4.78	4.84
40	0	4.78	8.5
	5	4.78	6.96
	10	4.78	6.02
	15	4.78	5.36
	20	4.78	4.9
60	0	4.78	10.4
	5	4.78	8.05
	10	4.78	6.64
	15	4.78	5.65
	20	4.78	4.96
80	0	4.78	12.2
	5	4.78	9.14
	10	4.78	7.27
	15	4.78	5.94
	20	4.78	5.02

Western Districts: Mount Isa

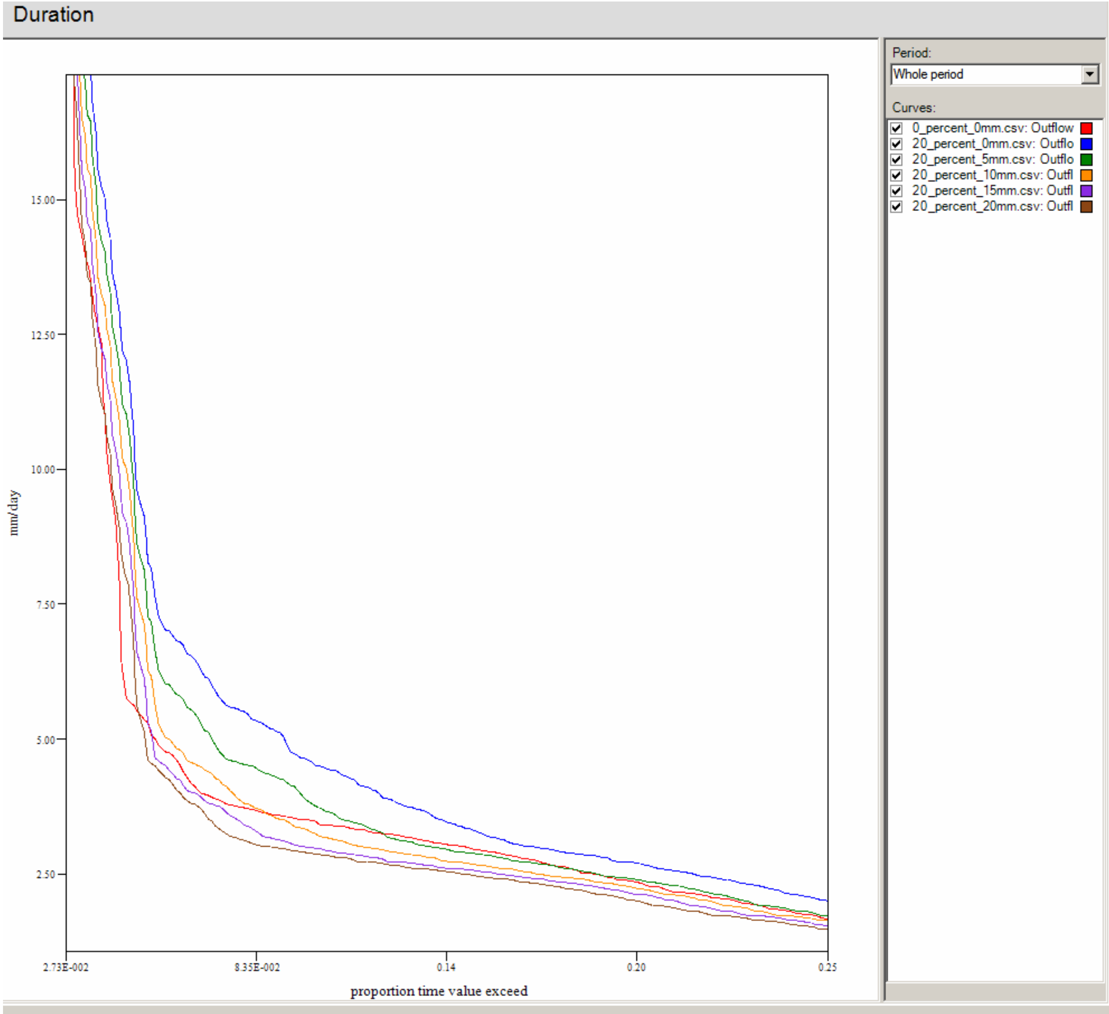
Total Fraction Impervious %	Daily Capture and Management mm/day	Target AVR (pre-development) ML/day	Actual AVR ML/year
20	0	0.67	1.39
	5	0.67	1.12
	10	0.67	0.95
	15	0.67	0.84
	20	0.67	0.76
40	0	0.67	2.11
	5	0.67	1.57
	10	0.67	1.23
	15	0.67	1
	20	0.67	0.86
60	0	0.67	2.83
	5	0.67	2.02
	10	0.67	1.51
	15	0.67	1.17
	20	0.67	0.95
80	0	0.67	3.55
	5	0.67	2.47
	10	0.67	1.79
	15	0.67	1.34
	20	0.67	1.05

Western Districts: Charleville

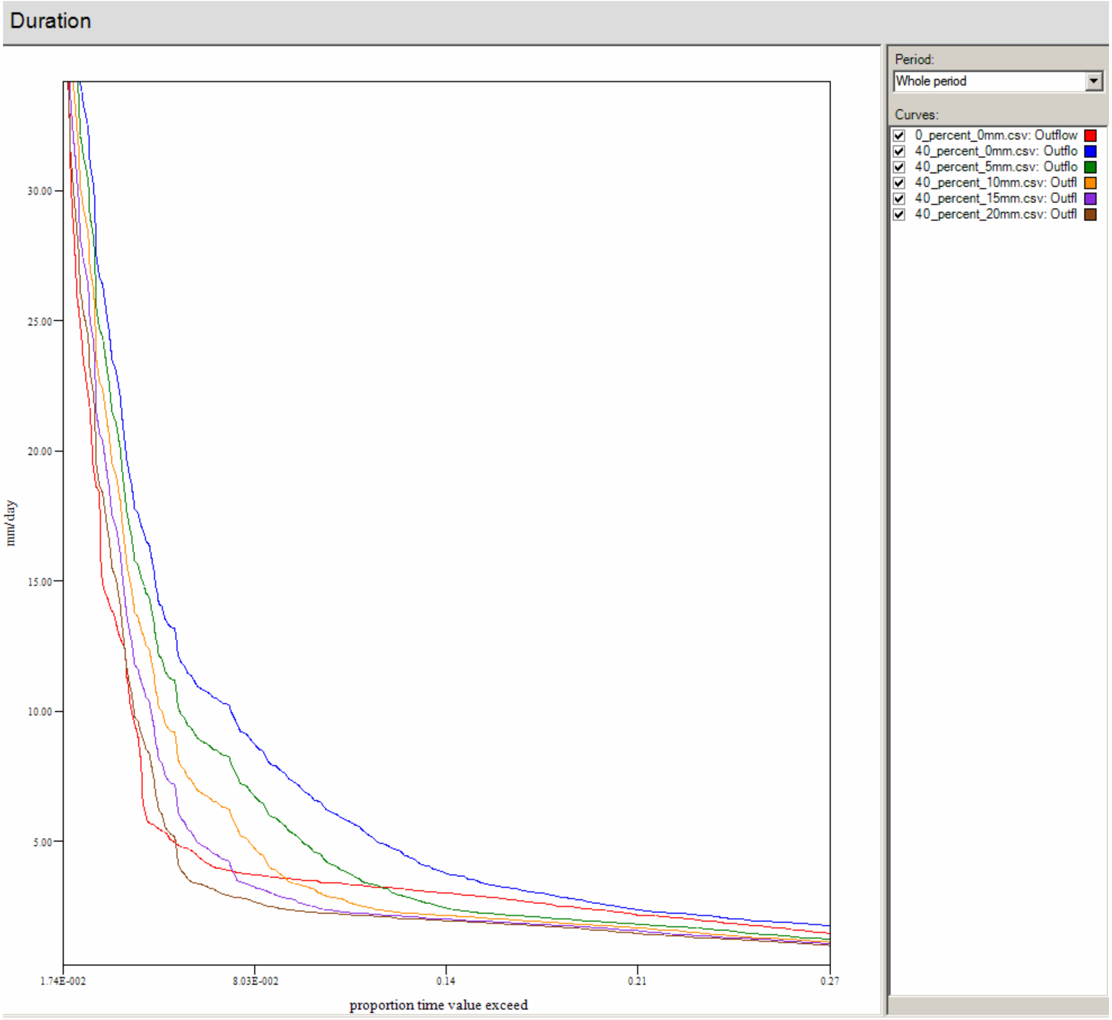
Total Fraction Impervious %	Daily Capture and Management mm/day	Target AVR (pre-development) ML/day	Actual AVR ML/year
20	0	0.381	1.14
	5	0.381	0.82
	10	0.381	0.68
	15	0.381	0.56
	20	0.381	0.48
40	0	0.381	1.9
	5	0.381	1.31
	10	0.381	0.97
	15	0.381	0.74
	20	0.381	0.57
60	0	0.381	2.66
	5	0.381	1.77
	10	0.381	1.26
	15	0.381	0.92
	20	0.381	0.67
80	0	0.381	3.42
	5	0.381	2.23
	10	0.381	1.55
	15	0.381	1.1
	20	0.381	0.76

Flow Duration Curves for each climatic region

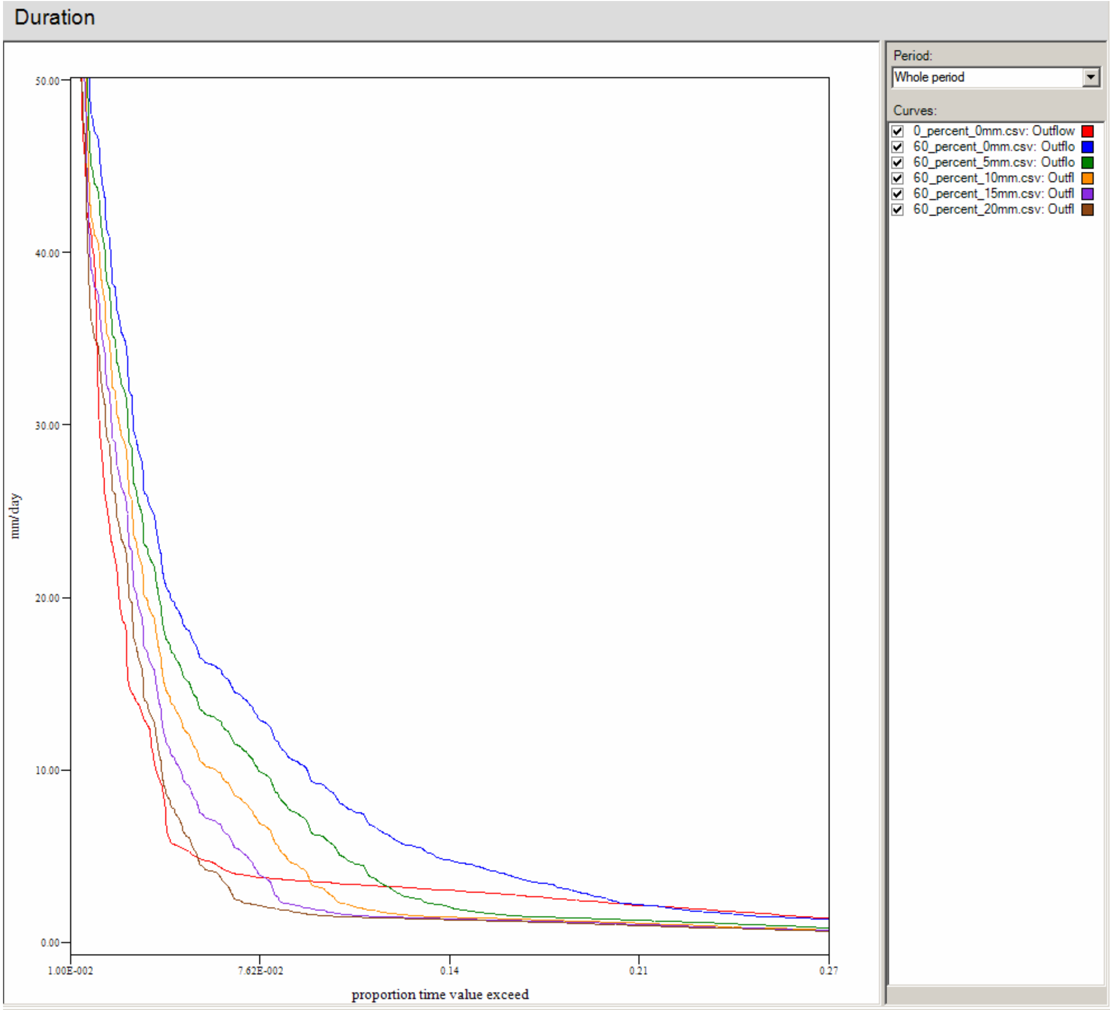
Eastern Cape York: Lockhart River



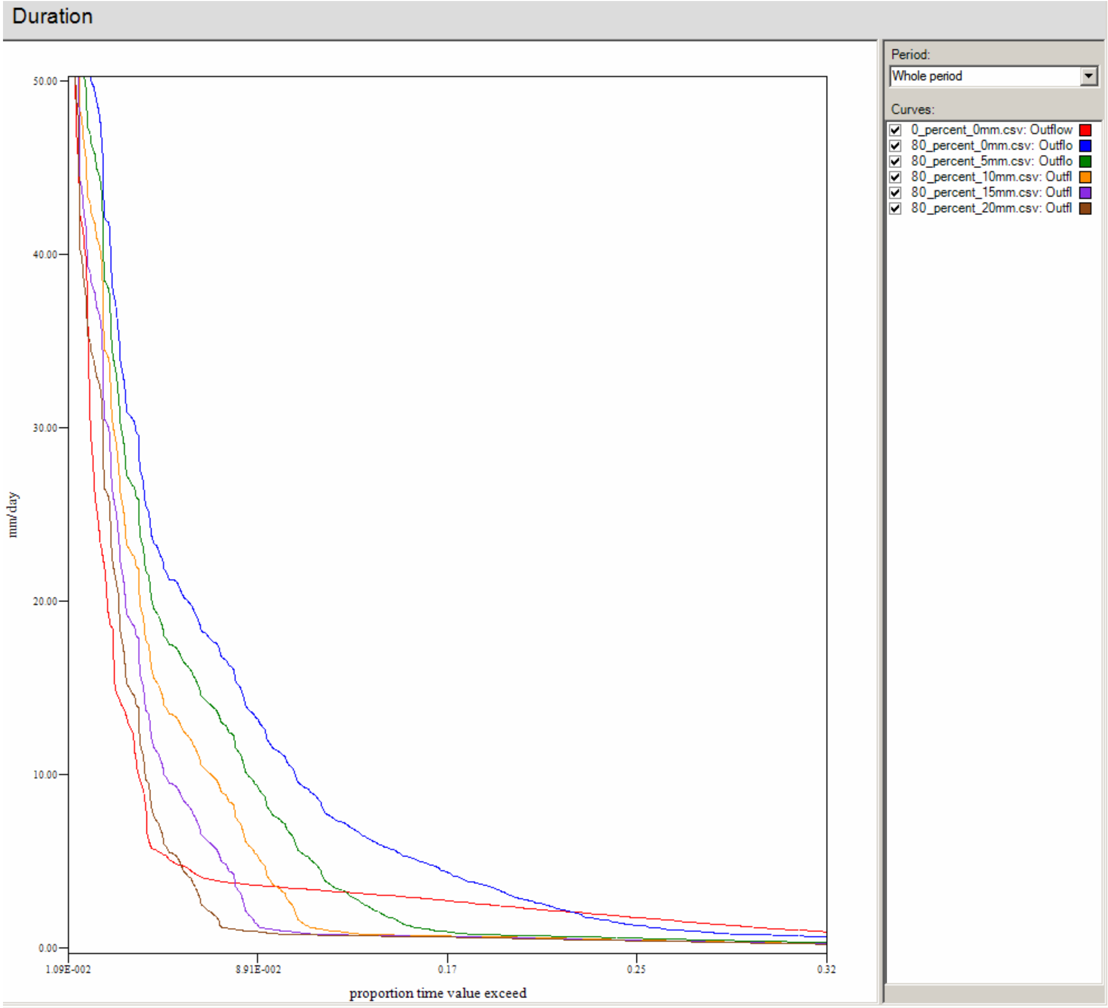
Lockhart River – 20% Total Impervious Flow Duration Curves



Lockhart River – 40% Total Impervious Flow Duration Curves

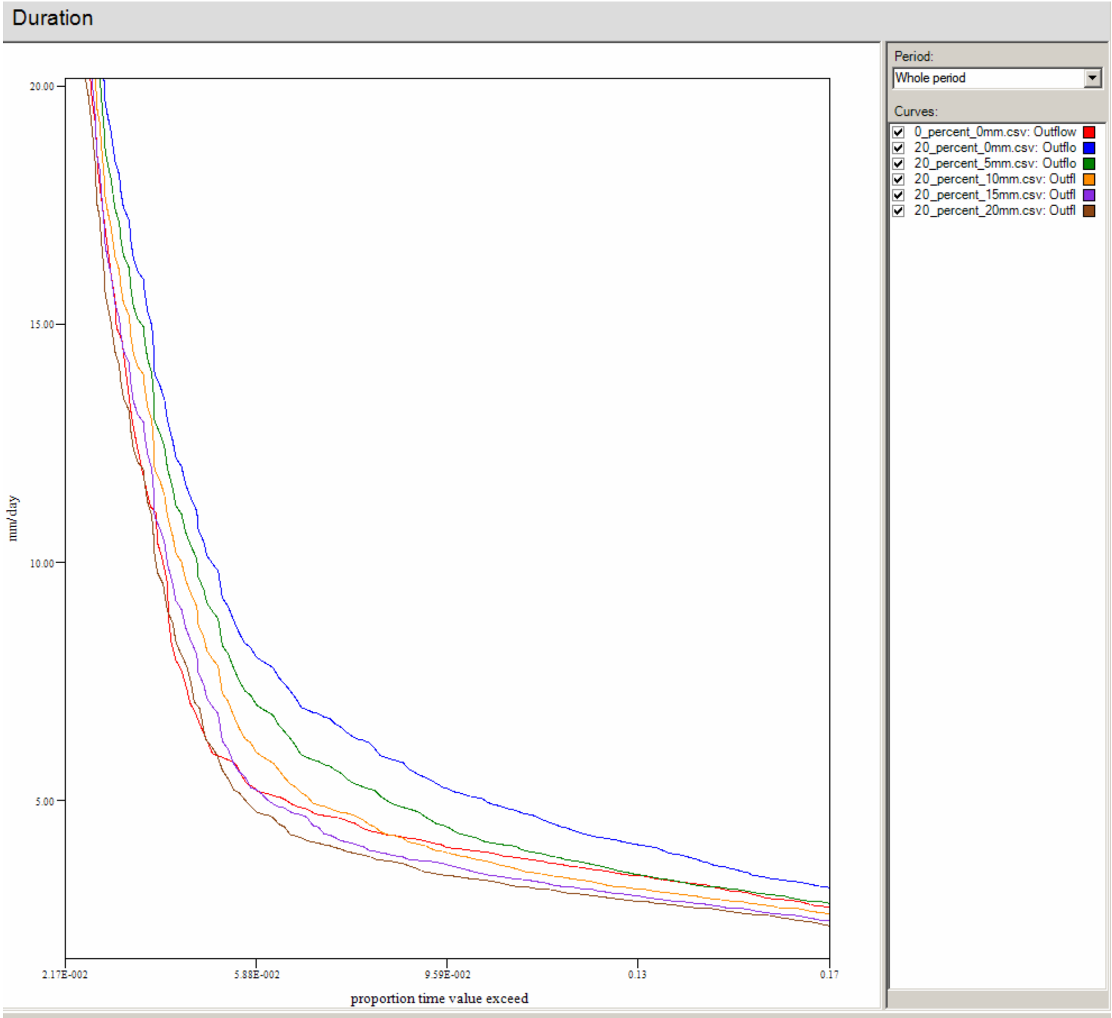


Lockhart River – 60% Total Impervious Flow Duration Curves

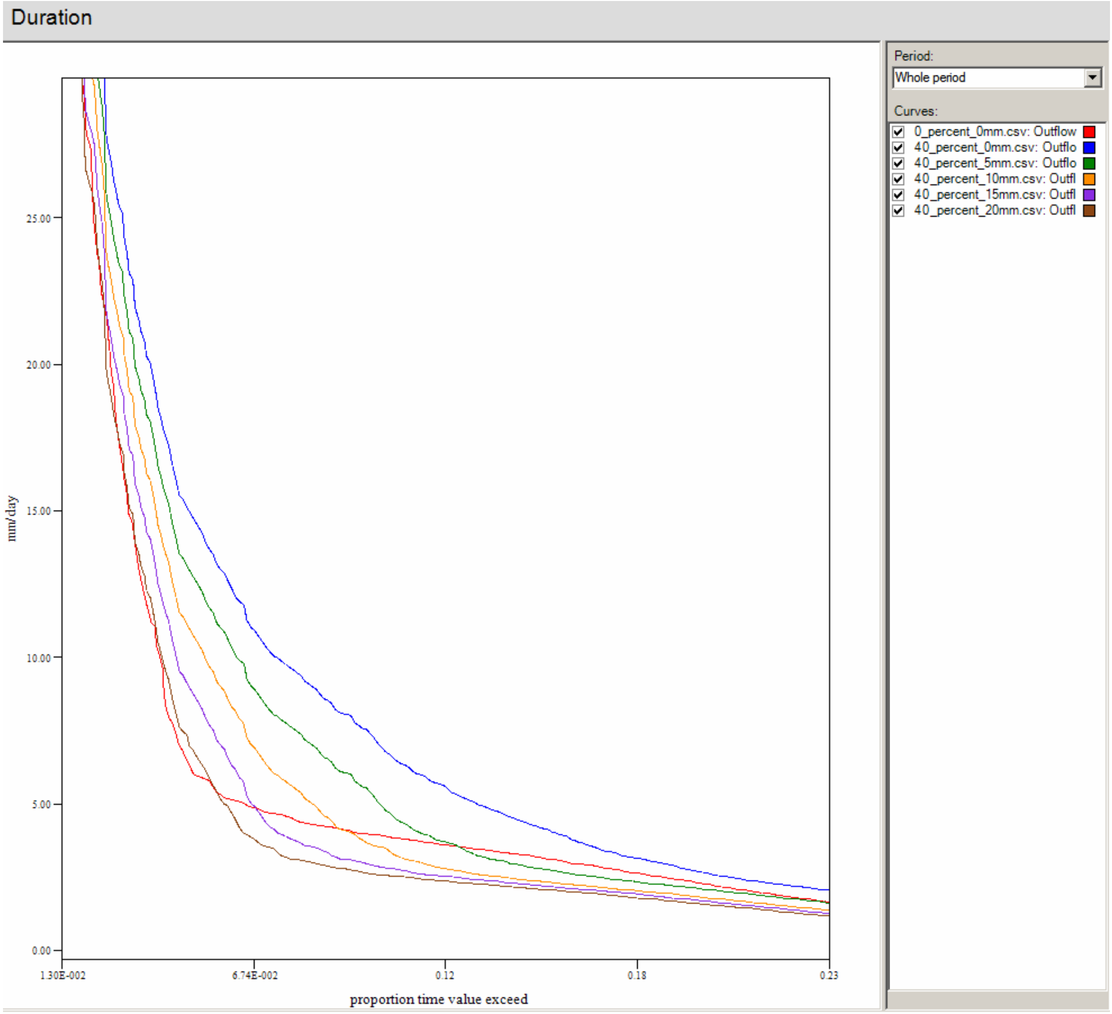


Lockhart River – 80% Total Impervious Flow Duration Curves

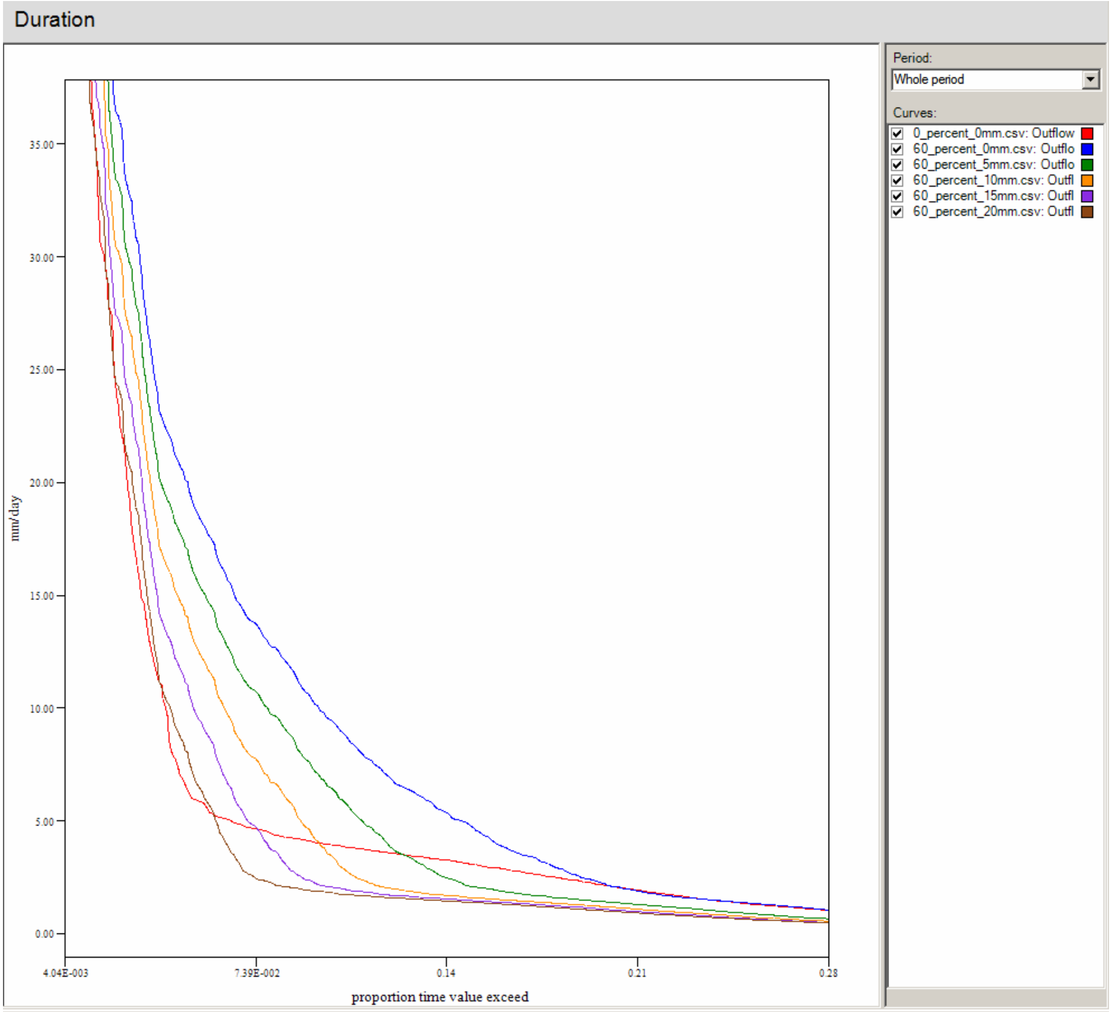
Central and Western Cape York (north): Weipa



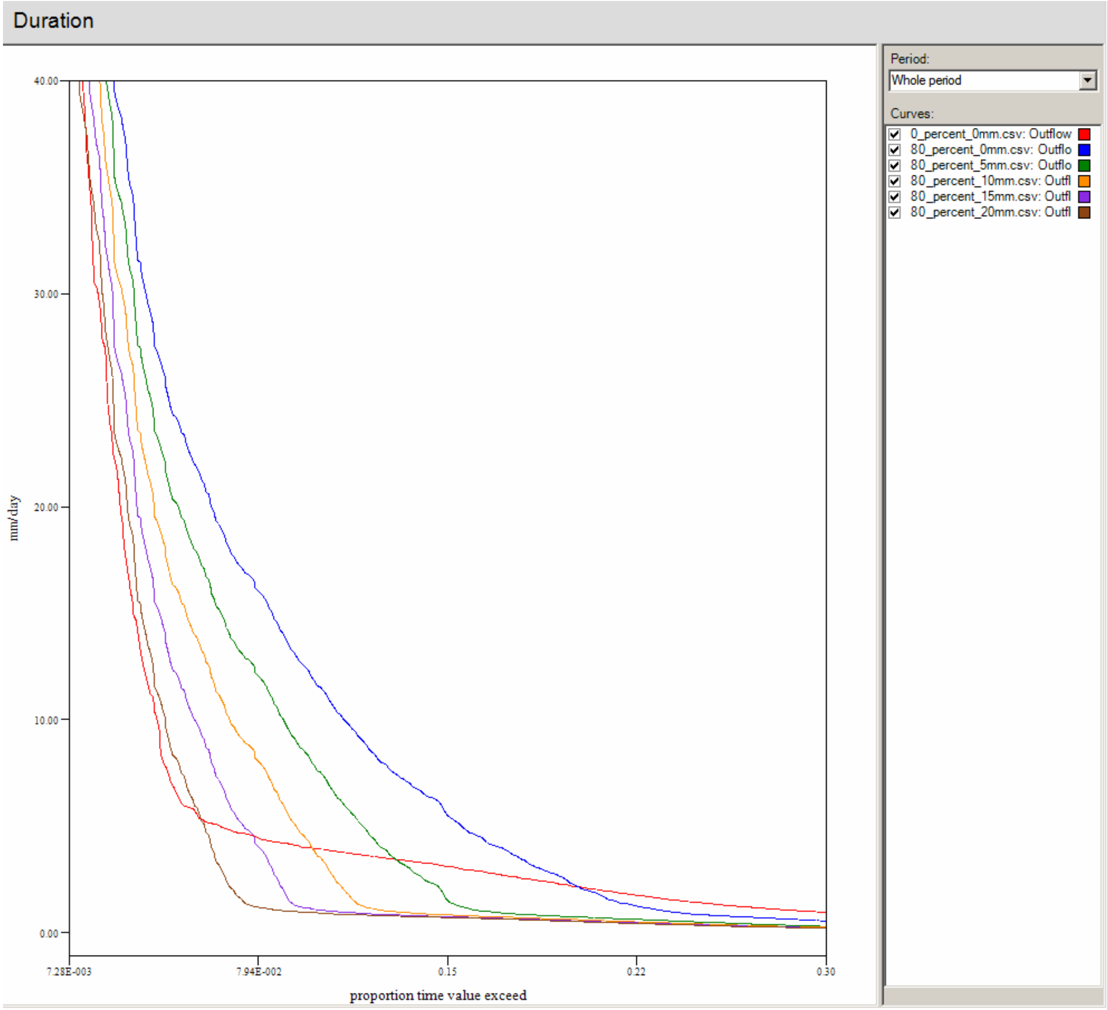
Weipa – 20% Total Impervious Flow Duration Curves



Weipa – 40% Total Impervious Flow Duration Curves

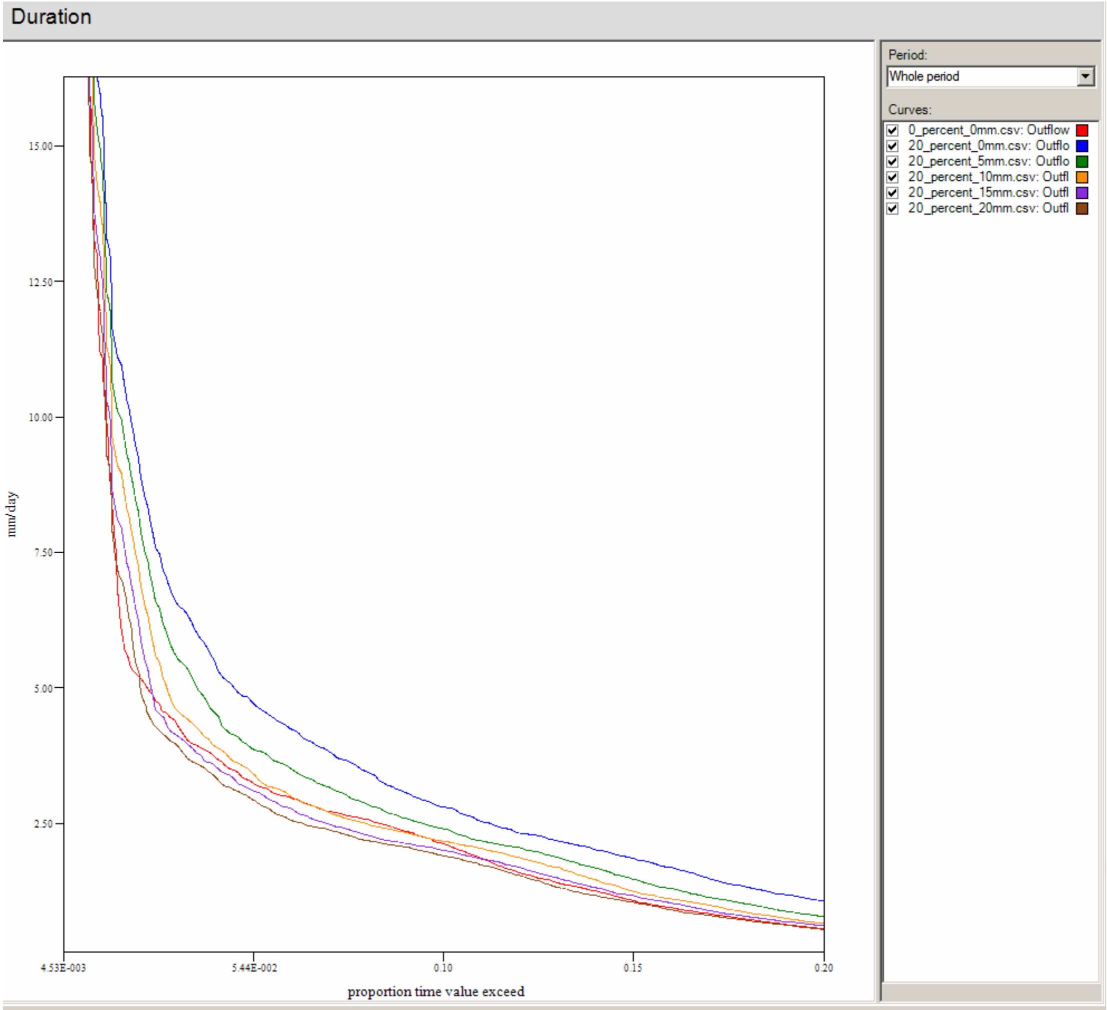


Weipa – 60% Total Impervious Flow Duration Curves

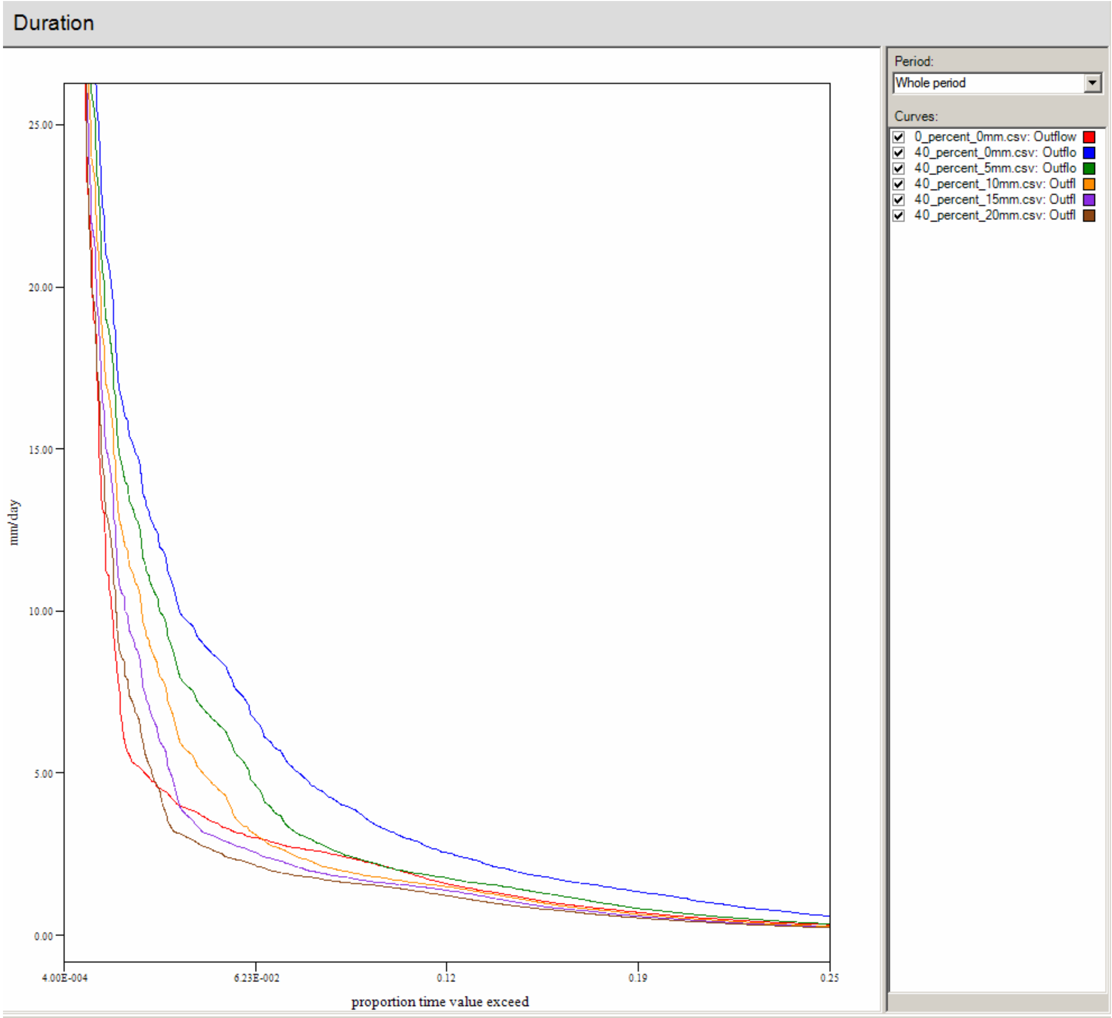


Weipa – 80% Total Impervious Flow Duration Curves

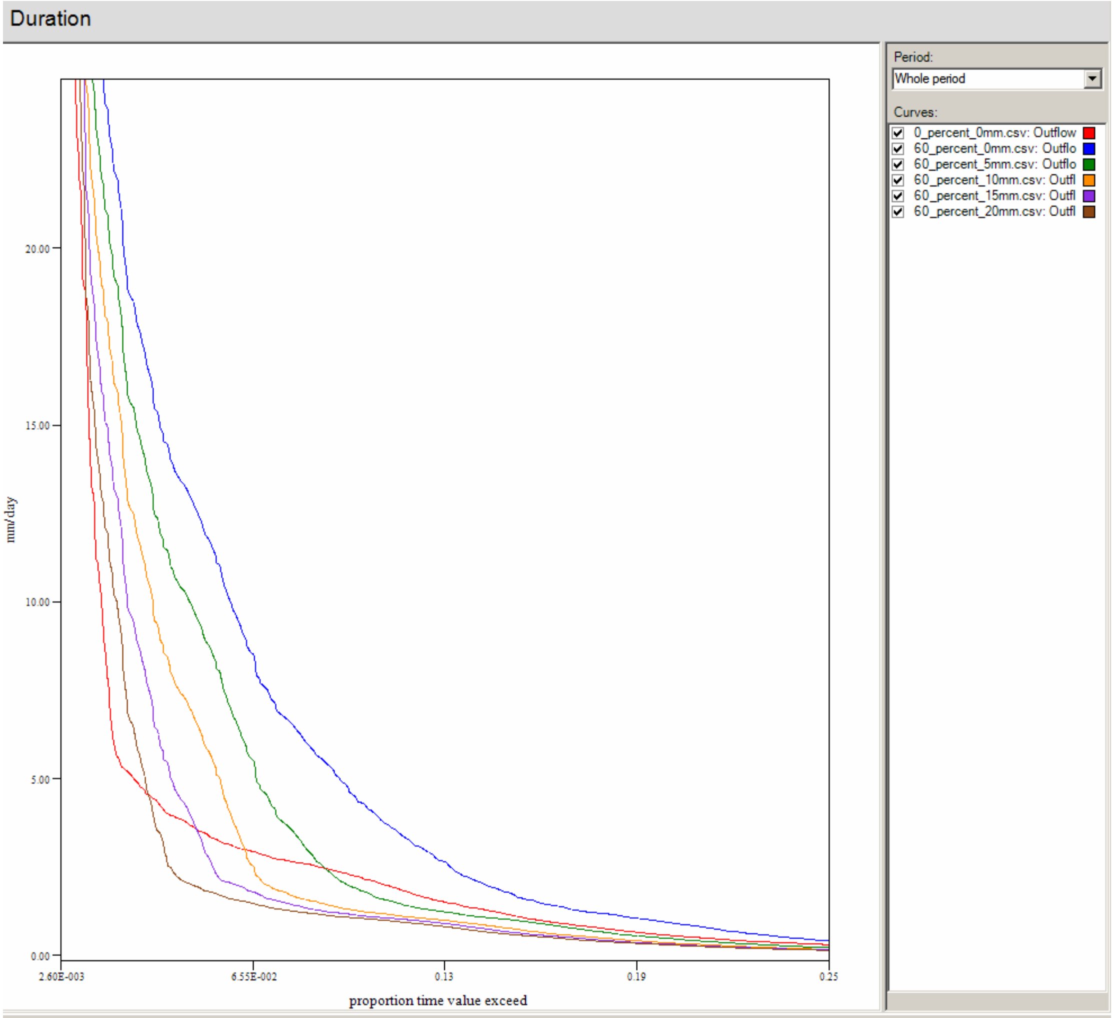
Central and Western Cape York (south): Palmerville



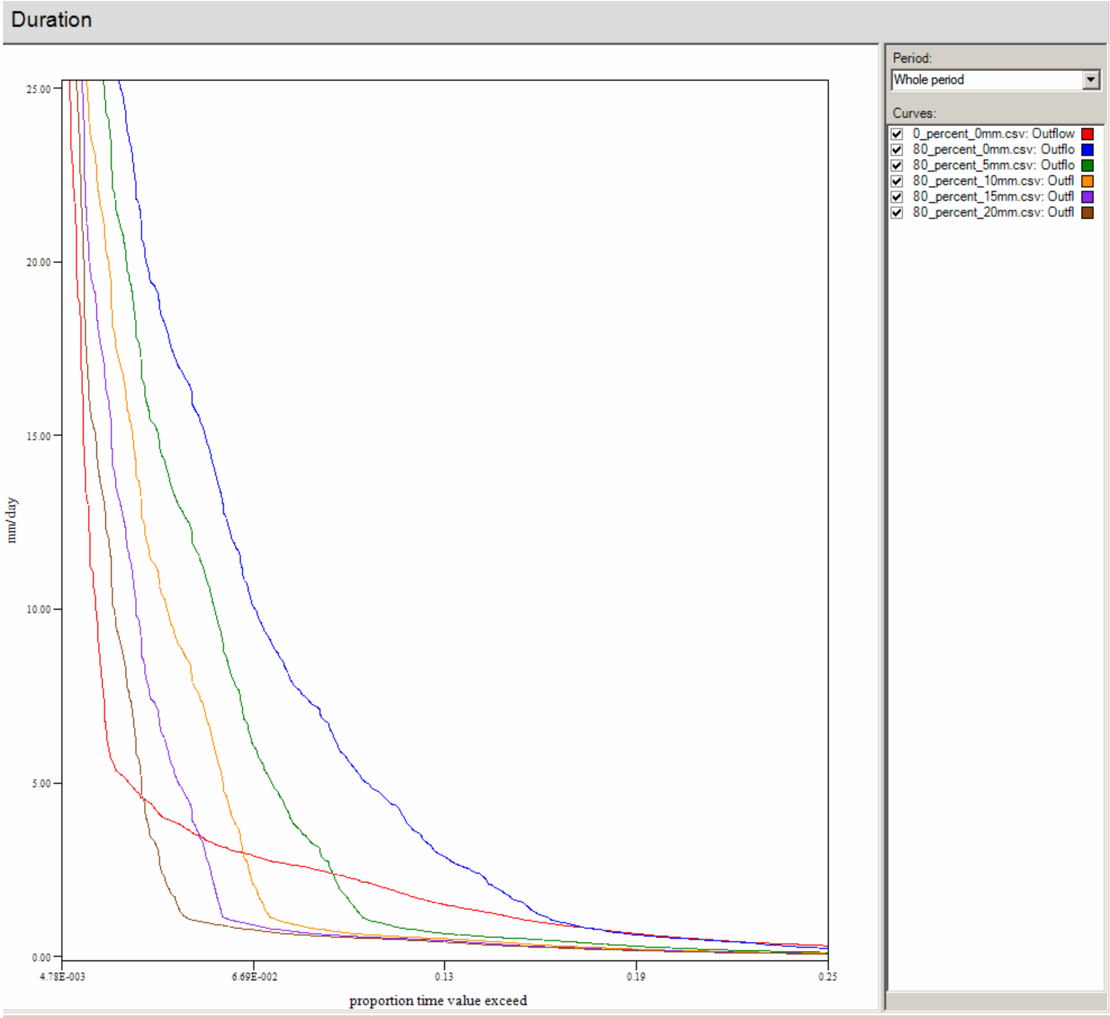
Palmerville – 20% Total Impervious Flow Duration Curves



Palmerville – 40% Total Impervious Flow Duration Curves

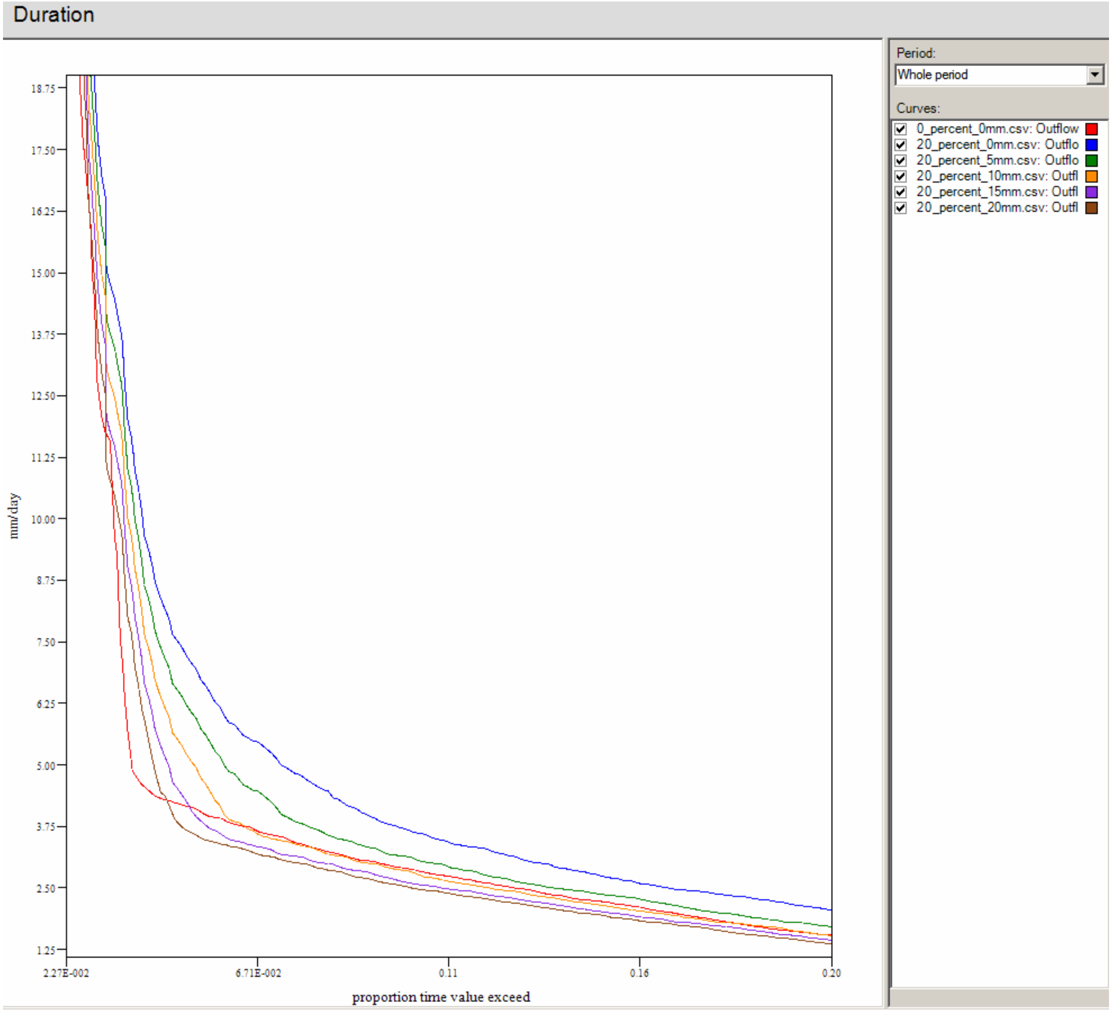


Palmerville – 60% Total Impervious Flow Duration Curves

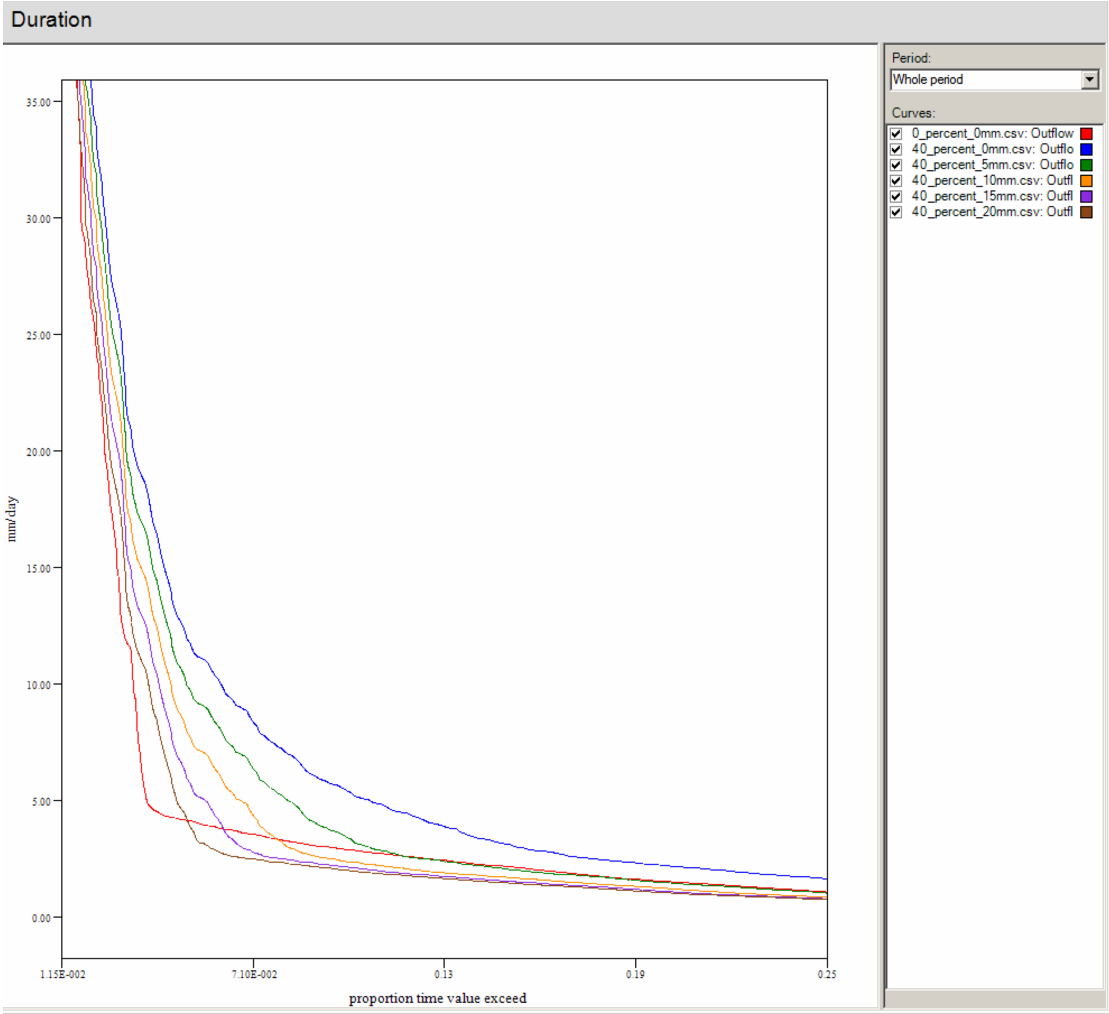


Palmerville – 80% Total Impervious Flow Duration Curves

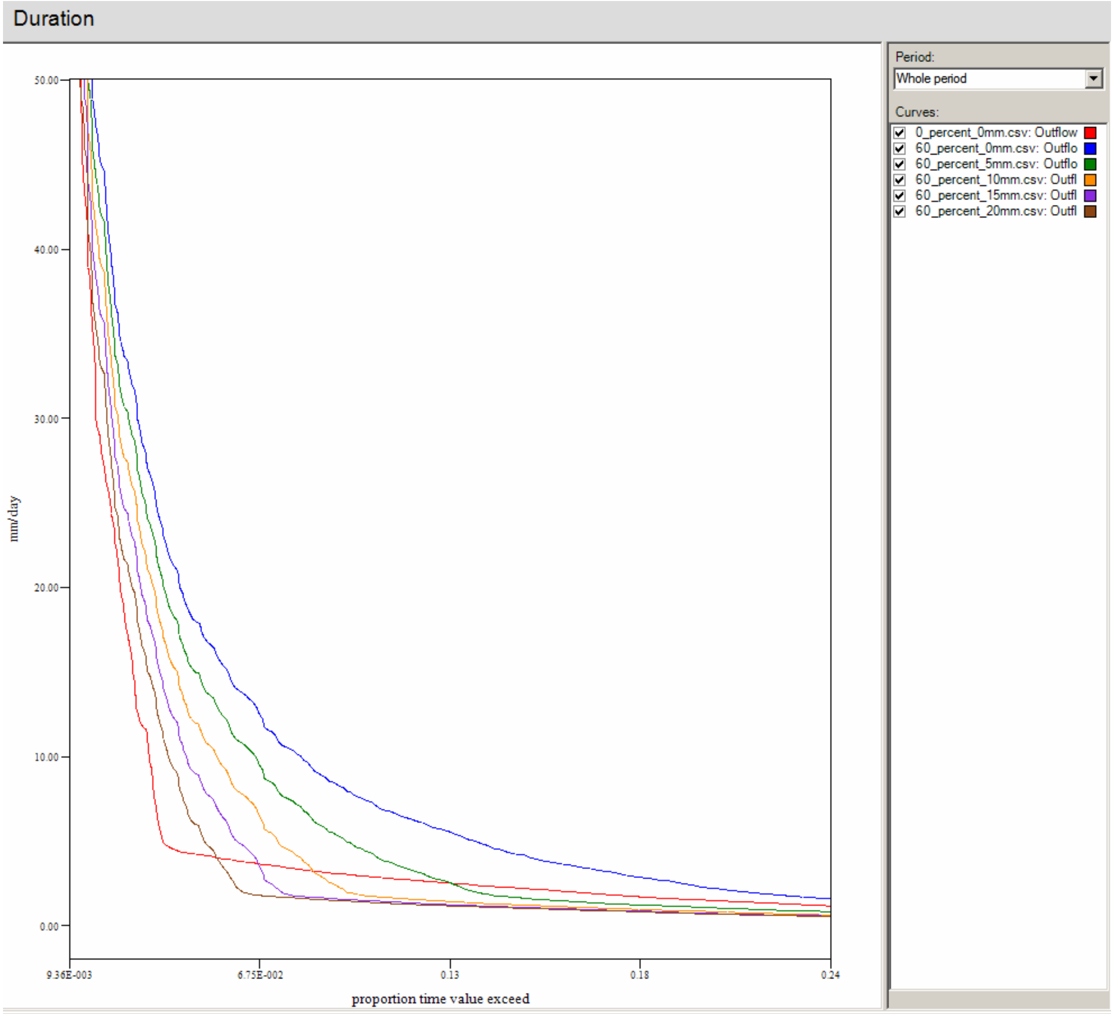
"Wet" Tropics: Cairns



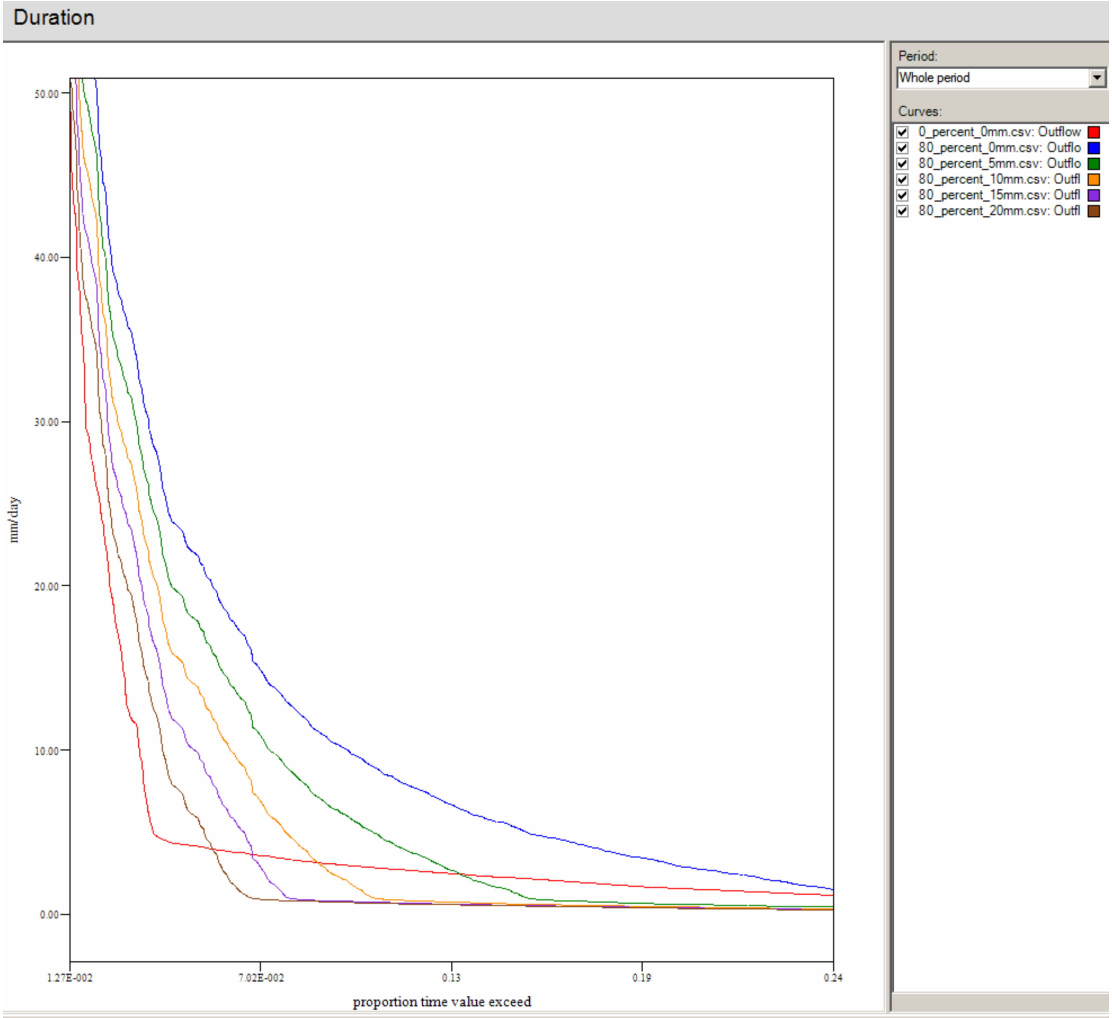
Cairns – 20% Total Impervious Flow Duration Curves



Cairns – 40% Total Impervious Flow Duration Curves

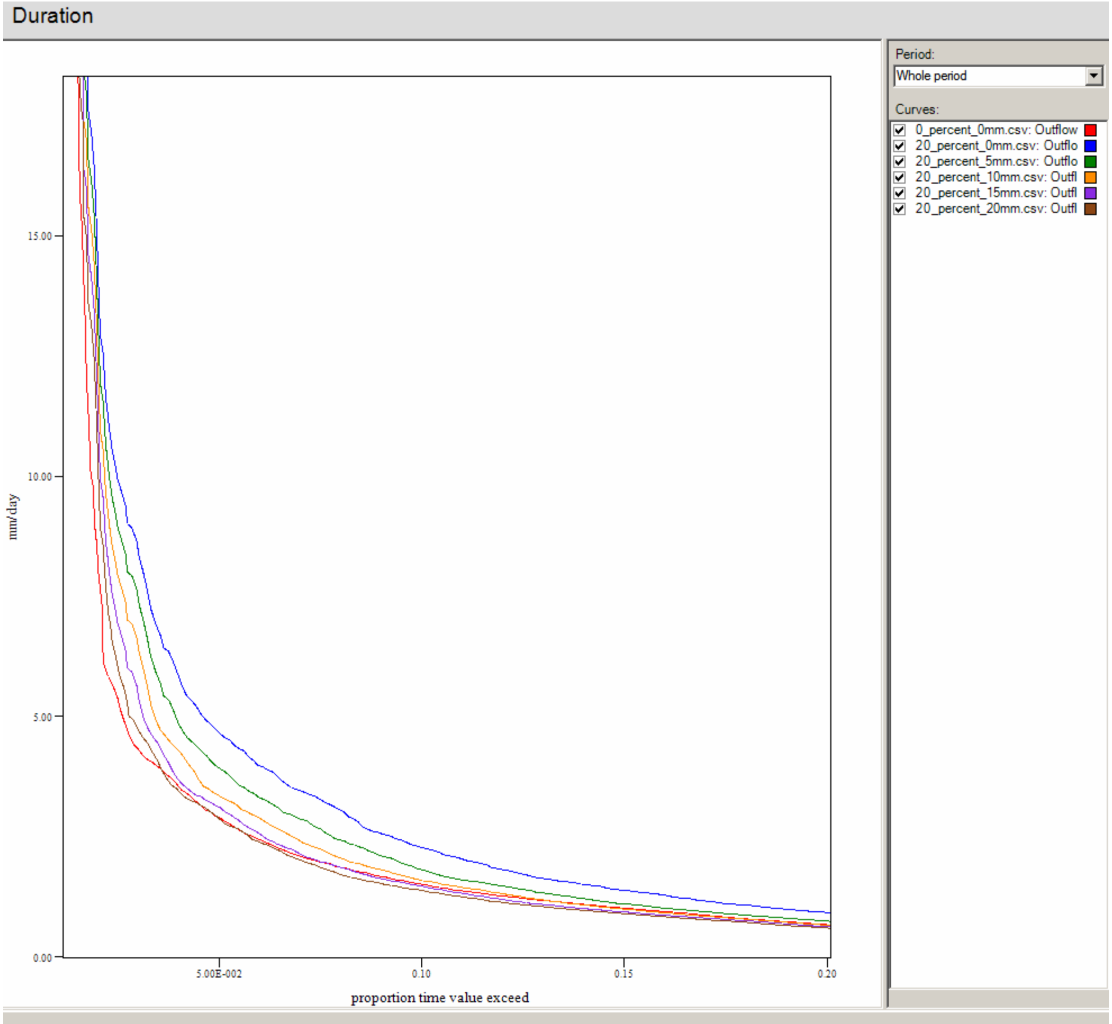


Cairns – 60% Total Impervious Flow Duration Curves

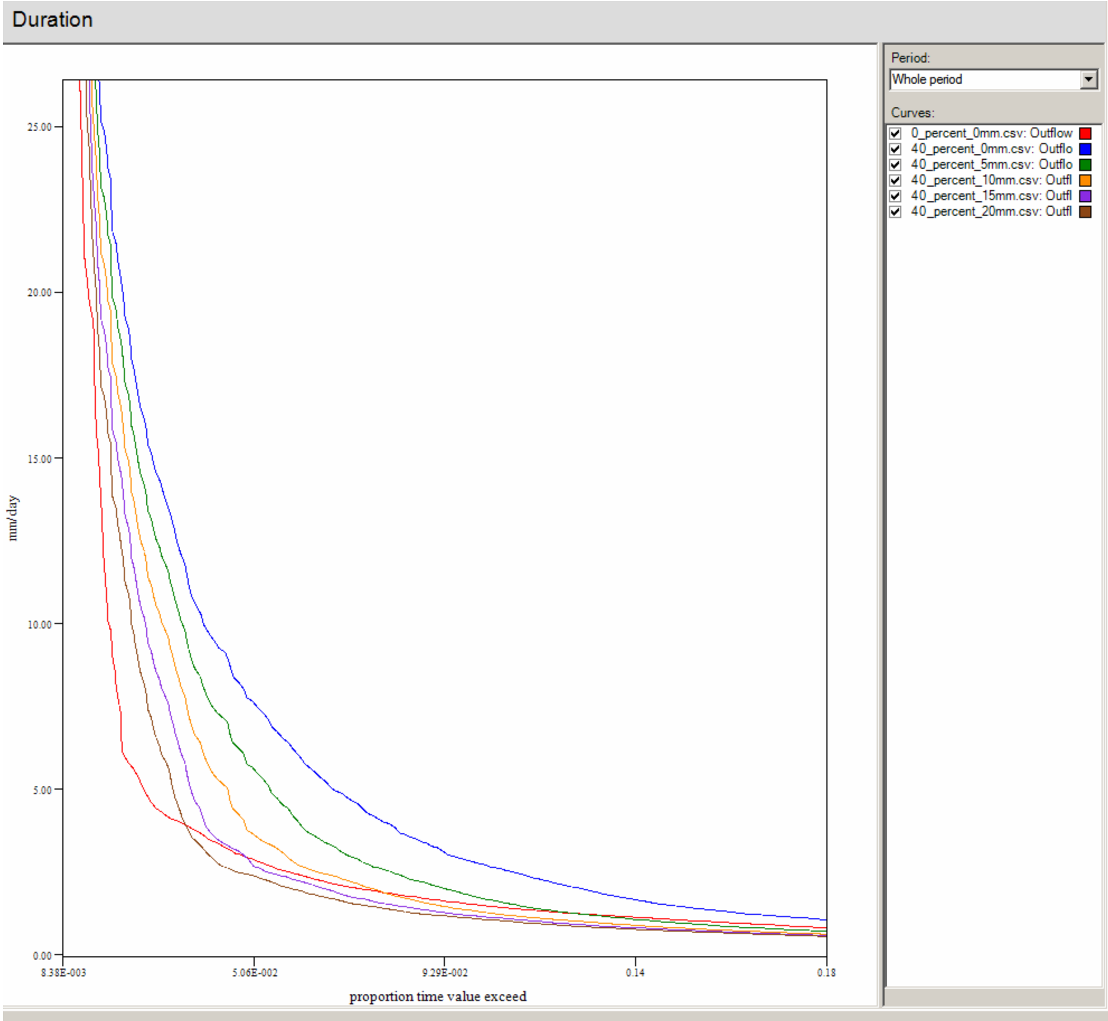


Cairns – 80% Total Impervious Flow Duration Curves

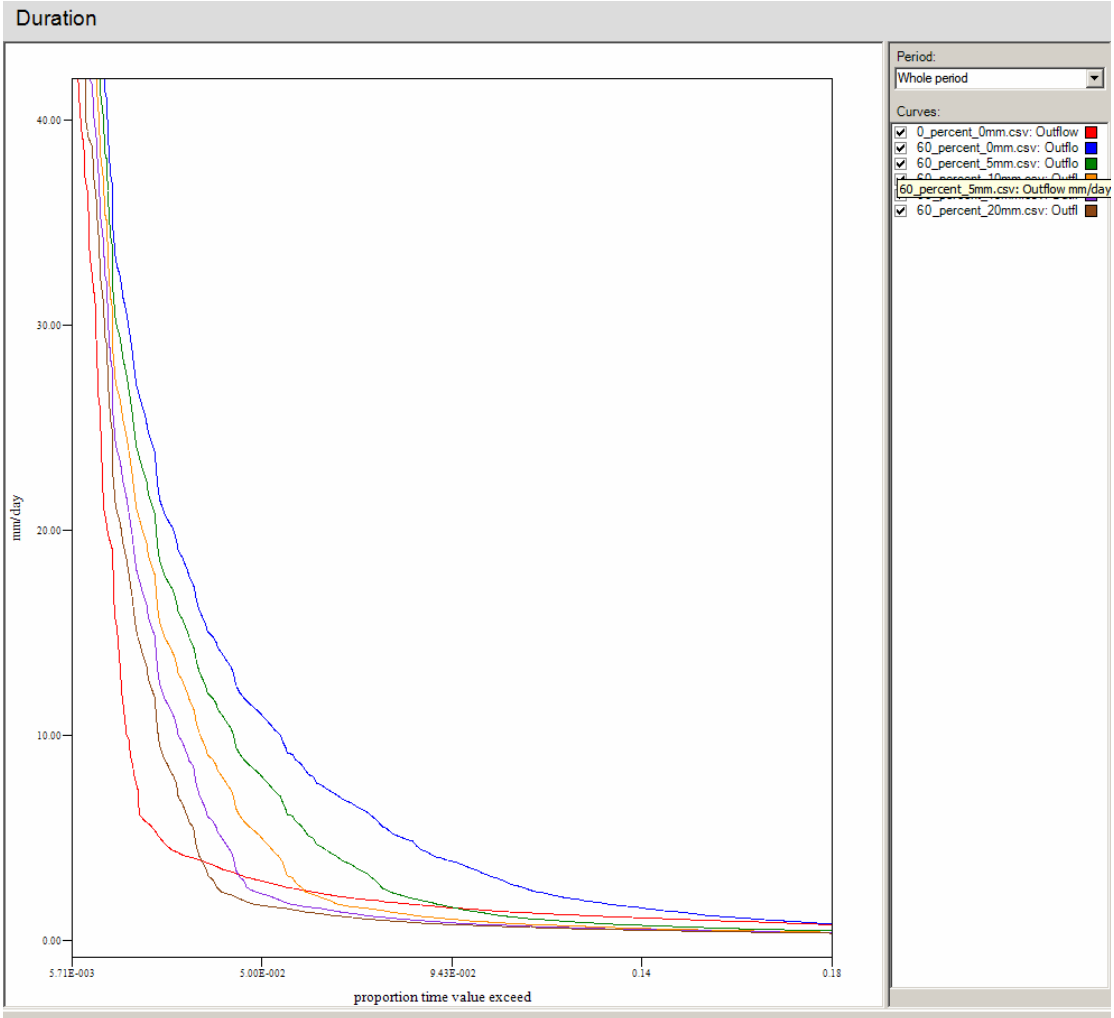
“Dry” Tropics: Townsville



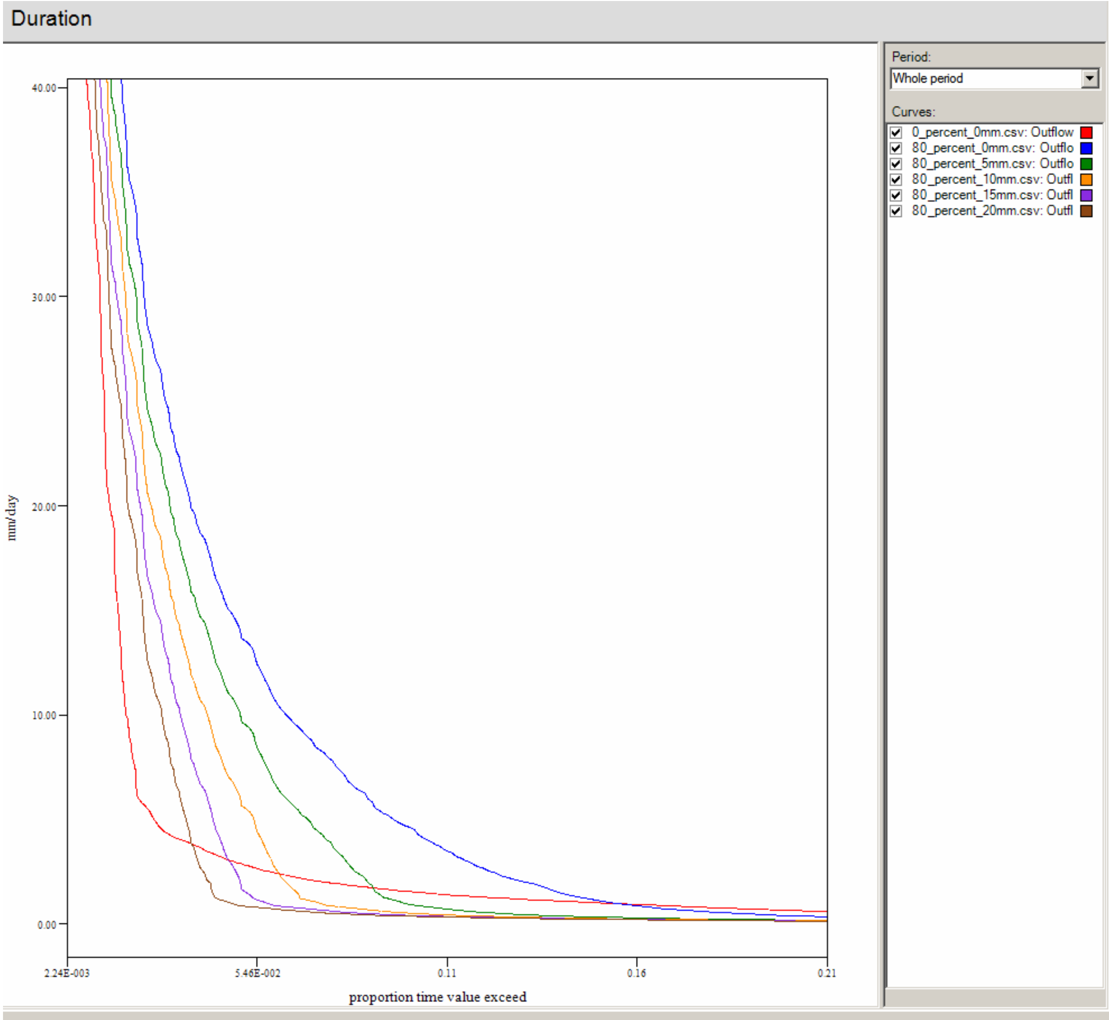
Townsville – 20% Total Impervious Flow Duration Curves



Townsville – 40% Total Impervious Flow Duration Curves

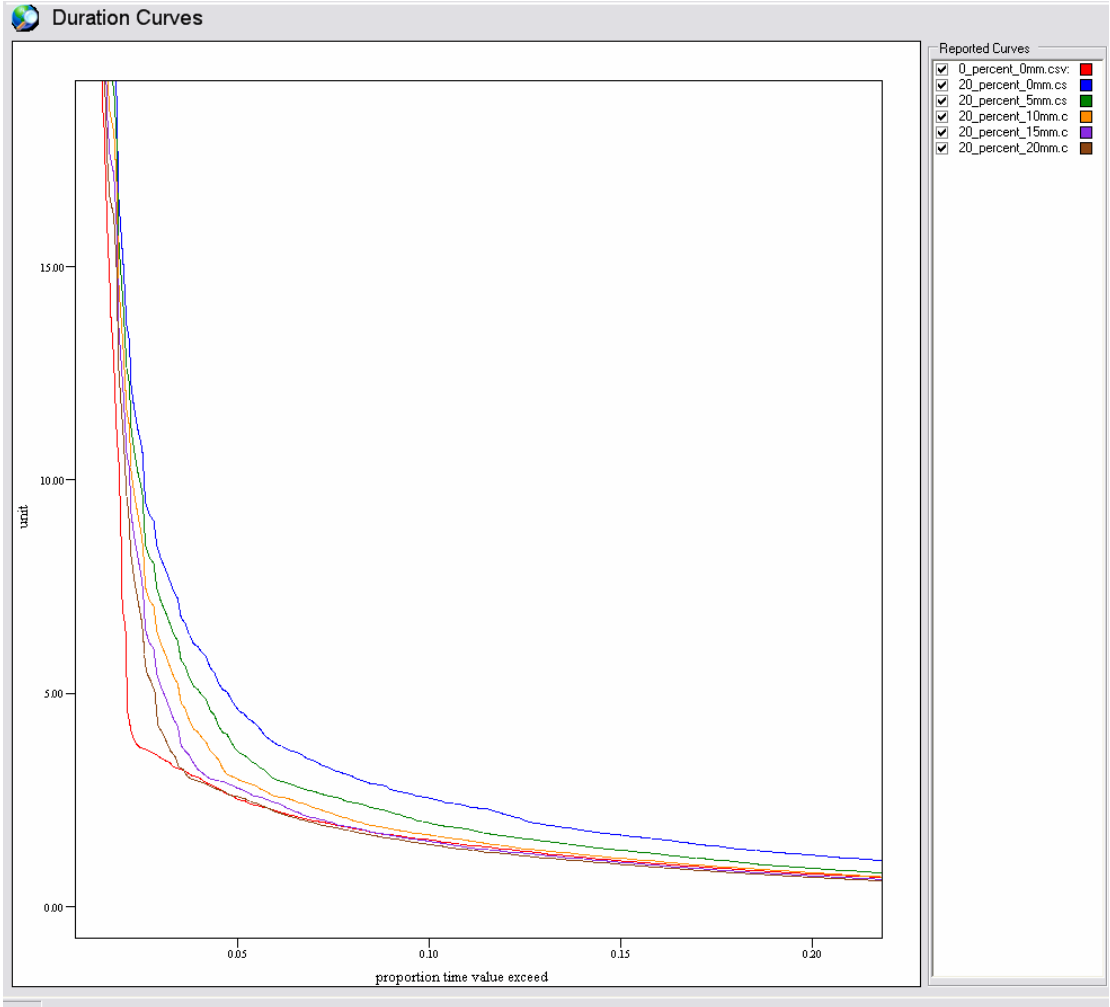


Townsville – 60% Total Impervious Flow Duration Curves

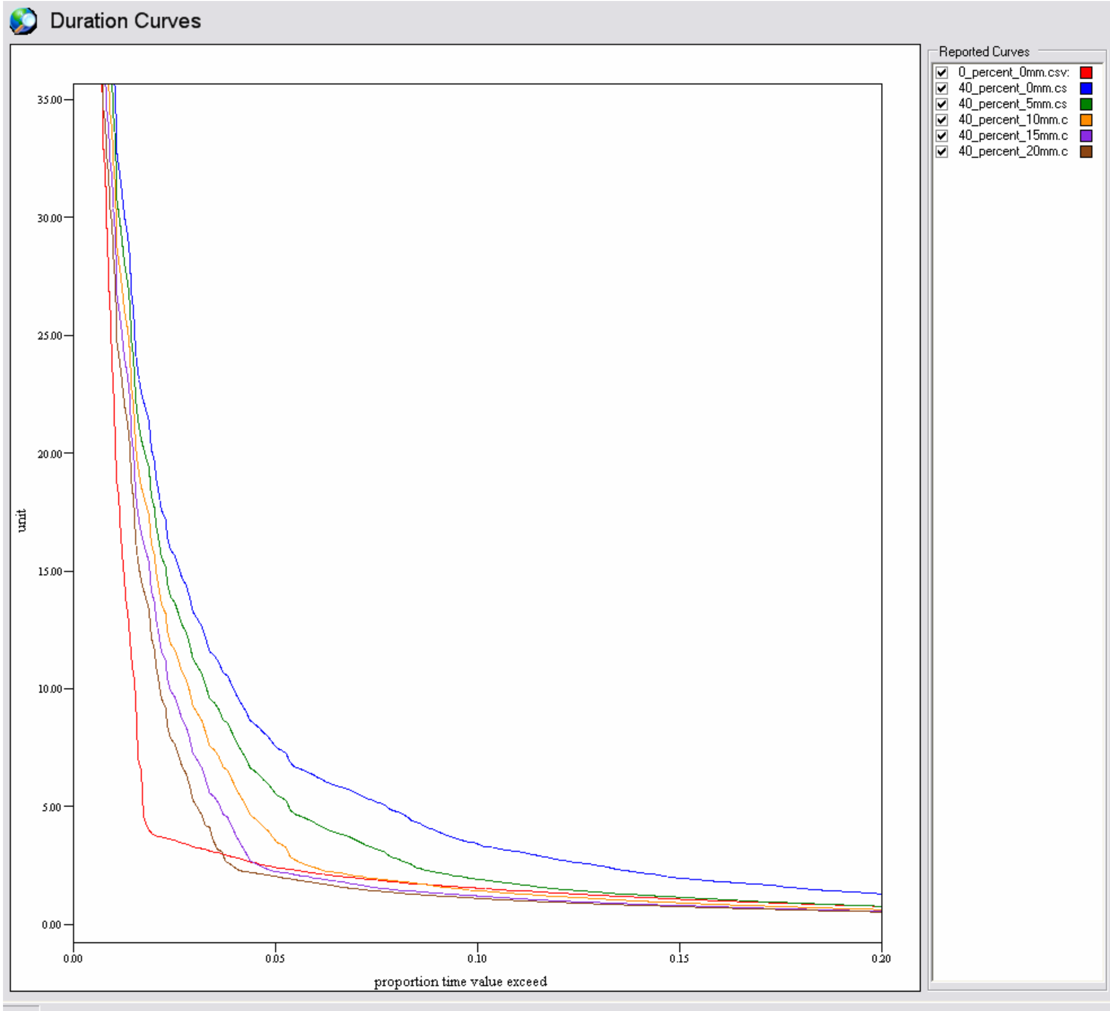


Townsville – 80% Total Impervious Flow Duration Curves

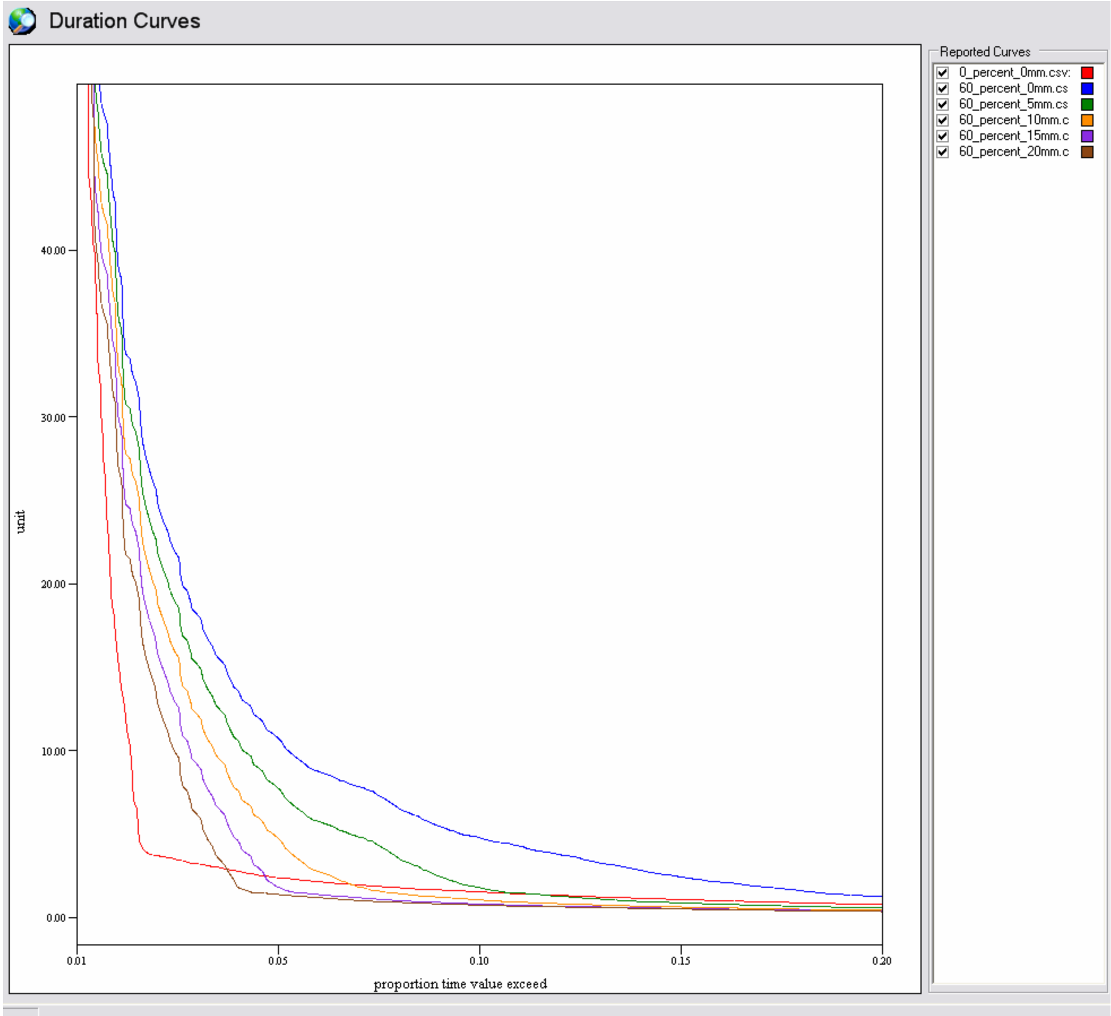
Central Coast (north): Mackay



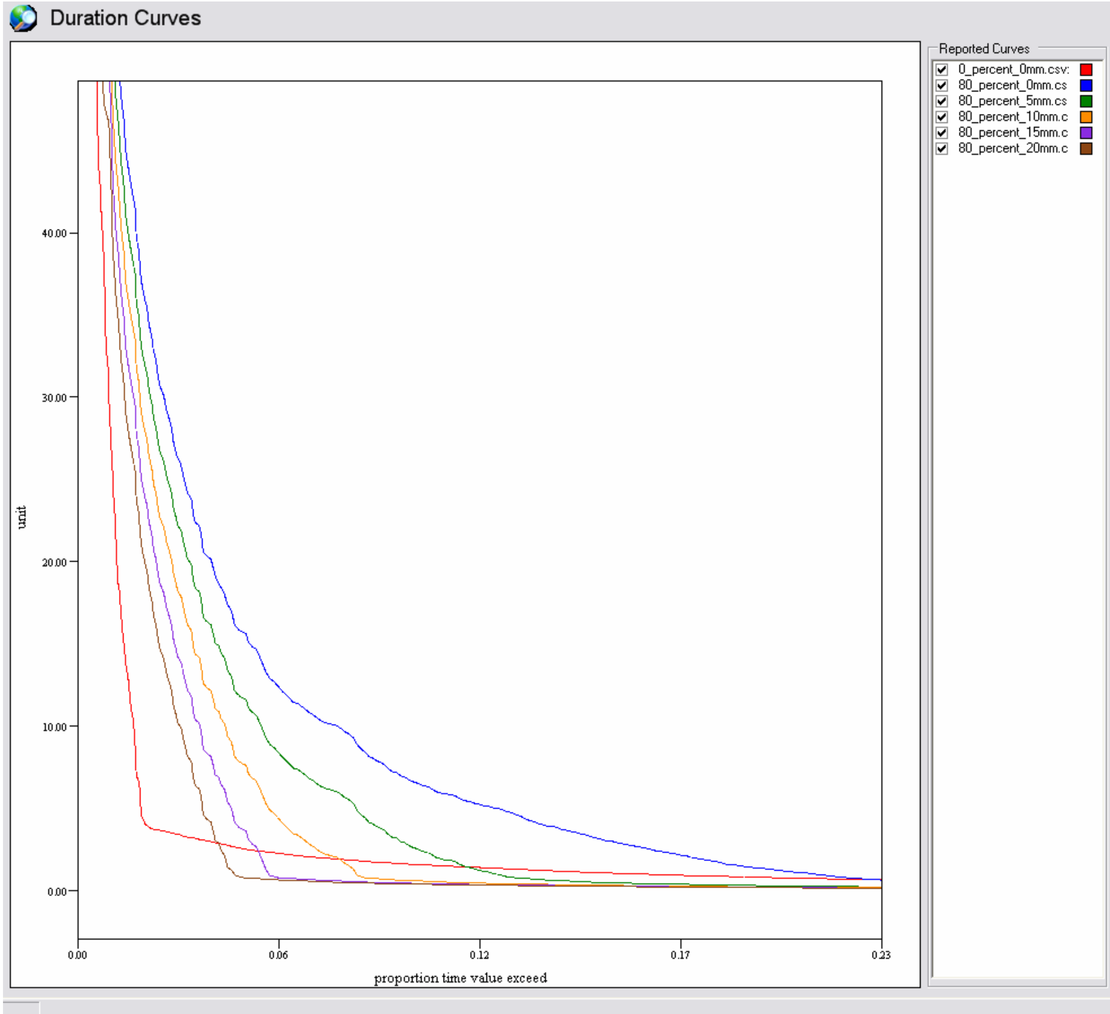
Mackay – 20% Total Impervious Flow Duration Curves



Mackay – 40% Total Impervious Flow Duration Curves

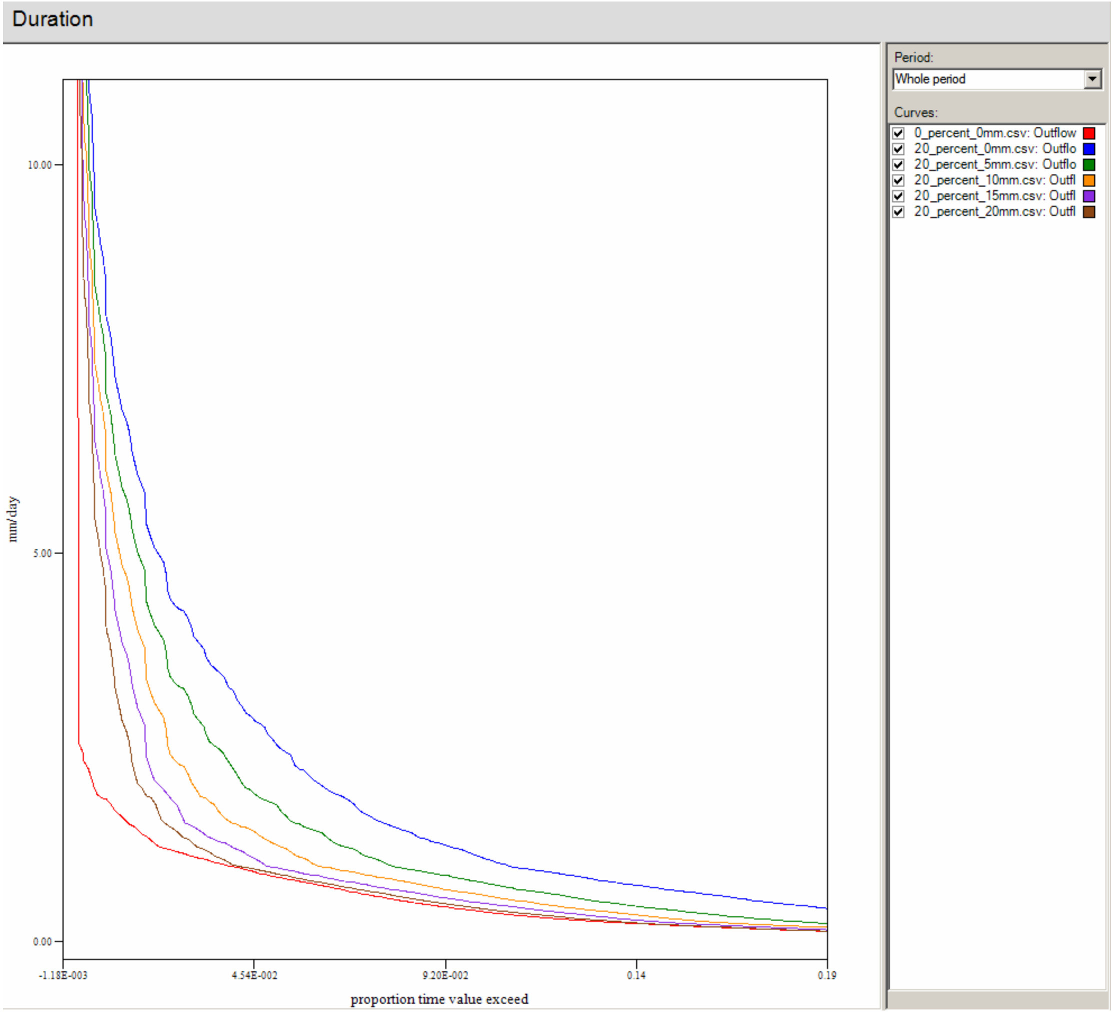


Mackay – 60% Total Impervious Flow Duration Curves

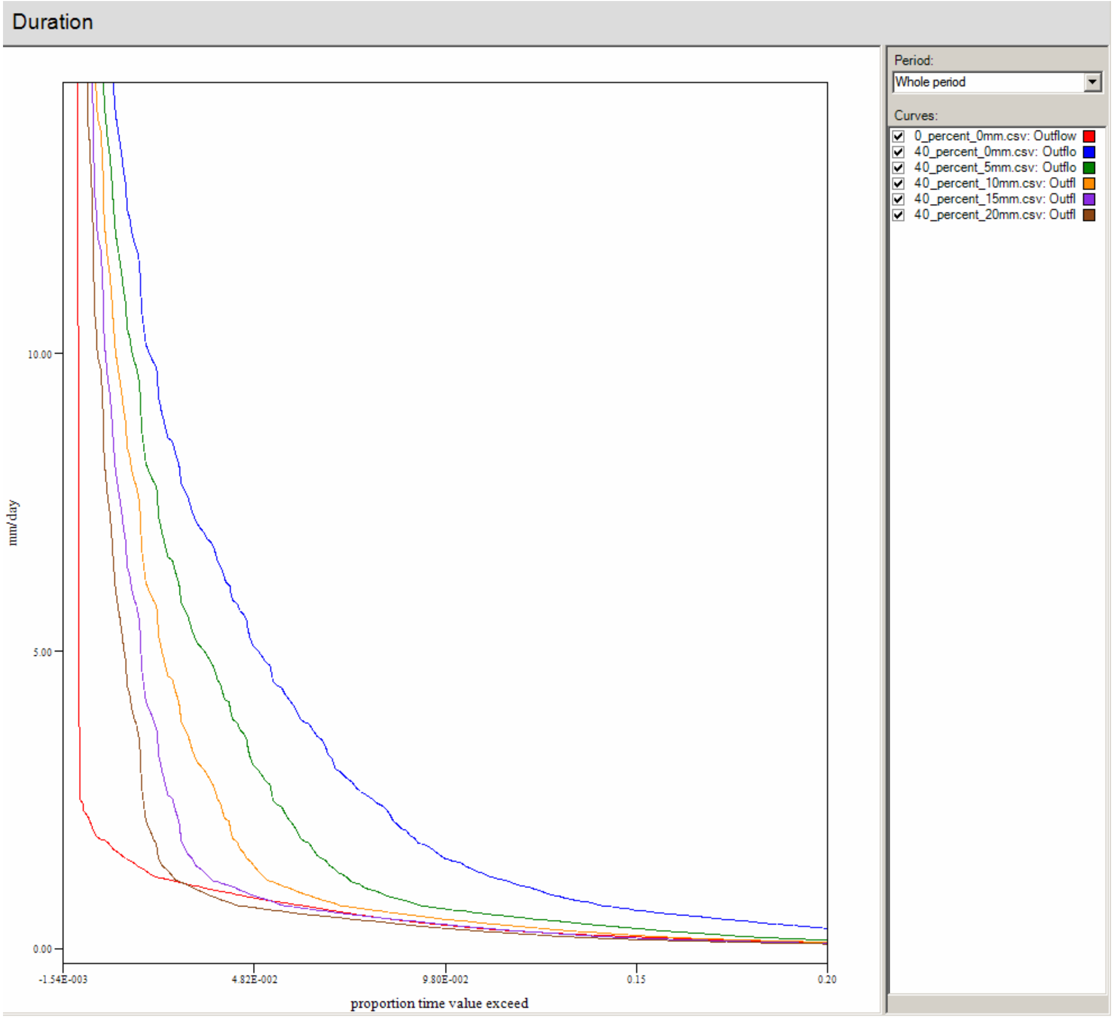


Mackay – 80% Total Impervious Flow Duration Curves

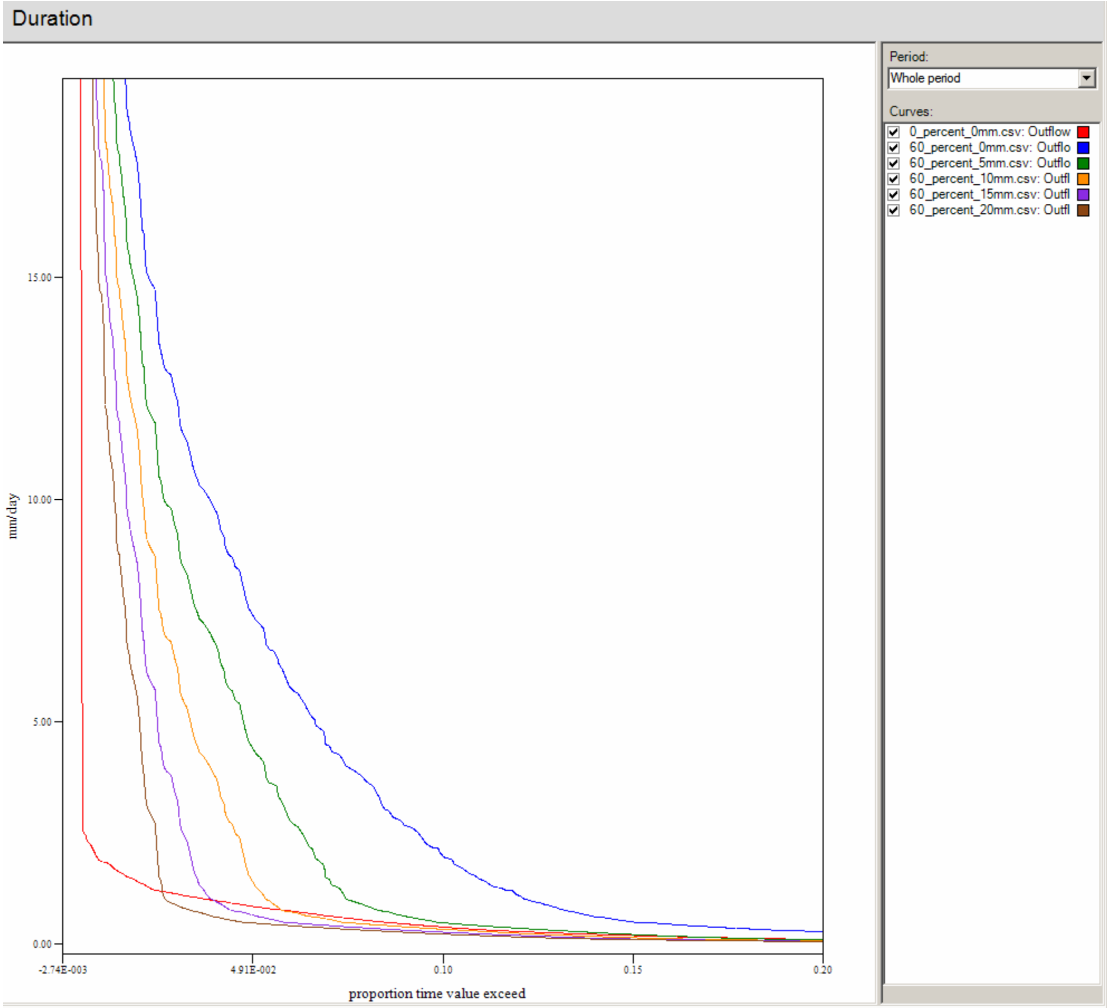
Central Coast (south): Rockhampton



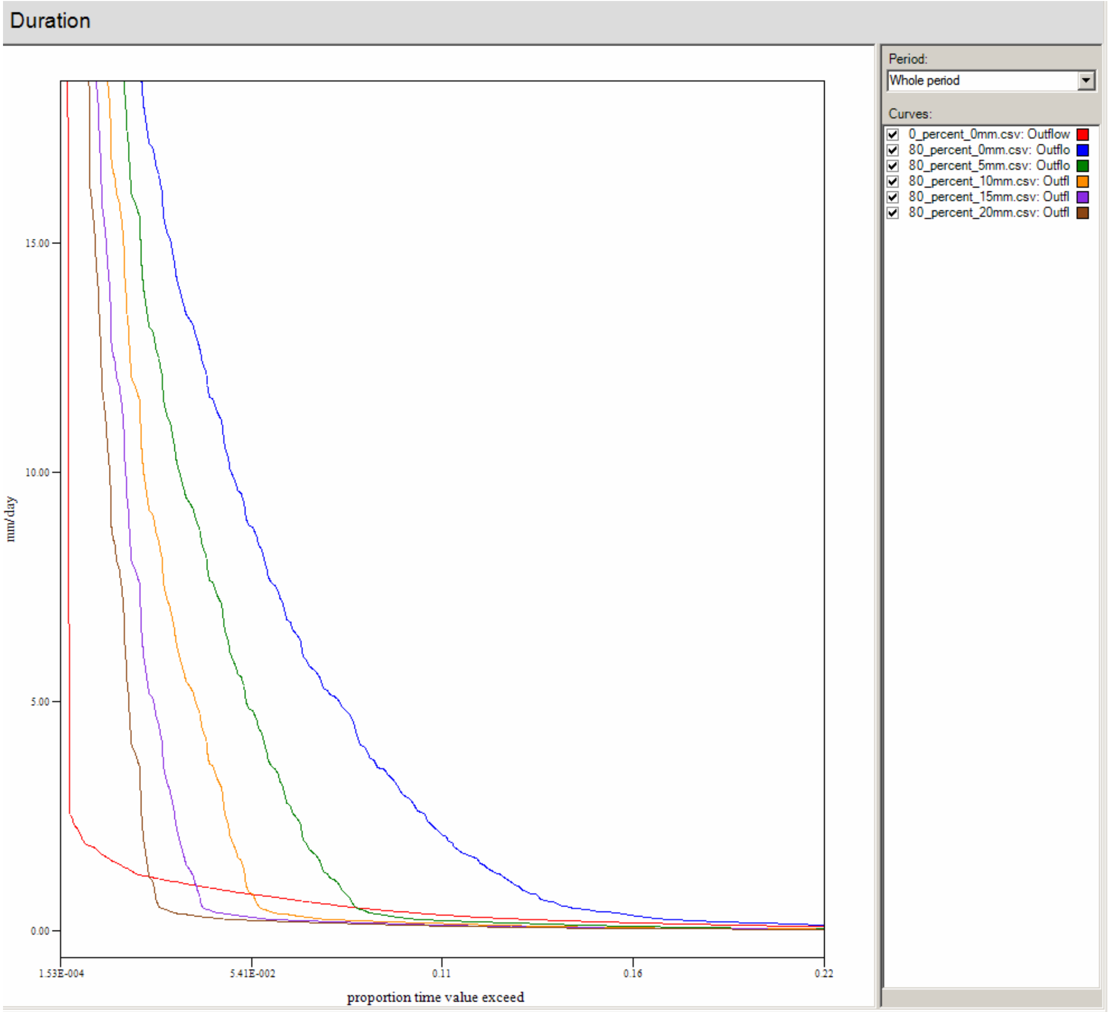
Rockhampton – 20% Total Impervious Flow Duration Curves



Rockhampton – 40% Total Impervious Flow Duration Curves

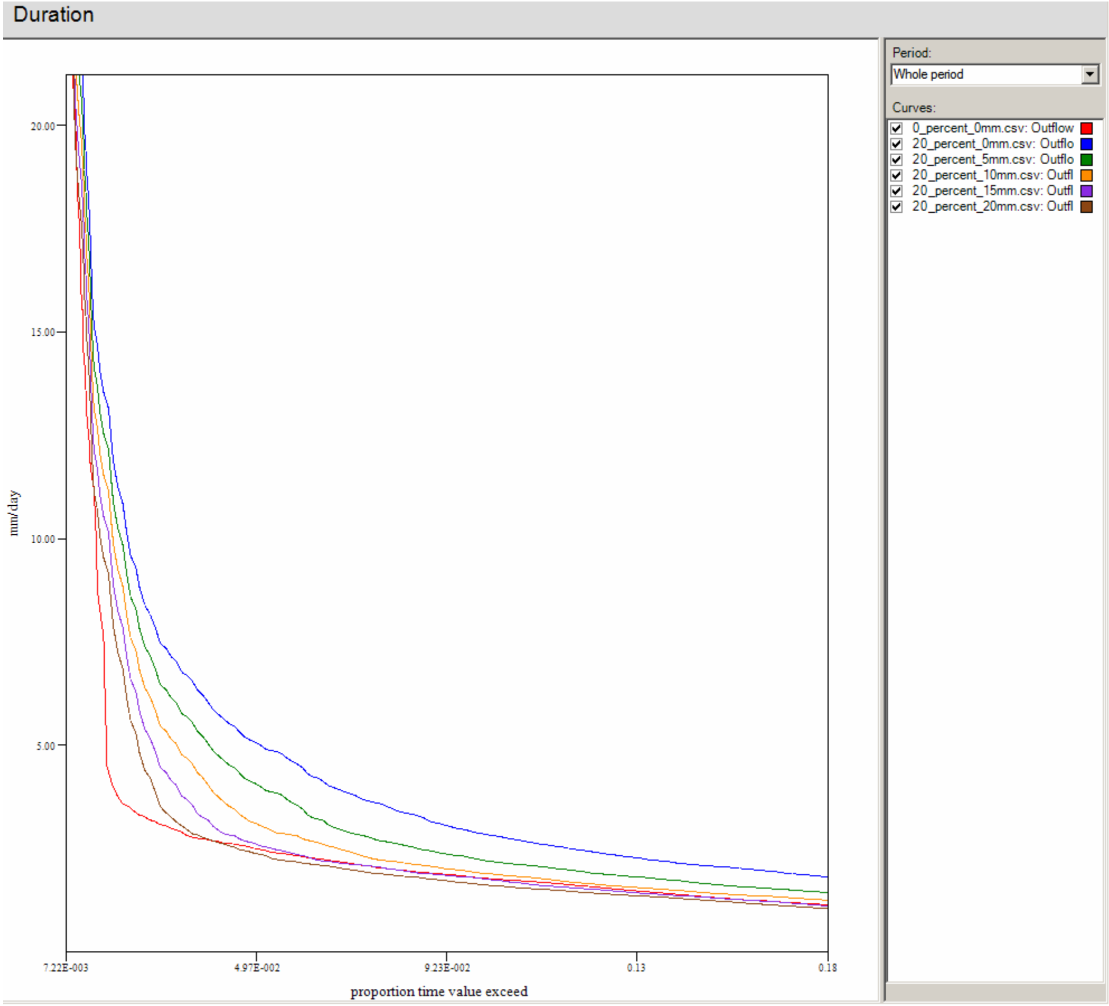


Rockhampton – 60% Total Impervious Flow Duration Curves

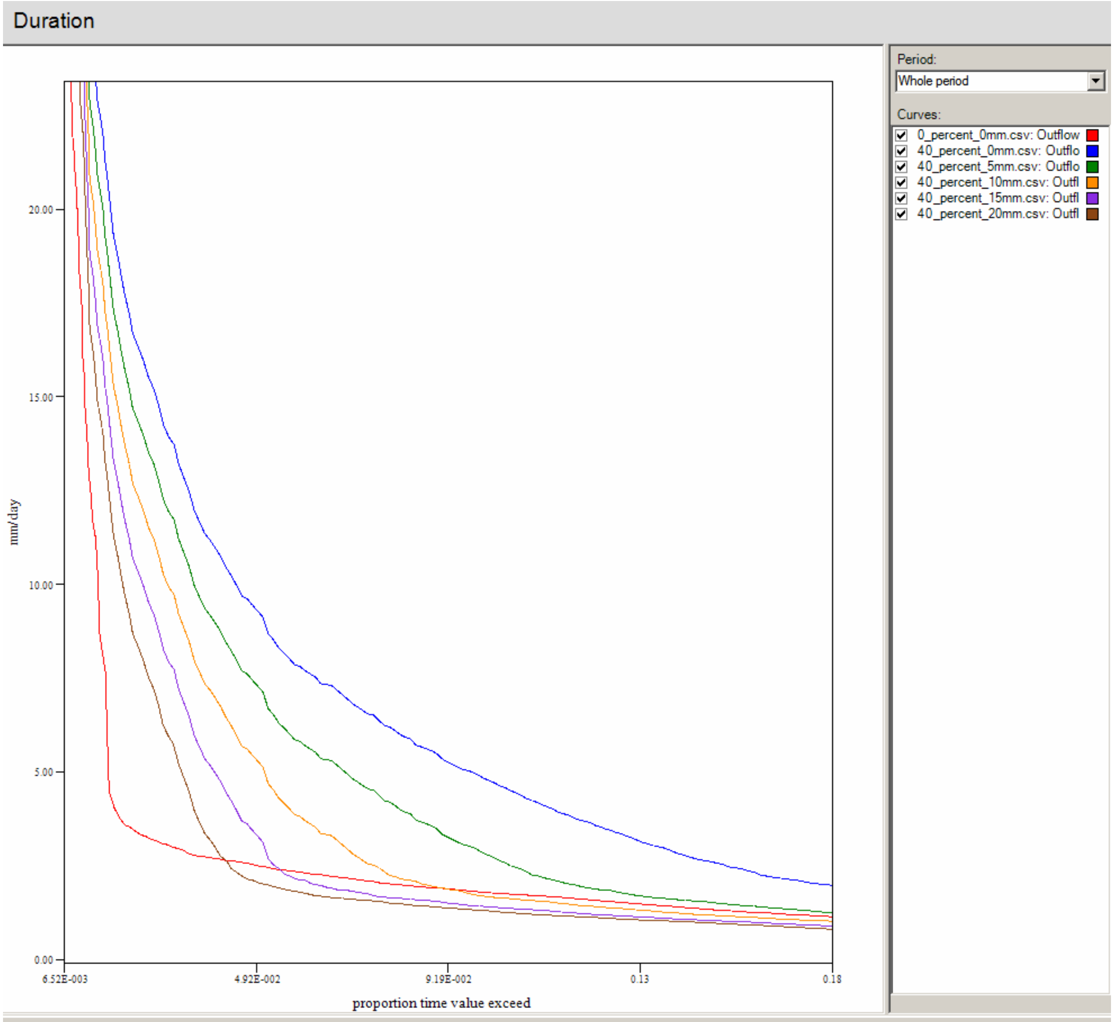


Rockhampton – 80% Total Impervious Flow Duration Curves

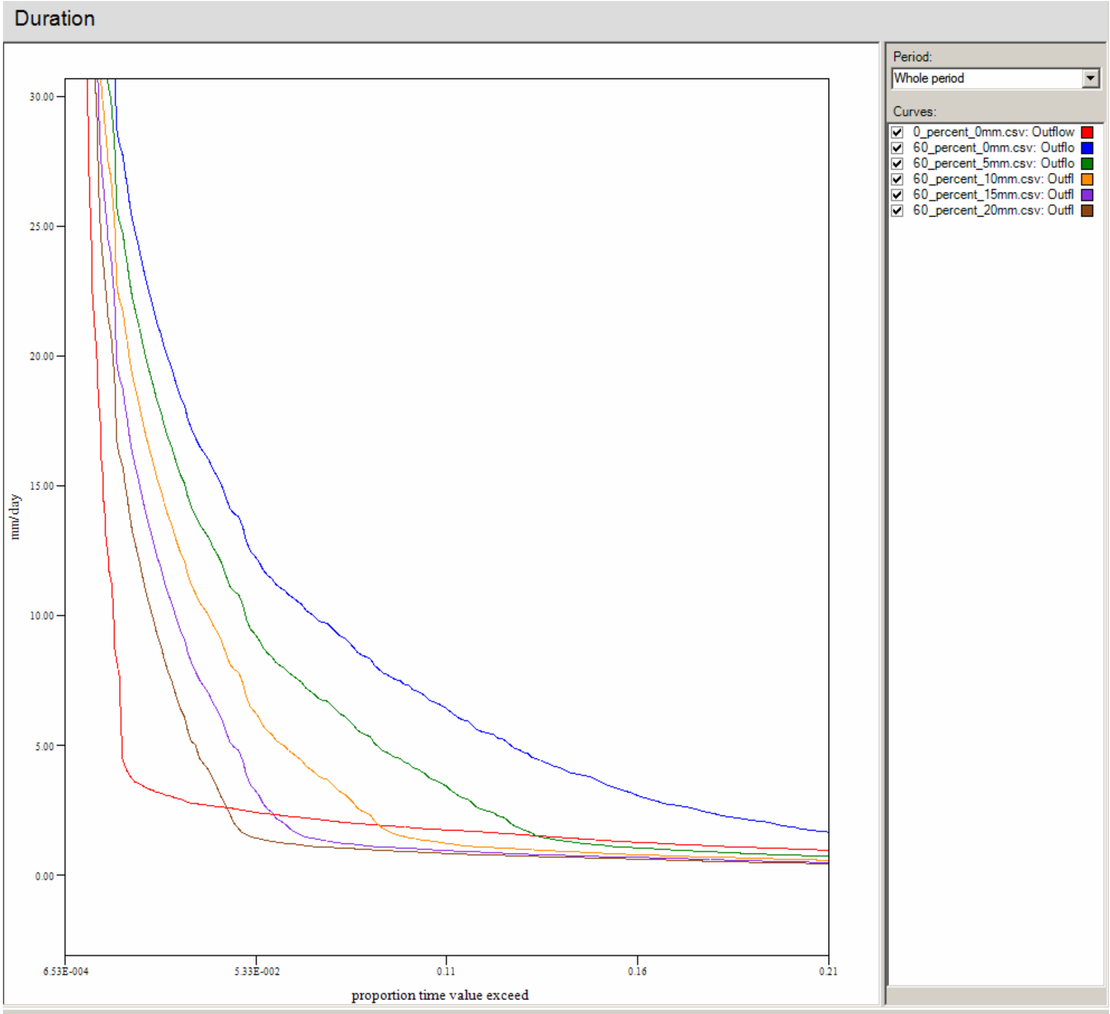
South East Queensland: Nambour



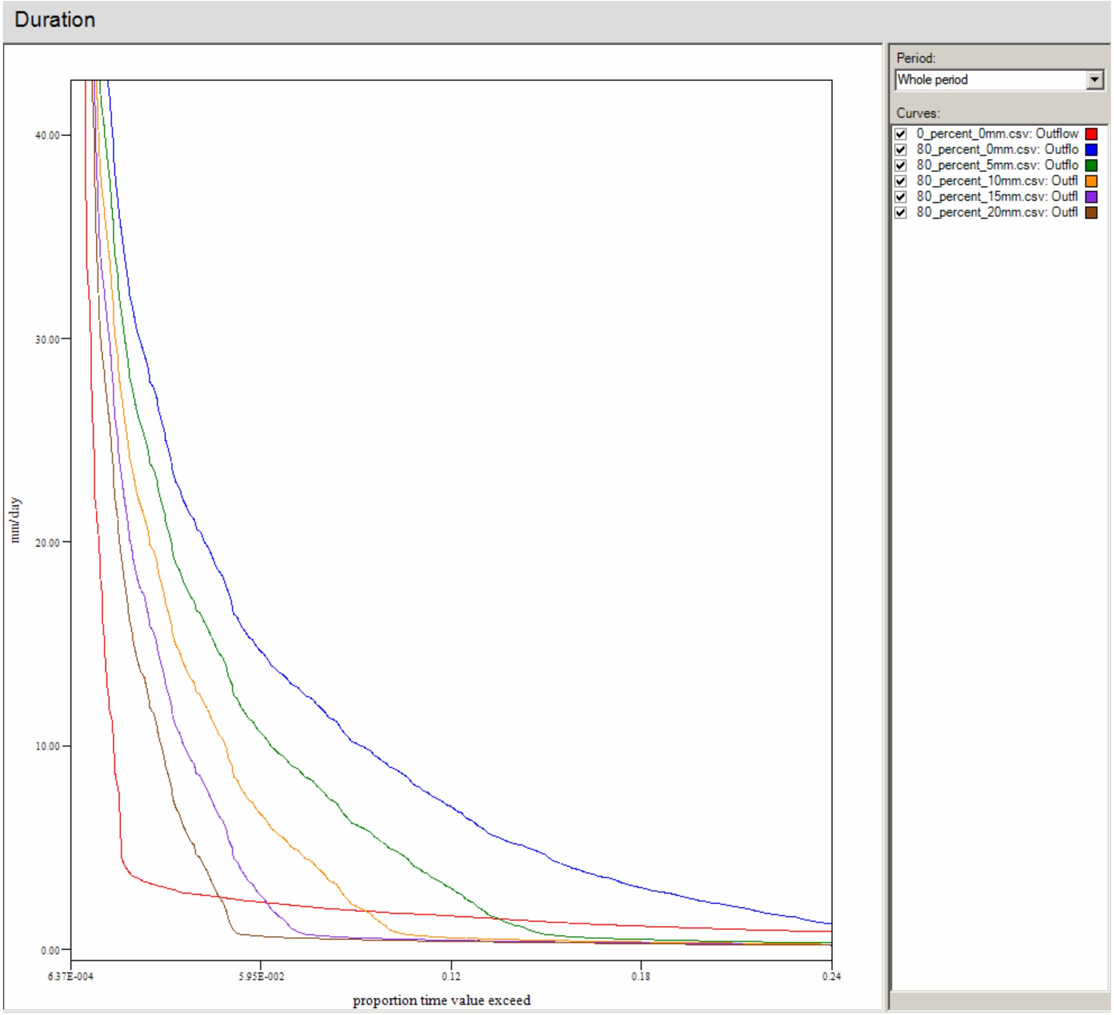
Nambour – 20% Total Impervious Flow Duration Curves



Nambour – 40% Total Impervious Flow Duration Curves

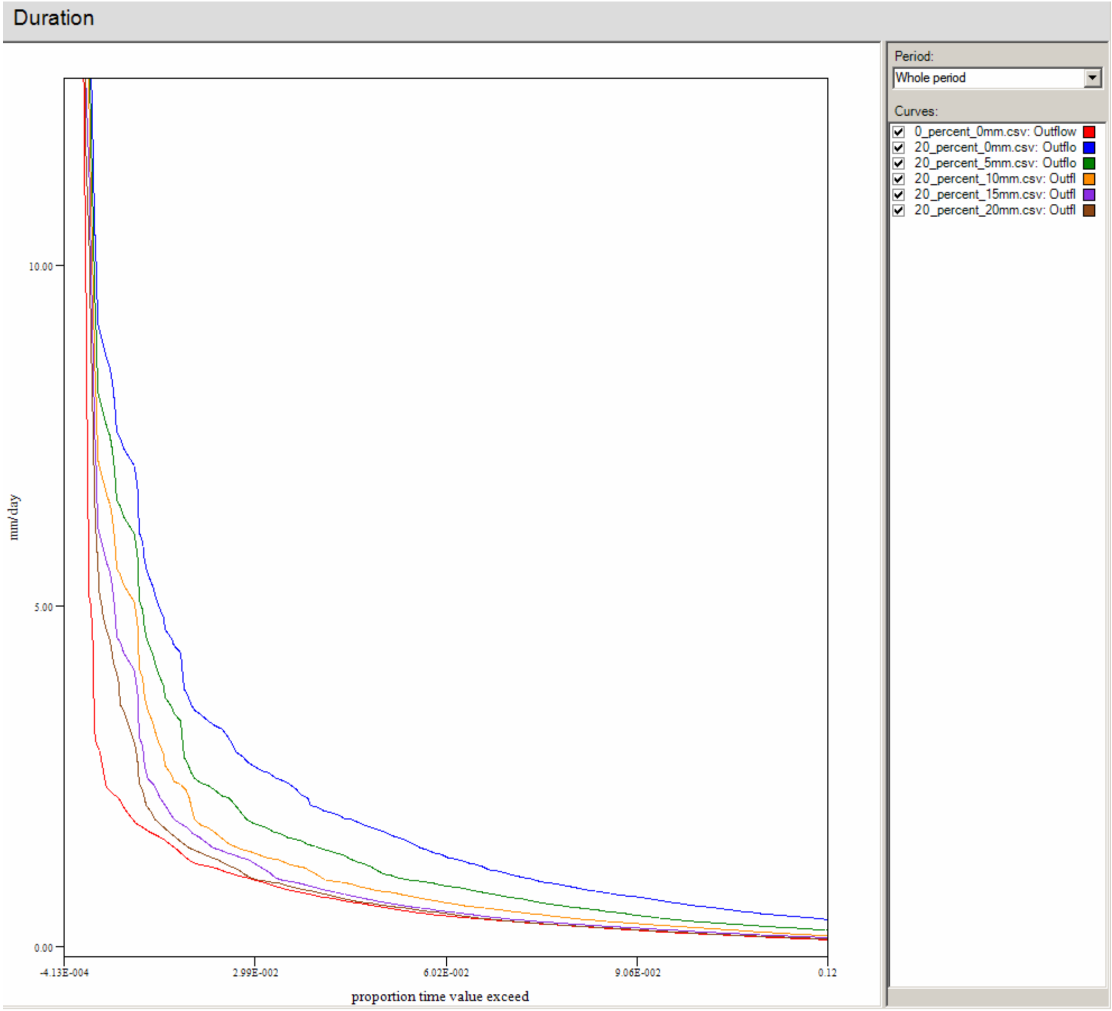


Nambour – 60% Total Impervious Flow Duration Curves

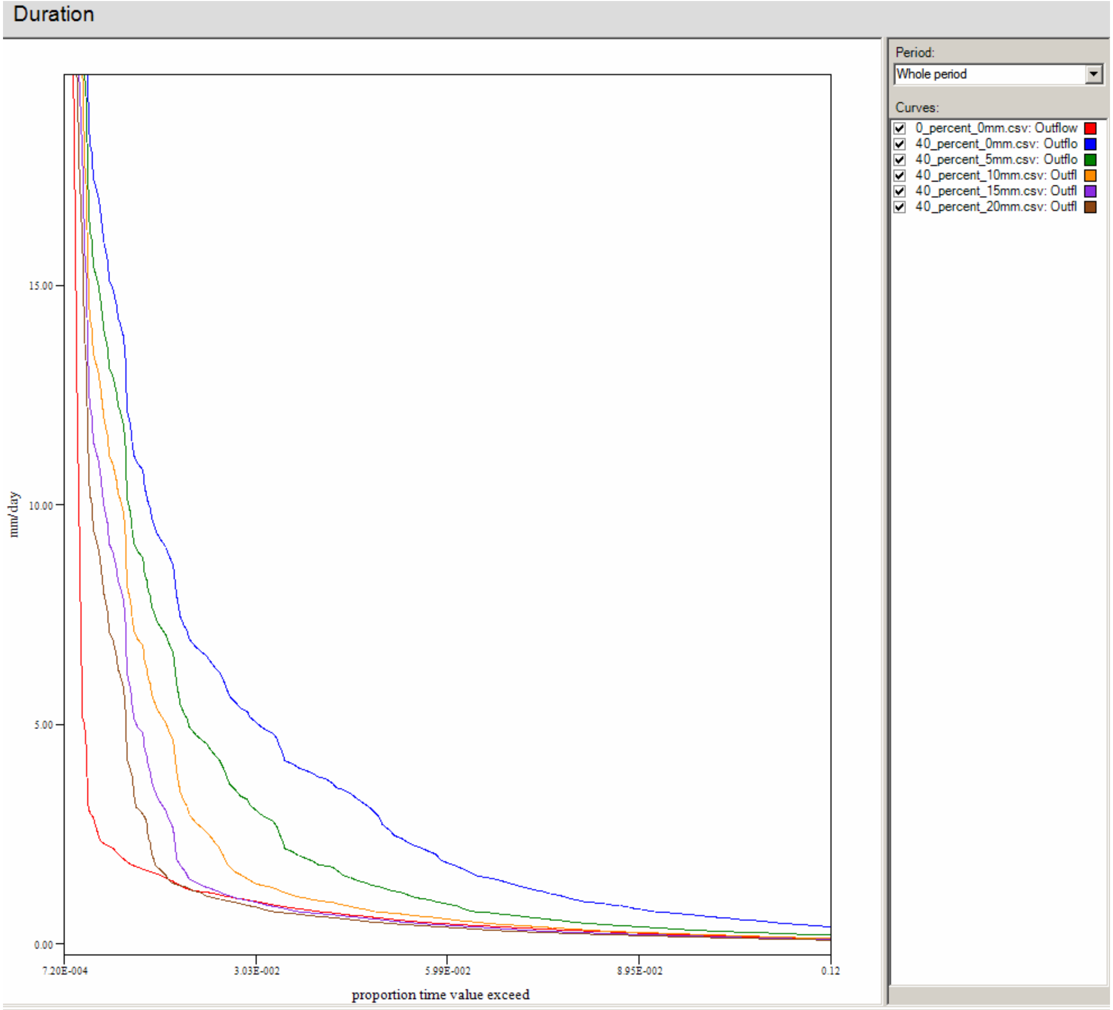


Nambour – 80% Total Impervious Flow Duration Curves

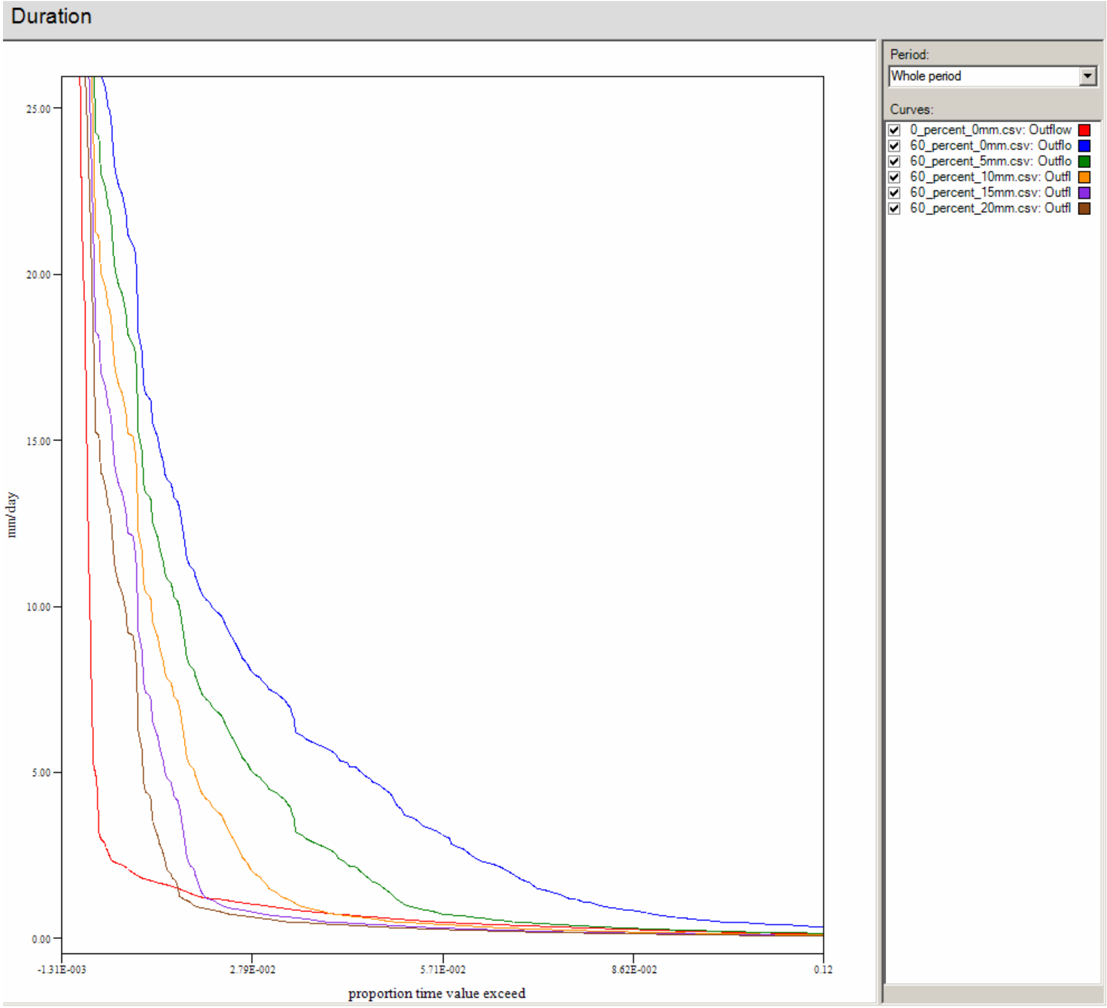
Western Districts: Mount Isa



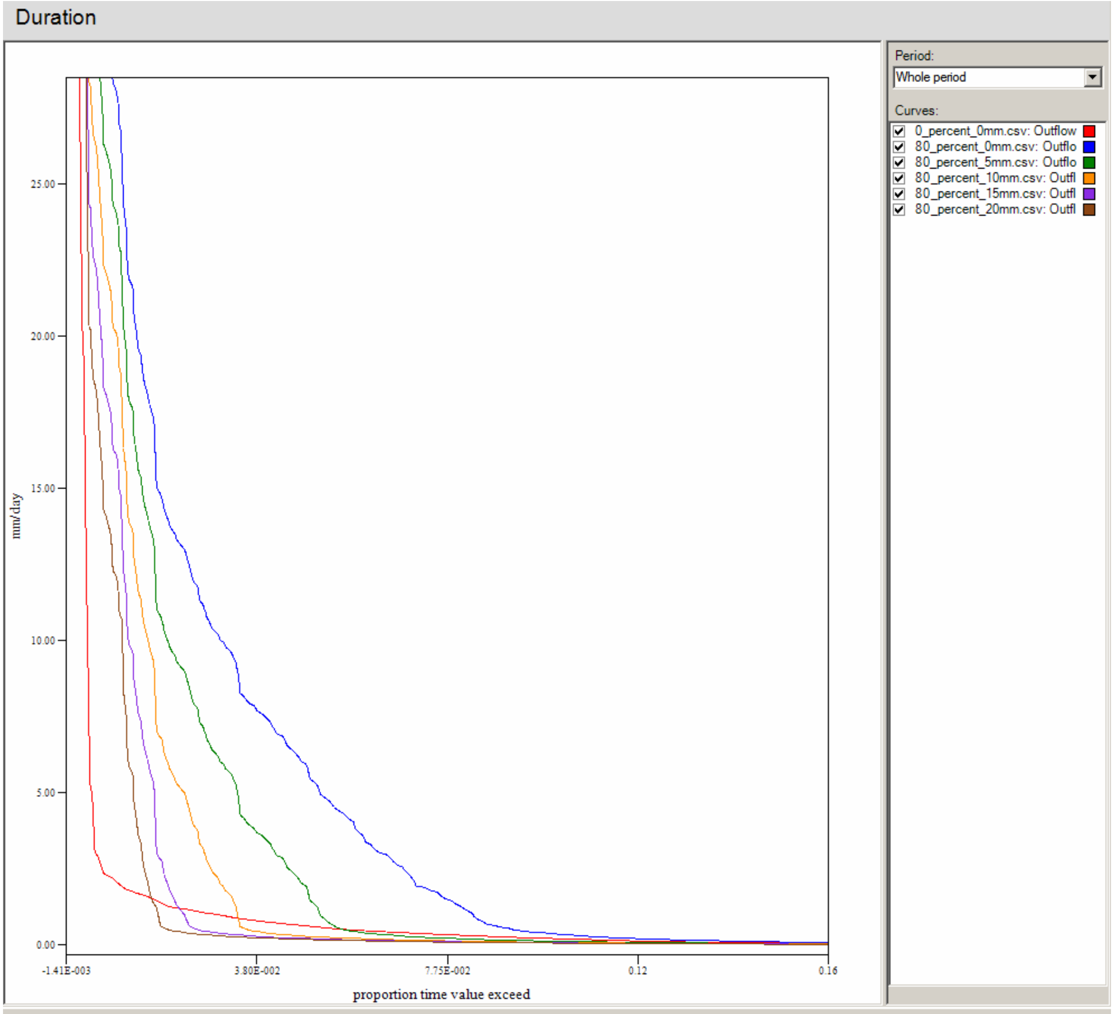
Mt Isa – 20% Total Impervious Flow Duration Curves



Mt Isa – 40% Total Impervious Flow Duration Curves

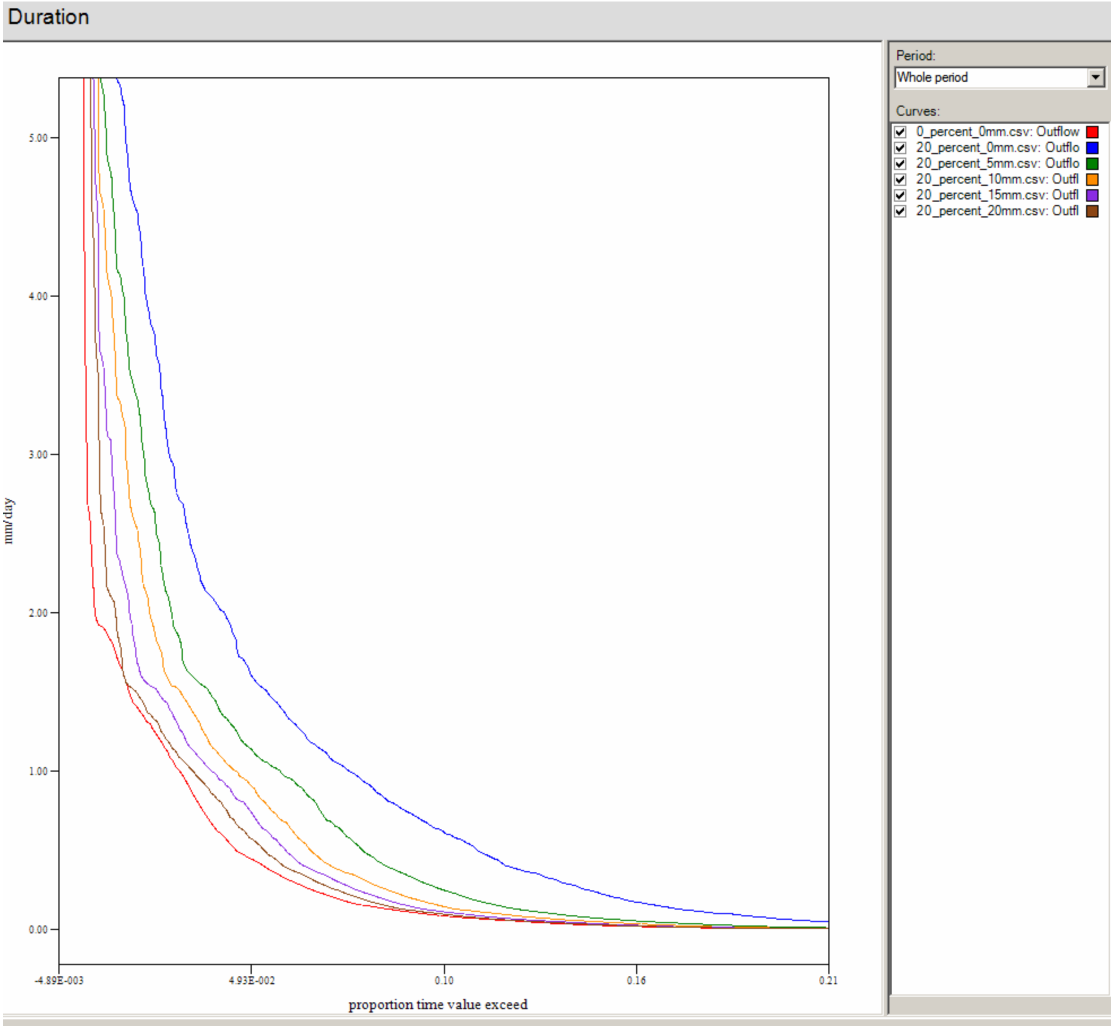


Mt Isa – 60% Total Impervious Flow Duration Curves

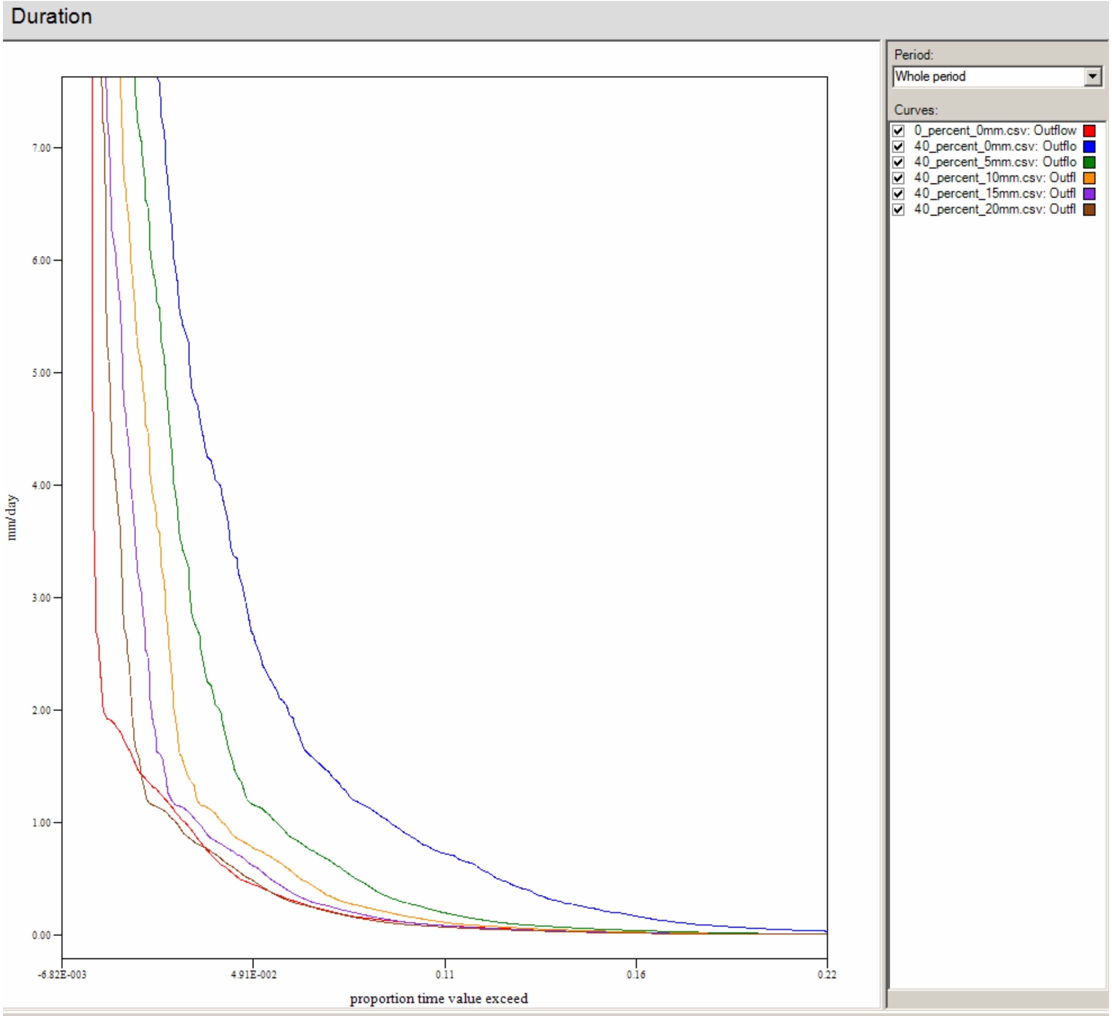


Mt Isa – 80% Total Impervious Flow Duration Curves

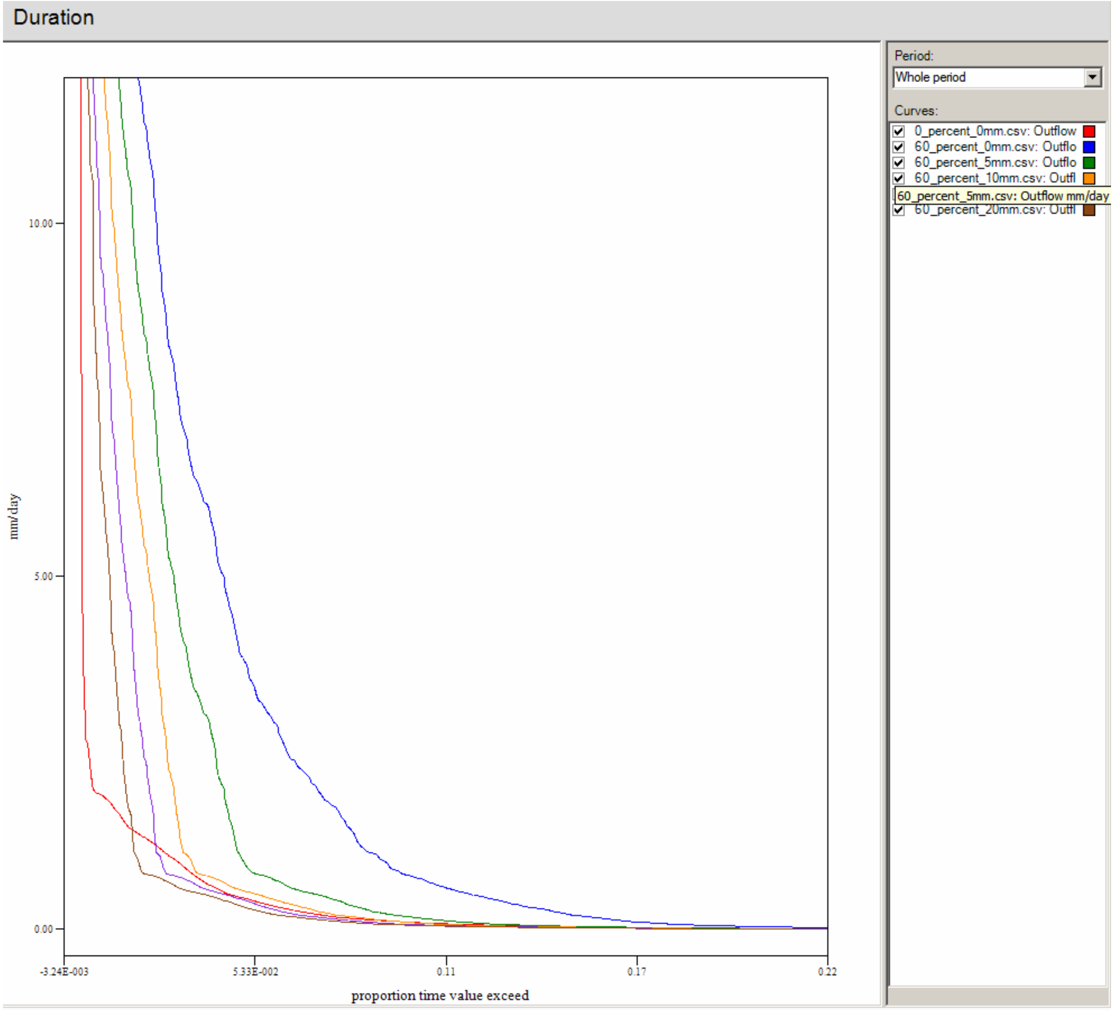
Western Districts: Charleville



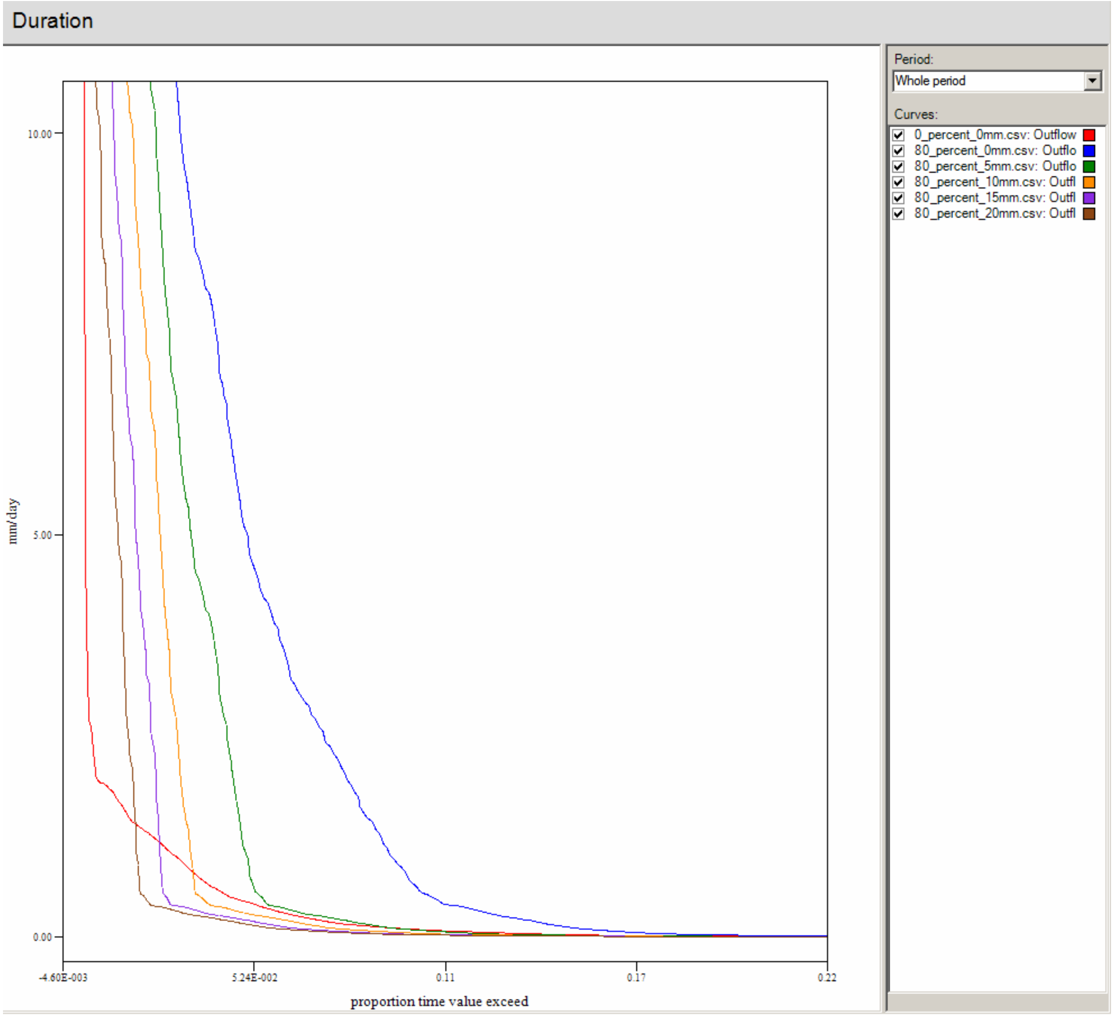
Charleville - 20% Total Impervious Flow Duration Curves



Charleville – 40% Total Impervious Flow Duration Curves



Charleville - 60% Total Impervious Flow Duration Curves



Charleville – 80% Total Impervious Flow Duration Curves