Stormwater Management Report

Lot 104 DP 751388, James Creek Road

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Prepared for: MPD Investments

UPR	Description	Date Issued	Issued By
3204-1008	1st issue for original client review	21/07/2019	Duncan Thomson
3204-1011	2nd issue for original client review	12/08/2019	Michelle Erwin
3204-1039	3rd issue for initial DA submission	19/10/2020	Duncan Thomson
3204-1075	4th issue for new client review	13/10/2021	Duncan Thomson
3204-1102	5th issue – updated post-DA lodgement in response to Council info request	20/05/2022	Duncan Thomson
3204-1118	6th issue – updated post-DA lodgement in response to additional Council RFI	29/03/2023	Duncan Thomson
3204-1121	7th issue – updated post-DA lodgement in response to additional Council RFI	29/05/2023	Duncan Thomson

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1. Introduction

1.1 Background

GeoLINK has been engaged by MPD Investments to prepare a stormwater management strategy for a proposed residential subdivision at Lot 104 DP 751388 James Creek Road, James Creek. This report summarises the stormwater management strategy for the proposed development and should be read in conjunction with the Statement of Environmental Effects and the associated design drawings.

1.2 Site Description

From a stormwater management perspective, the key features of the site are:

- The site is rectangular and has an area of approximately 33 ha.
- The site has been historically cleared and modified for agriculture, sugar cane production and cattle grazing.
- Vegetation at the site comprises improved pasture dominated by Kikuyu.
- The crest of a small hill is located slightly to the north-west of the centre of the site. From this crest, the land falls away in all directions.
- The slopes on the site are typically in the range of 3% to 10%.
- The highest level on the site is approximately 21 mAHD and the lowest level is approximately 4 mAHD.
- There are no permanent water bodies or watercourses located on the site.

1.3 Proposed Development

The design drawings provide details of the proposed development. The proposal is for subdivision of the site resulting in approximately 330 residential lots and associated infrastructure (e.g., roads, services). At the time of writing, the subdivision is proposed to occur in eleven stages, however it is noted that the number of stages, the number of lots in each stage and the sequence of staging will be influenced by the market at the time and possibly by the provision of services.

2. Design Criteria

Design criteria for stormwater management are specified in the *Clarence Valley Council Residential Zones Development Control Plan 2011 – Part H – Sustainable Water Controls* (Amendment No 7, in force 29 July 2022).

2.1 Stormwater Peak Flow Attenuation

Table H1 of the DCP states that post-development peak flows are not to exceed pre-development peak flows specified within council policy and design standards. It is understood that the relevant standard is the *Handbook of Stormwater Drainage Design*, which forms part of the *Northern Rivers Local Government Development Design Manual*. Accordingly, the stormwater peak flow attenuation target is to ensure that the peak flow from the proposed development does not exceed the existing peak flow from the site for the 5, 10-, 20-, 50- and 100-year average recurrence interval (ARI) events, for storm durations from 5 minutes to 3 hours.

2.2 Stormwater Treatment

Table H2 of the DCP lists the requirements for stormwater treatment, which are reproduced below as **Table 2.1**.

Table 2.1 DCP Stormwater Treatment Targets

Water Quality Parameter	*Default Target*
Gross Pollutants	90% of average annual load retained
Total Phosphorus (TP)	60% of average annual load retained
Total Nitrogen (TN)	45% of average annual load retained
Total Suspended Solids (TSS)	85% of average annual load retained

2.3 Stormwater Runoff Volumes and Frequency of Runoff

Table H2 of the DCP states the following requirement regarding stormwater runoff volumes and the frequency of stormwater runoff:

Stormwater runoff volumes and frequency reduced or maintained to the pre development through application of Harvesting, Retention, Infiltration and Detention as appropriate.

It is understood that the above requirement is rarely, if ever, enforced because it is almost impossible to implement a residential development on a previously undeveloped (i.e., 100% pervious) site without increasing the volume and altering the frequency of stormwater runoff discharging from the site. This is discussed further in **Section 3.2.3**.

3. Stormwater Management Strategy

3.1 Overview

3.1.1 Catchments and Discharge Locations

The existing topography of the site results in four stormwater catchments in the pre-development situation. The logical design response to the grading of the site is to continue managing stormwater in four catchments, with the four discharge locations being fairly close to the four corners of the site.

It would be difficult to have less than four stormwater discharge locations, because this would require substantial earthworks and landform alterations to force stormwater to drain in different directions compared to the existing situation. Also, such an approach would not be consistent with the design principles outlined in the DCP.

By retaining the four stormwater catchments, the resultant stormwater catchment areas are presented in **Table 3.1**. The post-development catchments will be different to the pre-development catchments because the post-development catchment boundaries will be dictated by the road and lot layouts. Refer to drawings 3204/C160 and 3204/C166 for the stormwater layout and catchment boundaries.

Table 3.1 Stormwater Catchment Areas

Catchment	*Pre-development area (ha)*	*Post-development area (ha)*
1 (north-west)	5.07	4.73
2 (north-east)	11.14	10.45
3 (south-east)	13.59	13.08
4 (south-west)	3.61	5.15
Total	**33.41**	**33.41**

3.1.2 Stormwater Management

Stormwater management will be provided using the following infrastructure:

- Rainwater tanks on each residential allotment
- Standard underground pit and pipe drainage system to collect and convey stormwater
- Four bioretention basins (one for each catchment)
- Infiltration trench for Catchment 1

Each dwelling will require a rainwater tank to meet the requirements of the NSW Building Sustainability Index (BASIX). It has been assumed that the average rainwater tank size will be 4.5 kL and the tank will be connected to appropriate indoor uses and outdoor taps. The rainwater tanks contribute to achieving stormwater management targets through the capture and reuse of roofwater runoff.

A bioretention basin will be located in a drainage reserve adjacent to the outlet of each catchment. Each basin will perform the dual function of providing peak flow attenuation and treatment of stormwater to meet the design criteria. There will also be some infiltration of stormwater through the base of the basins into the underlying soils, thereby reducing the volume and frequency of surface runoff from the site.

During regular, smaller rainfall events (e.g., less than 1 year ARI storm events), the focus is on the treatment of stormwater to protect downstream aquatic ecosystems. Most of the stormwater will temporarily pond on the surface of the basin and infiltrate down through the filter media (sandy loam soil) to be collected in the slotted under-drainage pipes. Some of the stormwater that infiltrates down to the base of the basin will continue to infiltrate into the underlying soils rather than being collected in the under-drainage pipes. More information regarding the stormwater treatment processes is provided in **Section 3.2.2**.

During infrequent, larger rainfall events (e.g., 5-year ARI storm events and larger), the focus is on the reduction of peak outflows to prevent detrimental impacts on downstream drainage systems, infrastructure, properties, and waterways. The function of the basin is to temporarily fill with stormwater, thereby buffering the flow and slowing the release of water from the developed catchment. In these larger rainfall events, stormwater will fill the basin to a greater depth (maximum depth approximately 1.1 m) and there will be controlled/ throttled outflow via low flow pipe outlets and a high flow weir. Once the rainfall ceases, the depth of water in the basin will drop to 200 mm within minutes. Assuming there is no additional rainfall and subsequent inflow to the basin, the remaining 200 mm of water will drain via infiltration within several hours.

An infiltration trench will be provided for the north-west Catchment 1 to provide additional stormwater flow management for this catchment. The purpose of the infiltration trench is to provide additional infiltration of stormwater for Catchment 1 and an associated reduction in surface water runoff. This will enable the long-term post-development water balance to closely match the pre-development water balance, as discussed in **Section 3.2.3.2**.

The infiltration trench will have the dimensions of 50 m long x 6 m wide x 0.3 m deep. It will be located underground to the south of the bioretention basin and be filled with clean rock or gravel. The infiltration trench will receive water via an underground pipe connection from the bioretention basin subsoil drainage collection system. Once the infiltration trench is full, water in the bioretention basin subsoil drainage system will simply discharge via an overflow pipe into the basin outlet scour protection area.

3.1.2.1 Consideration of Alternative Stormwater Management Options

Bioretention basins are an effective method of providing peak flow attenuation and treatment of stormwater and are widely utilised throughout Australia. Prior to the selection of end-of-line bioretention basins as the preferred approach, the following stormwater treatment options were considered:

- Roadside Swales / Bioretention Swales: The longitudinal grades of the roads will generally be too steep for swales to be suitable. There would also need to be individual driveway crossings over the swales (i.e., culverts) and this would increase the ongoing road reserve maintenance requirements.
- Distributed Bioretention Basins / Pods: As for the swales, the significant longitudinal road grades mean that it would be challenging to incorporate a large number of smaller bioretention basins (or pods) throughout the road network. Also, it would typically be more onerous and costly for Council to maintain a large number of smaller basins, rather than a small number of larger basins.
- Constructed Stormwater Wetlands: The significant surface gradients, particularly along the western site boundary, are not well suited to stormwater wetlands. Wetlands also typically require a larger footprint than bioretention basins to achieve the same level of stormwater treatment.

In general, it is difficult and impractical to incorporate stormwater peak flow attenuation into the stormwater treatment options listed above. As such, there would typically need to be additional end-of-line stormwater infrastructure to provide peak flow attenuation. Once again, this would increase the number of assets that need to be maintained by Council.

3.1.3 Stormwater Discharge Characteristics

The north-east Basin 2 and the south-east Basin 3 will discharge into the James Creek Road reserve, while the south-west Basin 4 will discharge into the Austons Lane road reserve. There is considerable flexibility regarding the configuration of the discharge from these basins. For example, the outflow from the basin can be configured to discharge at a single point, or a level spreader can be incorporated so that the flow is dispersed across a greater width. The preferred discharge configuration for these three basins will be discussed and agreed with Council during the detailed design. In each case, appropriate scour protection will be provided at the outlet. At this stage of concept design, an offset of at least 10 m has been provided from the toe of the basin batter to the discharge location at the boundary. This provides space for various outlet configurations to be considered during detailed design.

Stormwater outflow from the north-west Basin 1 will discharge across the western boundary onto the neighbouring rural lot. At the discharge location, the current landform is a relatively wide grassed gully, rather than a well-defined channel or creek. The proposed design for the Basin 1 discharge aims to mimic the current situation so that in the post-development scenario the stormwater flows across the property boundary in the same manner as at present. This will be primarily achieved by ensuring there is no change to the surface topography along the boundary at this location and for a buffer distance of approximately 10 m into the development site. A level spreader has been incorporated into the design to disperse the runoff across a greater width, similar to the existing situation. In regular, smaller rainfall events there will be flow along the low point of the shallow gully, with relatively low velocities and shallow depth. In larger rainfall events, the stormwater will flow across a wider section of the gully. The flow depths will still be relatively shallow, and the discharge will resemble sheet flow.

3.2 Modelling

The development of the site will result in an increase in the impervious area, which will lead to increases in the peak flow of stormwater emanating from the internal catchments. To ensure that the proposed stormwater system meets the peak flow attenuation targets for stormwater that discharges from the site, hydrologic and hydraulic calculations have been undertaken using a model developed with the DRAINS software.

The proposed land use changes and associated increase in impervious areas will also result in higher loads of water-borne contaminants being generated from the internal catchments. Compliance with the stormwater quality targets will, by default, require the vast majority of stormwater runoff from within the site to flow through treatment devices (such as bioretention systems) before discharging from the site. This will ensure the hydraulic ‘disconnection’ of runoff from impervious surfaces, thus significantly attenuating the impact of frequent flows on the ecological health of downstream waterways.
A conceptual stormwater treatment model was developed using the MUSIC software and this model was used to ensure that the stormwater system meets the stormwater quality targets. The MUSIC model incorporates rainwater tanks for each residential lot, the bioretention basins and the infiltration trench.

The MUSIC model was also used to simulate long-term water balances for the pre-development and post-development scenarios. These water balance simulations provide calculations of the average annual volumes of:

- Stormwater generated within the site
- Rainwater reused by households
- Evapotranspiration from the bioretention basins
- Infiltration into the underlying soils from the bioretention basins and infiltration trench
- Stormwater runoff discharged from the site (for both pre-development and post-development)

3.2.1 Stormwater Peak Flow Attenuation

The DRAINS model was used to design the basins from a stormwater peak flow attenuation perspective. The schematic and results from the DRAINS model are presented in **Appendix A**. The basin geometries used in the DRAINS model are presented in **Table 3.2** to **Table 3.5**.

The actual basin geometries, as designed and constructed, do not need to exactly match the geometries listed in the tables. However, the surface area of the base of the basin (i.e., at depth = 0 m) and the storage volume at the maximum water depth must be at least as large as the numbers listed in the tables.

Table 3.2 Basin 1 (NW catchment) Geometry

Depth of Water (m)	*Surface Area of Basin (m²)*	*Storage Volume of Basin (m³)*
0	1,020	-
1.10	1,935	1,615

Table 3.3 Basin 2 (NE catchment) Geometry

Depth of Water (m)	*Surface Area of Basin (m²)*	*Storage Volume of Basin (m³)*
0	1,275	-
1.10	2,170	1,885

Table 3.4 Basin 3 (SE catchment) Geometry

Depth of Water (m)	*Surface Area of Basin (m²)*	*Storage Volume of Basin (m³)*
0	1,660	-
1.10	2,560	2,310

Table 3.5 Basin 4 (SW catchment) Geometry

Depth of Water (m)	*Surface Area of Basin (m²)*	*Storage Volume of Basin (m³)*
0	1,365	-
1.10	2,370	2,040

Outflow from the basins will be controlled via low flow pipe outlets and a high flow weir. The outlet configurations utilised in the DRAINS model are listed below. Any changes to these outlet configurations during the detailed design phase would need to be validated with further modelling.

The outlet configuration for Basin 1 (NW catchment) is as follows:

- 2 x 525 mm diameter pipes.
- Weir with a crest level 900 mm above the floor of the basin and a crest length of 2.0 m.

The outlet configuration for Basin 2 (NE catchment) is as follows:

- 4 x 525 mm diameter pipes.
- Weir with a crest level 850 mm above the floor of the basin and a crest length of 10.5 m.

The outlet configuration for Basin 3 (SE catchment) is as follows:

- 6 x 450 mm diameter pipes.
- Weir with a crest level 800 mm above the floor of the basin and a crest length of 11.5 m.

The outlet configuration for Basin 4 (SW catchment) is as follows:

- 2 x 450 mm diameter pipes.
- Weir with a crest level 900 mm above the floor of the basin and a crest length of 4.0 m.

At this stage of concept design, it has been assumed that all of the basin outlet pipes (i.e. the 450 mm and 525 mm diameter pipes) will be 10 m long with a 1% longitudinal slope.

The upstream invert level of the basin outlet pipes will be set at a level that is 200 mm higher than the base of the basin (i.e., water ponds to a depth of 200 mm within the basin before flowing out of the pipes). This provides the extended detention depth for the basins and ensures that a substantial proportion of the stormwater captured in the basin infiltrates down through the basin's filter media soil layer. This is critical for the stormwater treatment function of the basin.

3.2.1.1 Results

The peak flows for the pre-development and post-development situations are presented in the following tables. It is evident from the results that the basins provide an adequate level of stormwater peak flow attenuation for all the relevant design storm events.

In fact, the peak flow attenuation goes well beyond the requirement for Basins 1, 2 and 4, with the post-development peak flows being significantly lower than the pre-development peak flows as listed below:

- Basin 1: post-development peak flows less than pre-development by an average of 47%
- Basin 2: post-development peak flows less than pre-development by an average of 12%
- Basin 4: post-development peak flows less than pre-development by an average of 26%

The design is more tightly optimised for Basin 3, with the post-development peak flows being less than the pre-development peak flows by an average of 6%.

Table 3.6 Peak Flows – Basins 1 and 2

Design Storm Event (ARI)	Basin 1 Peak Flows (m^3/s)		Basin 2 Peak Flows (m^3/s)	
	Pre-Development	Post-Development	Pre-Development	Post-Development
5 yr	0.79	0.42	1.53	1.42
10 yr	1.16	0.69	2.38	1.98
20 yr	1.42	0.76	2.88	2.53
50 yr	1.96	0.95	3.80	3.33
100 yr	2.21	1.12	4.30	3.82

Table 3.7 Peak Flows – Basins 3 and 4

Design Storm Event (ARI)	Basin 3 Peak Flows (m^3/s)		Basin 4 Peak Flows (m^3/s)	
	Pre-Development	Post-Development	Pre-Development	Post-Development
5 yr	1.78	1.75	0.52	0.45
10 yr	2.80	2.60	0.80	0.53
20 yr	3.41	3.25	0.95	0.58
50 yr	4.58	4.21	1.27	0.94
100 yr	5.17	4.82	1.45	1.18

3.2.1.2 Stormwater Discharge Characteristics

There is additional sensitivity regarding the north-west Catchment 1, because stormwater from Basin 1 will discharge across the western boundary onto the neighbouring rural lot. A level spreader has been incorporated into the design to disperse the runoff across a greater width, similar to the existing situation. The following table provides stormwater flow widths and depths at the north-west boundary, estimated using the DRAINS model.

Table 3.8 Stormwater Discharge Characteristics for Catchment 1

Design Storm Event (ARI)	Pre-Development Peak Flow (m^3/s)	Post-Development		
		Peak Flow (m^3/s)	Width of Flow at Boundary (m)	Maximum Depth of Water at Boundary (m)
5 yr	0.79	0.42	9	0.09
10 yr	1.16	0.69	11	0.11
20 yr	1.42	0.76	11	0.11
50 yr	1.96	0.95	12	0.12
100 yr	2.21	1.12	13	0.13

3.2.2 Stormwater Treatment

In each bioretention basin, stormwater runoff will be retained within an extended detention depth (200 mm) and then infiltrate down through the filter layer (sandy loam soil). Most of the excess water that drains to the bottom of the filter layer will be collected in slotted under-drainage pipes and conveyed to the discharge location. Some infiltrated water will continue to infiltrate down into the underlying soils rather than being collected in the under-drainage pipes. The surface of the bioretention basin will be densely planted with locally occurring native ground cover species.

Treatment of the stormwater occurs both on the surface of the bioretention system and within the filter layer. When storm inflows cause temporary ponding on the surface of the system, pollutants are removed from the stormwater through sedimentation and particulate adhesion onto the stems and leaves of the vegetation. The agitation of the surface layer of the soil caused by movement of the vegetation and the root systems prevents the accreted sediments clogging the filter layer. As stormwater percolates through the filter layer, fine particulates and some soluble pollutants are removed through processes such as adhesion onto the surface of the soil particles, biological transformation of pollutants by biofilms growing on the surface of the soil particles, and biomass uptake of nutrients and metals through the root systems of the vegetation.

The MUSIC model was used to quantify the pollutant removal provided by the bioretention basins and rainwater tanks.

3.2.2.1 Model Inputs

The MUSIC model was developed based on the guidance provided in the *NSW MUSIC Modelling Guidelines* (BMT WBM, August 2015) and the *MUSIC Modelling Guidelines* (Consultation Draft) (Healthy Land and Water, 2018). The model simulates a five year period using historical rainfall data from 1972 to 1976. This is the time period specified by Council to be used in MUSIC model simulations. This five year period has rainfall characteristics representative of the long-term rainfall record and also includes the 1974 extreme rainfall and flood event. Other key model inputs are listed below:

- Surface types:
  - Roof area assumed to be 300 m² per standard residential lot.
  - Driveway area assumed to be 30 m² per standard residential lot.
  - Road and footpath areas measured and calculated from subdivision design.
- Rainwater tanks:
  - Daily indoor demand (0.173 kL/day for 3 people per dwelling) from Table 6-1 of the *NSW MUSIC Modelling Guidelines.*
  - Annual outdoor demand (55 kL/yr) from Table 6-1 of the *NSW MUSIC Modelling Guidelines.*
  - Roof area that flows to rainwater tank assumed to be 80% of total roof area.
- Soil characteristics:
  - Silty clay parameters from Table 5-5 of the *NSW MUSIC Modelling Guidelines*, based on the geotechnical assessment by Regional Geotechnical Solutions reporting silty clay, with some sandy clay.
  - Infiltration rate of soils beneath bioretention basins and infiltration trench assumed to be 10 mm/hr, based on silty clay and sandy clay at the relevant depths.

3.2.2.2 Results

The MUSIC modelling results are summarised in **Table 3.9**, with the model schematic and results presented in **Appendix B**. The MUSIC-link report is presented in **Appendix C**. The results indicate that the predicted pollutant load reductions meet the adopted targets.

Table 3.9 Stormwater Pollutant Load Reductions

Pollutant	*Post-Development Load – without treatment (kg/yr)*	*Post-Development Load – with treatment (kg/yr)*	*Modelled Load Reduction (%)*	*Target Load Reduction (%)*
Total suspended solids	40,300	5,050	88	85
Total phosphorus	79.0	28.9	64	60
Total nitrogen	563	243	57	45
Gross pollutants	4,980	0	100	90

To provide additional assurance regarding the adequacy of the proposed stormwater treatment, an additional check has been undertaken against the pre-development scenario. For the pre-development scenario, two different land uses were tested. The first is an 'agricultural' land use, which is representative of sugar cane production or intensive cattle grazing. The second is a 'rural' land use, which is representative of a rural residential area and is more conservative because it predicts lower pollutant loads for the pre-development situation.

The results of the comparison are presented in the table below and indicate that the post-development pollutant loads will be less than the pre-development pollutant loads regardless of the assumed pre-development land use.

Table 3.10 Stormwater Pollutant Load Comparison to Pre-Development

Pollutant	*Pre-Development Load – agriculture (kg/yr)*	*Pre-Development Load – rural (kg/yr)*	*Post-Development Load – with treatment (kg/yr)*	*Is Post-Development less than Pre-Development?*
Total suspended solids	25,600	16,400	5,050	Yes
Total phosphorus	107	36.1	28.9	Yes
Total nitrogen	505	307	243	Yes
Gross pollutants	0	0	0	Equal

Some parameters are listed as 'failing parameters' in the MUSIC-link report in **Appendix C**. These parameters are listed in the following table, along with the source of the adopted value. Also, the impervious area is stated as 111.5% in the Project Details section on the first page of the MUSIC-link report. It is unclear why this value has been generated by the MUSIC-link report, because this does not match the overall impervious percentage of the post-development scenario, which is 50%.

Table 3.11 Source of Parameters reported as 'Failing' in MUSIC Model

Parameter	*Value*	*Source of Value*
Agricultural land use – Baseflow Total Nitrogen Mean (log mg/L)	0.04	*NSW MUSIC Modelling Guidelines, Table 5-6*
Agricultural land use – Baseflow Total Phosphorus Mean (log mg/L)	-1.05	*NSW MUSIC Modelling Guidelines, Table 5-6*
Agricultural land use – Baseflow Total Suspended Solids Mean (log mg/L)	1.3	*NSW MUSIC Modelling Guidelines, Table 5-6*
Agricultural land use – Stormflow Total Nitrogen Mean (log mg/L)	0.48	*NSW MUSIC Modelling Guidelines, Table 5-7*
Agricultural land use – Stormflow Total Phosphorus Mean (log mg/L)	-0.22	*NSW MUSIC Modelling Guidelines, Table 5-7*
Agricultural land use – Stormflow Total Suspended Solids Mean (log mg/L)	2.15	*NSW MUSIC Modelling Guidelines, Table 5-7*
Infiltration trench – Evaporative Loss as % of PET	0	Trench is underground, therefore no evaporative loss
Road surface type – Impervious Area Rainfall Threshold (mm/day)	1.5	*NSW MUSIC Modelling Guidelines, Table 5-4*
Roof surface type – Impervious Area Rainfall Threshold (mm/day)	0.3	*NSW MUSIC Modelling Guidelines, Table 5-4*

3.2.3 Stormwater Runoff Volumes and Frequency of Runoff

As noted in **Section 2.3**, Table H2 of the DCP states the following requirement with regard to stormwater runoff volumes and the frequency of stormwater runoff:

Stormwater runoff volumes and frequency reduced or maintained to the pre development through application of Harvesting, Retention, Infiltration and Detention as appropriate.

The DCP does not provide guidance as to how compliance with the above clause should be demonstrated. For example, should the pre-development and post-development runoff volumes be compared for a range of individual design storm events (e.g., 5, 10, 20, 50 and 100 year ARI events), similar to the peak flow attenuation assessment, or should the runoff volumes be checked over longer time periods (e.g., months, years) that incorporate multiple, varied rain events? Similarly, should the frequency of runoff be assessed for every event that causes discharge from the site, or only events that are above, below, or in between certain thresholds?

If the intention of the DCP is that the post-development stormwater runoff volume cannot exceed the pre-development stormwater runoff volume in any individual design storm event, or for any multi-event time period assessed using representative historical climate data, then it is suggested that this cannot be practically achieved for a residential development that is proposed on the previously undeveloped James Creek site.

A residential development incorporates a range of impervious surfaces, including roofs, roads and footpaths. For a previously undeveloped site, this increases the percentage of impervious area on the site from 0% to approximately 50%. This results in more stormwater runoff being generated when it rains. If the intention is to reduce the volume of stormwater runoff down to pre-development levels, options include:

- Capture, storage and reuse of roofwater using rainwater tanks
- Capture, storage and infiltration of stormwater into the underlying soils
- Capture, storage and reuse of stormwater at a subdivision scale

The first two of these measures are included in the development proposal. But they are not sufficient to reduce stormwater runoff volumes to pre-development levels across the whole development site for all individual design storm events and all multi-event time periods.

Therefore, a subdivision-scale stormwater harvesting scheme would be required if full compliance with the DCP clause was required. Such a scheme would need to be designed and justified based on exhaustive water balance modelling of a comprehensive range of individual storms and multi-event periods. It is highly likely that the stormwater would need to be treated to potable water standard so that it could be used for purposes that aren't already supplied by rainwater tanks, and large storage reservoirs would be required. The capital and operating costs of such a stormwater harvesting scheme would be very high. As such, this is not considered to be a reasonable and feasible option for this residential subdivision.

Given the above, full compliance with the DCP clause is considered to be unreasonable. Instead, the adopted approach has been to identify the specific issues or potential impacts that could be caused by changes to stormwater runoff volumes or frequencies and address those specific issues. These specific issues are discussed in the following sections.

3.2.3.1 Impacts on Stormwater Conveyance Infrastructure

With regard to stormwater conveyance or 'drainage' infrastructure located downstream of the site (e.g., culverts, channels, drains), it is suggested that increases in runoff volumes or frequencies would have a negligible impact. The key constraint for this infrastructure is the flow rate (m^3/s), not the volume (m^3) or frequency. For example, it is the flow rate that determines whether channel banks are overtopped, and it is the flow rate, and associated velocity, that primarily influences channel erosion and scour processes. The purpose of the stormwater peak flow attenuation requirements and measures (refer to **Section 3.2.1**) is to manage potential impacts associated with flow rates.

3.2.3.2 Impacts on Farmland Adjacent to Catchment 1

It is understood that there are concerns regarding potential impacts on the use of farmland located immediately to the west of the north-west Catchment 1. Specifically, it is understood that there are areas of the farm that become boggy and muddy after rainfall and can't be used for cattle grazing or movement of cattle. The concern is that increased stormwater runoff volumes and/or frequencies from the proposed residential development might increase the frequency and duration that these areas of the farm are unusable.

In response to the above concerns, substantial effort has been focussed on designing a stormwater management strategy for the north-west Catchment 1. The proposed strategy includes:

- Rainwater tanks on each residential allotment (as is the case throughout the proposed estate).
- A bioretention basin that is about 50% larger than what would be required to meet the standard peak flow attenuation and stormwater treatment requirements.
- An underground infiltration trench to further reduce the amount of surface runoff and infiltrate this water into the underlying soils to recharge groundwater.

The overall effect of the above measures is to ensure that the stormwater discharge across the western boundary gets as close as practically possible to mimicking the current pre-development situation. This is particularly the case in smaller, regular rainfall events (e.g., less than 1 yr. ARI), which are likely to have the most significant impact on day-to-day farm operations.

In larger, less frequent storm events (e.g. greater than 1 yr. ARI), there will actually be benefits associated with reduced peak flows compared to the pre-development situation, as detailed in **Section 3.2.1.1** and **Table 3.6** (refer to Basin 1 results). The attenuation of peak flows goes over-and-above standard requirements, with the post-development peak flows being substantially lower than the pre-development peak flows for all design storm events from the 1-year ARI through to the 100-year ARI. For these design storm events, the post-development peak flow ranges from 48% to 68% of the magnitude of the pre-development peak flow. This will reduce the risk and likelihood of scour and erosion within the downstream farmland.

As described in **Section 3.2.2.1**, the MUSIC model simulates a five-year period using historical rainfall data from 1972 to 1976.

A key outcome of the proposed strategy is that the long-term water balance extracted from the MUSIC model simulation indicates that the average annual surface water discharge across the western boundary in the post-development situation (21.0 ML/yr.) will be a very close match to the pre-development situation (21.2 ML/yr.). This is summarised in the following table. It is noted that the 'rainfall onto catchment' is 7% lower in the post-development scenario simply because the post-development catchment is 7% smaller than the pre-development catchment (refer to **Table 3.1**).

Table 3.12 Catchment 1 Water Balance

Water Balance Item	*Post-Development Scenario*	*Pre-Development Scenario*
Rainfall onto catchment	**54.7 ML/yr**	**58.7 ML/yr**
Evapotranspiration from vegetated/pervious surfaces within catchment	- 20.8 ML/yr	- 37.3 ML/yr
Water stored in soil	- 0.1 ML/yr	- 0.2 ML/yr
Stormwater generated within residential development	**= 33.8 ML/yr**	
Collection and reuse of roofwater via rainwater tanks	- 3.4 ML/yr	
Evapotranspiration losses from bioretention basin	- 2.2 ML/yr	
Infiltration into underlying soils from base and sides of bioretention basin	- 5.1 ML/yr	
Infiltration into underlying soils from infiltration trench	- 2.2 ML/yr	
Surface water discharge from site	**= 21.0 ML/yr**	**= 21.2 ML/yr**
% change from pre-development scenario	*- 1%*	

As per the above, the proposed stormwater management strategy has been designed to achieve a close match between the average annual surface water discharge from Catchment 1 in the post-development situation compared to the pre-development situation. But this is not to claim that there won't be differences in the surface water volume that flows across the boundary in individual rainfall events. To illustrate this, the outputs from the MUSIC model simulation for eight specific rainfall events are presented in the table below. The surface water volume that discharges from Catchment 1 is sometimes higher in the post-development scenario (red numbers), sometimes it is lower (blue numbers) and for other events there is a close match (green numbers). The outcome for a specific rainfall event depends on factors such as whether the soil is relatively saturated from recent rain, the intensity of the rainfall, and whether rainwater tanks are full from recent rain (for the post-development scenario).

Table 3.13 Catchment 1 – Surface Water Volumes for Specific Rainfall Events

Rainfall Date	*Rainfall (mm)*	*Pre-Development Surface Water Volume (kL)*	*Post-Development Surface Water Volume (kL)*	*Change in Volume (kL)*	*% Change in Volume*
21/03/1972	12	388	319	-69	-18%
23/01/1972	29	625	802	177	28%
21/06/1976	30	1479	1166	-313	-21%
11/11/1972	31	1024	1057	32	3%
18/02/1972	36	1235	1210	-25	-2%
07/01/1975	53	1158	1578	420	36%
22/04/1974	124	5124	4609	-515	-10%
11/02/1976	133	4522	4557	35	1%

3.2.3.3 Frequent Flow Impacts on Downstream Waterways

Increases in the frequency of stormwater runoff to natural waterways can have detrimental impacts on in-stream ecosystems. When comparing a pre-development 0% impervious catchment to a post-development catchment, a difference is that smaller rainfall events (e.g., 5 mm of rain) will not generate stormwater runoff in the pre-development situation because all of the rain will infiltrate into the ground, but similar rainfall events will generate stormwater runoff in the post-development situation due to impervious surfaces.

The general best-practice approach to managing the potential impact of increased frequency of runoff is to provide a stormwater management system that provides a method to capture the relatively small depth of stormwater generated from these smaller rainfall events and prevent it from being discharged as a pulse of surface water runoff to downstream waterways. The rainwater tanks and bioretention basins that are proposed as part of the development are best-practice methods of managing the potential impacts of frequent flows.

3.2.3.4 Water Balances for Catchments 2 to 4

The long-term water balances for Catchments 2 to 4 extracted from the MUSIC model simulation are presented in the following tables. It is noted that the 'rainfall onto catchment' values differ between the post-development and pre-development scenarios because the post-development and pre-development catchment areas are different, as per **Table 3.1**.

The MUSIC model simulation indicates that, for Catchments 2 to 4, the average annual surface water discharge across the site boundary will be higher in the post-development situation compared to the pre-development situation. This increase in the average annual stormwater volume is not expected to have a significant detrimental impact on downstream waterways or properties. These catchments discharge into designated watercourses or channels. As discussed in **Section 3.2.3.1** above, the key constraint for watercourses and channels is the flow rate (m^3/s), not the volume (m^3) or frequency of runoff. Stormwater peak flow attenuation measures are proposed (refer to **Section 3.2.1**) to manage potential impacts associated with flow rates.

Table 3.14 Catchment 2 Water Balance

Water Balance Item	*Post-Development Scenario*	*Pre-Development Scenario*
Rainfall onto catchment	**121.0 ML/yr**	**128.8 ML/yr**
Evapotranspiration from vegetated/pervious surfaces within catchment	- 43.3 ML/yr	- 81.9 ML/yr
Water stored in soil	- 0.2 ML/yr	- 0.5 ML/yr
Stormwater generated within residential development	**= 77.5 ML/yr**	
Collection and reuse of roofwater via rainwater tanks	- 8.0 ML/yr	
Evapotranspiration losses from bioretention basin	- 2.9 ML/yr	
Infiltration into underlying soils from base and sides of bioretention basin	- 8.3 ML/yr	
Surface water discharge from site	**= 58.3 ML/yr**	**= 46.4 ML/yr**
% change from pre-development scenario	*+ 26%*	

Table 3.15 Catchment 3 Water Balance

Water Balance Item	*Post-Development Scenario*	*Pre-Development Scenario*
Rainfall onto catchment	**151.4 ML/yr**	**157.4 ML/yr**
Evapotranspiration from vegetated/pervious surfaces within catchment	- 51.2 ML/yr	- 100.1 ML/yr
Water stored in soil	- 0.2 ML/yr	- 0.6 ML/yr
Stormwater generated within residential development	**= 100.0 ML/yr**	
Collection and reuse of roofwater via rainwater tanks	- 11.6 ML/yr	
Evapotranspiration losses from bioretention basin	- 3.8 ML/yr	
Infiltration into underlying soils from base and sides of bioretention basin	- 10.6 ML/yr	
Surface water discharge from site	**= 74.0 ML/yr**	**= 56.7 ML/yr**
% change from pre-development scenario	*+ 30%*	

Table 3.16 Catchment 4 Water Balance

Water Balance Item	*Post-Development Scenario*	*Pre-Development Scenario*
Rainfall onto catchment	**59.6 ML/yr**	**41.8 ML/yr**
Evapotranspiration from vegetated/pervious surfaces within catchment	- 21.6 ML/yr	- 26.6 ML/yr
Water stored in soil	- 0.1 ML/yr	- 0.1 ML/yr
Stormwater generated within residential development	**= 37.9 ML/yr**	
Collection and reuse of roofwater via rainwater tanks	- 4.3 ML/yr	
Evapotranspiration losses from bioretention basin	- 2.8 ML/yr	
Infiltration into underlying soils from base and sides of bioretention basin	- 6.1 ML/yr	
Surface water discharge from site	**= 24.6 ML/yr**	**= 15.1 ML/yr**
% change from pre-development scenario	*+ 63%*	

References

BMT WBM, (2015). *NSW MUSIC Modelling Guidelines.* Prepared for Greater Sydney Local Land Services.

Clarence Valley Council, (2011). *Clarence Valley Council Residential Zones Development Control Plan 2011.*

Healthy Land and Water, (2018). *MUSIC Modelling Guidelines (Consultation Draft).* Healthy Land and Water Limited, Brisbane, Queensland.

Water by Design, (2010). *MUSIC Modelling Guidelines (Version 1.0).* SEQ Healthy Waterways Partnership.

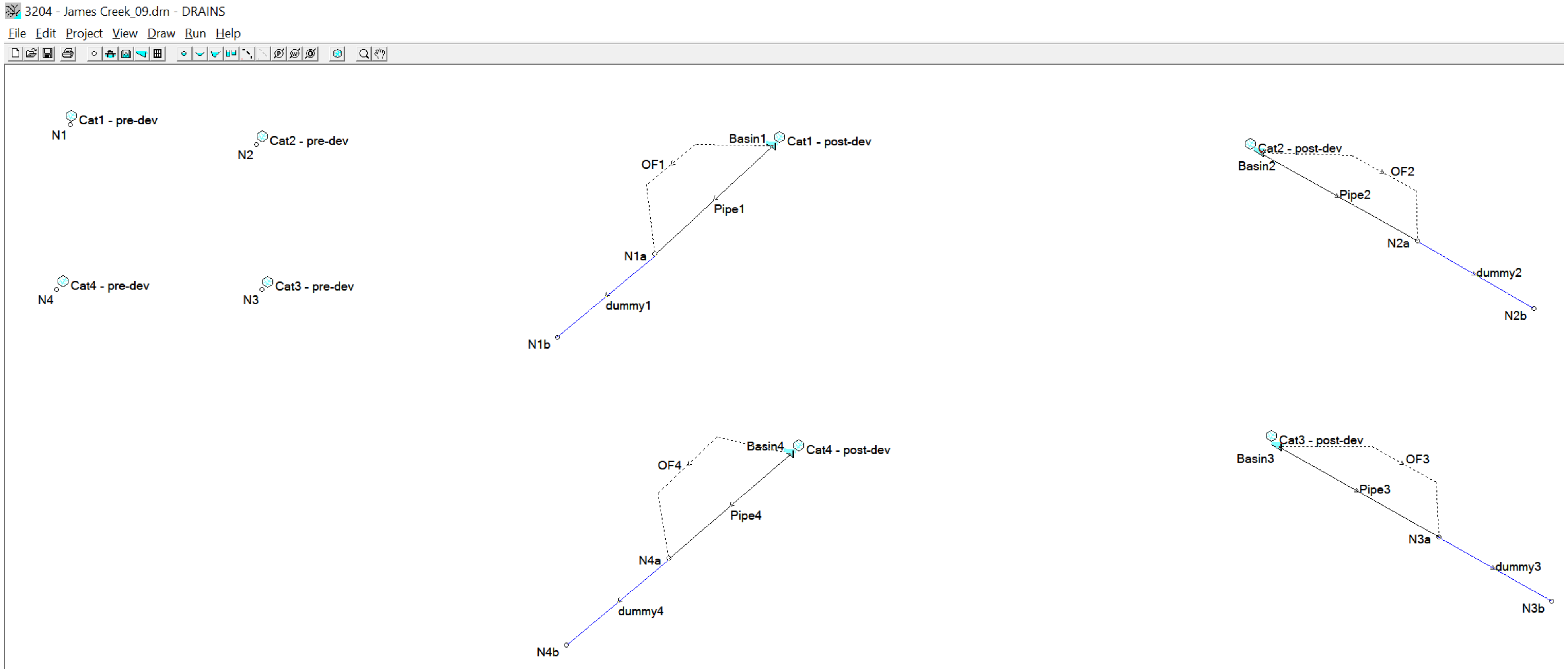
Copyright and Usage

Appendix A

DRAINS Model Schematic and Results

Schematic of Model Layout

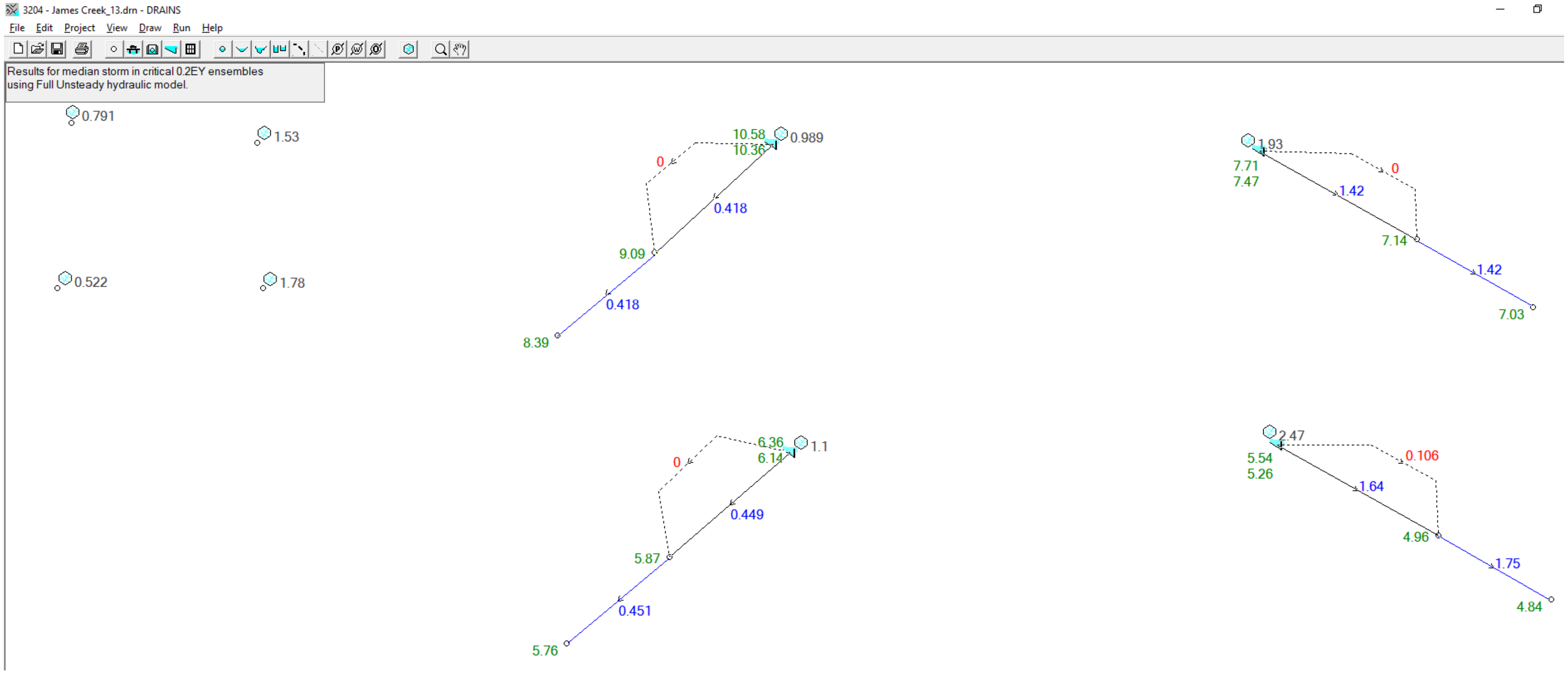
Notes: 1. Pre-development at left and post-development at right.



Results – 5yr ARI (0.2EY)

Notes: 1. Pre-development at left and post-development at right.

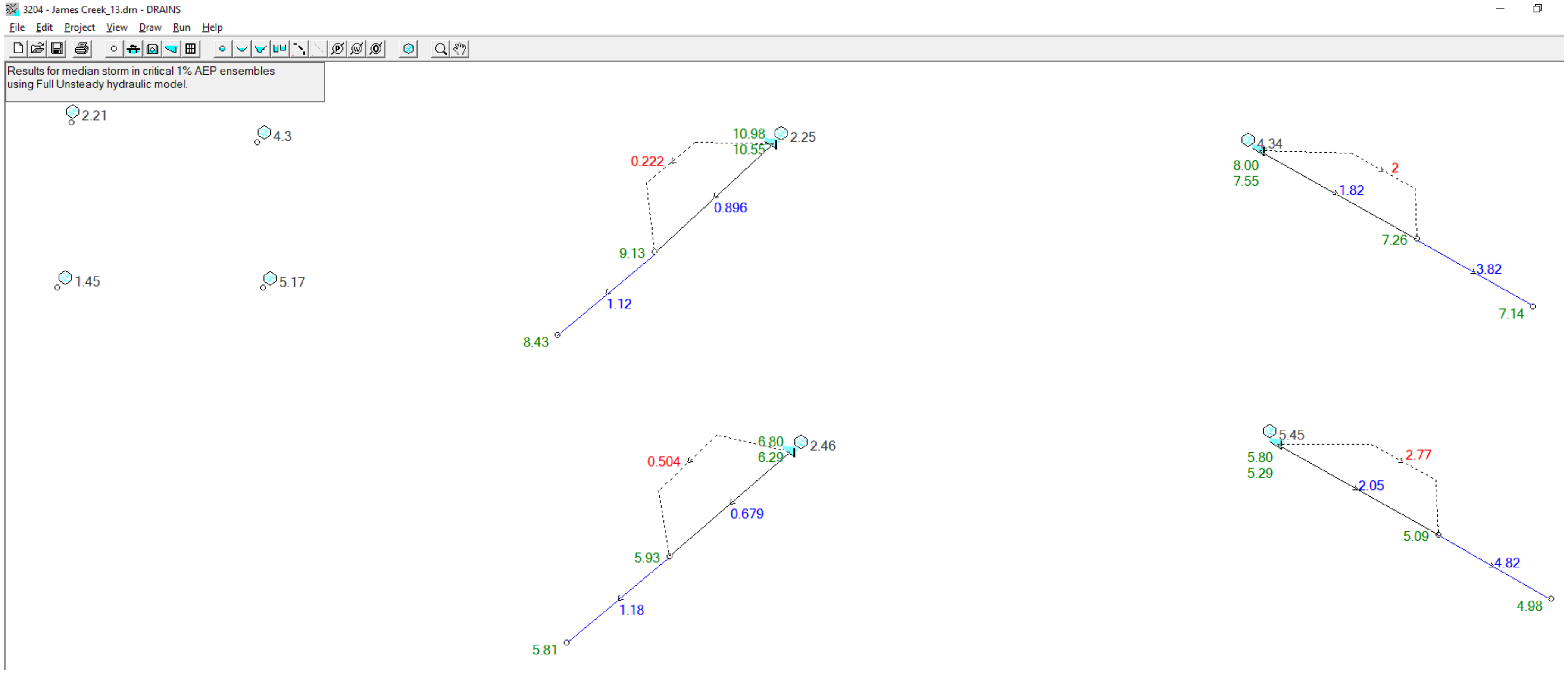
2. Black numbers are catchment inflows; blue numbers are peak flow rates in pipes/ channels; red numbers are peak flow rates in weirs; green numbers are peak water levels.



Results – 100yr ARI (1% AEP)

Notes: 1. Pre-development at left and post-development at right.

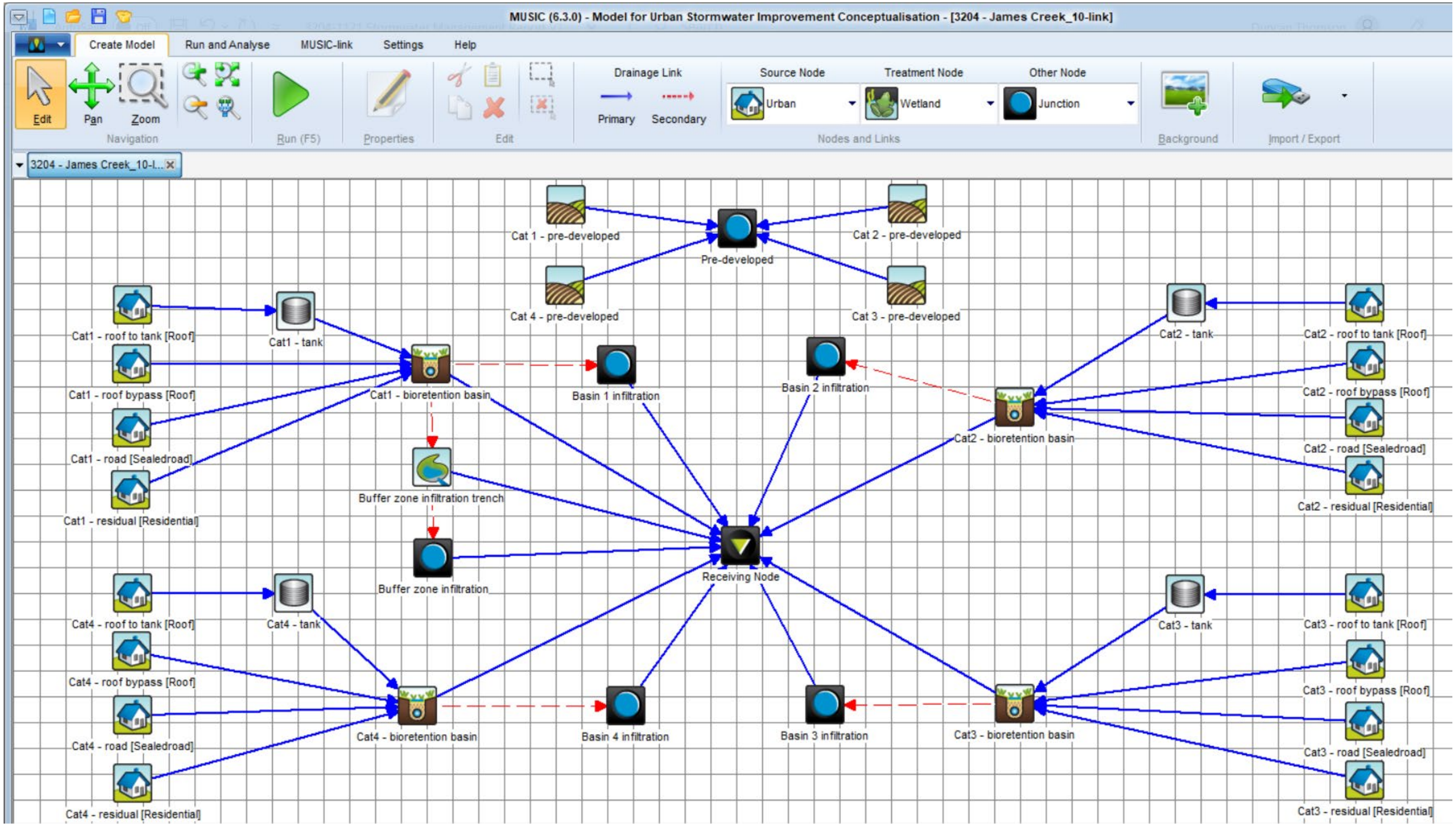
2. Black numbers are catchment inflows; blue numbers are peak flow rates in pipes/ channels; red numbers are peak flow rates in weirs; green numbers are peak water levels.



Appendix B

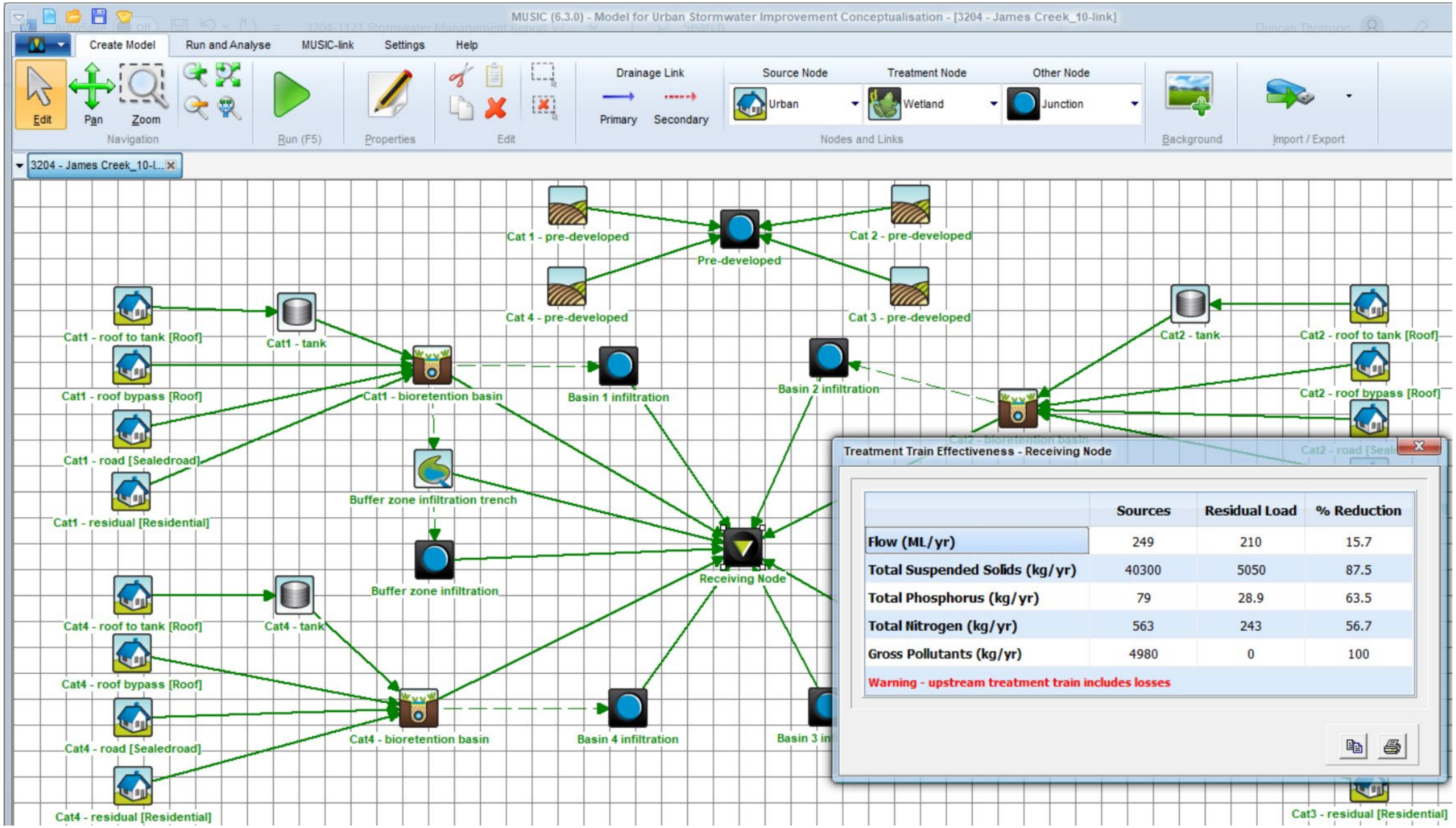
MUSIC Model Schematic and Results

Schematic



MUSIC (6.3.0) - Model for Urban Stormwater Improvement Conceptualisation - [3204 - James Creek_10-link]
Create Model
Run and Analyse
MUSIC-link
Settings
Help
Edit
Pan
Zoom
Navigation
Run (F5)
Properties
Edit
Drainage Link
Primary
Secondary
Source Node
Urban
Treatment Node
Wetland
Other Node
Junction
Nodes and Links
Background
Import / Export
Cat 1 - pre-developed
Cat 2 - pre-developed
Pre-developed
Cat 4 - pre-developed
Cat 3 - pre-developed
Cat1 - roof to tank [Roof]
Cat1 - tank
Cat1 - roof bypass [Roof]
Cat1 - bioretention basin
Basin 1 infiltration
Basin 2 infiltration
Cat1 - road [Sealedroad]
Cat1 - residual [Residential]
Buffer zone infiltration trench
Buffer zone infiltration
Receiving Node
Cat2 - tank
Cat2 - roof to tank [Roof]
Cat2 - roof bypass [Roof]
Cat2 - bioretention basin
Cat2 - road [Sealedroad]
Cat2 - residual [Residential]
Cat4 - roof to tank [Roof]
Cat4 - tank
Cat4 - roof bypass [Roof]
Cat4 - bioretention basin
Cat4 - road [Sealedroad]
Cat4 - residual [Residential]
Basin 4 infiltration
Basin 3 infiltration
Cat3 - bioretention basin
Cat3 - tank
Cat3 - roof to tank [Roof]
Cat3 - roof bypass [Roof]
Cat3 - road [Sealedroad]
Cat3 - residual [Residential]

Results


MUSIC (6.3.0) - Model for Urban Stormwater Improvement Conceptualisation - [3204 - James Creek_10-link]
Create Model
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Settings
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Treatment Node
Wetland
Other Node
Junction
Nodes and Links
Background
Import / Export
3204 - James Creek_10-l...
Cat 1 - pre-developed
Pre-developed
Cat 2 - pre-developed
Cat 4 - pre-developed
Cat 3 - pre-developed
Cat1 - roof to tank [Roof]
Cat1 - tank
Cat1 - roof bypass [Roof]
Cat1 - bioretention basin
Basin 1 infiltration
Basin 2 infiltration
Cat2 - tank
Cat2 - roof to tank [Roof]
Cat2 - roof bypass [Roof]
Cat1 - road [Sealedroad]
Cat1 - residual [Residential]
Buffer zone infiltration trench
Buffer zone infiltration
Receiving Node
Cat4 - roof to tank [Roof]
Cat4 - tank
Cat4 - roof bypass [Roof]
Cat4 - bioretention basin
Basin 4 infiltration
Cat4 - road [Sealedroad]
Cat4 - residual [Residential]
Cat3 - residual [Residential]
Treatment Train Effectiveness - Receiving Node
Sources | Residual Load | % Reduction
Flow (ML/yr) | 249 | 210 | 15.7
Total Suspended Solids (kg/yr) | 40300 | 5050 | 87.5
Total Phosphorus (kg/yr) | 79 | 28.9 | 63.5
Total Nitrogen (kg/yr) | 563 | 243 | 56.7
Gross Pollutants (kg/yr) | 4980 | 0 | 100
Warning - upstream treatment train includes losses

Appendix C

MUSIC-link Report

CLARENCE VALLEY COUNCIL

MUSIC-*link* Report

Project Details		Company Details	
Project:	Lot 104 DP 751388, James Ck Road	**Company:**	GeoLINK
Report Export Date:	26/05/2023	**Contact:**	Duncan Thomson
Catchment Name:	3204 - James Creek_10-link	**Address:**	Level 1, 64 Ballina St, Lennox Head
Catchment Area:	33.41ha	**Phone:**	02-6687-7666
Impervious Area*:	111.5%	**Email:**	duncan@geolink.net.au
Rainfall Station:	58076 GRAFTON		
Modelling Time-step:	6 Minutes		
Modelling Period:	1/01/1972 - 31/12/1976 11:54:00 PM		
Mean Annual Rainfall:	1160mm		
Evapotranspiration:	1327mm		
MUSIC Version:	6.3.0		
MUSIC-link data Version:	6.34		
Study Area:	North		
Scenario:	CVC Development		

* takes into account area from all source nodes that link to the chosen reporting node, excluding Import Data Nodes

Treatment Train Effectiveness		Treatment Nodes		Source Nodes	
Node: Receiving Node	**Reduction**	**Node Type**	**Number**	**Node Type**	**Number**
Flow	15.7%	Bio Retention Node	4	Urban Source Node	16
TSS	87.5%	Rain Water Tank Node	4	Agricultural Source Node	4
TP	63.5%	Infiltration System Node	1		
TN	56.7%				
GP	100%				

Comments

Refer to Stormwater Management Report for justification of failing parameters.

Passing Parameters

Node Type	Node Name	Parameter	Min	Max	Actual
Agricultural	Cat 1 - pre-developed	Area Impervious (ha)	None	None	0
Agricultural	Cat 1 - pre-developed	Area Pervious (ha)	None	None	5.07
Agricultural	Cat 1 - pre-developed	Total Area (ha)	None	None	5.07
Agricultural	Cat 2 - pre-developed	Area Impervious (ha)	None	None	0
Agricultural	Cat 2 - pre-developed	Area Pervious (ha)	None	None	11.13
Agricultural	Cat 2 - pre-developed	Total Area (ha)	None	None	11.13
Agricultural	Cat 3 - pre-developed	Area Impervious (ha)	None	None	0
Agricultural	Cat 3 - pre-developed	Area Pervious (ha)	None	None	13.6
Agricultural	Cat 3 - pre-developed	Total Area (ha)	None	None	13.6
Agricultural	Cat 4 - pre-developed	Area Impervious (ha)	None	None	0
Agricultural	Cat 4 - pre-developed	Area Pervious (ha)	None	None	3.61
Agricultural	Cat 4 - pre-developed	Total Area (ha)	None	None	3.61
Bio	Cat1 - bioretention basin	Exfiltration Rate (mm/hr)	None	None	10
Bio	Cat1 - bioretention basin	Extended detention depth (m)	None	None	0.2
Bio	Cat1 - bioretention basin	Filter depth (m)	None	None	0.5
Bio	Cat1 - bioretention basin	Hi-flow bypass rate (cum/sec)	None	None	100
Bio	Cat1 - bioretention basin	Orthophosphate Content in Filter (mg/kg)	50	50	50
Bio	Cat1 - bioretention basin	PET Scaling Factor	2.1	2.1	2.1
Bio	Cat1 - bioretention basin	Saturated Hydraulic Conductivity (mm/hr)	100	100	100
Bio	Cat1 - bioretention basin	Total Nitrogen Content in Filter (mg/kg)	800	800	800
Bio	Cat2 - bioretention basin	Exfiltration Rate (mm/hr)	None	None	10
Bio	Cat2 - bioretention basin	Extended detention depth (m)	None	None	0.2
Bio	Cat2 - bioretention basin	Filter depth (m)	None	None	0.5
Bio	Cat2 - bioretention basin	Hi-flow bypass rate (cum/sec)	None	None	100
Bio	Cat2 - bioretention basin	Orthophosphate Content in Filter (mg/kg)	50	50	50
Bio	Cat2 - bioretention basin	PET Scaling Factor	2.1	2.1	2.1
Bio	Cat2 - bioretention basin	Saturated Hydraulic Conductivity (mm/hr)	100	100	100
Bio	Cat2 - bioretention basin	Total Nitrogen Content in Filter (mg/kg)	800	800	800
Bio	Cat3 - bioretention basin	Exfiltration Rate (mm/hr)	None	None	10
Bio	Cat3 - bioretention basin	Extended detention depth (m)	None	None	0.2
Bio	Cat3 - bioretention basin	Filter depth (m)	None	None	0.5
Bio	Cat3 - bioretention basin	Hi-flow bypass rate (cum/sec)	None	None	100
Bio	Cat3 - bioretention basin	Orthophosphate Content in Filter (mg/kg)	50	50	50
Bio	Cat3 - bioretention basin	PET Scaling Factor	2.1	2.1	2.1
Bio	Cat3 - bioretention basin	Saturated Hydraulic Conductivity (mm/hr)	100	100	100
Bio	Cat3 - bioretention basin	Total Nitrogen Content in Filter (mg/kg)	800	800	800
Bio	Cat4 - bioretention basin	Exfiltration Rate (mm/hr)	None	None	10
Bio	Cat4 - bioretention basin	Extended detention depth (m)	None	None	0.2
Bio	Cat4 - bioretention basin	Filter depth (m)	None	None	0.5
Bio	Cat4 - bioretention basin	Hi-flow bypass rate (cum/sec)	None	None	100

Only certain parameters are reported when they pass validation

Node Type	Node Name	Parameter	Min	Max	Actual
Bio	Cat4 - bioretention basin	Orthophosphate Content in Filter (mg/kg)	50	50	50
Bio	Cat4 - bioretention basin	PET Scaling Factor	2.1	2.1	2.1
Bio	Cat4 - bioretention basin	Saturated Hydraulic Conductivity (mm/hr)	100	100	100
Bio	Cat4 - bioretention basin	Total Nitrogen Content in Filter (mg/kg)	800	800	800
Infiltration	Buffer zone infiltration trench	Area (sqm)	None	None	300
Infiltration	Buffer zone infiltration trench	Filter area (sqm)	None	None	300
Infiltration	Buffer zone infiltration trench	Hi-flow bypass rate (cum/sec)	None	None	100
Rain	Cat1 - tank	% Reuse Demand Met	None	None	70.03
Rain	Cat2 - tank	% Reuse Demand Met	None	None	70.012
Rain	Cat3 - tank	% Reuse Demand Met	None	None	70.02
Rain	Cat4 - tank	% Reuse Demand Met	None	None	69.97
Receiving	Receiving Node	% Load Reduction	None	None	15.7
Receiving	Receiving Node	GP % Load Reduction	90	None	100
Receiving	Receiving Node	TN % Load Reduction	45	None	56.7
Receiving	Receiving Node	TP % Load Reduction	60	None	63.5
Receiving	Receiving Node	TSS % Load Reduction	85	None	87.5
Urban	Cat1 - residual	Area Impervious (ha)	None	None	0.106
Urban	Cat1 - residual	Area Pervious (ha)	None	None	2.183
Urban	Cat1 - residual	Total Area (ha)	None	None	2.29
Urban	Cat1 - road	Area Impervious (ha)	None	None	0.781
Urban	Cat1 - road	Area Pervious (ha)	None	None	0.428
Urban	Cat1 - road	Total Area (ha)	None	None	1.21
Urban	Cat1 - roof bypass	Area Impervious (ha)	None	None	0.246
Urban	Cat1 - roof bypass	Area Pervious (ha)	None	None	0
Urban	Cat1 - roof bypass	Total Area (ha)	None	None	0.246
Urban	Cat1 - roof to tank	Area Impervious (ha)	None	None	0.984
Urban	Cat1 - roof to tank	Area Pervious (ha)	None	None	0
Urban	Cat1 - roof to tank	Total Area (ha)	None	None	0.984
Urban	Cat2 - residual	Area Impervious (ha)	None	None	0.278
Urban	Cat2 - residual	Area Pervious (ha)	None	None	4.238
Urban	Cat2 - residual	Total Area (ha)	None	None	4.517
Urban	Cat2 - road	Area Impervious (ha)	None	None	1.982
Urban	Cat2 - road	Area Pervious (ha)	None	None	1.070
Urban	Cat2 - road	Total Area (ha)	None	None	3.053
Urban	Cat2 - roof bypass	Area Impervious (ha)	None	None	0.576
Urban	Cat2 - roof bypass	Area Pervious (ha)	None	None	0
Urban	Cat2 - roof bypass	Total Area (ha)	None	None	0.576
Urban	Cat2 - roof to tank	Area Impervious (ha)	None	None	2.304
Urban	Cat2 - roof to tank	Area Pervious (ha)	None	None	0
Urban	Cat2 - roof to tank	Total Area (ha)	None	None	2.304

Only certain parameters are reported when they pass validation

Node Type	Node Name	Parameter	Min	Max	Actual
Urban	Cat3 - residual	Area Impervious (ha)	None	None	0.441
Urban	Cat3 - residual	Area Pervious (ha)	None	None	5.041
Urban	Cat3 - residual	Total Area (ha)	None	None	5.483
Urban	Cat3 - road	Area Impervious (ha)	None	None	2.167
Urban	Cat3 - road	Area Pervious (ha)	None	None	1.229
Urban	Cat3 - road	Total Area (ha)	None	None	3.397
Urban	Cat3 - roof bypass	Area Impervious (ha)	None	None	0.84
Urban	Cat3 - roof bypass	Area Pervious (ha)	None	None	0
Urban	Cat3 - roof bypass	Total Area (ha)	None	None	0.84
Urban	Cat3 - roof to tank	Area Impervious (ha)	None	None	3.36
Urban	Cat3 - roof to tank	Area Pervious (ha)	None	None	0
Urban	Cat3 - roof to tank	Total Area (ha)	None	None	3.36
Urban	Cat4 - residual	Area Impervious (ha)	None	None	0.139
Urban	Cat4 - residual	Area Pervious (ha)	None	None	2.280
Urban	Cat4 - residual	Total Area (ha)	None	None	2.42
Urban	Cat4 - road	Area Impervious (ha)	None	None	0.746
Urban	Cat4 - road	Area Pervious (ha)	None	None	0.423
Urban	Cat4 - road	Total Area (ha)	None	None	1.17
Urban	Cat4 - roof bypass	Area Impervious (ha)	None	None	0.312
Urban	Cat4 - roof bypass	Area Pervious (ha)	None	None	0
Urban	Cat4 - roof bypass	Total Area (ha)	None	None	0.312
Urban	Cat4 - roof to tank	Area Impervious (ha)	None	None	1.248
Urban	Cat4 - roof to tank	Area Pervious (ha)	None	None	0
Urban	Cat4 - roof to tank	Total Area (ha)	None	None	1.248

Only certain parameters are reported when they pass validation

Failing Parameters

Node Type	Node Name	Parameter	Min	Max	Actual
Agricultural	Cat 1 - pre-developed	Baseflow Total Nitrogen Mean (log mg/L)	0.074	0.074	0.04
Agricultural	Cat 1 - pre-developed	Baseflow Total Phosphorus Mean (log mg/L)	-0.88	-0.88	-1.05
Agricultural	Cat 1 - pre-developed	Baseflow Total Suspended Solids Mean (log mg/L)	1.4	1.4	1.3
Agricultural	Cat 1 - pre-developed	Stormflow Total Nitrogen Mean (log mg/L)	0.59	0.59	0.48
Agricultural	Cat 1 - pre-developed	Stormflow Total Phosphorus Mean (log mg/L)	-0.27	-0.27	-0.22
Agricultural	Cat 1 - pre-developed	Stormflow Total Suspended Solids Mean (log mg/L)	2.3	2.3	2.15
Agricultural	Cat 2 - pre-developed	Baseflow Total Nitrogen Mean (log mg/L)	0.074	0.074	0.04
Agricultural	Cat 2 - pre-developed	Baseflow Total Phosphorus Mean (log mg/L)	-0.88	-0.88	-1.05
Agricultural	Cat 2 - pre-developed	Baseflow Total Suspended Solids Mean (log mg/L)	1.4	1.4	1.3
Agricultural	Cat 2 - pre-developed	Stormflow Total Nitrogen Mean (log mg/L)	0.59	0.59	0.48
Agricultural	Cat 2 - pre-developed	Stormflow Total Phosphorus Mean (log mg/L)	-0.27	-0.27	-0.22
Agricultural	Cat 2 - pre-developed	Stormflow Total Suspended Solids Mean (log mg/L)	2.3	2.3	2.15
Agricultural	Cat 3 - pre-developed	Baseflow Total Nitrogen Mean (log mg/L)	0.074	0.074	0.04
Agricultural	Cat 3 - pre-developed	Baseflow Total Phosphorus Mean (log mg/L)	-0.88	-0.88	-1.05
Agricultural	Cat 3 - pre-developed	Baseflow Total Suspended Solids Mean (log mg/L)	1.4	1.4	1.3
Agricultural	Cat 3 - pre-developed	Stormflow Total Nitrogen Mean (log mg/L)	0.59	0.59	0.48
Agricultural	Cat 3 - pre-developed	Stormflow Total Phosphorus Mean (log mg/L)	-0.27	-0.27	-0.22
Agricultural	Cat 3 - pre-developed	Stormflow Total Suspended Solids Mean (log mg/L)	2.3	2.3	2.15
Agricultural	Cat 4 - pre-developed	Baseflow Total Nitrogen Mean (log mg/L)	0.074	0.074	0.04
Agricultural	Cat 4 - pre-developed	Baseflow Total Phosphorus Mean (log mg/L)	-0.88	-0.88	-1.05
Agricultural	Cat 4 - pre-developed	Baseflow Total Suspended Solids Mean (log mg/L)	1.4	1.4	1.3
Agricultural	Cat 4 - pre-developed	Stormflow Total Nitrogen Mean (log mg/L)	0.59	0.59	0.48
Agricultural	Cat 4 - pre-developed	Stormflow Total Phosphorus Mean (log mg/L)	-0.27	-0.27	-0.22
Agricultural	Cat 4 - pre-developed	Stormflow Total Suspended Solids Mean (log mg/L)	2.3	2.3	2.15
Infiltration	Buffer zone infiltration trench	Evaporative Loss as % of PET	100	100	0
Urban	Cat1 - road	Impervious Area Rainfall Threshold (mm/day)	1	1	1.5
Urban	Cat1 - roof bypass	Impervious Area Rainfall Threshold (mm/day)	1	1	0.3
Urban	Cat1 - roof to tank	Impervious Area Rainfall Threshold (mm/day)	1	1	0.3
Urban	Cat2 - road	Impervious Area Rainfall Threshold (mm/day)	1	1	1.5
Urban	Cat2 - roof bypass	Impervious Area Rainfall Threshold (mm/day)	1	1	0.3
Urban	Cat2 - roof to tank	Impervious Area Rainfall Threshold (mm/day)	1	1	0.3
Urban	Cat3 - road	Impervious Area Rainfall Threshold (mm/day)	1	1	1.5
Urban	Cat3 - roof bypass	Impervious Area Rainfall Threshold (mm/day)	1	1	0.3
Urban	Cat3 - roof to tank	Impervious Area Rainfall Threshold (mm/day)	1	1	0.3
Urban	Cat4 - road	Impervious Area Rainfall Threshold (mm/day)	1	1	1.5
Urban	Cat4 - roof bypass	Impervious Area Rainfall Threshold (mm/day)	1	1	0.3
Urban	Cat4 - roof to tank	Impervious Area Rainfall Threshold (mm/day)	1	1	0.3

Only certain parameters are reported when they pass validation