STORM Consulting

Water Sensitive Urban Design for Ducks Lane Precinct, Goulburn

Report Prepared for Goulburn City Council

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This report takes into account the particular instructions and requirements of our Client. It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

EXECUTIVE SUMMARY

The Ducks Lane precinct contains a total area of approximately 916.5 hectares located in the south east of Goulburn. Parts of this area are already developed and a significant area (draining to the Wollondilly River) will remain undeveloped. The area being developed is to include rural residential lots, an industrial zone, highway service zone and theme park. This area is within the Goulburn City Council local government area and is part of the Sydney Catchment Authority (SCA) drinking water catchments.

Goulburn City Council (Council) engaged Storm Consulting Pty Ltd (STORM) to undertake the following tasks:

- To undertake stormwater quality modelling for the purpose of assessing neutral or beneficial effect.
- To further develop Council's on-site detention and retention policy to be applicable to industrial lots with the whole of the Goulburn LGA.
- Explore opportunities for communal reuse between the Theme Park and adjacent Industrial Zone.
- To investigate the need for stream rehabilitation and make recommendations on a rehabilitation strategy for the purpose of estimating Section 94 Contributions.

This information will guide Council so that they may prepare an appropriate Development Control Plan (DCP) which needs to satisfy Council's own stormwater management plan requirements and those of the Sydney Catchment Authority (SCA).

This report documents the methodology and results:

- that will enable Council to form a broad on-site detention (OSD) policy for all industrial development in the Goulburn LGA. Our findings include a large reduction in the volume of storage required for detention when compared with the Upper Parramatta River Catchment Management Trust (UPRCT) policy previously applied in Goulburn. The recommendations from this report add to the work undertaken previously in the Common Street Business Park Report to accommodate various impervious percentages and areas not draining to the OSD system.
- that include the development of an on-site retention (OSR) policy for industrial development in Goulburn with similar characteristics to that analysed in this report.
- that will enable Council to satisfy the SCA by prescribing water quality controls to minimise the pollutant loads entering the downstream waterway to achieve a neutral or beneficial effect.
- of an investigation into the benefits of a communal stormwater reuse system to supply the industrial zone and theme park.

An initial investigation into communal stormwater reuse has shown there to be significant benefit in combining the industrial area's storage with the theme park. Based on the large roof areas available and potential water demand STORM found that a combined system could be designed to meet over 50% of the demand. The industrial zone tank should include provisions for an off-take to the theme park.

The creek corridors within the Ducks Lane precinct were assessed and recommendations made to revegetate and stabilise relevant sections of the bed and banks. The revegetation will reduce Council's maintenance burden, prevent the creek system from eroding and contribute to meeting Department of Infrastructure Planning and Natural Resource's (DIPNR) requirements for riparian management under the River's and Foreshores Improvement Act (RFIA). This will also help to achieve a neutral or beneficial effect of the development.

Several water quality management approaches have been developed and modelled for use within the precinct. STORM recommends that a source control solution be adopted. Thus rather than having end of pipe devices such as wetlands, all new development will be required to install source controls on site to achieve the SCA's requirements for neutral or beneficial effect.

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1.0 INTRODUCTION

Goulburn Council (now known as Greater Argyle Council) engaged STORM Consulting to prepare a water sensitive design strategy for the Ducks Lane precinct. This report is the outcome of that commission.

1.1. BACKGROUND

The Ducks Lane precinct area is approximately 916.5 hectares of partially developed land located south west of Goulburn's centre. Existing development within the precinct includes rural residential lots, an abattoir and the Hume Highway. Further development is to occur within the rural residential land, industrial land, and some commercial development in the form of a highway service zone. There is also a major tourist destination proposed within a portion of the rural investigation zone. The precinct is within the newly formed Greater Argyle (Council) Local Government Area and is also part of the Sydney Catchment Authority (SCA) drinking water catchments defined by SEPP No.58. Council is currently undertaking strategic planning for the precinct, which will incorporate a Section 94 Contribution Plan to manage the future development within the Ducks Lane precinct.

Given that a substantial part of the precinct is located within the highly sensitive SCA drinking water catchments there is a need to protect those catchments from the potential impacts of development. It is well documented that development can lead to the degradation of water quality in receiving waters and have a dramatic effect on the hydrological regime. Construction of large impervious surfaces reduces natural stores of water in the soil profile. This leads to significant increases in:

- the frequency of runoff (often by a factor of 10),
- the peak flows for runoff events, and
- the volume of runoff events.

Traditional approaches to stormwater management would implement either on-site or communal detention which would reduce peak flows while ignoring low flows and water quality and missing out on the opportunity to create a viable non potable source of water supply.

Council (based on advice by STORM in previous reports) has developed an on-site detention (OSD) policy which is applicable to only industrial areas within the Goulburn LGA. Further work was however required to ensure that this policy was to be applicable to cover all types of development with the LGA. This work is documented in detail in this report.

This report presents the results of investigations into the application of on-site controls (on-site detention and retention) and also the opportunity to harvest rainwater runoff from developments. This report (and its accompanying plans) also includes recommendations on the rehabilitation and stabilisation of the creek systems that drain the site.

1.2. SCOPE OF REPORT

STORM has been commissioned to undertake 5 key tasks associated with the strategic planning for water sensitive urban design in the Ducks Lane precinct. These include:

Task 1 – Lot based peak flow assessment (extension of previous on-site retention and detention work).

Task 2 – Water quality planning and assessment for the purpose of ensuring neutral or beneficial effect.

Task 3 – Investigating a communal stormwater reuse strategy

Task 4 – Creek assessment and rehabilitation.

Task 5 – Reporting the findings and outcomes.

2.0 LOCAL CONDITIONS

2.1. HYDROLOGY

Rainfall data used in calculations for the Ducks Lane Precinct has been obtained from the Bureau of Meteorology. Key hydrological statistics obtained from the Bureau are summarised below in Table 1. Approximately 27 years of good quality daily rainfall data was used that extended from 1971 to 2002 (portions of data between 1975 and 1979 were missing).

Table 1 - Rainfall statistics for Goulburn (Progress Street)

Statistic	Annual Average
Mean rainfall – mm	672.7
Median (5th decile) rainfall - mm	651.2
9th decile of rainfall - mm	854.3
1st decile of rainfall - mm	420.3
Mean number of raindays	127.2

Source: The Bureau of Meteorology.

The average annual evaporation rate for Goulburn is 1200mm/year. Goulburn is therefore in a net evaporation area.

2.2. SOILS

According to Council's Stormwater Management Plan (Goulburn City Council, 2000), Goulburn's soil profiles generally have poor drainage characteristics. Soil properties are described as having moderate permeability, moderate topsoil erodibility, low subsoil erodibility and moderate shrink-swell potential.

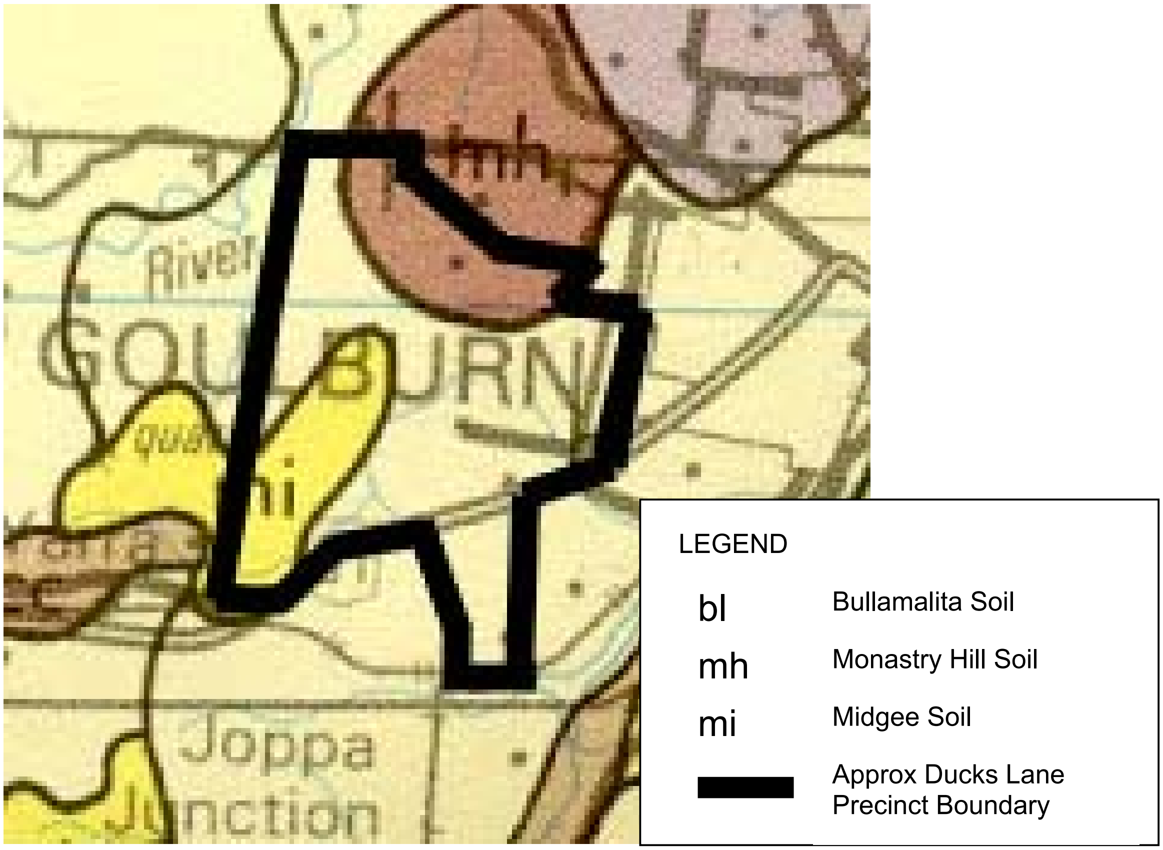
The Ducks Lane precinct overlays three different soil landscapes (refer to Figure 1); the Bullamalita, Monastry Hill and Midgee soil landscapes. Their respective properties are presented in Table 2.

Table 2 – Soil Characteristics

	Characteristics				
Soil Landscape	Drainage	Permeability	Erodibility (top soil)	Erodibility (subsoil)	Shrink / Swell Potential
Bullamalita	Poor	Slow	High	High	Low
Monastry Hill	Impeded	Moderate	Moderate	Low	Moderate
Midgee	Well Drained	Moderate	High	High	Low

Source: Soil Landscapes of Goulburn (Soil Conservation Service of NSW)

Figure 1 – Ducks Lane Precinct Soil Landscapes



Source: Soil Landscapes of the Goulburn 1:250,000 Sheet

2.3. VEGETATION

There are no significant stands of vegetation within the Ducks Lane precinct (as noted on the constraints map prepared by Council – Figure 2).

Vegetation based on the local soil types has been determined as part of the soil mapping undertaken in developing the "Soil Landscapes of Goulburn 1:250,000 Sheet". The native vegetation within the Bullamalita soil landscapes consists of savannah woodland that includes yellow box and red gum. It has also been noted that brittle gum occurs on the boundary of Bullamalita and Midgee soil landscapes. The vegetation most commonly associated with Midgee soil landscape is however a dry sclerophyll forest of red stringybark and scribbly gum. Similarly to Bullamalita, the Monastry Hill soil landscape is a savannah woodland of yellow box and Blakeys red gum.

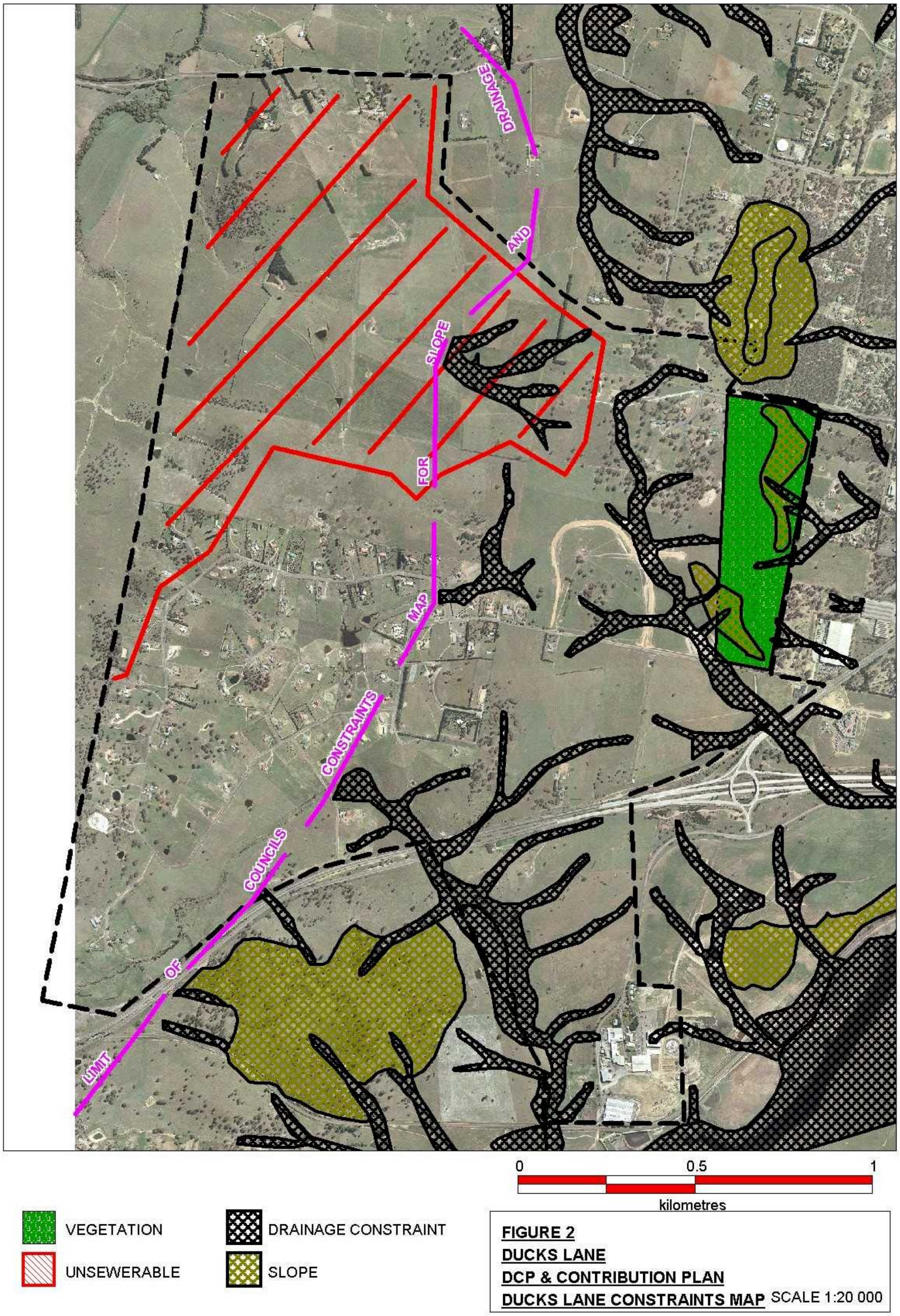
2.4. EXISTING DEVELOPMENT

There is considerable existing development and supporting infrastructure in the area within the Ducks Lane precinct.

There are currently significant parcels of rural residential land already developed north of the Hume Highway. These rural residential lots have an average area of just over 2.0 hectares. An abattoir and water treatment ponds are located south of the Hume Highway. The remaining area is all rural grazing land with limited development.

Existing development is shown in the background of Figure 2.

Figure 2 – Ducks Lane Constraints



Source: Council's DCP and Contribution Plan

2.5. FUTURE SITE DEVELOPMENT

Further development is planned in isolated pockets to the north of the Hume Highway. Goulburn City Council (GCC) has classified the area to the north of the precinct draining to the Wollondilly River (approximately 294ha) as being subject to sewer constraints. This area will not be developed at present due to these sewer constraints.

A total area of 191.5ha is designated as suitable for Rural Residential development. If future development is similar to the existing rural residential areas within the Ducks Lane precinct then there is likely to be only about 9% of the area converted from pervious to impervious area.

An area of 3.5ha adjacent to the Hume Highway is designated as a Highway Service Centre and is likely to attract a fast food chain and hotel within the zone. Adjacent to the Highway Service Zone a bulky goods storage is planned which will take up the entire 33.8ha's zoned as Industrial. This bulky goods storage is likely to have a large roof area (approximately 27ha) that will have the potential to supply reuse water for the site and potentially other sites within the area.

(a) Adjacent to the industrial zone, a significant block (37.8ha) is zoned as Rural Investigation. A theme park and special event facilities are planned within this area as part of the Pictura Tourist Complex. This theme park will showcase the history and settlement of Australia's past, present and future through a series of villages dating from the 1850's to the future 2050. It will also include farming, and mining exhibits together with special events facilities like conference centre and outdoor seating. The proposal also includes a wetland which is intended to be part of a water recycling and conservation program together with on-site storage for water reuse. At present this development is being considered as to whether the proposal should be assessed by the Minister and the Department of Infrastructure and Natural Resources (DIPNR) or by GCC. It is understood from STORM's conversation with Alistair Mein from DIPNR, if it is assessed by the Minister and DIPNR it will be considered as Integrated Development.

3.0 REGULATORY REQUIREMENTS

3.1. GOULBURN CITY COUNCIL

The Stormwater Management Plan (SMP) outlines Council's broader objectives in regard to new developments and stormwater quality management. Relevant objectives contained within the SMP include:

- Urban development should only occur in areas where a land capability study has indicated that area is physically capable of supporting the proposed type of development without causing significant soil erosion, land slip or water pollution;
- Water-sensitive urban design principles should be incorporated in the development;
- A strong emphasis should be placed on the management of stormwater at or near the source. This applies to both the quantity and quality of stormwater;
- The reuse of stormwater for non-potable purposes should be encouraged. This should be undertaken in the context of total water cycle management;
- Where appropriate "natural" channel designs should be adopted in preference to grass or concrete lined floodways, unless there are specific requirements for a lined channel;
- Site specific studies should be undertaken to identify the sustainable pollutant export from the development site. In the absence of these studies, there should be no net increase in the average annual load of pollutants critical to the health of receiving water ecosystems and human health, under post-development conditions. If this cannot be achieved, an 'offset' scheme could be developed where contributions are obtained from developers for rectifying existing problems affecting the 'health' of watercourse and water bodies within the catchment;
- Soil and water management practices should be implemented during the construction phase of the development to minimise soil erosion and sediment export;
- The applicable ANZECC water quality guidelines should be met for water bodies receiving stormwater runoff that is used for water supply purposes;
- The impact of urban stormwater on weed propagation and growth in bushland should be minimised;
- The impact of stormwater on public health and safety should be minimised;
- Opportunities for the multiple use of drainage facilities are to be encouraged, to the degree that they are compatible with other management objectives;
- The visual amenity and landscaping opportunities of stormwater systems are to be optimised;
- Peak flows from the development site should be attenuated so that there is no net increase in flows for event from the 1 year to 100 year average recurrence interval;
- The risk of property damage due to stormwater and groundwater should be minimised;
- The disruption to traffic and pedestrians during frequent storm events should be minimised;
- Protect and maintain natural wetlands, watercourses and riparian corridors; and
- Use of vegetated flow paths maximised.

Quantitative and qualitative stormwater management objectives that were generated for new development through the stormwater management planning process are presented in Tables 3 and 4 below.

Table 3 - Quantitative Stormwater Objectives for New Developments

Pollutant/Issue	**Retention Criteria**
Coarse Sediment	80% of average annual load for particles ≤ 0.5 mm
Fine Particles	50% of average annual load for particles ≤0.1 mm
Total Phosphorus	45% of average annual pollutant load
Total Nitrogen	45% of average annual pollutant load
Litter	90% of average annual litter load > 5 mm
Hydrocarbons, motor fuels, oils and grease	90% average annual pollutant load

Source: Goulburn Council Stormwater Management Plan, 2000

Table 4 - Qualitative Stormwater Objectives for New Developments

Pollutant/Issue	**Management Objective**
Runoff Volumes	Impervious areas connected to the stormwater drainage system are minimised.
	Reuse of stormwater for non-potable purposes maximised.
	Use of vegetated flow paths maximised.
Stormwater Quality	Use of stormwater infiltration 'at source' where appropriate.
Riparian Vegetation and Aquatic Habitat	Protect and maintain natural wetlands, watercourses and riparian corridors. All natural (or unmodified) drainage channels within the site which possess either: • base flow • defined bed and/or banks; or • riparian vegetation are to be protected and maintained. "Natural" channel design should be adopted in lieu of floodways in areas where there is no natural (or unmodified) channel.
Flow	Alterations to natural flow paths, discharge points and runoff volumes from the site to be minimised. The frequency of bank-full flows should not increase as a result of development. Generally, no increase in the 1.5 year and 100 year peak flows.
Amenity	Multiple use of stormwater facilities to the degree compatible with other management objectives.
Urban Bushland	Impact of stormwater discharges on urban bushland areas minimised.

Source: Council's Stormwater Management Plan, 2000

3.2. SYDNEY CATCHMENT AUTHORITY

SEPP No.58 requires that the SCA assess and consent to development within the drinking water catchments. The SCA is required to assess the development proposal in relation to Clause 10 of SEPP No.58 – matters for consideration, specifically:

(a) Whether the development or activity will have a neutral or beneficial effect on the water quality of rivers, streams or groundwater in the hydrological catchment, including during periods of wet weather;

(b) Whether the water quality management practices proposed to be carried out as part of the development/activity are sustainable over the long term; and

(c) Whether the development/activity is compatible with relevant environmental objectives and water quality standards for the hydrological catchment when these objectives and standards are established by Government.

Clearly there is an inconsistency between Goulburn Council (2002) objectives and the objectives of the SCA. Council's quantitative objectives are load based not outcome based. The SCA's objectives for new developments should therefore override those of Council's quantitative stormwater objectives. It is suggested that Council objectives do not become the benchmark by which the quantitative result of this water cycle management plan is to be measured. It is recommended however that the qualitative objectives set by Council are still applicable to any new development.

The SCA does not have prescribed distances required to buffer natural watercourses from sewered urban developments. The Ducks Lane development is to be sewered once a new treatment plant is constructed.

3.3. DEPARTMENT OF INFRASTRUCTURE PLANNING & NATURAL RESOURCES

The Department of Infrastructure Planning and Natural Resources (DIPNR) administers the Rivers and Foreshores Improvement Act (RFIA). Some of the creeks within the Ducks Lane precinct will be subject to approval under this Act.

All waterways require a 40m setback from the top of the bank, however under Part 3(a), a permit can be issued to build structures within the setback (ie. GPTs, stream rehabilitation). The creeks shown in Figure 1 would be likely to be administered by DIPNR.

4.0 ISSUES & CONSTRAINTS

Council has undertaken constraints mapping for the Ducks Lane precinct area shown in Figure 2. Further information on the constraints follows.

4.1. SOIL CONSTRAINTS

Table 2 in Section 2.2 of this report details the characteristics of the soils found within the Ducks Lane precinct. The Bullamalita soil type has low drainage and permeability properties. The Monastry Hill landscape has impeded drainage characteristics with moderate permeability. This limits the types of measures applicable for use in these soil areas within the Ducks Lane precinct. Infiltration is not recommended for use with the area unless soil permeability tests are undertaken to confirm suitable permeability rates. The Midgee soil type however well drained with moderate permeability. This area underlays the existing rural residential subdivision in the west of the precinct, and is likely to result in better infiltration opportunities.

According to the SMP, Goulburn has no identified areas suffering from salinity at the time of dry land salinity mapping by the DLWC in the 1980's. There is evidence of small areas of salinity in Goulburn's South (near Bungonia Road) at the effluent Irrigation Farm and on Kenmore Land.

Development on the site may require geotechnical investigations to determine the extents of these constraints with regard to their impact on soil acidity, foundation hazard and foundation design.

5.0 ON-SITE STORMWATER QUANTITY MANAGEMENT

5.1. ON-SITE RETENTION

The use of rain tanks for the harvesting and reuse of stormwater for non-potable purposes is recommended within the Ducks Lane precinct. This is called on-site retention and is aimed at reducing both the frequency and volume of runoff from a developed site. On site retention is a management tool that aims to:

1. Provide a viable alternative supply of water for non potable purposes.

2. Reduce the frequency and volume of runoff from the roof area of the developed site.

Previous studies have already been undertaken within the Goulburn area. The reader needs to refer to the Mary's Mount Water Sensitive Urban Design prepared by STORM and also the Common Street Water Sensitive urban design report prepared by STORM for further information on the estimated performance and assumptions of the on site retention of water.

Principally the previous work by STORM found that the use of a rain tank with a volume of 20kL storage for every hectare of industrial land developed (with a minimum of 20 kL) is optimal. In the Mary's Mount Water Sensitive Urban Design Report the use of rain tanks of 10 kL/household (as a minimum) was recommended as the optimal for residential land.

5.2. ON-SITE DETENTION

OSD systems can be used to restrict the peak stormwater flows post development to that which would occur prior to development. OSD systems have three main elements:

1. Discharge Control – limiting the flow from the site by the use of a pipe, orifice or other means.

2. Storage – either a closed tank or above ground depression detained to contain the excess volume of stormwater unable to get through the discharge control.

3. Overflow Management –a spillway or dedicated flow path used to direct stormwater in extreme storm events or in system failures away from items that will be adversely affected by these flows.

An on-site retention policy for industrial development which stipulates a permissible site discharge and site storage requirement has already been undertaken and documented as part of the Common Street Business Park WSUD Report (STORM 2003). The work reported within the Ducks Lane report further develops the previous work to incorporate a range of development densities and scenarios to make the OSD policy more robust and applicable to any type of industrial development within Goulburn.

5.2.1. Background

The Common Street Business Park report documents the creation of an OSD policy for industrial development within this precinct that could extend to include the Goulburn LGA. The main aims of this policy is to limit the peak flows leaving the site post development to ensure that:

- The there is no loss of life or damage to property arising from an increase in peak flows leaving a development.

- Environmental harm or damage does not occur as a result of an increase in peak flows arising from the creation of large impervious areas.

The OSD policy aims to ensure that new developments and redevelopments do not increase peak stormwater flows in any downstream area during major storms up to and including the 100 year ARI (1% Annual Exceedence Probability) storm events.

As part of this policy 'Control Standards' were recommended as follows:

- Permissible Site Discharge (PSD) – which specifies a maximum allowable discharge from the developed site.
- Site Storage Requirement (SSR) – the volume of storage that needs to be constructed and verified expressed as a rate per hectare.
- Minimum Outlet Size – designed to limit the potential blockage of the outlet.
- Maximum permissible surface ponding depths – various, maximum 600mm (potentially deeper where safety is ensured) for public health and safety reasons.
- Safety Fences – fencing required when gentle side slopes cannot be accommodated.
- Overland flow paths created to ensure a failsafe system is put in place.

The OSD analysis was based on a typical 1 hectare industrial lot which assumes:

- Impervious roof area of 5,000m^2;
- Impervious access, parking and hard-stand area of 3,000m^2; and
- Pervious landscaping and protection of ecological services, 2000m^2.

The analysis optimised the SSR and PSD of the OSD system using the lot breakdown presented above. The recommended values were a PSD of 215L/s/hectare and an SSR of 140m^3/hectare

If these values are adopted then the peak flows for storms of all duration will be reduced to equal to or less than their pre-development level (for the development scenario noted). This also assumes that 100% of the lot area drains to the OSD system.

Council has found that it is not possible in all cases to ensure that 100% of the site drains to the OSD system and also that not all developments fits typical densities.

The work presented below responds to Council's findings noted above by further developing the original Common Street work to generate SSR's and PSD's for sites that have various densities (or impervious area) as well as compensatory storage where parts of the site cannot drain to the OSD tank.

5.2.2. Methodology

5.2.2.1. Permissible Site Discharge

To ensure that new developments do not increase peak stormwater flows in any downstream area during major storms up to and including the 100 year ARI event, the stormwater discharged from a developed site must be the same as the stormwater discharged from the area in it's natural state. The peak stormwater flow from the site in its natural state therefore becomes the Permissible Site Discharge (PSD) for the developed site.

Note that matching pre-development peak flows and post-development peak flows may not be an adequate policy where there are existing flooding and drainage problems. In such a situation, a retrospective policy that requires detention volumes over and above that required to match pre-development and post-development peak flows may be required. This principle has been applied in some instances in Goulburn in the past.

The pre-development peak 100-year stormwater flows were determined by developing a RAFTS model to simulate the following natural conditions on site:

- typical 1-hectare rural catchment
- 5% of the area impervious
- an average slope of 7%
- manning's n of 0.06

This model was run for a 100 year ARI storm event with durations including the 10, 20, 30, 60, 120, 180, and 360 minute storms. The peak flow values from each of these storms represent the target for post-development peak flows.

A separate RAFTS model was constructed for an industrial lot with the following conditions:

- total area of developed land 1-hectare
- site slope of 2%
- manning's n of 0.015 and 0.025 for impervious and pervious areas respectively

Three separate development scenarios were then modelled:

1. 10% of the area impervious
2. 50% of the area impervious
3. 90% of the area impervious

Previously in the Common Street Business Park report an impervious percentage of 80% was used. The three additional development scenarios above were then modelled with:

- 100% of the area draining to the OSD system
- 90% of the area draining to the OSD system
- 80% of the area draining to the OSD system
- 70% of the area draining to the OSD system

The PSD and SSR for each development scenario and bypass arrangement were adjusted until the post-development peak flow rates matched the pre-development flow rates (for each storm duration). It should be noted that the PSD is intrinsically linked to the SSR.

Also STORM assessed the impact of the imperviousness of the area bypassing the OSD by comparing the PSD and SSR results for both impervious and pervious areas. It was found that pervious areas bypassing the OSD system generated higher rates of storage and lower rates of discharge when compared with impervious areas. Therefore pervious bypass areas were adopted for this study to ensure conservative values.

An orifice plate is to be fitted to the discharge point of the OSD tank or storage basin to control the amount of stormwater discharged from the site. This is sized to limit the stormwater discharge to the PSD. The size of the orifice is based on the depth of the storage. A depth of 1m has been used in this modelling.

The results are presented in Table 11 below.

5.2.2.2. Site Storage Requirement

The Site Storage Requirement (SSR) is the volume of water to be detained to achieve the PSD. The site storage required can be created either above or below ground.

Three different storage configurations were tested previously to determine the sensitivity of the SSR to different storage configurations. From this analysis it was found that there was no significant difference in the results and a storage tank with a depth of 1m was adopted.

Once again a RAFTS model was used to determine the required storage for each development scenario. From this model we were able to determine the impact of various impervious areas within the lot on the SSR. We were also able to determine the changing SSR volume as the area bypassing the system increased. The results of this analysis are included in Table 12 below.

5.2.3. Results

The SSR and PSD results from the RAFTS analysis are presented separately in Tables 11 and 12. Extended tables showing the interpolated values are presented in Appendix A

Graphs of these tables have been created as a tool to be incorporated into the OSD policy and are also included in Appendix A.

Table 5 – Permissible Site Discharge (l/s/ha) for On-site Detention Systems
(with varying impervious areas and areas bypassing the system)

	Percentage of Development Area Draining to OSD System			
% Impervious	100	90	80	70
10	277	268	255	253
50	225	211	208	203
90	212	198	180	150

Table 6 – Site Storage Requirement (m^3/ha) for On-site Detention Systems
(with varying impervious areas and areas bypassing the system)

	Percentage of Development Area Draining to OSD System			
% Impervious	100	90	80	70
10	20	32	39	43
50	86	104	115	134
90	152	172	185	204

Each of these tables presents a rate per hectare. It should be noted that this is a rate per hectare of catchment draining to the OSD system.

If the PSD and the respective SSR presented in the tables above are adopted then the peak flows for storms of all duration will be reduced to equal to or less than their pre-development level for the scenario selected. Note that work undertaken assumed that no overflow from the storage is allowed to occur in any storm event up to and including the 100 year ARI storm event.

In addition to these values it is recommended that:

- Council require a failsafe system to be put in place. That is, a defined overland flow path must be created to ensure that in events larger than the 100 year ARI storm event or in the case that when the orifice blocks that water can flow unimpeded out of the development.

- Council requires that orifice plates are to be tack welded into place to ensure that developers cannot tamper and remove the orifice plate.

- The OSD storage have a restrictive covenant placed over it to ensure that Council has some legal recourse should the developer decide to partially prevent flow from entering the tank/storage etc or even to alter the system.

- Council also needs to be conscious of the fact that roof and property drainage systems are not designed to convey the 100 year ARI flow. This means that overland flow will occur as gutter systems overflow in large events. Council therefore needs to ensure that all overland flow is to be directed into the OSD storage or it will not function as intended.

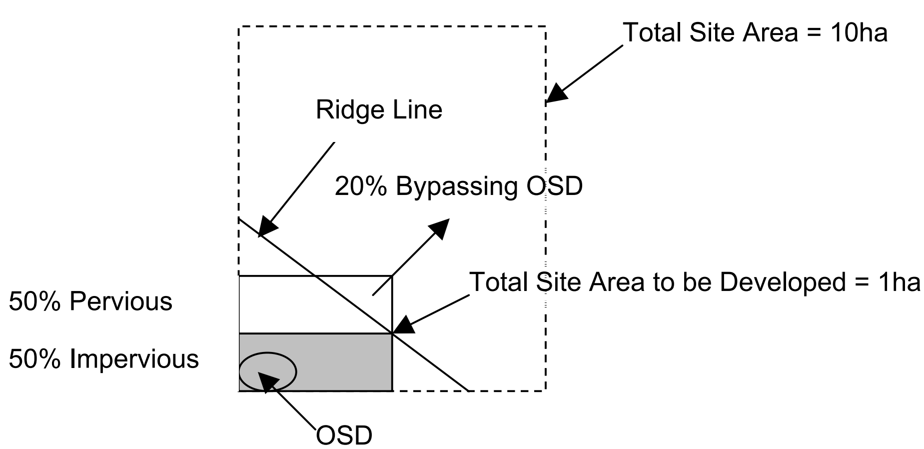
- Council take advantage of the relative ease of fitting "water quality" controls into OSD systems. For example a "maximesh" screen placed over the orifice plate will protect the orifice from blocking and also provide a water quality benefit. Achieving nutrient removal inside the OSD tank may also be possible through the use of filtration and a silt trap prior to the outlet. Water quality is addressed in detail within Chapter 7 of this report.

- Council must require that an annual maintenance inspection be undertaken by a qualified civil engineer and notice served to Council stating that the OSD system remains in place, will function as intended and is free from debris and litter.

5.2.4. Application of Results

To clarify how the PSD and SSR results are to be applied to manage post development flows, the following example is provided.

Example:



Although the total site area is 10ha, only 1ha of the total area is to be developed. As the undeveloped area will remain unchanged the flows leaving this area will also be unchanged and is therefore not included within the OSD calculations.

The total area being developed (1ha) is 50% impervious and has 20% of its total area bypassing the OSD system. Therefore only 80% of the site drains to the OSD system. Based on this information the appropriate rates are selected from the table and multiplied by 0.8 to determine the storage required and the orifice size.

(SSR) 0.8 x 115 = 94m^3

(PSD) 0.8 x 208 = 166.4l/s

From this information the orifice size can be determined using the following formula:

$Ao = Q / Cd (2g * H)^{0.5}$

Where:
Ao = cross sectional area of orifice (m^2)
Q = Permissible Site Discharge = 0.215 (m^3/s/hectare)
Cd = discharge coefficient (0.62 for sharp edged orifice)
g = acceleration due to gravity (9.8m/s^2)
H = head of water (m) above the orifice (measured from the centre of orifice to max storage level)

6.0 CREEK ASSESSMENT

6.1. BACKGROUND

STORM has undertaken a broad assessment of the stability and health of Run o' Waters Creek based on a site inspection conducted on 16 December 2003.

The area assessed was the reach of creek adjacent to the abattoir extending north through the Ducks Lane DCP area.

This assessment was used to determine a suitable rehabilitation strategy and to provide indicative costs so that Council can include the upgrade works within it's Section 94 apportionment for the Ducks Lane precinct. Further detailed investigation of the current creek system will be required prior to undertaking any specific works.

Refer to drawings L295-P01 and L295-P02 for presentation of results and recommendations for the Run o' Waters creek rehabilitation.

6.2. RESULTS

The major issues affecting the area of interest are:

- lack of native riparian vegetation within the creek corridor;
- weed growth, in particular willow trees and blackberry bushes; and
- several constructed rock weirs which are contributing to stream erosion.

Other minor issues identified included bank erosion, scouring and sudden changes in bed slope.

6.3. RECOMMENDATIONS

To address the issues outlined above the following steps are recommended (refer also to drawings L295-P01 and L295-P02):

- Extensive weed removal and revegetation with native riparian vegetation - while specific sites are identified on the maps, this applies as a general recommendation for the whole creek corridor.
- Weir removal - the constructed rock weirs should be removed to reduce bank erosion. There may be heritage issues which will could prevent or constrain their entire removal. This must be followed up by Council.
- Allowances should be made for possible requirement of bed control and bank stabilization measures. This is only necessary in a small number of locations such as where weir related erosion has been severe and in the upper part of the tributary system where there has been severe scouring or significant change in bed slope.
- Scour protection to be installed downstream of storages.
- General de-stocking of the area to reduce erosion on the creek banks.

6.4. COST ESTIMATES

Based on the recommendations above the following information is provided so Council is able to apportion Section 94 contributions for the site.

Revegetation for Run o' Waters Creek & Tributaries

Area	201,081m^2
Rate	$10 per m^2
Cost Estimate	**$2,010,810**

Revegetation for Other Creeks

Area	67,758m^2
Rate	$10 per m^2
Cost Estimate	**$677,580**

Bank and Bed Stabilisation Works for Run o' Waters Creek & Tributaries

Cost Estimate	**$200,000**

The above estimate is based on standard in-stream structures, bank revetment and rip rap works determined from the site assessment and areal photography. This estimate include costs for installation of sediment and erosion control measures. No designs have been undertaken to verify estimates.

Willow Removal for Run o' Waters Creek & Tributaries

Approx. No. of Trees	100
Rate	$300 per tree
Cost Estimate	**$30,000**

The number of trees was estimated using information obtained from the site inspection and areal photographs.

Vegetation Management Plans will also be required for the creeks at an estimated cost of $30,000. These plans will include engineering details and bed and bank works.

Based on a developable area of 280.4ha, the total cost per hectare of development for Run o' Water Creek rehabilitation only is $8,099, or $10,515 to include all creek revegetation.

7.0 WATER QUALITY MANAGEMENT

7.1. JUSTIFICATION

The SCA requires that the Ducks Lane precinct achieve a neutral or beneficial effect on the water quality leaving the site. In order to assess the water quality leaving the site both pre-development and post-development water quality models have been constructed.

7.2. LIMITATIONS OF WATER QUALITY MODELLING

Water quality modelling relies on a multitude of factors. There is a lack of calibrated data available within Australia and in the absence of calibrated data the best available information is used. This places limits on the accuracy of water quality modelling.

Water quality modelling is generally load based and to a lesser extent process based.

The model adopted by STORM uses the MUSIC computer software. MUSIC (the Model for Urban Stormwater Improvement Conceptualisation) is suitable for simulating catchment areas of up to 100 km^2 and utilises a continuous simulation approach to model water quality. Parameters adopted by MUSIC include sub-catchment areas, proportion of impervious area and hydrologic parameters.

By simulating the performance of stormwater management systems, MUSIC can be used to determine if these proposed systems and changes to land use are appropriate for their catchments and are capable of meeting specified water quality objectives (CRC 2002). The water quality constituents modelled in MUSIC of relevance to this report include Total Suspended Solids (TSS), Total Phosphorus (TP) and Total Nitrogen (TN). The model is particularly sensitive to impervious area and it is therefore important to ensure that the lot development characteristics are carefully determined.

The first version of the model has had some notable faults, however the second version of this model has recently been released and should rectify some of these faults. As this is only a recent release we have had limited time to assess all potential amendments to the model. The MUSIC model is considered to be one of the best planning tools available at the current time.

7.3. MUSIC MODELLING

As noted above pre- and post development models were created in MUSIC.

When using daily rainfall data in MUSIC it disaggregates the daily rainfall into 6 minute time steps. The result of this is that a short storm event may be stretched over a number of days which is simply not an adequate representation of typical hydrologic conditions on smaller catchments.

At present there is only daily and 5-minute rainfall data available for the Goulburn area. To improve the accuracy of the model output we have used 6-minute rainfall data from Melbourne which has an average annual rainfall of 655mm and an average evapotranspiration of 1,050mm. There is negligible difference to the Goulburn statistical data of 672 mm for average annual rainfall and 1,200 mm for evapotranspiration. Moreover we consider that the rainfall patterns in both Melbourne and Goulburn are similar.

Thus for the purpose of modelling water quality (with its relatively large error bands) with a suitably short (ie 6 minute) time step we have adopted this data. There was also a need to adopt a short time step to ensure that swales and other devices with a short time of concentration were being adequately modelled. Modelling the effect of swales with the use of daily rainfall has been shown to misrepresent the water quality processes that occur and so a short time step is essential.

STORM contends that it is better to use 6 minute rainfall data from Melbourne that is close in characteristics to Goulburn rainfall than to use daily rainfall from Goulburn, in this case.

The pre-development model represents the current site development. It therefore includes agricultural areas, rural residential lots and other developed areas with impervious percentages estimated using aerial photography. It also includes swales as part of the stormwater conveyance system within the rural residential areas. The creation of the pre-development model forms the basis on which to compare the impacts and mitigation of future development.

It is possible when using MUSIC to adopt the default event mean concentration (EMC) data for various urban land uses. These are based on a review of stormwater quality in urban catchments undertaken by Duncan (1999). In the post-development models we have altered the nitrogen EMC load rates from roof nodes to reflect atmospheric deposition only.

For detailed information on the load rates and parameters used within the MUSIC models prepared for Ducks Lane refer to Appendix C.

Swales were modelled as the stormwater conveyance system within the rural residential areas in all of the post-development models. It is understood from Council that a rural road profile will be adopted throughout the future rural residential areas. This profile typically includes drainage depressions on either side of the road which act as grassed swales.

The dams within the drainage corridor were converted to ponds in accordance with the creek management plans. The converted dams were included in the models for scenarios 2 and 3 and were sized from Councils cadastre information with an assumed depth of 1.5m.

The effect of rainwater tanks in both a residential and industrial context was modelled using a sedimentation pond node and selecting the water reuse option. For the industrial lots, the potential amount of water used by introducing rainwater tanks was estimated using results found from the analysis of reuse potential from the industrial catchment undertaken in Chapter 5. These figures were used to determine the amount of reuse from a typical rural residential subdivision and included within the model.

The proposed wetland within the Pictura Tourist Complex was included in scenarios 2 and 3 of the post-development models. The wetland was sized using information from the briefing package sent to GCC and a typical water depth of 0.4m.

STORM developed three post-development scenarios:

1. No Controls;

2. Reuse Only;

3. At Source Controls using Stormfilters®;

The first *No Controls* scenario was developed to model a do nothing scenario. This scenario does not include reuse, converted dams or the wetland within the Pictura Tourist Complex.

The *Reuse Only* (scenario 2) included reuse at source as a control in the rural residential, industrial and highway service areas. The rural residential area included reuse at 20kL/lot with an average lot area of 2.2Ha. Reuse within the industrial lot and highway service centre was calculated at a rate 20kL/ha (refer to section 5 for further information on the amounts and yields used). The wetland from the Pictura Tourist Complex is however included in this model.

The *At Source Controls* (scenario 3) included both reuse and Stormfilters® (manufactured by Ingal Environmental Services) as part of the on-site detention system. A generic node developed by Ingal Environmental Services using measured StormFilter® performance was included in the model to simulate the effect of the system. The wetland from the Pictura Tourist Complex is also included in this model. It should be noted that while StormFilters® and wetland have been modelled any at source measure is appropriate should it meet Council's quantitative SMP retention criteria (refer to Table 3 for these values).

The water quality benefit derived from the revegetated and stabilised creek systems was not accounted for.

It should also be noted that at present the area within the Ducks Lane DCP is un-sewered. Council is preparing to construct a Sewerage Treatment Plant (STP) with a capacity of 3,000ep to service the area as part of the South Goulburn Sewerage Scheme. Once this scheme proceeds there will be significant benefits to water quality as a result of decommissioning on-site septic systems. The effect of septic systems in the pre-development model has not been included, nor has the effect of the STP in the post-development models.

7.4. RESULTS

The load rates generated by the MUSIC models for the different scenarios are presented below in Table 7. Table 8 interprets these loads and presents the percentage change between pre and post-development.

Table 7 – MUSIC Pollutant Loads from Total Catchment

Scenario	**Total Suspended Solids** (kg/yr)	**Total Phosphorus** (kg/yr)	**Total Nitrogen** (kg/yr)
0 Pre-Development (Current Development)	41,800	128	1,070
1 Post-Development (No Controls)	69,100	183	1,550
2 Post – Development (Reuse Only)	31,200	116	1,120
3 Post – Development (At Source Controls)	23,700	97	1,040

It can be seen from Table 7 that post-development scenarios 2 and 3 demonstrate a reduction of TSS and TP loads compared with the *No Controls* scenario (scenario 1). However, only the *At Source Controls* scenario is likely to satisfy SCA's requirements to achieve a neutral or beneficial effect on the water quality leaving the site. Only the *At Source Controls* scenario resulted in nitrogen loads that are marginally higher than the pre-development case. The actual percentage retention of pollutant loads through the use of the various water quality controls compared to the pre-development scenario is presented in Table 8.

Table 8 – Percentage Change in Pollutant Loads (compared to Pre-Development Loads)

Scenario	**Total Suspended Solids** (%)	**Total Phosphorus** (%)	**Total Nitrogen** (%)
1 Post – Development (No Controls)	-65 *	-43	-43
2 Post – Development (Reuse Only)	25	9	-5
3 Post – Development (At Source)	43	25	3

* A negative value is an increase and a positive value is a reduction

There is a significant discrepancy between the retention rates specified in council's SMP and the SCA's requirement for SEPP58. The SMP is a guide for new developments whereas the SCA's conditions are based on protecting the quality of Sydney's drinking water. It is suggested that the SCA requirements be met as a minimum for future development within this catchment.

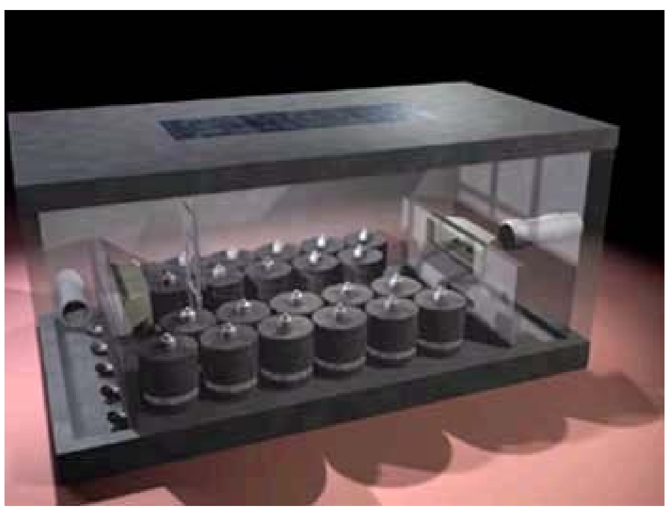
These water quality results are dependant on the installation of a number controls including the proposed wetland as part of the Pictura Tourist Development. Should this development not proceed it is important that any new development on this site include water quality treatment equal to (or better than) Council's qualitative SMP retention criteria (refer to Table 3 for these values).

7.5. DISCUSSION

It is evident from the results presented that post-development controls are required. The *At Source Control* scenario performed better than the *Reuse Only* scenario.

The *At Source Control* scenario modelled included reuse and Stormfilters® sourced through Ingal Environmental Services. Stormfilters® is a flow-through stormwater filtration system consisting of a tank that houses rechargeable cartridges filled with a variety of filter media such as gravel and perlite. These cartridges trap particulates and absorb pollutants such as dissolved metals, nutrients, and hydrocarbons. These devices are best installed as an additional chamber to the on-site detention system for each lot. This reduces Council's maintenance commitment, however Council will need to install rigorous controls to ensure that owners properly maintain the device. Also critical to the use of StormFilters® is the installation of Enviropods® as pre-treatment. Without the necessary pre-treatment the StormFilters® would potentially clog.

Figure 3 – Stormfilter® by Ingal Environmental Services



The installation of these devices at source is consistent with treatment train and water sensitive principles. It also has the added benefit that if one system fails the whole system is not jeopardised, unlike an end of pipe scenario. At source treatment systems are also more easily isolated should any individual lot have a spill.

StormFilters® are able to be installed underground and are therefore ideally suited for installation as part of an underground OSD system. This has significant cost savings as these devices can be integrated within the storage for the site. It is for these reasons that STORM has specifically recommended these devices.

Stormfilters® is one cost effective solution for on-site pollution management, however there may be other equally viable devices available. We understand that Council are not in a position to recommend a particular device, therefore Council's quantitative SMP retention criteria should be stipulated – refer to Table 3 for these values.

7.6. COST ESTIMATES

The following estimates have been based on a quote received from Ingal Environmental Services to supply and install a StormFilters® sized to treat a 6 hectare catchment. The total cost was in the order of $25,000 which has been used as the basis for calculating the costs for the installation of these devices within the Ducks Lane precinct. This information is to give Council an understanding of the typical cost to install these devices. It should be noted that this cost does not include the cost of the OSD.

At Source - Stormfilters®

Supply & Installation Stormfilters® cartridges and pre-cast vault to service 6 hectares each:

Highway Service Centre:

Catchment Area (Ha)	0.58
Rate	$25,000
Cost estimate	**$14,500**

Industrial Zone:

Catchment Area (Ha)	33.8
Rate	$25,000
Cost estimate	**$140,833**

At Source – Enviropods®

Rate / pit insert installed	$750

These estimates do not include maintenance – this will be undertaken by the owner/occupier at their expense.

8.0 RECOMMENDATIONS

8.1. ON-SITE CONTROLS

Based on the analysis undertaken, the following recommendations are made:

- All future rural residential lots (greater than 2,000m^2) are required to install a minimum 10kL rainwater tank plumbed for both internal and external uses.
- Further analysis of the Highway Service Centre is required once more information on the type of development is available. Initial indications show that a high level of reuse can be achieved. It is recommended that Council require tanks be installed in accordance with the 20kL/ha of development condition.
- A reuse system based on tank sizes of 20kL may be installed to service both the Bulky Storage Goods Depot within the Industrial Zone and the Pictura Tourist Complex. The communal system can demonstrate a significant reuse benefit. The combined roof area of the two developments creates a larger capture area which then increases the yield. It is recommended that the tank be sized to meet a minimum of 80% of the (non-drinking) water demand. The Pictura Tourist Complex is likely to have a number of smaller tanks within the model towns precincts and working farm. These can act independently or can be topped up from the communal storage tank. The combined reuse system intended to service the Conference facilities and Beyond 2050 building should be connected as part of the combined Bulky Goods Storage Depot and Pictura Tourist Complex roof capture and storage system.

Each development should submit a "water management plan" at DA stage which addresses water quality, the on site retention (water reuse) and on-site detention policy to be developed by Council. This water management plan (WMP) should:

i. nominate the type of development and therefore the expected water usage.

ii. nominate where rainwater (treated or non-treated) can be used in process or production.

iii. calculate the sizing and locate both the rain tank and the OSD storage and configuration for the site. The rain tank is to be sized on a requirement of 20kL/hectare of industrial and commercial development or 10kL per rural residential lot. The OSD based on the percentage of impervious area within the development together with an allowance for areas bypassing the system. Refer to Appendix A for table and graphs for PSD and SSR.

iv. identify on site water quality controls that are to be put in place, whether inside the OSD system or not.

STORM recommends that source controls be installed to meet Council's quantitative SMP retention criteria in Table 3.

Control standards for minimum outlet size, ponding depths, safety fences, and internal drainage systems from the Upper Parramatta River Catchment Trust's On-site Detention Handbook are recommended.

It is recommended that Council develop a formal and clear DCP based on the recommendations and work undertaken and documented in this report.

8.2. CREEK MANAGEMENT

Areas for bed protection, bank stabilisation and weed removal located on drawings L295-P01 and P02 be investigated further and a detailed plan of management in conjunction with a vegetation management plan developed.

Creek revegetation with locally native riparian species be undertaken for the Run o' Waters Creek and if possible all other creeks within the Ducks Lane precinct boundary.

8.3. WATER QUALITY CONTROLS

STORM recommends that source controls be installed to meet Council's quantitative SMP retention criteria in Table 3. Due to the proposed OSD system, STORM recommends that the Stormfilters® be installed in accordance with manufacturers specifications as the quality management option at source. These systems are to be incorporated with the OSD system. Installation of Enviropods® on all stormwater collection pits is also recommended.

Should the Pictura Tourist Park development proceed the wetland proposed should include Enviropods® on all stormwater collection.

A rural residential road profile with grassed swales on both sides of the road is to be constructed throughout the remaining rural residential area.

9.0 REFERENCES

ANZECC (1992) Australian Water Quality Guidelines for Fresh and Marine Waters, National Water Quality Management Strategy. Australian and New Zealand Environment and Conservation Council.

Coombes P, Frost A and Kuczera G (2001) Impact of Rainwater Tank and On-site Detention Options on Stormwater Management in the Upper Parramatta River Catchment- Draft Report.

DLWC (1998) Constructed Wetlands Manual, NSW Department of Land and Water Conservation.

Duncan (1999) Urban Stormwater Quality: A Statistical Overview, Report 99/3, Cooperative Research Centre for Catchment Hydrology

Goulburn City Council (2003) Draft Goulburn Development Control Plan No.13 – Common Street Business Park and Common Street Business Park Contributions Plan.

CRCCH (2004) MUSIC V2.0 User Manual

XP-RAFTS2000 Model and User Manual

STORM (2003) Water Sensitive Urban Design for Carr Street, Goulburn

Sydney Water (1995) Estimation of stormwater and sewer loads in the Sydney-Illawarra Region. Prepared for the Clean Waterways Program, in Reference 2.

Upper Parramatta River Catchment Trust (1999) On-site Detention Handbook – 3rd Edition.

APPENDIX A

ON-SITE DETENTION TABLES AND GRAPHS

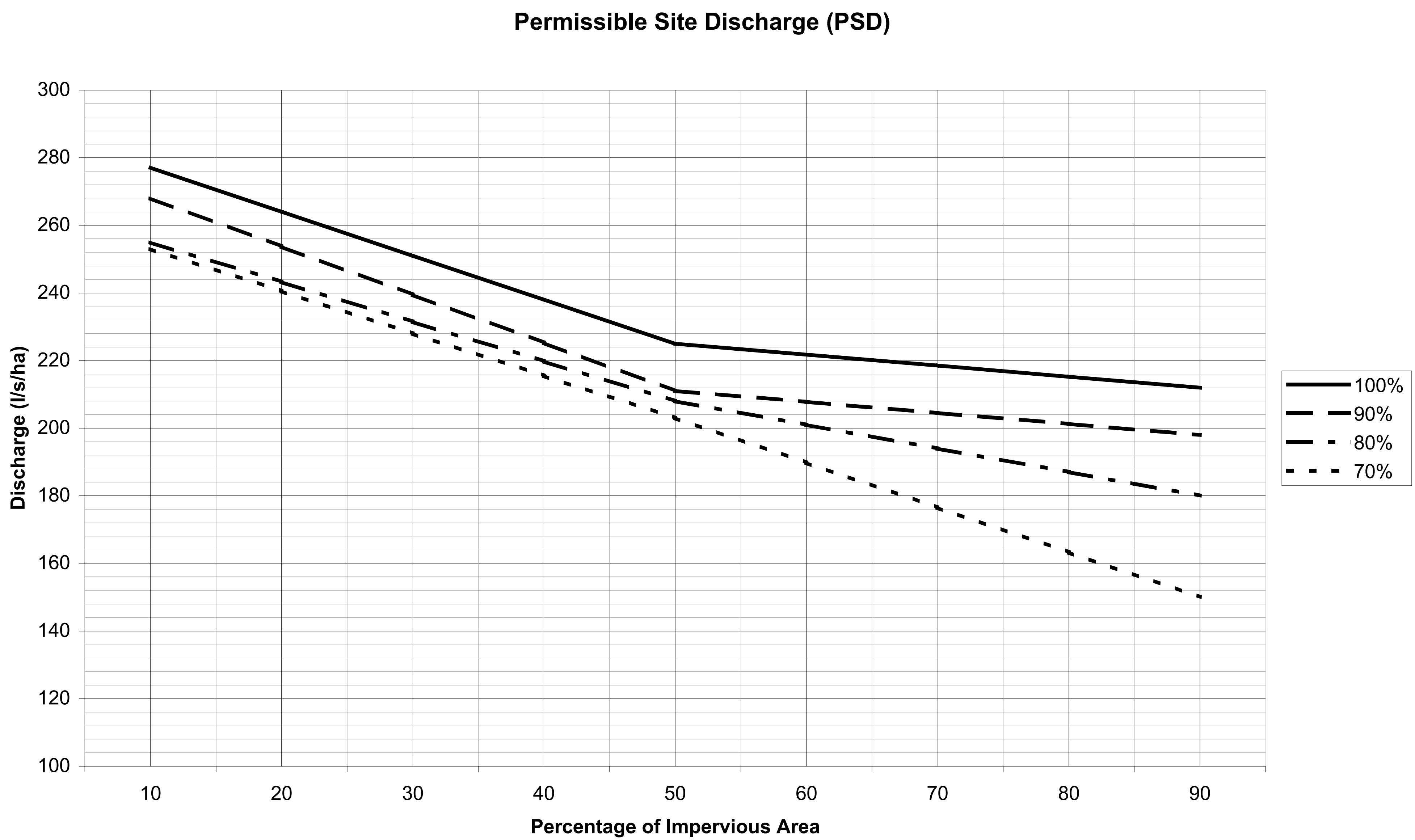
APPENDIX A ON-SITE DETENTION TABLES AND GRAPHS

Permissible Site Discharge for On-site Detention Systems

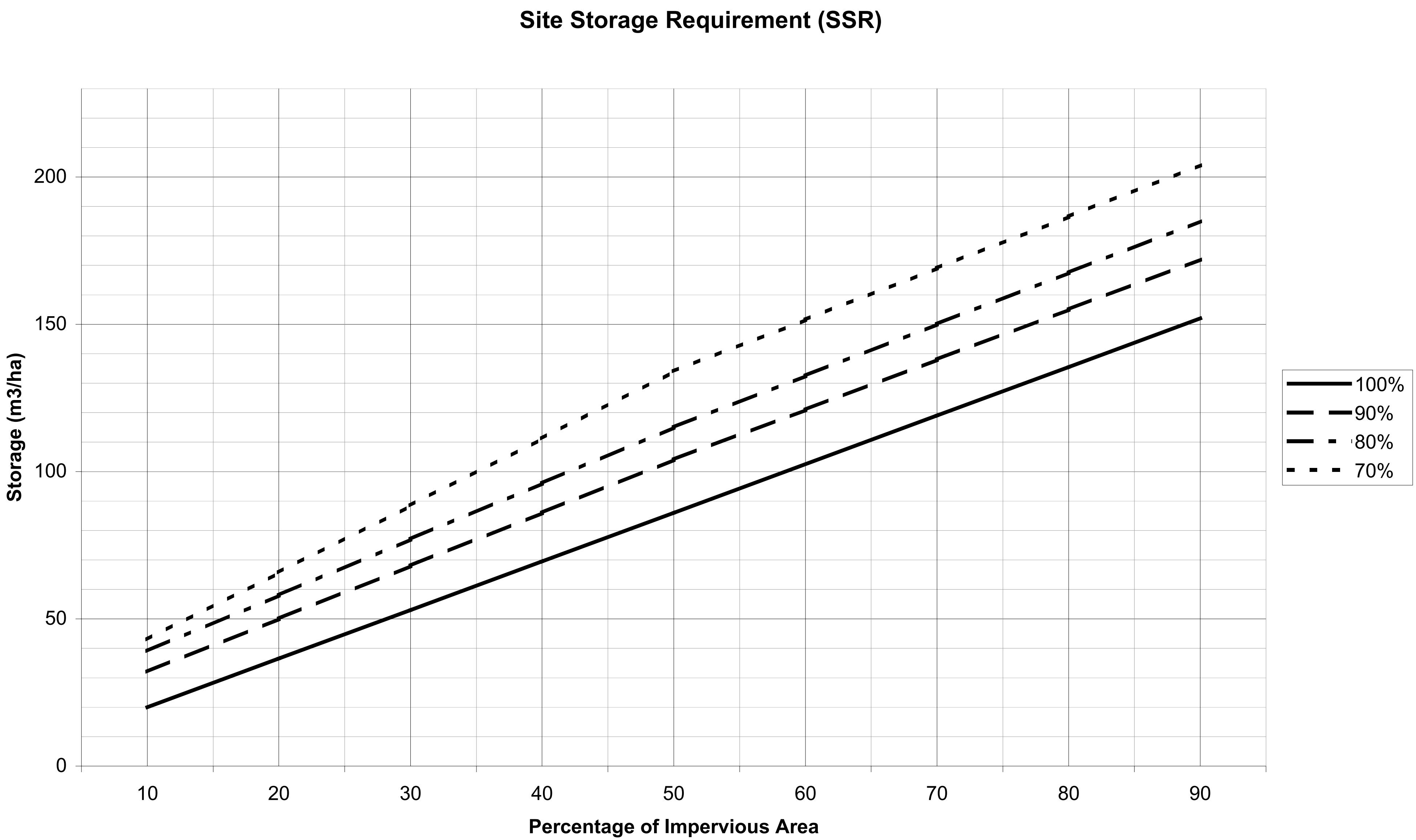
	Percentage of development area draining to OSD system						
Percent Impervious	100	95	90	85	80	75	70
10	277	273	268	262	255	254	253
20	264	259	254	249	243	242	241
30	251	245	240	236	232	230	228
40	238	232	225	223	220	218	216
50	225	218	211	210	208	206	203
60	222	215	208	204	201	195	190
70	219	212	205	199	194	185	177
80	215	208	201	194	187	175	163
90	212	205	198	189	180	165	150

Site Storage Requirement for On-site Detention Systems

	Percentage of development area draining to OSD system						
Percent Impervious	100	95	90	85	80	75	70
10	20	26	32	36	39	41	43
20	37	43	50	54	58	62	66
30	53	61	68	73	77	83	89
40	70	78	86	91	96	104	111
50	86	95	104	110	115	125	134
60	103	112	121	127	133	142	152
70	119	129	138	144	150	160	169
80	136	145	155	161	168	177	187
90	152	162	172	179	185	195	204



Permissible Site Discharge (PSD)
300
280
260
240
220
200
180
160
140
120
100
Discharge (l/s/ha)
10
20
30
40
50
60
70
80
90
Percentage of Impervious Area
100%
90%
80%
70%


Site Storage Requirement (SSR)
Storage (m3/ha)
0
50
100
150
200
10
20
30
40
50
60
70
80
90
Percentage of Impervious Area
100%
90%
80%
70%

APPENDIX B

CREEK REHABILITATION DRAWINGS

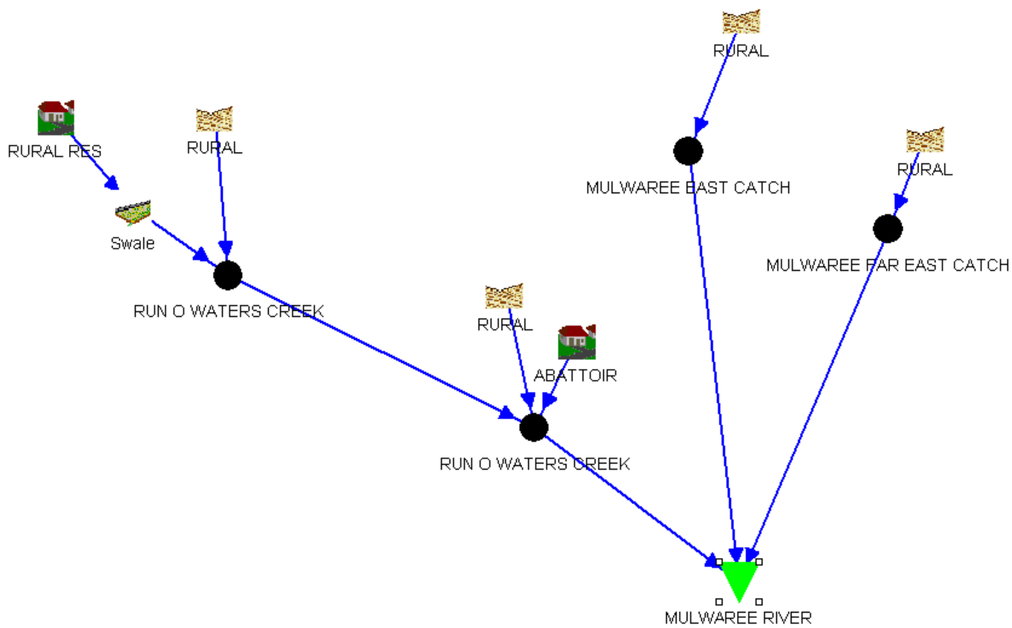
APPENDIX C

MUSIC MODEL NODE PARAMETERS

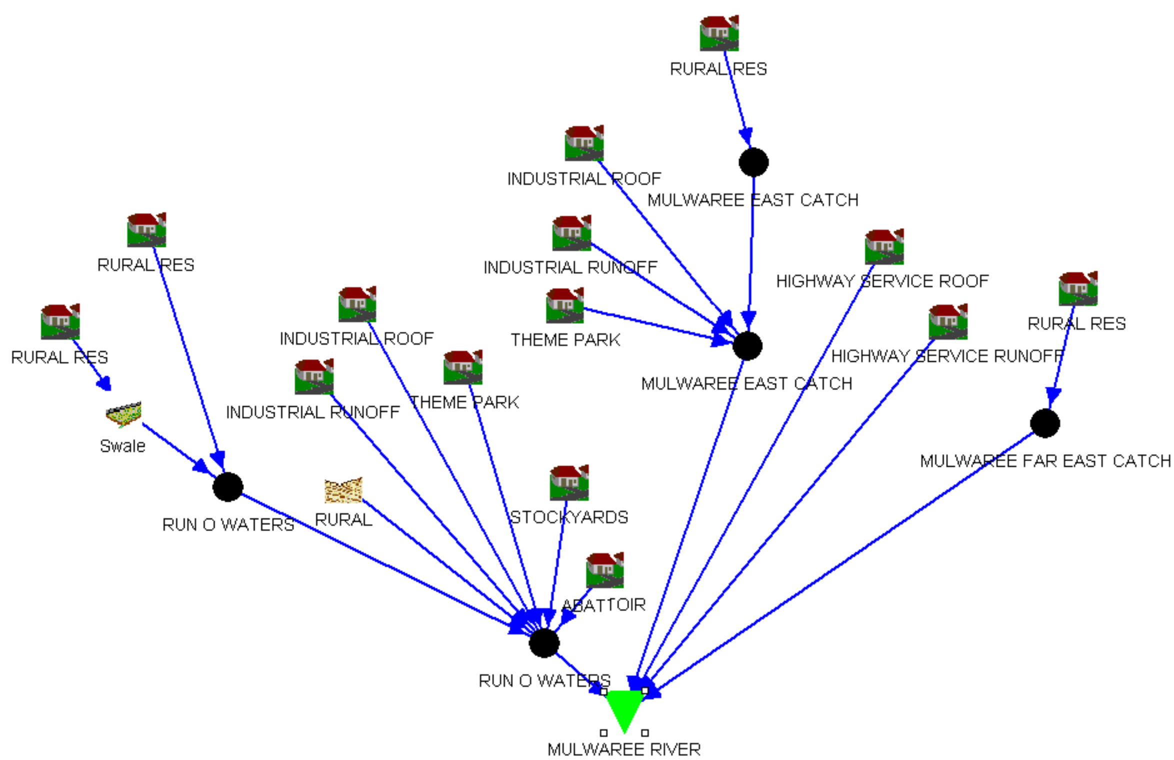
APPENDIX C MUSIC MODEL NODE PARAMETERS

MUSIC MODEL SETUP

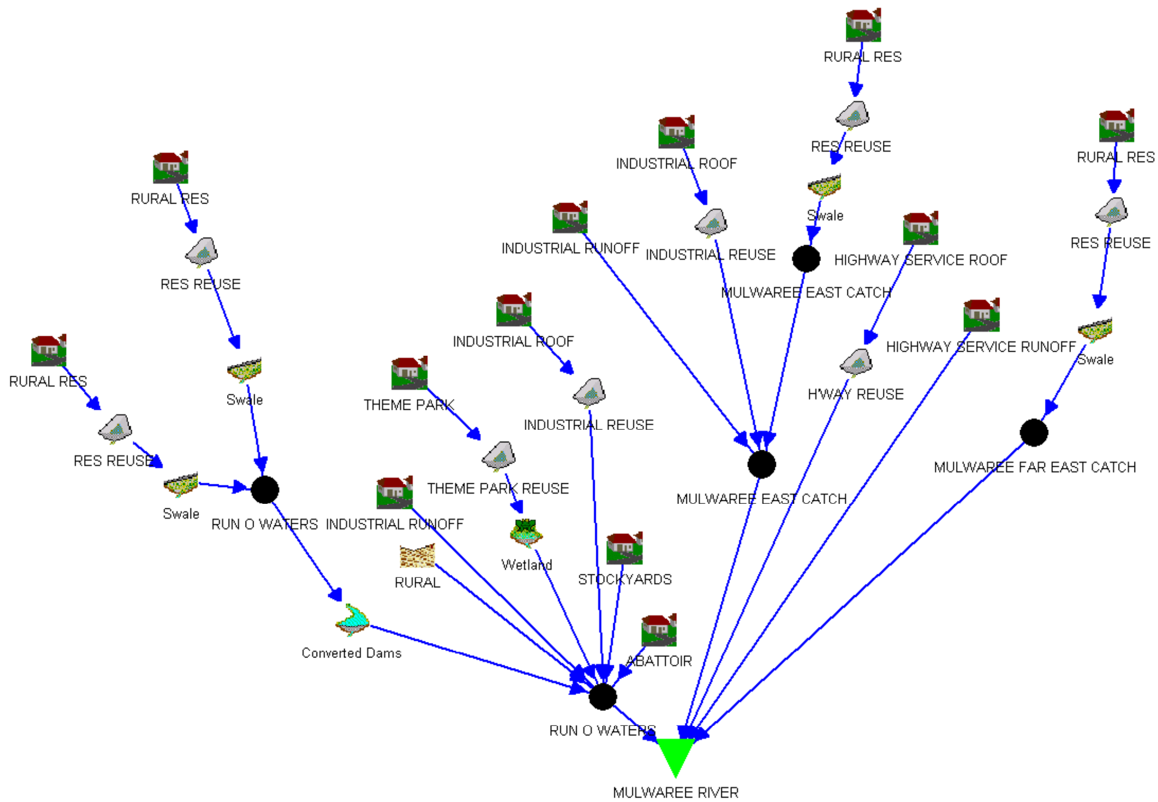
Pre Development



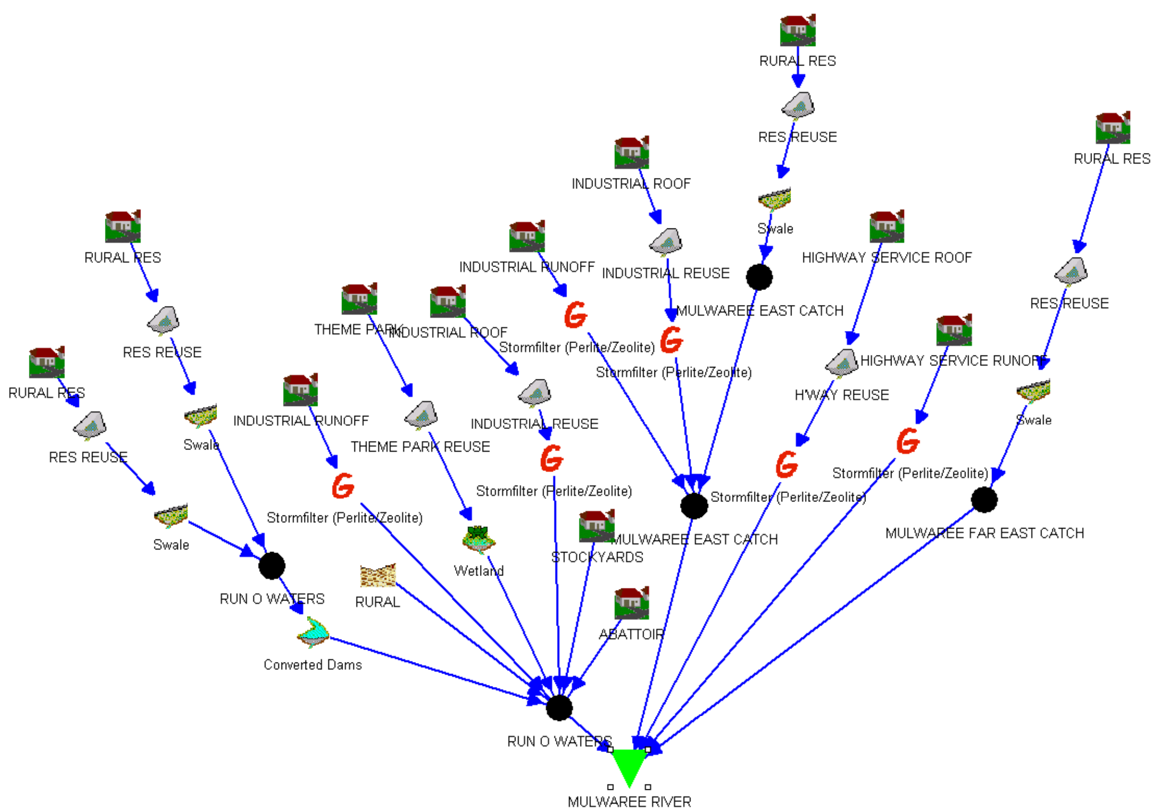
Post Development – Scenario 1
No Controls



Post Development – Scenario 2
Reuse Only



Post Development - Scenario 3
Reuse and Source Controls



MUSIC Node Parameters:

Parameter	Units	Pre Development			Post Development								
		Rural Grazing Land	Rural Res	Abattoir	Rural Res	Rural Grazing Land	Ind Roof	Ind Runoff	H'way Service Roof	H'way Service Runoff	Theme Park	Abattoir	Stock yard
Areas													
Total Area	ha	335.3	255.4	23.2	473.5	28.2	27.00	6.8	1.75	1.4	38.7	23.2	13.1
Impervious	%	2	9	61	9	9	100	100	100	90	40	61	5
Pervious	%	98	91	39	91	91	0	0	0	10	60	39	95
Impervious Area Properties													
Rainfall Threshold	%	1	1	1	1	1	1	1	1	1	1	1	1
Pervious Area Properties													
Soil Storage Capacity	mm	150	150	150	150	150	150	150	150	150	150	150	150
Initial Storage	% of capacity	25	25	25	25	25	25	25	25	25	25	25	25
Field Capacity	mm	100	100	100	100	100	100	100	100	100	100	100	150
Infiltration Capacity Coefficient - a		50	50	50	50	50	50	50	50	50	25	50	50
Infiltration Capacity Exponent - b		2	2	2	2	2	2	2	2	2	2	2	2
Groundwater Properties													
Initial Depth	mm	50	50	50	50	50	50	50	50	50	50	50	50
Daily Recharge Rate	%	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Daily Baseflow Rate	%	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Daily Deep Seepage Rate	%	0	0	0	0	0	0	0	0	0	0	0	0
Total Suspended Solids - Base Flow Conc													
Mean	log mg/l	1.4	1.1	1.1	1.1	1.1	0.92	1.699	0.92	1.699	1.1	1.1	1.1
SD	log mg/l	0.13	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Estimation Method		mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean
Serial Correlation (Rsquared)		0	0	0	0	0	0	0	0	0	0	0	0
Total Suspended Solids - Storm Flow Conc													
Mean	log mg/l	2.3	2.2	2.2	2.2	2.2	1.222	2	1.222	2	2.2	2.2	2.2
SD	log mg/l	3.1	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Estimation Method		mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean
Serial Correlation (Rsquared)		0	0	0	0	0	0	0	0	0	0	0	0
Total Phosphorus - Base Flow Conc													
Mean	log mg/l	-0.88	-0.82	-0.82	-0.82	-0.82	-1.332	-1.004	-1.332	-1.004	-0.82	-0.82	-0.82
SD	log mg/l	0.13	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Estimation Method		mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean
Serial Correlation (Rsquared)		0	0	0	0	0	0	0	0	0	0	0	0
Total Phosphorus - Storm Flow Conc													
Mean	log mg/l	-0.27	-0.45	-0.45	-0.45	-0.45	-1.03	-0.699	-1.03	-0.699	-0.45	-0.45	-0.45
SD	log mg/l	0.3	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Estimation Method		mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean
Serial Correlation (Rsquared)		0	0	0	0	0	0	0	0	0	0	0	0
Total Nitrogen - Base Flow Conc													
Mean	log mg/l	0.074	0.32	0.32	0.32	0.32	-0.257	-0.084	-0.257	-0.084	0.32	0.32	0.32
SD	log mg/l	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Estimation Method		mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean
Serial Correlation (Rsquared)		0	0	0	0	0	0	0	0	0	0	0	0
Total Nitrogen - Storm Flow Conc													
Mean	log mg/l	0.59	0.42	0.42	0.42	0.42	0.049	0.224	0.049	0.224	0.42	0.42	0.42
SD	log mg/l	0.26	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Estimation Method		mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean
Serial Correlation (Rsquared)		0	0	0	0	0	0	0	0	0	0	0	0