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Water Sensitive Urban Design
Clyde Street Precinct
Goulburn

Report Prepared for
Greater Argyle Council

Project No. L364

August 2004

Prepared by:
STORM CONSULTING PTY LTD

_ANALYSIS
_CONSENSUS
_DESIGN
_MANAGEMENT

Head Office
Suite 3, 6 West Street
Pymble NSW 2073
Australia
T +61 (02) 9499 4333
F +61 (02) 9499 4311
www.stormconsulting.com.au

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EXECUTIVE SUMMARY

Approximately 213 hectares of residential development is planned for the Clyde Street area to the north west of Goulburn. This area is within the Greater Argyle Local Government Area and is in the hydrological catchment of Sydney's drinking water supply.

Greater Argyle Council (Council) has engaged Storm Consulting Pty Ltd (STORM) to undertake stormwater and water cycle investigations and make recommendations specific to developing the Clyde Street area so that Council may prepare an appropriate Development Control Plan (DCP) that will satisfy its own requirements and those of the Sydney Catchment Authority (SCA).

STORM developed a peak flow hydrological model (XP-RAFTS) to determine the changes to the peak flows that would arise after development of Clyde Street. From the Rafts model it was observed that all of the nodes experience higher flood peaks post development. The increase in peak flows, where they occur, are not expected to impact on the development site as the flows will be conveyed through the trunk drainage corridors. The exception to this is where the natural creek profile is to be retained as agreed with DIPNR – ie. the portion of the Eastern Waterway that is below Clyde Street. It is recommended that any development site in the Eastern Waterway sub-catchment be required to match pre-development peak flows to prevent increased flow velocities in the natural creek downstream.

The flow assessment study is considered to be conservative as it does not account for the effects that rainwater tanks have on peak storm flows. Past studies demonstrate that, for similar developments in the Goulburn area, rainwater tanks have a significant attenuation effect on peak flows in all storms up to and including the 100 year ARI.

The flow assessment study has enabled minimum creek corridor widths to be determined. These minimum widths represent the minimum areas required for flood conveyance. The study assumes that formation of a "natural" trunk drainage system would occur in areas that currently do not have any identifiable drainage characteristics. STORM has recommended that these creek corridors be vegetated to ensure their long term viability, stability and water quality benefits.

The stormwater treatment train that is recommended for adoption includes:

- Source controls: plumbed rainwater tanks (and not infiltration).
- Conveyance Controls: grassed swales.
- End of Line Controls: sand filter.

Estimates of the predevelopment and post development water quality have found that the post development water quality is likely to be slightly better than the predevelopment water quality – this is based on 20kL rainwater tanks for each lot, swales treating runoff from minor roads and sand filter (swales on the ring road not included). This should satisfy the "neutral or beneficial effect" development requirements of SEPP58 but does not achieve the reduction targets set in Council's SMP. The inclusion of a swale on the ring road has been shown to meet both the neutral or beneficial effect requirement and the reduction targets.

Provision of swales on the ring road – in addition to the above measures – would enable Council's SMP targets to be met. This is one of the measures that could be adopted if it is necessary to achieve the SMP reduction targets. It is acknowledged that Council prefer traditional kerbs on the ring road as heavy traffic such as buses will use the route. For this reason, STORM suggests that, an alternative such as broken kerb may be adopted to meet both traffic management and water quality objectives. If swales are to be included on the ring road, the plans must allow for sufficient road width to accommodate the swales in addition to other services that may be required, such as footpaths: this should be considered by Council's planners when preparing other parts of the Clyde Street DCP.

The total estimated costs for Section 94 Contributions would be $3,536,200. This may equate to a cost of about $7,072 per lot, assuming 500 lots as advised by Council.

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1. INTRODUCTION

1.1. Background and Context

Approximately 213 hectares of land is planned for residential development in the Clyde Street precinct situated north-west of Goulburn. This area is within the Greater Argyle Council Local Government Area and is situated in the hydrological catchment of Sydney's drinking water supply.

Greater Argyle Council (Council) has engaged Storm Consulting Pty Ltd (STORM) to undertake investigations and make recommendations specific to developing the Clyde Street area so that Council may prepare a Development Control Plan (DCP) that provides guidance on the appropriate management of stormwater.

1.2. Objectives

The objectives are to provide Council with a water sensitive urban design strategy in support of a development control plan for the Clyde Street development precinct. The water sensitive urban design strategy is to document and provide measures that can be implemented to appropriately manage stormwater in the Clyde Street precinct and meet the requirements of:

1. Council's SMP;

2. The Drinking Water Catchments Regional Environmental Plan No. 1 (REP1): in particular the Neutral or Beneficial (NorB) Effect Test, which developers will be required to demonstrate in their DA submissions to Council.

The strategy is to also provide approximate costs of stormwater-related works to assist Council with determining a Section 94 Contribution Plan for the Clyde Street release area.

1.3. Scope

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

Task 1 – Rainwater Tank Analysis
Task 2 – Trunk Drainage Corridor Determination
Task 3 – Water Quality Planning and Assessment
Task 4 – Creek Health Assessment

1.4. Cautionary Note on the Use of Data in This Report

The flow rates shown in this report apply to specific sections of the Clyde Street precinct and are based on a number of critical assumptions. At no point should these rates be adopted to guide a design in any way or reduce the responsibility to carefully undertake the requisite design calculations.

Each proposal for development within the Clyde Street precinct would still need to be supported with a detailed assessment of water cycle management - flows and water quality - based on the design conditions relevant to that proposed development. Work undertaken for this project is based on broad planning policies and detailed lot layouts were not understood at the time of preparing this report.

2. CATCHMENT CONDITIONS

2.1. General Topography and Drainage

The Clyde Street development precinct has variable topography with moderate to steep slopes in the upper parts of the catchment and gentle slopes at the lower parts.

The catchment covers an area of 213 hectares. Most of the runoff is conveyed in two unnamed drainage lines – for convenience, these are referred to as the Eastern Waterway and Western Waterway (according to their relative geographical locations) – as illustrated in Figure 1. The two creeks drain directly into the Wollondilly River, as does runoff from land directly adjacent the river. The Wollondilly River forms part of the Northern boundary of the precinct.

2.2. Soils

The Clyde Street Precinct overlays the following two different soil landscapes as described by the "Soil Landscapes of the Goulburn 1:250,000 Sheet":

- Monastry Hill
- Sooley

The Monastry Hill soil landscape underlays the area of largely un-developable land to the south west of the site. The Sooley soil landscape underlays the remainder of the site.

The characteristics of each of these landscapes are presented in **Table 1** below.

Table 1. Soil Landscapes

Parameter	Monastry Hill	Sooley
Surface Condition	Friable	Friable
Drainage	Impeded	Impeded
Soil Permeability	Moderate	Moderate
Available Water Holding Capacity	High	High
pH	6.5	6.5
Soil Salinity	Not evident	Not evident
Erodibility (topsoil)	Moderate	Moderate
Erosion Hazard	Low	Low

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

Disturbance of either of the soil landscape surfaces for urban development will create significant short term erosion problems. This is of particular concern due to Clyde Street precinct's close proximity to the Wollondilly River. Sediment and erosion control will need to be rigorously managed in the area to prevent gullying and sheet erosion.

2.3. Vegetation

This Monastry Hill and Sooley soil landscapes are associated with a savannah woodland vegetation community which typically includes yellow box and Blakely's Red Gum.

2.4. Creeks

The upper reaches of the Western Waterway are incised and eroded and there are several farm dams on the creek. The lower reaches of the Western Waterway are poorly defined: the flow path widens as the land flattens out and sheet flow is typical in this section. The last 150m of the Western Waterway (where it flows into the Wollondilly River) is classified as a river under the R&FI Act (refer to Section 2.6.3 for further details).

The upper reach of the Eastern Waterway (above the intersection with Clyde Street) is a gentle drainage depression. In the reach between Clyde Street and the Wollondilly River, the Eastern Waterway is showing signs of stress, with erosion and head-cutting occurring within and adjacent to the creek – also through this section, the creek is classified as a river under the R&FI Act (refer to Section 2.6.3 for further details).

2.5. Site Development

2.5.1. Existing

Currently, development within the Clyde Street precinct is agricultural and rural residential on very large lots. The land is mostly cleared, vegetated with grazing pasture on agricultural land and gardens and lawn on residential lots.

A water treatment plant is situated on several lots near the southern boundary of the development area – these are excluded from the developable area. Near the water treatment plant is a hillside with woodland vegetation – this will be left as is.

Adjacent the Wollondilly River, on the eastern side of the precinct, is the site of the old water treatment works. Council has advised that a management plan is in place for this site.

2.5.2. Future

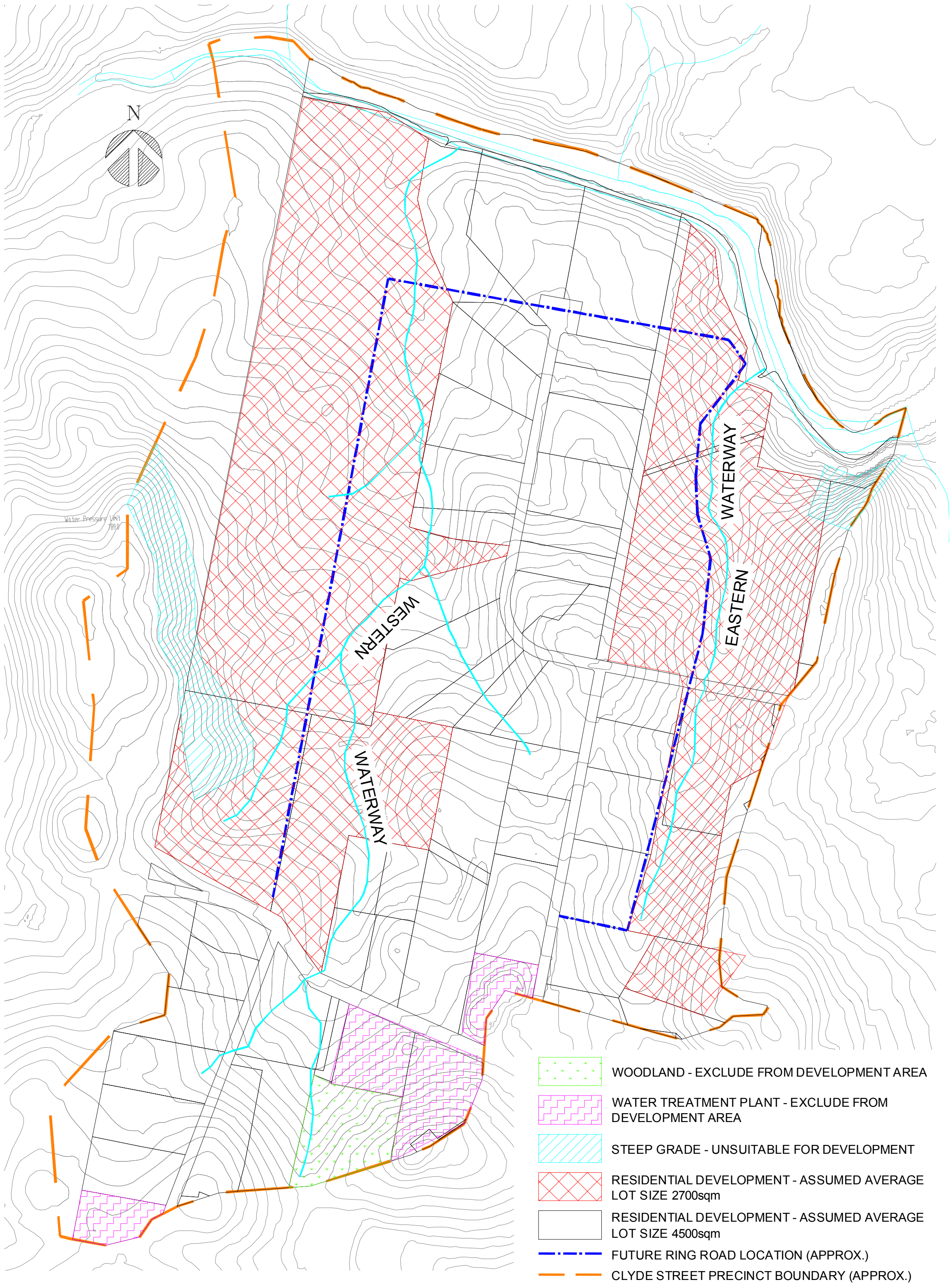
The Clyde Street precinct is planned for residential development as illustrated in Figure 1. Council advised that the minimum lot size for the precinct will be 2,000m^2, but that due to constraints – such as existing land use,– the following development patterns could be expected:

- Given that parts of the Clyde Street precinct already have residential properties, it is expected that these lots would be developed at a lower density – for this reason, an average lot size of 4,500m^2 is adopted for 117 hectares of the precinct.
- Existing large lots that are currently used for grazing cover around 80 hectares of the precinct. It is expected that this land could be developed at a higher density with an average lot size of 2,700m^2.

- The remaining land – approximately 16 hectares – is used by the water treatment plant and other areas are un-developable due to steep grades and woodland.

Council proposes a ring road through the Clyde Street precinct and have advised a conceptual location for this road. The ring road is illustrated in Figure 1.

Figure 1: Clyde Street Development Precinct – Layout Plan



2.6. Requirements

2.6.1. Council's Stormwater Management Plan

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 Table 2 and Table 3 on the following page.

Table 2 - 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 3 - 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)

2.6.2. Drinking Water Catchments REP No 1

Under the Drinking Water Catchments Regional Environmental Plan No. 1 (REP1), all new development proposals within the hydrological catchment of Sydney's drinking water supply must be assessed for their effect on water quality. Development proponents therefore are required to submit a water cycle management plan for consideration by the SCA. This plan needs to determine:

- Whether the development will have a neutral or beneficial effect on the water quality of rivers (including pollutant flows, loads or concentrations)

- The impact of the development on receiving waters
- Water cycle management strategies and best management practices, including maintenance and monitoring, to address any potential impacts
- The long term sustainability of water cycle management strategies

2.6.3. DIPNR

The DIPNR administers the *Rivers and Foreshores Improvement Act 1948* (R&FI Act). An officer from the Department of Infrastructure Planning and Natural Resources (DIPNR) attended an inspection of the study area to determine the extent of rivers as defined under the R&FI Act.

STORM together with the DIPNR and Council have mapped the extents of the rivers in the study area. The DIPNR officer has advised that these rivers will require a 10m buffer from top of bank for riparian protection purposes. A Part 3(a) permit would be required to build any structures within the buffer (ie. GPTs, stream rehabilitation).

The rivers and riparian zones are shown on the Water Sensitive Urban Design Plan provided in Appendix B.

The Water Management Act (2000) should not be applicable to the Clyde Street area unless bores or water storage dams are installed.

3. WATER MANAGEMENT STRATEGY

For many years, stormwater has been treated as a quantity problem whereby stormwater was disposed into drainage systems that took it away as quickly as possible. As a result, more concentrated and faster stormwater flows were generated downstream which required large scale management solutions that are costly to construct and maintain.

Over the last ten years stormwater quality has been included together with quantity in management strategies; however they were typically separate management approaches. It is only more recently that stormwater quantity and quality has been integrated with the total water cycle and the philosophy of Water Sensitive Urban Design applied.

Water Sensitive Urban Design (WSUD) applies a treatment train approach to the management of the water cycle on new or existing development. The water cycle is generally broken down into three main phases of controls:

1. Source Controls - at the lot scale of development. Are paid for by the house owner and maintained by the house owner. Examples are rainwater tanks with plumbed reuse and infiltration trenches to infiltrate overflows from the rainwater tanks
2. Conveyance Controls - between the lot and the end of pipe system. Examples are grassed swales, bio-retention trenches, pipes and channels.
3. End of Line Controls - Lower down in the catchment and aim to treat large contributing areas. Typical examples are wetlands, sand filters, GPTs, vegetated uptake systems and the like.

Each of these controls needs to be considered in context with the water processes. This develops a systematic approach to the management of the total water cycle.

3.1. Source Controls

On-site controls to manage water quantity typically employ on-site detention (OSD) and on-site retention (OSR) devices. Traditionally this has been in the form of an on-site detention system or infiltration trench. More recently, rainwater tanks have re-emerged to combine OSD and OSR in one device. Further information on rainwater tanks is presented below.

3.1.1. Rainwater Tanks

Due to the research undertaken by University of Newcastle, the environmental benefits of rainwater tanks are now better understood. Not only can they significantly reduce the household potable water demand (by up to 50%) but they are also a potential at-source quantity and quality management device.

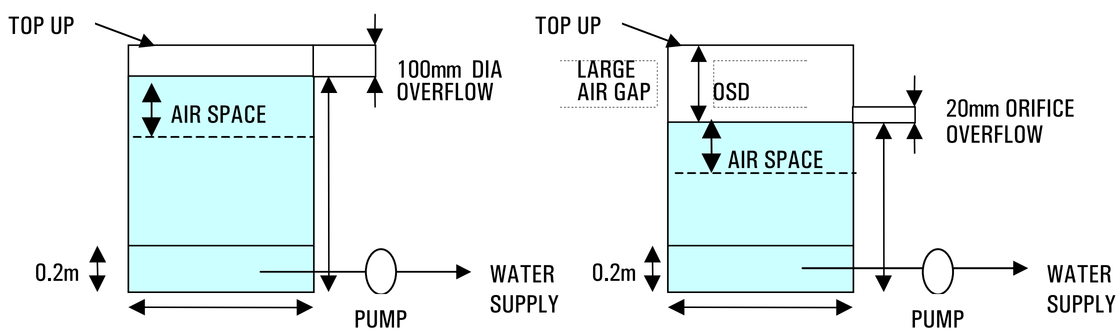
The installation of rainwater tanks reduces the volume of rainfall runoff from the site by the amount of available space in the tank. This reduces the number of runoff days so that the developed site more closely mimics the pre-development condition.

Quantity Benefits

When rainwater tanks include OSD, not only is the total volume of rainfall runoff reduced but also the peak rate of runoff. Research in this area by Coombes (2001) has demonstrated that up to 40% of the capacity of a rainwater tank can be used for OSD, and this amount increases when air space is provided in the tank. Over a 1,000-year synthetic period, the tanks were predicted to be able to contribute to the reduction in peak flows during 90% of major storm events. This work has since led to the acceptance of rainwater tanks as an OSD device in the Upper Parramatta River Catchment Trust (UPRCT) program.

Figure 2 shows the difference between a tank configured for OSD and one that is not.

Figure 2 - 10kL Rainwater Tank Configuration (with and without OSD)



Typical Configuration **Maximum OSD Configuration**

Quality Benefits

After any extended dry period, it is good practice to let the first rainwater runoff bypass the tank. This first rain will wash or flush the roof catchment and usually contains higher amounts of accumulated dust, bird droppings, leaves and other debris. Diversion of the first 0.2 – 0.5mm is considered sufficient and devices should be sized accordingly. By removing this first flush water the water quality entering downstream is improved.

3.2. Conveyance Controls

Conveyance controls are typically designed to:

- manage the stormwater flows to and from roads
- manage the stormwater flows collected from the end of the road system to the trunk drainage corridor
- manage the flows within the trunk drainage corridor

3.2.1. Grassed Swales

Grassed swales provide a system to control, treat and dispose of stormwater runoff from the road catchment. They are often used as an alternative to the traditional kerb and gutter systems in standard residential developments and are found extensively within rural residential road profiles.

Quantity Benefits

Grassed swales have the following quantity management characteristics:

- reduced runoff volumes
- reduced peak flows, and

- infiltration

Quality Benefits

Grassed swales can also treat pollutants such as sediment, attached nutrients and hydrocarbons by trapping and storing them for breakdown by soil micro-organisms within the topsoil. It is critical that swales have slopes less than 6% in order to operate effectively.

3.3. End of Line Controls

End of line controls provide the final water quality improvement before discharge to the downstream system. When a WSUD approach is utilised the size of the end of line treatment is significantly reduced and often may not be necessary at all.

There are many end of line controls available including wetlands, ponds, sedimentation basins, sand filters, GPTs, vegetated uptake systems and hybrid versions of each of these controls.

The need for an end of line control was assessed during the MUSIC modelling process (detailed in Section 7). For the purpose of this strategy a wetland was assessed.

3.3.1. Wetland

The primary objective of most constructed wetlands is water quality improvement of surface runoff. However, constructed wetlands may also be designed to achieve other objectives including habitat, biodiversity, recreation, aesthetics and education. Constructed wetlands require ongoing maintenance and operation involvement to ensure they continue to function as intended.

Quantity Benefits

Wetlands can be designed with an extended detention capability to help attenuate peak flows.

Quality Benefits

Where they are designed to improve water quality, wetlands are an efficient and effective means for removal of suspended solids, phosphorus and nitrogen.

3.3.2. Sand Filter

Sand filters are presented as an alternative to a constructed wetland. The reason is that the site may not be suitable for a constructed wetland due to the climate – this will not be known until a water balance for a constructed wetland is undertaken (this is outside the scope of this strategy). A sand filter would utilise only about half the land area that a wetland requires to achieve the same level of treatment, and the land above the sand filter (which is installed beneath ground level) would be multifunctional as a grassed reserve.

Quantity Benefits

Sand filters are designed with a surcharge basin above the ground level, providing flow attenuation benefits.

Quality Benefits

Sand filters are effective and efficient at removing suspended solids, phosphorus and nitrogen. Experience indicates that sand filters provide a more consistent and reliable level of pollutant removal than wetlands.

3.4. Drainage Corridors

3.4.1. Creek Remediation and Riparian Corridor

The reach of the Eastern Waterway defined as a river under the R&FI Act is eroded and unstable: remediation requirements include works to stabilise and revegetation to enhance riparian corridor value. These requirements were determined in consultation with DIPNR during a site inspection. The remediation concepts are provided in Plans P01 and P02 in Appendix B.

DIPNR advised that a 10m setback either side of top of bank is necessary to provide a riparian corridor. This is the area that will need to be revegetated and no development may occur within this zone without a part 3(a) permit (refer to plan P03 for the area covered by riparian buffer).

Revegetation of the creek banks is critical to ensuring creek health and adequate water quality. The use of endemic native species is advised and should include a mix of grasses, shrubs and deep rooted trees. Refer to Section 2.3 for a list of appropriate vegetation species to be used within the creek corridor.

As the natural profile will be retained for this reach of the waterway, the level of a 1 in 100 year average recurrence interval (ARI) flood event was estimated at two sections along the waterway. This basic assessment showed that the 100 year ARI flood event will be contained within the riparian corridor, so a more detailed assessment (complex hydraulic model) was not deemed necessary at this stage.

The lowest 150m of the Western Waterway, which is defined as a river under the R&FI Act, does not require remediation. The riparian corridor setbacks also apply to this reach.

3.4.2. Trunk Drainage

The remaining waterways – those that are not rivers as described in the section above – are a mix of incised and eroded natural channels and poorly defined drainage lines. Formation of a "naturalised" drainage system (trunk drainage corridor) will be necessary in these areas. The majority of the trunk drainage will need to be formed by excavation, though parts may suit construction by filling adjacent to the channels, to ensure that the lots are constructed above the estimated 100 year ARI water levels. The trunk drainage corridor will need to be vegetated (As explained in Section 4.1.4, a Manning's n of 0.08 was adopted in hydrological model – the trunk drainage should be vegetated to achieve this roughness).

4. STRATEGY EFFECTIVENESS

The strategy is effective if it meets Council, DIPNR, SCA and REP1 requirements.

4.1. Quantity Modelling

4.1.1. Effect of Rainwater Tanks on Peak Flows

In addition to reducing the potable water demands, rainwater tanks provide pollutant removal benefits and onsite detention to assist with attenuation of peak flows.

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

Further work undertaken by STORM for the Carr Street development found that rain tanks sized at 20kL/household used in combination with a street swale system allowed the development to meet the pre-development stormwater flows without any additional detention. The lots within this development were 2,000m^2 or greater and are directly applicable to the size of development proposed within the Clyde Street precinct.

4.1.2. Rainwater Tank Sizing

Estimating Daily Water Demand

Water demand is affected by a number of factors and varies widely across the state. Factors such as householder wealth, temperature, average rainfall, the size of gardens, the perceived availability of water, the number of days since the last rainfall event, the soil type and the type of rainfall experienced all affect the demand for water.

In order to get an accurate understanding of the likely average water demand, a representative sample of metered water usage was analysed. The sample included residential properties on Oakwood and Wollondilly avenues, Boomerang Drive and Cathcart Street. These properties represent a typical residential area with a level of affluence and attitude/behaviour likely to be found in the proposed Clyde Street development area.

The block sizes in these representative developments were found to range in size from approximately 1,000 to just over 3,000m^2. Parts of the Clyde Street development area are expected to have lots of average size 2,700m^2 while other parts are expected to have lots of average size 4,500m^2. Given the large lot size planned, those properties that were less than 1,900m^2 were removed from the sample. The average size of the lots remaining in the sample was 2,150m^2. The average usage (L/m^2/d) of the lots was determined and then extrapolated to determine the average usage of a 2,700m^2 lot. As the bulk of water supplied is used within the home, it is anticipated that the 4,500m^2 average lots will not consume much more than that consumed by a lot of size 2,700m2.

The average metered water consumption for the sample area is shown in Table 4 below.

Table 4 - Average Metered Water Consumption

Quarter	Average Metered Water Use (kL/lot/day)
Dec – Feb	1.158
March – May	0.985
June – Aug	0.888
Sept – Nov	0.996

For the purpose of constructing a daily water balance model, the daily indoor and external house usage was disaggregated (Table 5 below). The disaggregation was based on typical indoor usage for a family of four living in a house (STORM Consulting 2002) with the difference between the metered readings and the typical indoor use considered to be external house uses.

Table 5 - Average Metered Water Use on a Residential Development (with Indoor and External house disaggregation)

Month	(1) Indoor Disaggregated Use (L/day)	(2) External House Disaggregated Use (L/day)	(3) Average Metered Water Use (L/day)
January	615	543	1158
February	613	545	1158
March	616	369	985
April	670	378	985
May	607	378	985
June	599	289	888
July	601	287	888
August	603	285	888
September	607	389	996
October	610	386	996
November	609	387	996
December	609	549	1158

Note: (3) – (1) = (2)

Daily Water Balance

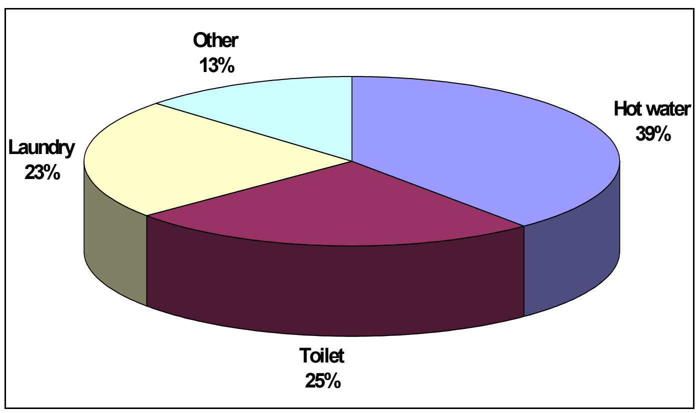
A daily water balance of a single, typical house was undertaken by STORM to determine the water usage for a typical household. The daily balance involved the construction of a spreadsheet with a daily accounting of rainfall runoff from the roof of a typical house into a tank followed by draw down of the tank through indoor and outdoor consumption. Typical roof areas supplied by Council's planners were between 300m^2 and 500m^2, a roof area of 400m^2 was used in the daily water balance though a sensitivity analysis was also carried out.

The water consumption rates used in the balance were those shown in Table 6. Daily rainfall data for the weather station in Progress Street, Goulburn (station number 070263) was used. Rainfall data from 1971 to 2002 was included in the water balance.

It was assumed that a simple top up mechanism of the tanks would be used to top up the tank when it was dry, as previously shown in Figures 2 and 3. The rainwater tank would need to be constructed with a mains water bypass to enable mains water to be supplied directly into the house during a power failure.

In order to further model indoor water use, the daily indoor demand was also disaggregated. The results of the disaggregation are shown graphically in Figure 4. Hot water, laundry and toilet make up 87% of indoor daily water use of a typical household.

Figure 4 - Breakdown of Daily Indoor Water Use in a Household



(Source: Coombes *et al*, 2001)

The daily water balance assumed that rainwater would be used for everything except drinking water. That is, rainwater would be used for hot water supply, laundry supply, toilet flushing (87 percent of indoor water use) and outdoor irrigation.

The results of the daily water balance are shown in Table 6 on the following page.

Table 6 – Daily Rainfall Water Balance for a Typical Lot

Roof Area	Tank Size (m^3)	% of total demand supplied by tank	Top-up Required (kL/yr)	Spills/yr
$300m^2$	6	32.8	218	10.7
	10	37.0	202	6.0
	16	40.1	191	3.2
	20	41.5	186	1.8
$400m^2$	6	37.9	199	16.7
	10	44.0	176	10.5
	16	48.8	159	6.9
	20	51.5	149	5.1
$500m^2$	6	41.6	185	22.5
	10	49.0	158	15.9
	16	55.3	135	10.8
	20	58.9	122	8.6

Note: Based on a total water demand of 367kL/yr/lot.

The NSW State Government has recently introduced BASIX. The BASIX requirements are being phased in throughout 2004 and 2005. From 1 July 2004, applications for new homes in Sydney must be accompanied by a BASIX certificate that demonstrates how savings in potable water demand and energy will be met. For other areas in NSW – including the Greater Argyle LGA – a BASIX certificate will need to accompany applications for new homes submitted on or after 1 July 2005. Further details can be found at www.basix.nsw.gov.au

BASIX requires demand for potable water to be reduced by 40%. Local Councils cannot make it mandatory to achieve a reduction of more than the 40%. However, Councils remain responsible for the management of stormwater. If the stormwater management strategy happens to result in a reduction of potable demand that is greater than 40%, then this is acceptable – because the reduction is an incidental benefit of stormwater management, not a direct result of an attempt to reduce consumption of potable water.

The results detailed in Table 6 indicate that to achieve a 40% reduction of potable water, 16kL, 10kL and 6kL tanks are required for homes with roof area of $300m^2$, $400m^2$ and $500m^2$ respectively. However, as mentioned above, the objective is not only to reduce potable water demand but to also manage stormwater quality and flow regime.

Under the pre-development scenario, the Goulburn area experiences up to 6 runoff days per year on average. Referring again to Table 6, the tanks that have average spills per year matching, or approaching the runoff days are: 10kL tank for homes with a roof area of $300m^2$, 20kL tank for homes with a roof area of $400m^2$ and a tank greater than 20kL for homes with a roof area of $500m^2$

As a roof area of $400m^2$ is the average for the purpose of determining the WSUD strategy, a 20kL tank is recommended as the minimum tank size for adoption.

4.1.3. Trunk Drainage Modelling

In order to determine the effect of development on stormwater peak flows and flooding, a RAFTS model was constructed. XP-RAFTS 2000 is a non-linear runoff routing model used to determine the stormwater flows (Q) from a catchment in a proscribed storm event. These stormwater flows were then incorporated into the Manning's equation in order to determine the minimum flow widths required to allow for the safe conveyance of flood flows. This assessment did not consider flood flows from the Wollondilly River or backwater effects from the river - it only considered flood flows generated on the Clyde Street site. This assumption is considered valid over 95% of the DCP area however where backwater effects do have an impact close to the Wollondilly the corridors may need to be wider. It is considered that as development will not be permitted by Council to occur below the 100 year ARI flood level anyway, this should not be a cause for concern.

4.1.4. RAFTS Inputs

- The RAFTS model was run for the 100 year ARI storm event.
- The impervious area resulting from development was calculated to be approximately 28% of the developable area. This impervious percentage is lower than other developments in the area due to larger lot sizes and a lower density of development.
- Conservative loss rates of 1.5 mm for impervious and 5 mm for pervious areas were adopted in the RAFTS model.
- Overland flow roughness coefficients of 0.04 predevelopment and 0.015 for impervious areas and 0.025 for pervious areas post development were adopted.
- A range of storm durations for the 100yr ARI were analysed including 10, 20, 30, 60, 120, 180 and 360 minute durations.
- The flood assessment assumed that vegetated, relatively narrow, low maintenance channels would convey flood flows rather than the current regime which is conveyed across the site as one broad, low sheet flow. The channels have side slopes of 1 in 4, depths up to 1.0m, and velocity depth (vd) multiples between 0.3 and 1.0.
- Width to Depth ratios for sizing the creeks were based on those indicated in the Brisbane City Council Natural Channel Design Guidelines (2000) for non cohesive soils.
- The Manning 'n' adopted for these creeks was 0.08 which allows for mass planting to occur. This would also satisfy riparian corridor requirements. Planting at a density of 1 tree per $4m^2$ with some shrubs and a heavy cover of native grasses would result in a Manning's n value of 0.08 (Brisbane City Council, Natural Channel Design Guidelines 2000).
- It is noted that the Clyde Street precinct boundary coincides with the catchment boundary. Further subdivision within the development boundary was undertaken in order to assess the sub-catchment boundaries within the site.

4.1.5. RAFTS Results

The peak flows for the predevelopment and post development scenarios are presented for each node below in Table 7. The sub-catchment locations are presented in the Clyde Street WSUD - RAFTS Catchment Plan Drawing P01.

Table 7 - RAFTS 100 year ARI Pre and Post Development Flows

Node	Max Flow (m^3/s)	
	Pre Development	Post Development
C1	1.26	1.464
C2A	1.375	1.807
C2B	3.464	5.44
C3	1.236	1.772
C4	1.851	2.397
C5	0.9658	1.341
C6	2.227	3.041
C7	2.097	2.972
C8	1.146	1.63
C9	1.183	1.473
C10A	3.149	4.798
C10B	1.005	1.411
C11	1.791	2.301
C12A	1.605	2.161
C12B	0.8635	1.204
C14A	1.374	1.889
C14B	3.341	4.336
C14C	0.7072	0.9541
C15	2.877	4.132
C16	4.223	5.911
C17A	0.7737	1.009
C18A	2.089	2.895
C18B	3.923	4.933
C19	2.957	4.108
J1	5.487	7.524
J2	7.265	9.549
J3	8.845	11.452
J4	2.097	2.972
J5	15.097	18.754
J6	18.333	22.681
J7	1.851	2.397
J8	22.37	27.07
J9	25.141	30.224
J10	1.26	1.464
J11	28.44	34.445
J12	3.923	4.933
J13	4.361	5.401
J14	10.942	13.088
RIVOUT	40.038	48.134

From the RAFTS model it was observed that all of the nodes experience higher flood peaks post development. The increase in peak flows, where they occur, are not expected to impact on the development site as the flows will be conveyed through the trunk drainage corridors.

The exception to this is where the natural creek profile is to be retained as agreed with DIPNR – ie. the portion of the Eastern Waterway that is below Clyde Street. It is recommended that any development in the Eastern Waterway sub-catchment be required to match pre-development peak flows to prevent increased flow velocities in the natural creek downstream. It is also recommended that Council require that each subdivision within the DCP area also achieve compliance with the need to keep pre and post development peak flows the same. Creek corridors have been modelled using the higher post development flows and this will allow for communal detention to occur usually at the bottom of the subdivision. Thus it is necessary to allow for the post development flows to be conveyed down to the detention facility if one needs to be created.

These results may only be applied to the site as presented in this report. In the event that Council alter the proposed extent and nature of development within the Clyde Street precinct the results would need to be reassessed.

4.1.6. Provision of Trunk Drainage

The results from the RAFTS model were used to determine trunk drainage requirements throughout the development. The width of flow was determined by solving the Manning equation for a typical trapezoidal channel shape with side slopes of 1 in 4.

In terms of defining where trunk drainage begins, it was determined that trunk drainage ought to be provided wherever peak flows will exceed 3 m^3/s. This threshold was selected on the basis that flows below 3 m^3/s can economically be conveyed within pipes – as trunk drainage involves land-take, piping these flows would provide the most economical outcome. Moreover we also considered the minimal corridor width that was viable from a riparian management point of view. This is considered to be about 5m. It was found that in order to comply with a reasonable width to depth ratio (one leading to a stable creek morphology) that a flow of about 3 m^3/s would require a corridor of over 5m thus also satisfying the minimum viable corridor criteria.

Table 8 provides trunk drainage widths at selected points. The trunk drainage requirements are further illustrated in Plan P03 in Appendix B.

It should be noted that even though the results show the peak flow from C16 being above 3 m^3/s about 60% of the flow at this node will directly flow into the Wollondilly River system - not into the creek system. For this reason, trunk drainage has not been provided to convey flows in the C16 catchment.

Table 8 - RAFTS Post Development 100 year ARI Flow Rates and Widths

Node	Max Flow (m^3/s)	Top Width (m) (not including buffer zone)	Overall Width (m) (including buffer zone)
C2A	1.807	NA[1]	
C2B	5.44	11.20	22.400
C9	1.473	NA[1]	
C10A	4.798	14.97	29.936
C14A	1.889	NA[1]	
C15	4.132	10.19	20.376
C16	5.911	NA[1]	
C18A	2.895[2]	8.45	18.452
J1	7.524	12.68	25.368
J2	9.549	13.86	27.728
J3	11.452	17.68	35.360
J4	2.972[2]	8.51	18.508
J5	18.754	30.75	50.752
J6	22.681	35.80	55.800
J7	2.397	NA[1]	
J8	27.07	38.21	58.208
J9	30.224	41.30	61.296
J10	1.464	NA[1]	
J11	34.445	43.80	63.796
J12	4.933	10.24	20.480
J13	5.401	10.87	21.744
J14	13.088	23.48	43.480

Table 8 allows for the establishment of land take requirements for flood conveyance through the precinct. The overall width presented includes the top width plus a buffer: the buffer either side of the channel equates to 50% of the top width up to a maximum of 10m, or a minimum of 5m wherever the 50% would result in less than 5m. So, the total buffer width - added to channel top width - is in the range of 10m to 20m. This buffer zone is multi-functional, providing for bank stability, access for maintenance and recreational value.

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[1] As peak flows at this point is below 3 m^3/s, trunk drainage not required.

[2] Close to 3 m^3/s, hence trunk drainage commences at this point.

4.2. Quality Modelling

STORM has investigated pre and post development water quality by examining three key pollutants associated with stormwater runoff, primarily Total Suspended Solids (TSS), Total Phosphorus (TP) and Total Nitrogen (TN).

Water quality modelling can provide an estimate of pollutant export loads and runoff volumes for a catchment under different land uses. By comparing estimates of export pollutant loads from the existing land uses with proposed land uses such as a subdivision, an indication of the effects of development on receiving waters can be obtained. It is then transparent whether the strategy meets Council's and the SCA's water quality requirements.

The water quality model adopted by STORM is MUSIC (the Model for Urban Stormwater Improvement Conceptualisation) which was developed by the CRC for Catchment Hydrology. MUSIC uses a continuous simulation approach to model water quality and is suitable for simulating catchment areas of up to 100 km^2.

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 (CRCCH 2004).

It is important to note that the model is only a representation of what is actually happening on the ground and is only as accurate as the information and assumptions incorporated into the model. The site being modelled is large and the changes associated with the proposed development are also likely to be large, therefore the variations between pre- and post-development loads shown in this model are expected to be significant.

4.2.1. Development

A pre-development model was built to estimate the pollutant loads from the site in its current land use. Post-development models were then built to compare the pollutant loads generated from the development with different treatment scenarios, specifically:

- No Treatment Controls
- Treatment Controls – Scenario 1: rainwater tanks, grass swales on some roads, end of line treatment
- Treatment Controls – Scenario 2: rainwater tanks, grass swales on all roads, end of line treatment

Comparing the pre-development and post-development pollutant loads demonstrates whether a neutral or beneficial effect on water quality is achievable from the proposed development. Comparing the loads resulting when no treatment controls are provided with the scenario where treatment controls are implemented, allows estimation of the percentage reduction of loads in the post-development scenario.

4.2.2. Inputs

Climate Data

The MUSIC User Manual (CRCCH 2004) suggests that the time-step should not be greater than the time of concentration of the smallest sub-catchment, but consideration should also be given to the smallest detention time of treatment nodes in the system. To accurately model the performance of the treatment nodes, a 6-minute time step was chosen.

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. The table below compares the statistical data from both Melbourne and Goulburn.

Table 9 Comparison of average annual rainfall and evapotranspiration for Goulburn and Melbourne

Source	Average Annual Rainfall (mm/year)	Average Areal Potential Evapotranspiration (mm/year)
Goulburn	672	1200
Melbourne	655	1050

STORM has reviewed the rainfall patterns in both Melbourne and Goulburn and has concluded that they are similar with both locations experiencing frequent light bursts of rainfall and about the same average annual rainfall depth.

Average areal potential evapotranspiration was obtained from the Bureau of Meteorology website. This data is shown in Table 10.

Table 10 Average Areal Potential Evapotranspiration

Month	Average Areal Potential Evapotranspiration (mm/month)	Month	Average Areal Potential Evapotranspiration (mm/month)
January	150	July	40
February	120	August	55
March	105	September	80
April	75	October	120
May	65	November	135
June	40	December	150

(Source: Bureau of Meteorology, 2004)

Information on areas and land use has been ascertained through consultation with Greater Argyle Council

Event Mean Concentrations

MUSIC can be run with the event mean concentration (EMC) data for various urban land uses. It also has default pollutant load parameters, which were determined based on a review of stormwater quality in urban catchments undertaken by Duncan (1999). However, these parameters can be changed to reflect different land uses and associated pollutant loads.

The EMC values used in the MUSIC model for the Clyde Street precinct were taken, as far as possible, from Australian Runoff Quality (ARQ). Refer to Appendix A for details of parameters used.

4.2.3. Configurations

All results and comparisons are made at the receiving node labelled 'Wollondilly River'.

Pre Development

The current landuse throughout the catchment is primarily agricultural including residential establishments on very large lots. The impervious areas include existing road, roof and other structure surfaces. Refer to Appendix E for a graphical representation of the model configuration.

Post Development (No Controls)

Separate nodes were set up to represent:

- Lots: A node for each of roof area and landscaped area. The roof area, which is 100% impervious, is based on an average roof size of 400sqm per lot. The lot landscaping is calculated allowing 300sqm of hard surface area per lot – the 300sqm was selected instead of a %age impervious to allow for the differing lot sizes.
- Roads: Separate nodes to represent the ring road and other roads. The ring road was treated separately because Council advised a preference for the ring road to have a standard kerb – thereby not accommodating swales. Separating the ring road from other roads allowed swale treatment to be applied to these separately – treatment scenario 2 provides swales only on all roads, whereas treatment scenario 1 does not provide swales on the ringroad. Road reserves were assumed to take up 10% of the developable area: this allows for a mix of road with lots fronting only one side (as would be the case where roads are adjacent to waterways) and road with lots fronting both sides. The area allocated to road includes the road and any reserve and is assumed to be 70% impervious.
- Undeveloped: Areas that were not developable included steep areas, lots currently accommodating the water treatment plant and a small lot with existing woodland.

Note that the existing impervious area (as calculated for the pre-development scenario) is accommodated in the post-development model in addition to all new impervious areas introduced by roads, roofs and other hard surfaces. This is a conservative approach. Also, for modelling purposes, it is assumed that all the developable area will in fact be developed – given that there are existing dwellings that will require their own curtilage, this assumption is conservative.

The results from this model give an indication of the pollutant loads generated from source nodes representing the proposed development.

Post Development (Rainwater Tanks, Swales, Wetland)

This model has identical sources to the No Treatment Controls model, however, the proposed treatment measures are included:

- Rainwater tanks
- Grassed swales
- Wetland

Rainwater Tanks

Rainwater tanks to service each house (modelled as sedimentation pond nodes to include first flush removal and water use) – based on 20kL rainwater tanks as Council advised this would be the minimum required in the development.

Swales

Grassed swales, 3m wide, included on both sides of the road:

Note that for Treatment Scenario 1 swales were not applied to runoff from the proposed ring road, but only to other roads in the development.

Treatment Scenario 2 provided swales for all road runoff. This would be possible with the use of broken kerb on the ringroad or providing the swale in the median-strip.

The swales will capture runoff from roads plus the non-roof areas of the lot. The overflow from raintanks may not be conveyed within the swale, as the swales will be less effective in reducing total pollutant loads.

Wetland or Sand Filter

Wetland at the bottom of the Western Creek sub-catchment. Note that the wetland has a surface area of 3,000m^2. Given the catchment above the wetland is 150Ha, generally the surface area of the wetland would be 30,000m^2 to treat all catchment runoff. As the model indicated that a smaller wetland was sufficient for pollutant removal, it is essential that the wetland be positioned off-line: otherwise it will not have ample opportunity to treat low flows.

It is also important to note that although a wetland has been included (as Council indicated a preference for this treatment device to compensate for the proposed ring road runoff not receiving treatment) in MUSIC for the purposes of determining pollutant loads retained, a water balance for the wetland has not been undertaken. Given the Goulburn climate and lack of base flow on the site, a water balance may show that the wetland dries out, or has very low water levels for extended periods: This would be unsightly and may compromise wetland function. Also, with the long winter that is experienced in Goulburn, the plants will be in senescence for extended periods.

An alternative to the wetland would be a sand filter. It is installed below surface with a surcharge basin on top: this area could be multifunctional as a recreation reserve. As a general rule, a sand filter would require about half the land area of the wetland.

The strategy recommends a sand filter instead of a wetland to provide the end of line treatment required. Modelling of the sand filter has not been undertaken in MUSIC, so the size for the sand filter has yet to be determined. When the sand filter is sized, it must provide at least the same removal efficiency as the wetland that was assumed in STORM's MUSIC model.

4.2.4. Results

Following are the results for all three modelled scenarios. The total pollutant loads from the development in each scenario are expressed in kilograms per year. The reduction rate is expressed as a percentage and compares the resulting pollution where treatment measures are provided versus a situation where no treatment is provided (ie. comparing the post-development no controls with post-development with treatment).

Table 11 Total Pollutant Loads and Reductions

Parameter	Pre-Development (kg/yr)	Post-Development No Treatment	Council's SMP Targets	Post-Development Results With Treatment Scenario 1		Post-Development Results With Treatment Scenario 2	
		(kg/yr)	(Reduction)	(kg/yr)	(Reduction)	(kg/yr)	(Reduction)
TSS	19,700	37,500	80% coarse 50% fine	6,380	83% Total	3,680	90%
TP	60	101	45%	36	64%	33.8	67%
TN	463	801	45%	461	42%	443	45%

Neutral or Beneficial Effect

In both treatment scenarios, the post-development pollutant loads are less than pre-development pollutant loads for all parameters (TSS, TP and TN). Therefore, it is reasonable to conclude that the development can meet the neutral or beneficial effect requirements with implementation of appropriate treatment measures.

Council's SMP

Treatment Scenario 1 fell short of the TN target set in Council's SMP, so Treatment Scenario 2 was developed to determine additional treatment required for the target to be met. As the results above demonstrate, the added treatment provided by swales along the ring roads enables the reduction targets to be achieved.

Table 12 Summary of Results:

Scenario	Meets Neutral or Beneficial Effect?	Achieves Quantitative Targets Set in Council's SMP
No Treatment	No	No
Treatment Scenario 1	Yes	Yes for TP ad TSS, Falls short on TN
Treatment Scenario 2	Yes	Yes

5. COSTS

Cost estimates are based on creek remediation, provision of trunk drainage and construction of a sand filter as described in this report.

The following is NOT included in the cost estimate:

- Culvert augmentation if required.
- Works to rectify current erosion problems along Clinton Street: note that we are recommending provision of trunk drainage in the area of catchment above Clinton Street to convey flows across Clinton Street and into the Western Waterway. Our costs for trunk drainage allow for this, but as mentioned above, do not provide for augmentation of culvert or other road crossing if required.
- Swales along roads (to be provided by developer).
- Any treatment along the ring road servicing the development area.
- Rainwater tanks.
- Council propose that trunk drainage reserves be multifunctional. Our costs for trunk drainage only allow for earthworks and vegetation – the do not include provision of other infrastructure, such as footpaths, along these reserves.

If Council wish to adopt the recommendation to provide swales along the ring road, this will result in additional cost.

Table 13 - WSUD Strategy Costs

Item		Cost
Provision of Trunk Drainage	Earthworks (78,200 m^3 at $10/$m^3$)	$782,000
	Vegetation (139,480 m^2 at $15/$m^2$)	$2,092,200
Creek Remediation	Structures	$92,000
	Revegetation (18,000 m^2 at $15/$m^2$)	$270,000
Water Quality	Sand Filter[3]	$300,000
TOTAL		$3,536,200

Notes:

1. Vegetation and revegetation is estimated at a cost of $15 per square metre. Vegetation and revegetation costs are a significant component of the total: any fluctuation in the rate for this has a significant impact on the costs.

[3] Note: Wetland cost estimated includes construction cost only (earthworks, control structures and vegetation). For the purpose of determining developer contributions under Section 94 it would be appropriate to capitalise the cost of wetland maintenance. Wetland maintenance is estimated at $15,000 for the first year, $10,000 every year thereafter.

2. The MUSIC model was based on use of a wetland, not a sand filter. This cost is approximate only and is based on the general rule that sand filters cost twice as much as wetlands to provide the same level of treatment. The size and cost of the sand filter can only be determined by modelling and design.

6. RECOMMENDED STRATEGY

6.1. Source Controls

6.1.1. Raintanks

It is recommended that a 20 kL tank be adopted as the minimum tank size. It is recommended that the water from the rainwater tank is used for laundry supply, external house uses, hot water supply and toilet flushing. Drinking of rainwater is not recommended. Encouraging but not enforcing the use of first flush water diversion devices (which bypass the first 0.5 mm of rainfall) is also recommended. In addition to this, the rainwater tank is to be topped up from the mains water supply to maintain the supply to the house during dry periods with a mains water bypass direct to the dwelling in the event of power failure.

6.1.2. Detention

Detention should be provided at the lot level on properties in the Eastern Waterway sub-catchment to ensure the peak flows do not increase in the waterway, as this may impact on creek stability. Previous experience in the Goulburn area – specifically, the Carr Street development – demonstrated that raintanks and grassed swales provided sufficient detention to match pre-development peak flows up to the 5 year ARI event. To realise this benefit, the raintanks need to be optimised for onsite detention. Modelling would be necessary to confirm if this is the case and determine if the extent of any additional detention if required.

If additional detention is necessary, this could be accommodated at the lot level using landscaping practices such as depressed areas to collect and detain overflow from raintanks. Further detention could be provided, if necessary, by communal detention.

6.2. Conveyance Controls

Essential: It is recommended that grassed swales are adopted to treat road runoff. As a minimum, swales are necessary on minor roads (to meet neutral or beneficial effect).

Desirable: It is understood that Council desire the ring road to be a kerbed road due to the heavy traffic loads expected (buses servicing the area). Traditional kerbing does not accommodate swales, however there are alternatives such as broken kerbing that will allow Council's traffic management objectives to be met as well as allow for the provision of swales along the ring road. Swales would need to be provided along the ring road to meet the SMP reduction target.

6.3. End of Line Controls

A sand filter is recommended on the lower section of the Western Waterway.

6.4. Creek Management

It is recommended that trunk drainage is provided as described in this study.

For those waterways defined as rivers under R&FI, the remediation works described in this study – which include stabilisation and revegetation – should be undertaken using approved techniques.

6.5. Summary

It is recommended that Council, the SCA and DIPNR adopt this report and implement the proposed WSUD plan. The assessment work undertaken by STORM has found that the proposed plan is likely to achieve a minor beneficial effect on the drinking water catchments. This statement is based on the conservative modelling approach adopted by STORM.

7. REFERENCES

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APPENDIX A
MUSIC Modelling Details

Table A1 Source Node - Rainfall Runoff Parameters

MUSIC Soil Parameter	Agricultural Node	Roof	Road & Ringroad	Lot Landscaping	Undeveloped
Percentage Impervious (%)	Av. 3%	100	30	Av. 13%	Av. 12%
Impervious Area Properties:					
Rainfall Threshold (mm/day)	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*
Pervious Area Properties:					
Soil Storage Capacity (mm)	150	10	150	150	
Initial Storage (% of capacity)	25	0	25	25	
Field Capacity (mm)	50	0	50	50	
Infiltration Capacity Coefficient - a	50	50	50	50	
Infiltration Capacity Exponent - b	2	2	2	2	2
Groundwater Properties:					
Initial Depth	50	0	50	50	50
Daily Recharge Rate (%)	0.65	0	0.65	0.65	0.65
Daily Baseflow Rate (%)	0.85	0	0.85	0.85	0.85
Daily Deep Seepage Rate	0	0	0	0	0

Table A2 Source Node – Derivation of Event Mean Concentrations

The EMC values used in the MUSIC model for the Clyde Street precinct were taken, as far as possible, from Australian Runoff Quality (ARQ). The table below describes the derivation of EMC values:

Node Type in Clyde Street Model	Based on ARQ Landuse Type	Stormflow	Baseflow	EMC
Agricultural (Pre-development)	Agricultural	Used default values in MUSIC as these closely matched ARQ values.		= Stormflow + Baseflow
Undeveloped	Agricultural	As above.		
Lot Landscaping	Residential	ARQ values.	Derived from relationship between stormflow and baseflow values of 'All Urban' Landuse type in ARQ.	= Stormflow + Baseflow
Road and Ringroad	All Roads	ARQ values.		= Stormflow + Baseflow
				= Stormflow + Baseflow
Roof	All Roofs	ARQ values for TSS and TP. As ARQ does not have values for TP, referred to figures provided by Monash University.		= Stormflow + Baseflow

Table A3 Source Node - Event Mean Concentrations

Node	Parameter	EMC (mg/L)	Base Flow (33%)		Storm Flow (67%)	
			Base	Log Base	Storm	Log Storm
Agricultural	TSS	225	25.1	1.40	200	2.3
	TP	0.669	0.132	-0.880	0.537	-0.27
	TN	5.08	1.19	0.074	3.89	0.59
Lot Landscaping	TSS	140	10.4	1.017	130	2.114
	TP	0.582	0.182	-0.740	0.400	-0.398
	TN	4.99	2.19	0.340	2.80	0.447
Ringroad	TSS	210	15.5	1.190	195	2.29
	TP	0.365	0.115	-0.940	0.250	-0.602
	TN	3.76	1.66	0.220	2.10	0.322
Road	TSS	50.5	15.5	1.190	35.0	1.544
	TP	0.255	0.115	-0.940	0.14	-0.854

	TN	2.66	1.66	0.220	1.00	0
Roof	TSS	202	2.82	0.450	200	2.30
	TP	0.600	0.06	-1.200	0.54	-0.270
	TN	4.68	0.79	-0.100	3.89	0.590
Undeveloped	TSS	225	25.1	1.40	200	2.30
	TP	0.67	0.132	-0.880	0.537	-0.270
	TN	5.08	1.19	0.074	3.89	0.590

TSS – Total Suspended Solids

TP – Total Phosphorus

TN – Total Nitrogen

Table A4 Source Node - Areas

Scenario	Nodes	Area (Ha)
Pre Development	Agricultural	213
Post Development	Lot Landscaping	157.6
	Ringroad	6.56
	Road	13.2
	Roof	20.1
	Undeveloped	15.5

Table A5 Treatment Node Parameters

Parameter	
Grassed Swales – Scenario 1	
Low Flow Bypass (m^3/s)	0
Total Length* (m)	11,395
Base Width (m)	1
Top Width (m)	3
Bed slope	0.03
Depth (m)	0.25
Vegetation Height (m)	0.15
Seepage Loss (mm/hr)	3.6
Rainwater Tanks	
No. of Tanks	1 x 20kL tank per lot
Surface Area (m^2)	5107
Permanent Volume (m^3)	10,035
Seepage Loss (mm/hr)	0
Evaporative Loss as % of PET	0
Equivalent Pipe Diameter (mm)	10,232
Overflow weir width (m)	100
Reuse (ML/yr)	160
Wetland	
Low Flow Bypass (m^3/s)	0
High Flow Bypass (m^3/s)	100
Inlet Pond Volume (m^3)	750
Pond Surface Area (m^2)	3000
Extended detention depth (m)	1
Permanent Pool Volume (m^3)	1500
Proportion Vegetated	0.5
Equivalent Pipe Diameter (mm)	200
Overflow Weir Width (m)	10

* Total length includes swales on both sides of the road

Figure A1 Pre-Development Model Layout

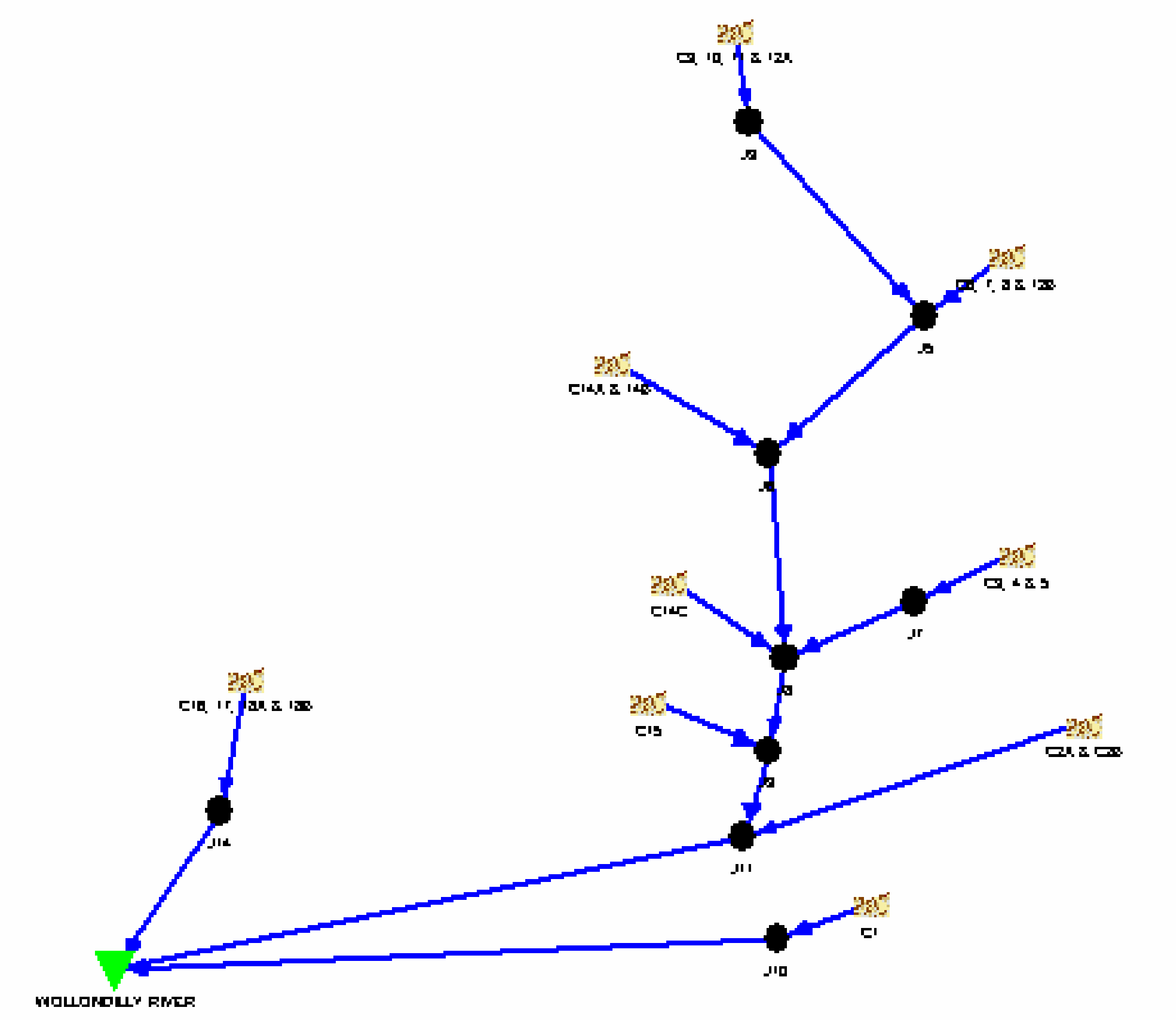
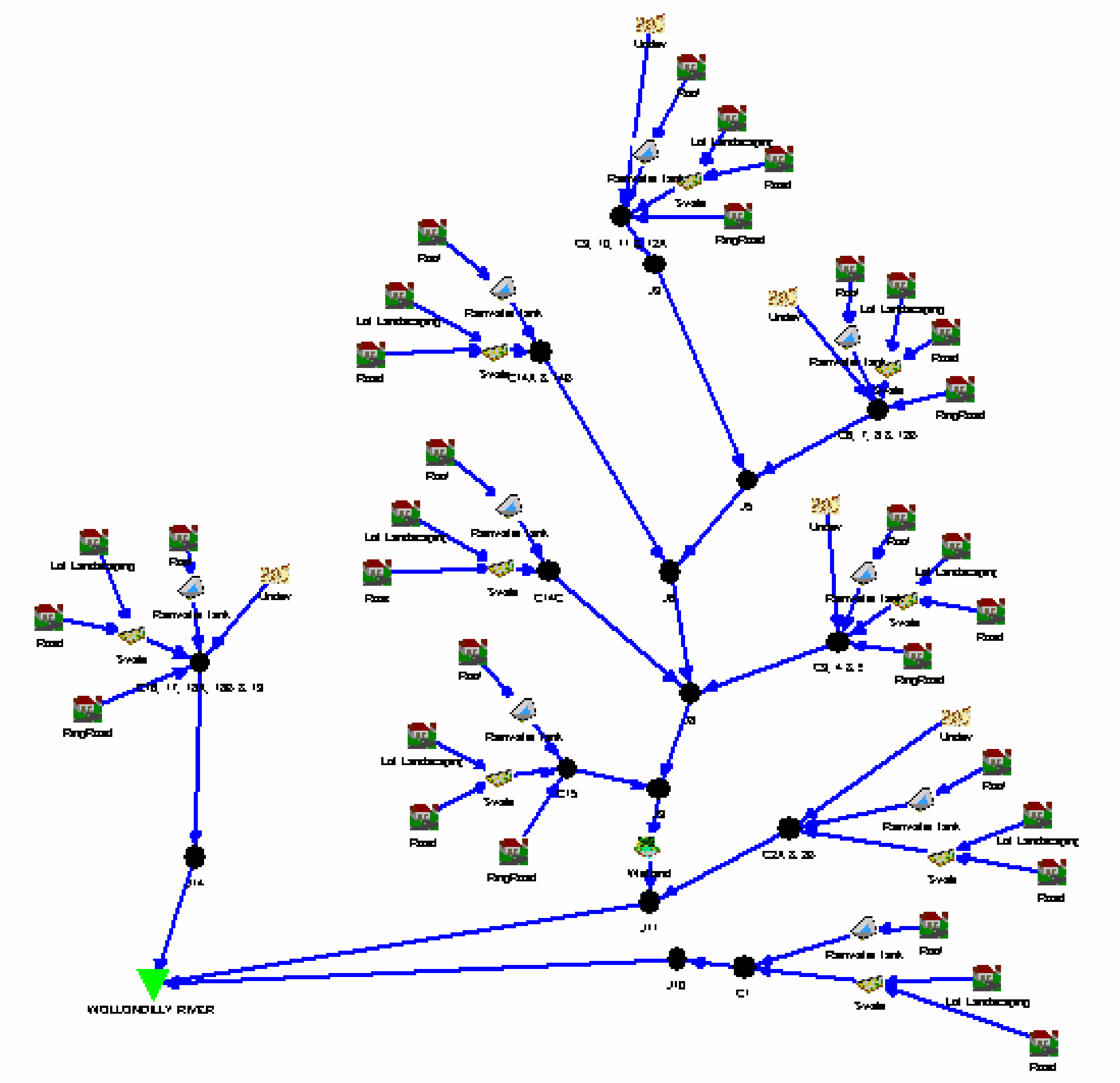


Figure A2 Post-Development Treatment Controls Model Layout



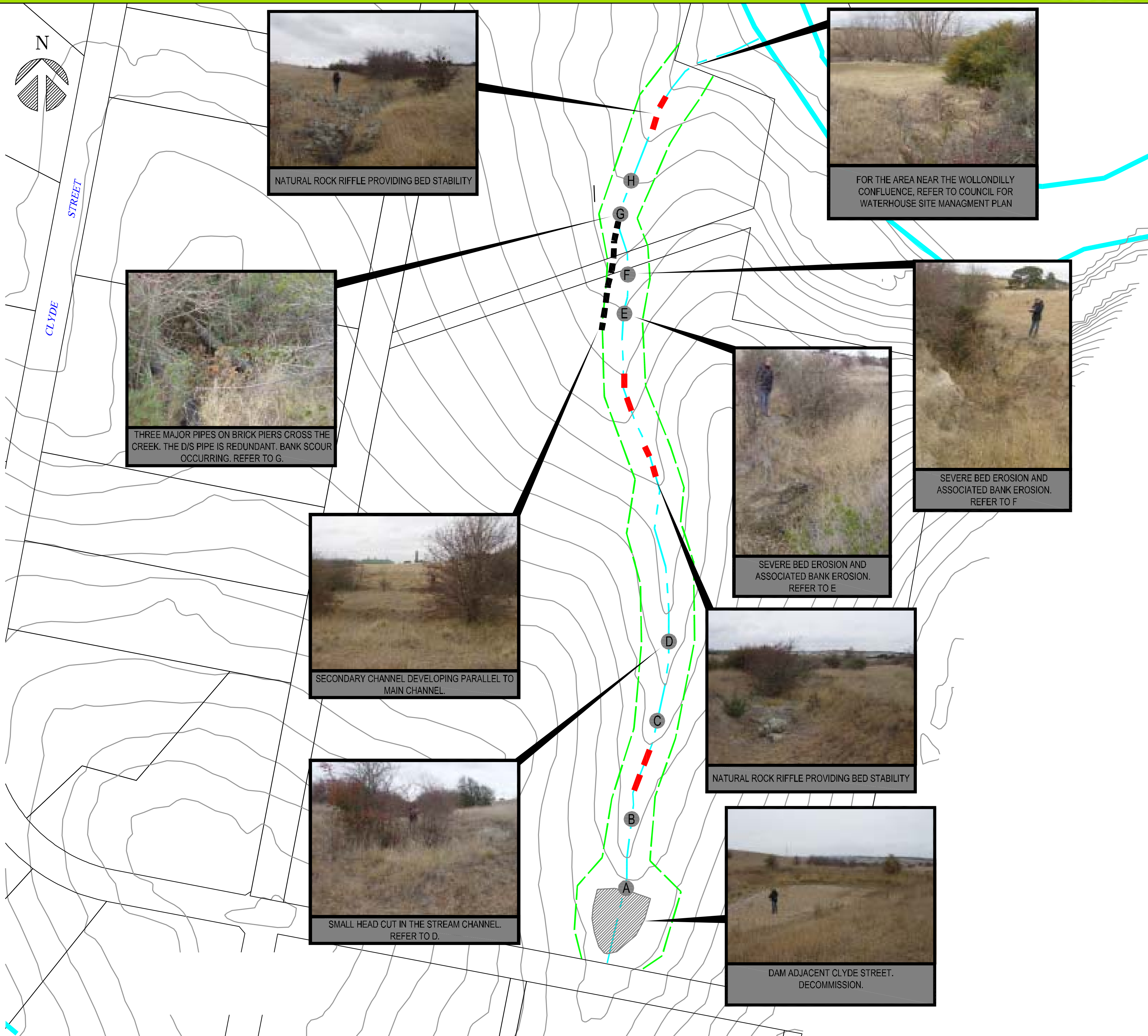
APPENDIX B
Strategy Plans

STORM_CONSULTING SUITE 3, 6 WEST STREET PYMBLE NSW, AUSTRALIA 2073 PH: +61 2 9499 4333 FAX: +61 2 9499 4311 www.stormconsulting.com.au

POINT	PROPOSED STRUCTURE	NOTES
A	DECOMMISSION EXISTING DAM	N.A.
B	RIFFLE	REFER TO PHOTO 1 ON L364/P02
C	SCHUBERGER SILL	REFER TO PHOTO 2 ON L364/P02
D	SCHUBERGER SILL	REFER TO PHOTO 2 ON L364/P02
E	RIFFLE	REFER TO PHOTO 1 ON L364/P02
F	SCHUBERGER SILL	REFER TO PHOTO 2 ON L364/P02
G	BANK REVETMENT	REFER TO PHOTO 3 ON L364/P02
H	SCHUBERGER SILL	REFER TO PHOTO 2 ON L364/P02

LEGEND

- H — STREAMWORKS REQUIRED. SEE TABLE ABOVE FOR DETAILS.
- EXISTING DAM
- SECONDARY CHANNEL
- CREEK CENTRELINE
- 10m REVEGETATION BOUNDARIES (SEE DIAGRAM 1 ON L364/P02)
- NATURAL BEDROCK CONTROL



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ISSUE	ZONE	REVISION	BY	CKD	DATE
A		FOR COMMENT	DR	RW	28/6/04
B		RE-ISSUED	TC	LSF	5/08/04

COORD. ORIGIN: ISG | SCALE: 1:1250 | DATUM: AHD | DATE: JUNE 2004 | DRAWN: DR | DESIGNED: RW | CHECKED: RW

CLIENT: GREATER ARGYLE COUNCIL 184-194 BOURKE STREET CIVIC CENTRE GOULBURN NSW 2580

CLYDE STREET PRECINCT WSUD

RECOMMENDED CREEK REMEDIATION

DRAWING: L364/P01 SHEET: 1 OF 3 A1

PHOTO 1: EXAMPLE OF RIFFLE STRUCTURES

PHOTO 2: EXAMPLE OF SCHUBERGER SILL

PHOTO 3: EXAMPLE OF BANK REVETMENT

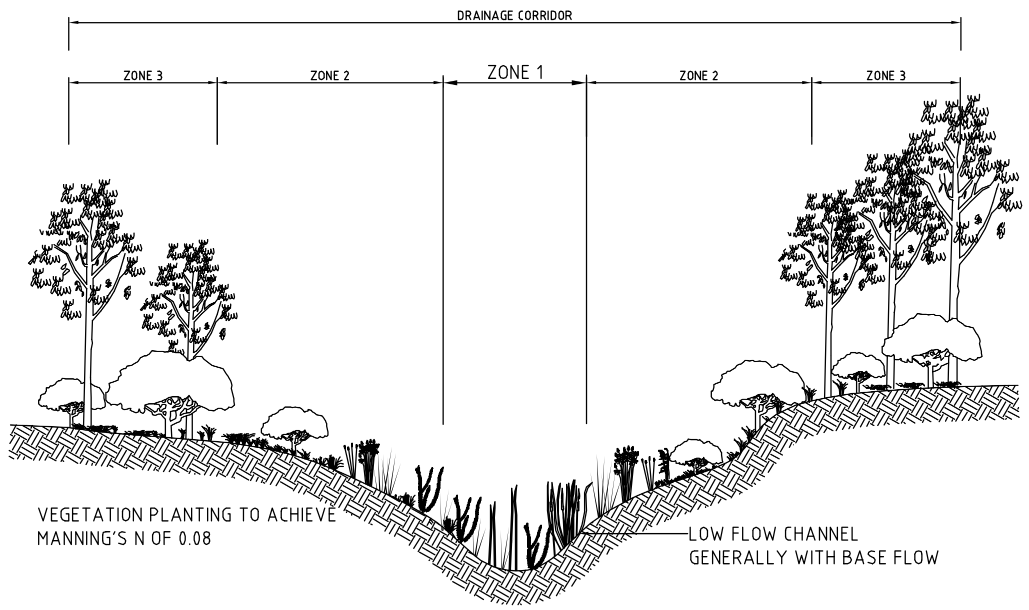

DIAGRAM 1: TYPICAL STREAM PLANTING ZONATION - REVEGETATION AREA

NOT TO SCALE

STORM_CONSULTING

ISSUE	ZONE	REVISION	BY	CKD	DATE	ISSUE	ZONE	REVISION	BY	CKD	DATE
A		FOR COMMENT	DR	LSF	7/9/04						
B		RE-ISSUED	TC	LSF	5/08/04						

COORD. ORIGIN: ISG		SCALE: 1:5000	CLIENT: GREATER ARGYLE COUNCIL 184-194 BOURKE STEET CIVIC CENTRE GOULBURN NSW 2580	CLYDE STREET PRECINCT WSUD RECOMMENDED CREEK REMEDIATION	DRAWING: L364/P02
DATUM: AHD		DATE: JULY 2004			SHEET: 2 OF 3
DRAWN: TC	DESIGNED: RW	CHECKED: LSF			A1

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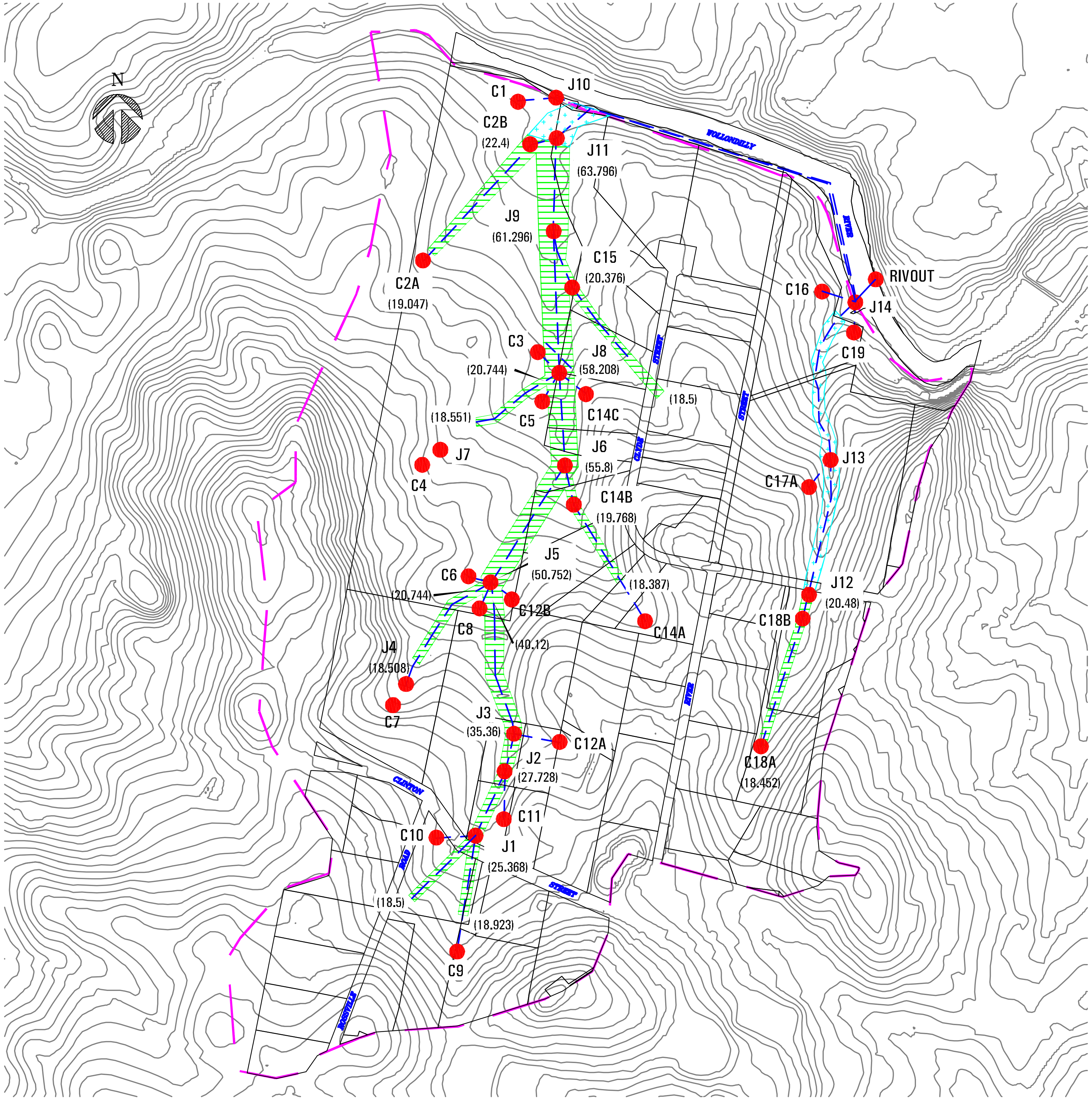

LEGEND

AREA 10m FROM TOP OF BANK IDENTIFIED BY DIPNR FOR ESTABLISHMENT OF RIPARIAN CORRIDOR

AREA REQUIRED FOR TRUNK DRAINAGE

CLYDE STREET DCP BOUNDARY.

NODE (FROM RAFTS MODEL)

J12 NODE LABEL (FROM RAFTS MODEL)

(20.48) TRUNK DRAINAGE WIDTH (m)

NOTE

1) 2m CONTOURS SHOWN

2) DIPNR: DEPARTMENT OF INFRASTRUCTURE, PLANNING, & NATURAL RESOURCES

3) DRAINAGE CORRIDOR LOCATIONS SHOWN ARE APPROXIMATE ONLY AND MUST BE CONFIRMED ON SITE. PROVIDE DRAINAGE LENGTHS DO NOT INCREASE (WOULD REQUIRE WIDER DRAIN)

STORM_CONSULTING

ISSUE	ZONE	REVISION	BY	CKD	DATE	ISSUE	ZONE	REVISION	BY	CKD	DATE
A		FOR COMMENT	NL	LSF	7/9/04						
B		RE-ISSUE	TC	LSF	5/08/04						

COORD. ORIGIN: ISG	SCALE: 1:5000
DATUM: AHD	DATE: JULY 2004
DRAWN: TC DESIGNED: NL	CHECKED: LSF

CLIENT: GREATER ARGYLE COUNCIL 184-194 BOURKE STREET CIVIC CENTRE GOULBURN NSW 2580

CLYDE STREET PRECINCT WSUD

TRUNK DRAINAGE

DRAWING: L364/P03

SHEET: 3 OF 3

A1