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EC East Subcatchment Management Plan Technical Report Volume 1 - Management Study

Submitted to:
Marrickville Council
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REPORT

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Executive Summary

Marrickville Council has embarked on a catchment management process that is based on the concept of collaborative planning and the holistic approach of total water cycle management. The Council aims to develop a water sensitive city where the community actively participates in future development and renewal to achieve a water sensitive urban environment.

After undertaking a research project with Monash University, the Council has prepared a document titled ‘Subcatchment Planning for Sustainable Water Management – Guidelines for Councils’, which spells out in detail the steps required to achieve sustainable water management at a local level. These guidelines provide the basis for preparing the subcatchment management plan.

Based on these guidelines, the Marrickville Local Government Area (LGA) has been subdivided into 22 subcatchments for developing local subcatchment management plans. Eastern Channel (EC) East Subcatchment is one of these local areas for which Marrickville Council has commissioned Golder Associates to prepare a management plan.

Subcatchment Description

The EC East subcatchment area is a typical urban catchment with an approximate area of 131 ha. The primary landuse within the catchment is residential with some commercial and industrial. Development in the residential areas is characterised by high-density terrace housing with very few free-standing homes. There are also high-density villa-style developments in the subcatchment. There are several educational institutions in the area including a TAFE institute.

A variety of businesses operate along Victoria Road, Edgeware Road, Enmore Road and Princes Highway. A major shopping mall, the Marrickville Metro, is also located in the subcatchment. There are also several light to medium industrial establishments in the south-west of the subcatchment. In addition, several places of worship are also present within the subcatchment. The subcatchment is dotted with several open spaces, parks and playgrounds

Planning Approach

A planning approach was developed that invited participation from a vast array of stakeholders related to the catchment. These stakeholders included the local community, various government departments, local schools and the Council staff from the Integrated Urban Water Management (IUWM) Group that has been set-up within Council for holistic water planning purposes.

A number of vision sessions and planning forums were held with the stakeholders where goals were defined for sustainable water management in the EC East subcatchment. This stakeholder consultation was undertaken by the Council in association with the Cooks River Sustainability Initiative (CRSI) and facilitated by Golder Associates.

Subcatchment Physical Profile

One of the tasks for undertaking planning for the EC East subcatchment was to define the physical profile of the subcatchment. In this regard, a water balance for the catchment was established to quantify the water cycle in the subcatchment. The inflow into the subcatchment includes potable water from Sydney Water and rainfall whereas outflow from the subcatchment include stormwater runoff and wastewater discharge. There are also losses within the subcatchment that include leakage from potable supply, infiltration and evapotranspiration and consumption by the residents.

A summary of the water balance is presented in the following table:

EC East Subcatchment Water Balance

Component	Volume (kL/year)
	Inflow to Subcatchment
Rainfall	1,460,000
Potable water imported to the subcatchment	661,000
Component	**Outflow to Subcatchment**
Potable water leakage	49,000
Consumed by residents	9,000
Garden and open space watering	27,000
Infiltration and evapotranspiration	492,000
Stormwater runoff	968,000
Discharge to sewer	576,000
Volume of sewage reaching ocean	490,000

As part of physical profiling, a detailed stormwater analysis of the subcatchment was also undertaken. This analysis helped in establishing the existing overland flow behaviour in the subcatchment for various design rainfall events. Hydrologic and hydraulic modelling was undertaken to achieve this objective. Damages to the properties were also estimated for various design flood events.

The results of the stormwater analysis confirmed the drainage hotspots in the subcatchment. These locations include the intersection of May St and Campbell St, intersection of Railway Parade and Edgeware Rd, intersection of Alice St and Edgeware Rd and flooding of Edinburgh Rd and Murray St near the industrial area.

A water quality model was also developed for the subcatchment as part of physical profiling task. Estimates of major urban pollutants such as suspended solids, common nutrients (phosphorus and nitrogen) and gross pollutants were established for the subcatchment. The modelling results are presented in the following table:

Stormwater quality modelling results for the EC East Subcatchment

Attribute	Land Use							
	Industrial	Commercial	Residential		Roads	Open space	Special purposes	Total
			2c	2a, 2b				
Area (ha)	**15**	**7**	**1**	**57**	**31**	**6**	**13**	**131**
Total Suspended Solids (kg/yr)	24,300	10,300	2,060	78,400	124,000	1,710	8,020	248,790
Total Phosphorus (kg/yr)	39	17	3	127	151	5	19	361
Total Nitrogen (kg/yr)	289	122	25	929	618	38	144	2,165

Attribute	Land Use							
	Industrial	Commercial	Residential		Roads	Open space	Special purposes	Total
			2c	2a, 2b				
Gross Pollutants (kg/yr)	3,570	1,510	315	12,200	7,040	339	1,930	26,904

Subcatchment Management Options

Based on the outcome of the consultation process and further discussions with Council's IUWM working group, a list of options were identified to manage water in the subcatchment. These options included water reuse options to minimise the potable water demand in the subcatchment and stormwater quality improvement options to minimise transfer of pollutants to the receiving waters of Cooks River. Options for managing stormwater flooding were also identified. The options for stormwater quality improvement and water reuse are listed below:

(WR stands for 'Water Reuse' and SWQ stands for 'Stormwater Quality' in the following text)

- SWQ1 + WR: Rainwater tanks to allow substitution of stormwater for non potable water needs within individual and multi unit dwellings.
- SWQ2: A bioretention basin in Simpson Park to improve the quality of stormwater exiting the surrounding 10.3 ha catchment.
- SWQ3: 1A bioretention basin in TAFE Park to improve the quality of stormwater exiting the surrounding 3.8 ha catchment.
- SWQ4: A bioretention swale along the southern side of Pemell St, Newtown to improve the quality of stormwater exiting the surrounding 1.18 ha catchment.
- SWQ5: A bioretention swale along the northern side of Goodsell St, St Peters to improve the quality of stormwater exiting the surrounding 1.23 ha catchment.
- SWQ6: Rain Gardens on redeveloping sites in the St Peters triangle area as part of the DCP for the locality.
- SWQ7 + WR: Stormwater collection tanks in Camdenville Park to collect stormwater and supply it as irrigation water to Camdenville Park.
- SWQ8 + WR: Stormwater collection tanks in Camdenville Park to collect runoff from nearby factory roofs to supply irrigation water for Camdenville Park.
- SWQ9 + WR: Use of Sealed Wetland in Camdenville Basin to Treat and Enable Reuse of Catchment Runoff.

The following stormwater management options were identified:

- Option R1 – Pit/pipe infrastructure at Railway Parade and Edgeware Rd intersection.
- Option R2 – Pits/pipes infrastructure at Alice St and Edgeware Rd intersection.
- Option R3 – Detention basin in Simpson Park.
- Option R4 – Detention basin in TAFE Park.
- Option R5 – Pit/pipe infrastructure in Sarah St .

- Option R6 – Overland flowpath in Sloane St.
- Option R7 – Pit/pipe infrastructure in Goodsell St, May Lane and Council St.
- Option R8 – Increase capacity of Sydney Water Corporation Trunk Drainage downstream of Alice St and Edgeware Road intersection to the Eastern Channel.
- Option R9 – Optimisation of Drainage at Corner of Campbell St and May St.
- Option R10 – Expansion of Camdenville Oval Detention Basin.

Hydraulic and water quality modelling was undertaken to assess the performance of these options.

In addition the following property modification and flood emergency response modifications were considered for flood risk management purposes:

Property modification measures

- Effective land use planning and development controls;
- House raising;
- Voluntary purchase of flood affected properties; and
- Flood proofing of buildings.

Emergency response modification measures

- Provision of flood warning systems
- Update of Local Flood Plan (a sub-plan of DISPLAN)
- Keeping SES up-to-date with the flood intelligence
- Public awareness and education
- Flood markers at flooding 'hotspots'

Option Assessment

The water management options identified in this study were evaluated using the Quadruple Bottom Line assessment involving economic, social, governance and environmental considerations. A number of criteria related to the three considerations were identified for option assessment purposes. The adopted criteria were varied in nature and could not be quantified by a single measure. A multi-criteria analysis was therefore adopted to undertake qualitative as well as quantitative assessment to develop a single platform for option assessment.

In addition treatment and water reuse efficiencies for various stormwater quality improvement and water reuse options were used in the option assessment.

Recommended Options

Based on the above considerations, a preliminary recommendation is provided for possible implementation of the following options in the EC East subcatchment.

- Update Council's OSD Policy
- Update Local Flood Plan in association with SES
- Public awareness campaign in association with SES

- Provision of flood markers
- Flood data collection
- Bioretention basin at Simpson Park
- Drainage upgrade at corner of Campbell St and May St
- Irrigation of Camdenville Oval using street runoff
- Rain gardens at redevelopment sites

Further options were also identified that may also be suitable for implementation. These options include:

- Rainwater tanks
- Drainage upgrade at Alice Street and Edgeware Road intersection
- Bioretention swale in Goodsell St
- Drainage upgrade for improvement of Railway Parade
- Bioretention swale in Pemell St

Some of the proposed options are expensive to implement. Keeping in view Council's likely constraint in securing funds for these options, a staged implementation of these options has also been proposed.

The above options provide significant benefits in terms of water quality improvement and/or flood management.

The report for the EC East Subcatchment Management Plan is presented in the following two volumes:

- Volume 1 – Management Study
- Volume 2 – Stormwater Drainage Study

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GLOSSARY

(Adopted from Floodplain Development Manual, Department of Environment, Climate Change and Water, NSW)

Annual Exceedence Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded each year; it would occur quite often and would be relatively small. A 1%AEP flood has a low probability of occurrence or being exceeded each year; it would be fairly rare but it would be relatively large.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Creek Rehabilitation	Rehabilitating the natural 'biophysical' (i.e. geomorphic and ecological) functions of the creek.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. e.g. some roads may be designed to be overtopped in the 1 in 1 year or 100%AEP flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood fringe	The remaining area of flood-prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding.
Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.

Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.
Flood planning levels	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. The concept of FPLs supersedes the “Standard flood event” of the first edition of the Manual. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.
Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
High hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.

Integrated survey grid (ISG)	ISG is a global co-ordinate system based on a Transverse Mercator Projection. The globe is divided into a number of zones, with the true origin at the intersection of the Central Meridian and the Equator.
Low hazard	Flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood	The flood calculated to be the maximum that is likely to occur.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Annual Exceedence Probability.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface which defines the ground level of a chosen area.

1.0 INTRODUCTION

Marrickville Council has embarked on a catchment management process that is based on the concept of collaborative planning and the holistic approach of total water cycle management. The Council aims to develop a water sensitive city where the community actively participates in future development and renewal to achieve a water sensitive urban environment. This, however, requires a break from the past practices of a narrow focus on individual water issues in a catchment. It also requires institutional changes to establish political will and a management structure that is conducive to bringing about this change.

A recent report by the International Water Centre (IWC, 2009) has identified that the key issues perceived by Australian water professionals that hinder the evolution of water sensitive cities relate to the institutional, political and economic considerations. Thus, institutional and political reform is paramount in water sensitive evolution of the urban settings.

Since 2002, Marrickville Council has adopted a sustainable urban water management program and adopted the above management principles to develop a catchment management program.

1.1 Objectives

The objective of this study is to prepare a subcatchment management plan for the EC East Subcatchment for sustainable management of the water cycle in the complex urban environment of the subcatchment. This objective is to be achieved through a 'collaborative planning' approach by engaging the community and other stakeholders in the subcatchment. The management plan identifies the issues associated with the urban water cycle and presents a number of options to manage the water cycle effectively. In particular it describes:

- The subcatchment water balance
- Water re-use options in the subcatchment and their impact on the water cycle and subcatchment runoff quality
- Stormwater quality improvement options
- Stormwater flooding management options

The study has produced a management plan that describes various options that can be implemented in the EC East Subcatchment.

The location of the EC East Subcatchment is presented in Figure 1.

2.0 PLANNING APPROACH

2.1 Genesis of the Planning Approach

A research project was undertaken by Marrickville Council in collaboration with University of New South Wales and later Monash University to examine the physical, social and organisational characteristics of three urban catchments within the Marrickville Local Government Area (LGA). The project was titled 'River Life – Sustainable Water Environments' that provided the blue print for Urban Stormwater Integrated Management (USWIM) approach, which is currently being followed by the Council. This approach is based on establishing leadership within the Council, collaboration among Council professionals and extensive stakeholder consultation.

Another significant aspect of the USWIM program is the emphasis on catchment analysis on a small scale such that the local issues are highlighted and addressed effectively by taking into account the values of the local community. Previously, catchment management plans have been developed for large catchment systems, which by and large have been inefficient in bringing about the change that is required to achieve a water sensitive city.

Based on the above consideration, the Marrickville LGA has been subdivided into 22 subcatchments for developing local subcatchment management plans. EC East Subcatchment is one of these catchments and this study details the preparation of the EC

2.2 Planning Approach Details

In view of the collaborative planning approach required for management of the urban water cycle, Marrickville Council has established Integrated Urban Water Management (IUWM) group within the Council. This group has representations from all relevant sections of the Council and brings together the engineering, social, environmental and planning expertise within the Council. The integrated approach adopted by Council is innovative in nature and is a direct result of the new water planning approach adopted by the Council.

The USWIM project also provided the blue print for preparing the document titled 'Subcatchment Planning for Sustainable Water Management – Guidelines for Councils', which spells out in detail the steps required to achieve sustainable water management at a local level. These guidelines provide the basis for preparing the subcatchment management plan. The ten steps that have been proposed in these guidelines for undertaking sustainable water planning are:

1) Establish in-house commitment to the sustainable water planning process
2) Review project budget and organisational capacity – assess budget/resource requirements and shortfalls
3) Assemble a multi-disciplinary team
4) Identify the physical planning units, for example, single subcatchments, multiple subcatchments, or neighbourhoods
5) Undertake context mapping:
    a. Social profiling
    b. Organisational profiling – in house and external agencies
    c. Physical profiling
6) Determine the water budget
7) Engage the community – envisioning, subcatchment planning
8) Prepare subcatchment management plans – integrate Action Plan and Masterplan from visioning, goal setting, modelling and scenario
9) Implement solutions
10) Communicate outcomes

Marrickville Council has undertaken the first four steps and identified a number of subcatchments in the LGA for planning purposes. For the EC East subcatchment, steps five to eight have been completed. This study provides the outcomes from these steps and presents a management plan for the EC East Subcatchment.

2.2.1 Current Development Control Plans

There are several Development Control Plans (DCP) related to water management that are relevant to the EC East Subcatchment:

Energy Smart Water Wise (DCP 32)

Provides water efficient design guidelines for new building works, ranging from home renovation to larger residential developments. Also applies to commercial, retail and industrial buildings and other non-residential developments. Amended 5 November 2001.

Stormwater and On Site Detention Code

Provides advice on Council's policy on on-site detention, outlines design standard for stormwater infrastructure as well as requirements for construction and permanent sediment control measures. Adopted 16 February 1999.

Cooks River Floodplain (DCP 30)

Provides Councils' definition of flood liable land within the Cooks River catchment and outlines the Council's draft flooding code. Adopted 1 October 1998. EC East Subcatchment lies outside of the Cooks River Floodplain.

2.3 Vision, Goals and Actions

The collaborative planning approach offered the opportunity to all the subcatchment stakeholders to provide input to the future planning for water management. To facilitate this process, the Council along with Cooks River Sustainability Initiative (CRSI) devised a consultation process that captured the local values and aspirations of the community in consultation with the government stakeholders for effective planning of the subcatchment.

Under this approach a vision for the subcatchment was developed that captured the aspirations of the community. Based on this vision, the goals for achieving a sustainable water management in the catchment were identified. The goals were then used to define actions that were required to achieve the desired objectives. These actions along with other considerations provided the basis for defining the EC East Subcatchment management options.

2.4 Stakeholder Engagement

One of the key elements of the integrated planning approach is effective involvement with the key stakeholders in the subcatchment. Essentially, collaborative planning involves the subcatchment community and government, non-government and private stakeholders working together in a collaborative and co-operative environment to create a vision, and develop realistic goals and actions to achieve the vision. The outcomes of a collaborative planning approach include greater commitment, transparency and accountability in making decisions and implementing actions.

Community engagement for the EC East Subcatchment was undertaken between June 2007 and May 2009 by Marrickville Council officers, CRSI staff and the consultant team. Three key stages in the community consultation undertaken for the subcatchment planning were community water surveys, vision sessions and planning forums. The Community Water Survey was undertaken in June 2008 by Marrickville Council and CRSI.

Consultation for the subcatchment planning mainly involved residents and other stakeholders including school students and principals, businesses and industries in the subcatchment. The vision sessions involved the community and schools, whereas planning forums also included the rest of the stakeholders.

Prior to this consultation process, a letter was sent to the community inviting them to participate in the vision sessions and the planning forums. An information booklet was also produced to provide the background information on the EC East Subcatchment and the planning process. A copy of the booklet was made available on Council's website for download by the community.

2.5 Community Water Survey

A water survey was undertaken by the Council to determine community attitude towards water management in the EC East subcatchment. Marrickville Council in association with CRSI mailed a questionnaire to 3,274 households in the subcatchment in June 2008. The community provided a healthy response with 635 returned questionnaires, representing 19% of households in the subcatchment.

In the majority of the subcatchment the residents (75%) show a good level of knowledge related to rainfall and runoff in the area. The vast majority of respondents (81%) stated that they used water saving devices in their houses. The survey respondents are highly receptive to using filtered rainwater and treated recycled water, particularly for non-contact uses such as watering the garden, flushing toilets, and washing the car.

Details of the Community Water Survey are presented in Appendix A.

2.6 Community Flood Survey

A community questionnaire was distributed to EC East Subcatchment residents in February 2009 seeking information specifically about stormwater ponding and overland flooding within the subcatchment.

Details of the Community Flood Survey are presented in Volume 2, Appendix A.

2.7 Visioning Sessions

The key objective of the vision sessions was to set a future vision for the EC East Subcatchment to 2050. Five vision sessions were held, involving three adult groups (18 people) and two primary school classes (49 children).

2.7.1 Adult Groups

The vision sessions involving 18 adult residents were held on 24 March, 2 April, and 12 May 2009. The participants contributed ideas to develop a vision related to the water cycle in the subcatchment. They were asked to think ahead to the year 2050 and their vision for water use and management in that year. The ideas emanating from this exercise were then collated into a draft vision and goals for further discussion in the planning forums.

2.7.2 Children Groups

Two school groups were consulted regarding their vision for water in the EC East Subcatchment as follows:

- Years 5/6 at St Peters Public School on 6 April 2009
- Years 5/6 at Camdenville Public School on 8 April.

The children were invited to think about the water cycle in the subcatchment and asked about where water comes from and where it goes after use, and how they use water. The children thought ahead to the future and came up with ideas for sustainable water use and management, which they drew (see Figure 1), wrote or talked about.

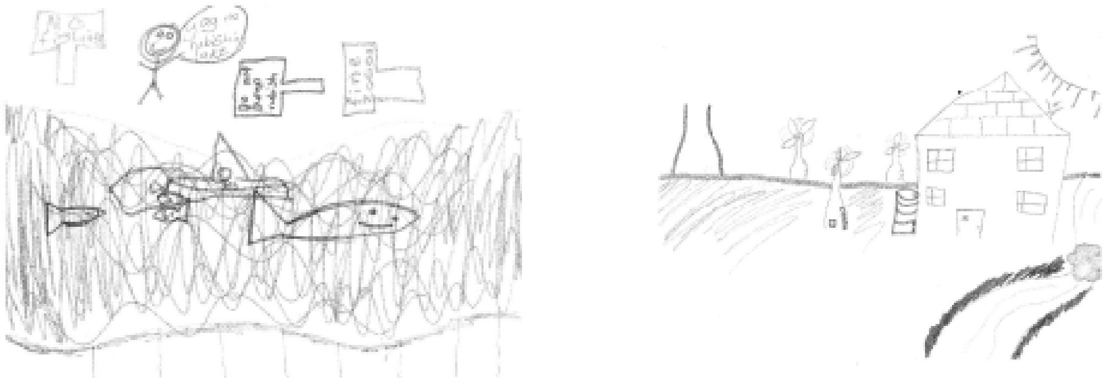

Figure 1: Examples of water drawings from local school children

Further details of the vision sessions are provided in APPENDIX A.

2.8 Planning Forums

Two planning forums were held at Camdenville Public School on Wednesday 20 May 2009 (Planning Forum 1) and Wednesday 27 May 2009 (Planning Forum 2). The purpose of planning forums was to identify goals for undertaking sustainable water management in the EC East subcatchment. These forums were also used to refine the vision for the subcatchment.

Members of the community and various stakeholders were invited to participate in these forums. Community members involved in the previous vision sessions, a Marrickville Councillor, the principals of St Peters and Camdenville Public schools, Centre Manager of Marrickville Metro, and a representative from Sydney Water attended the planning forums.

The goals for the 2050 vision were set during the planning forums. In addition, interim goals for 2019 (ten years into the future) were also set during these forums.

APPENDIX A provides further details of the planning forums.

2.9 Vision and Draft Goals

Table 1 below sets out the vision and the goals for 2050 and 2019 for the EC East subcatchment developed through community consultation**.**

Table 1: Vision and Draft Goals for 2050 and 2019 for the EC East Subcatchment

Vision		**2050 Goals**	**2019 Interim Goals**
In 2050 we are happy, recognise our dependence on natural systems and we value water. We have a profound sense of achievement with respect to the changes to our subcatchment and lifestyles. We are leaders in sustainable practice and innovative design. Our society is active and engaged, and collaborative processes have influence beyond the subcatchment.	1	100% of the people understand and own the EC EAST subcatchment vision and goals	70% of people are aware of and understand the vision and goals.
			Permanent public and commercial community bodies (e.g. schools and businesses) own and promote the vision.
			50% of people are actively involved in at least one of the actions contributing to the 2050 goals.
	2	EC East has a reputation as a leader in sustainable practices.	2019 goals not defined
	3	Public streets and open spaces are co-managed	2019 goals not defined

Vision	**2050 Goals**		**2019 Interim Goals**
		by local people.	
In 2050, a holistic approach is taken in the design, maintenance and improvement of the local natural and built environment. All new development is considerate of future generations, and water sensitive technologies are familiar, affordable and widely used.	4	Public streets and open spaces have multiple functions and are retrofitted with water sensitive technologies.	A minimum of five WSUDs have been built in the EC East subcatchment, for example Marrickville Metro retrofitted to harvest rainwater, and bioretention ponds.
			All spaces retrofitted with WSUD are built as open classrooms that showcase innovations, multiple functions with scope to be replicated on small and large scales.
	5	100% of the new buildings meet a high level of sustainability standards.	Policy for new development on water use, recycling and site permeability with an aim of at least 50% of water from rainwater and greywater is reused within the catchment.
			Permanent incentives to enable policies to be adopted by all stakeholders without discouraging growth, including rebates for sustainable measures and promotion of local businesses that are adopting environmental methods.
Our waterways, wetlands and green spaces are thriving urban ecosystems that support cultural activities, recreation or local food production	6	Eastern Channel is naturalised.	2019 goals not defined
	7	99% of water is sourced from within the subcatchment and made fit for re-use / export: a) only 25% of water runs off the sub-catchment into the Cooks River b) potable water is only used for essential purposes.	30% of water is sourced from within the subcatchment and made fit for re-use.
			Only 50% of water runs off the subcatchment and into the Cooks River (assumed natural conditions)
			10% of potable water is used for essential purposes (consumption)
	8	Stormwater flooding is minimised through sustainable water management in the subcatchment	2019 goals not defined

The goals identified by the community were taken into account to identify the water management options in the EC East Subcatchment.

3.0 SOCIAL PROFILE

The EC East Subcatchment has a diverse population and represents the inner city culture of the Sydney Metropolitan area. According to the 2006 census data, the total population of EC East subcatchment is 7661, which gives a population density of approximately 5850 persons per km^2 for the 1.31km^2 subcatchment.

There are 3073 individual dwellings in the EC East Subcatchment. Approximately 2300 (74%) of dwellings are individual households. Another 726 dwellings consist of flats, units or apartments. The number of people per dwelling ranges from an average of 2.4 in detached homes to 1.6 in flats, units or apartments. Table 2 provided breakdown of population for various types of dwellings.

Table 2: Population distribution for various types of dwellings in EC East

Dwelling type	EC East Subcatchment (%)	Numbers of dwellings	Marrickville LGA	Sydney Urban Centre	Number of persons per dwelling	Catchment population in various dwelling types
Separate house	18%	561	37%	61%	2.4	1346
Semi-detached, row or terrace house, townhouse etc.	56%	1731	26%	12%	2.2	3808
Flat, unit or apartment:	24%	726	36%	26%	1.6	1162
Other dwelling:	2%	55	1%	0%	2.1	116

A large proportion (31%) of the population was born overseas and 14% of the population speaks languages other than English at home. The population is relatively young with 72% of the population younger than 44 years. The dominant age group is 25-34 (28%). This is reflected in the nature of the households within the catchment, where 73% of the population consists of either two or fewer than two persons per household. Approximately 50% of households are rental.

Approximately 60% of the population has a tertiary qualification. The majority (68%) of the population is employed with 44% of the population earning more than the Sydney average earnings of approximately $1,550 per week.

An important population statistic is that a large proportion of the population (43%) has lived less than five years in the subcatchment. This is typical of inner city suburbs where there is greater population movement of younger people. This social characteristic of the subcatchment can impact on the future planning for the local community.

Further details of the social profile for the subcatchment are presented in APPENDIX A.

3.1 Land Use

The main land use within the subcatchment is residential with approximately 3031 residential land parcels. Development in the residential areas is characterised by high-density terrace housing with very few free-standing homes. There are also high-density villa-style developments in the subcatchment. There are several educational institutions in the area including a TAFE institute. A variety of commercial and businesses operate along Victoria Road, Edgeware Road, Enmore Road and the Princes Highway. A major stand-alone shopping centre, The Marrickville Metro, is also located in the subcatchment.

Figure 2 presents land use zoning within the catchment, as per Marrickville LEP 2001. It is noted that a new LEP with new land use zones was placed on public exhibition between 4 November 2010 and 28 February 2011 and is now being finalised.

There are also several light to medium industrial establishments in the south-west of the subcatchment. In addition, several places of worship are also present within the subcatchment.

The subcatchment is dotted with several open spaces, parks and playgrounds, though several of them are very small in size. They range from the 2.8 ha Camdenville Park to the 0.015 ha Francis Street playground.

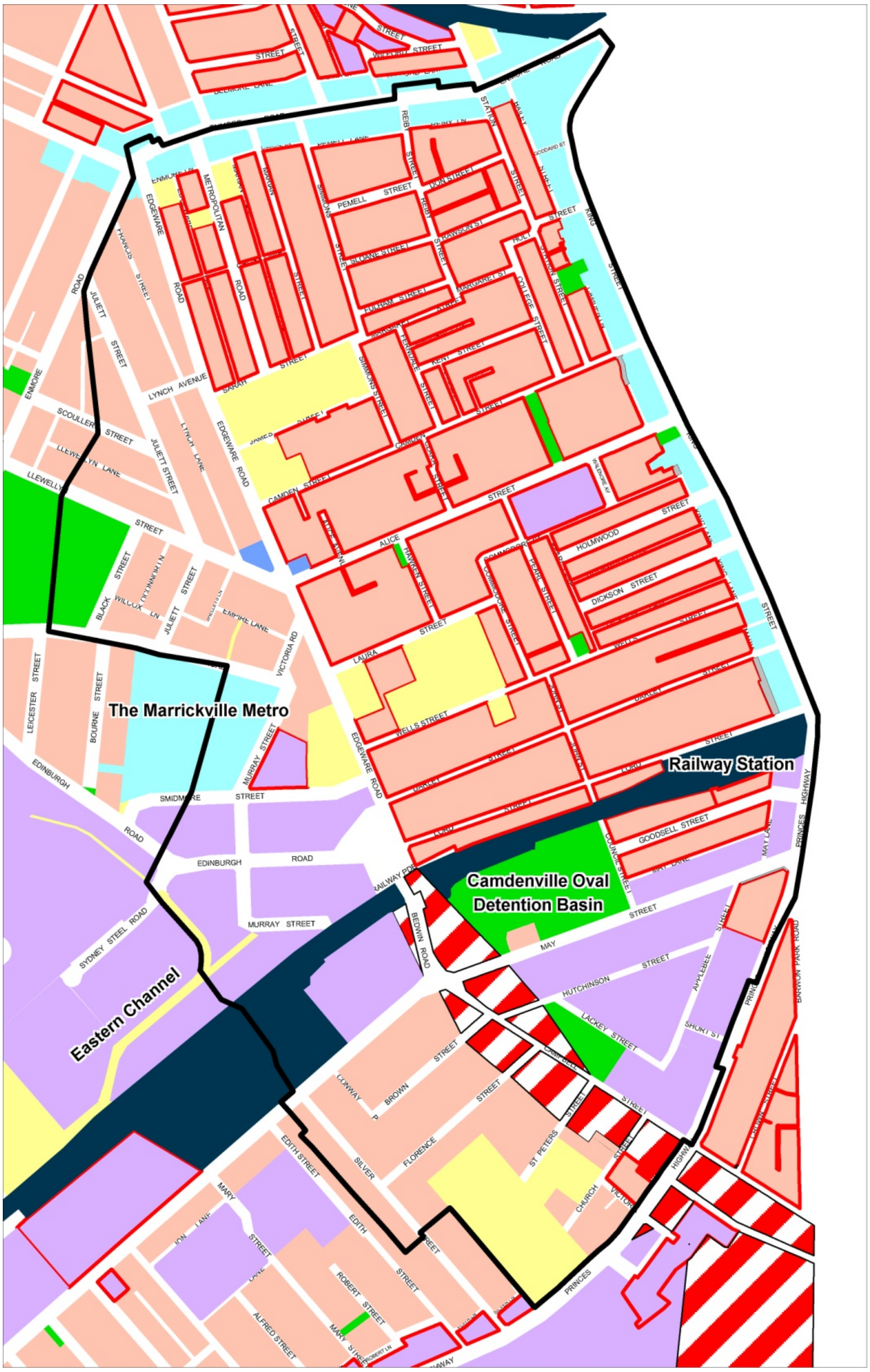

Figure 2: Land Use Zoning within EC East Subcatchment

4.0 PHYSICAL PROFILE

A physical profile of the catchment was developed for the EC East Subcatchment to define the water cycle in the subcatchment. It draws together the outcomes of the water cycle analysis in the subcatchment and helps identify the options to manage the water cycle effectively.

The urban water cycle involves various processes that need to be understood in detail for effective planning of the subcatchment. To achieve this objective, a water balance, water quality and hydrologic/hydraulic modelling program was undertaken for the EC East subcatchment. This modelling quantifies various elements of the water cycle and helps in understanding the role each element plays in the water cycle.

The EC East Subcatchment area is a typical urban catchment with an approximate area of 131 ha (Figure 3). The primary landuse within the catchment is residential with some commercial and industrial landuse. The catchment has high runoff potential, with approximately 95 ha (75%) of the catchment being impervious. In general, the subcatchment is quite steep and has fairly extensive street drainage. However, a substantial part of the subcatchment does not have street drainage and the runoff is carried overland within the road reserves as part of a kerb and guttering arrangement.

Figure 3: Topographical features of EC East Subcatchment

4.1 Climate

Marrickville LGA lies to the immediate southwest of the Sydney CBD. The typical altitude is 10 to 20 m above sea level. The nearest meteorological station is at Sydney Airport, which lies some 4 km to the east of the catchment. Table 3 shows the long term climate averages at Sydney Airport (Bureau of Meteorology [BOM] Station No. 066037).

Table 3: Long term historical climate conditions

Statistic Element	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
Mean maximum temperature (Degrees C) for years 1939 to 2010	26	26	25	23	20	18	17	18	21	23	24	26	22
Mean minimum temperature (Degrees C) for years 1939 to 2010	19	19	17	14	11	9	7	8	10	13	15	18	13
Mean daily temperature (Degrees C) for years 1939 to 2011	23	23	21	19	15	13	12	13	15	18	20	22	18
Mean rainfall (mm) for years 1929 to 2010	95	113	115	106	100	121	69	77	61	71	80	73	1081
Decile 5 (median) monthly rainfall (mm) for years 1929 to 2010	72	82	82	81	81	93	52	48	46	47	67	60	1046
Mean daily sunshine (hours) for years 1976 to 2010	7.6	7.2	6.9	6.9	6.2	6	6.6	7.8	7.9	7.9	7.6	7.9	7.2
Mean daily solar exposure (MJ/(m*m)) for years 1990 to 2010	24	21	18	14	10	9	10	13	17	21	22	24	17
Mean monthly evaporation (mm) for years 1974 to 2010	223	179	164	126	90	75	84	115	147	183	195	229	1825

The mean annual temperature is 18 degrees. This mean temperature is indicative of a warm climate, which enables plant growth throughout the year. Frosts are rare. There is a nine degree difference between the yearly average minimum and maximum temperatures. This relatively small diurnal change in temperature is indicative of coastal lowland climates.

Both the mean and median monthly rainfalls exceed 1000 mm/year. This suggests a humid (wet) climate, where plants would have only moderate moisture stress. The closeness of the mean and median annual rainfall suggests year to year variation in rainfall is low, at least compared with much of the rest of Australia.

Solar radiation has a more than two fold variation during the year. This is typical of the mid latitude regions of the world. The average annual evaporation is 1825 mm.

4.1.1 Climate Change

The climate change projections for the Sydney Metropolitan Area (CSIRO, 2007) suggest a drier and hotter future climate. The catchment runoffs are likely to reduce due to reduced rainfall and higher evapotranspiration rates. The water quality of the runoff and the receiving waters is likely to suffer due to low flows and higher temperatures causing algal blooms in nutrient rich environment. The salinity profiles of the local soils may also change due to reduced rainfall, runoff and stream flows.

Although the annual rainfall is likely to reduce in the future, the intensity of the rainfall events is likely to increase with consequent increase in the catchment flooding and related damages.

4.2 Water Balance

Water balance analysis provides an opportunity to highlight potential drinking water savings through rainwater and stormwater harvesting. It also provides an indication of the likely quality of the stormwater leaving the subcatchment.

The water balance analysis requires estimation of water inflows and outflows or losses within the subcatchment.

The inflows to the subcatchment include:

- Mains water supply imported from Sydney Water (SW)
- Rainfall in the subcatchment area.
- Groundwater inflow. However, it is of limited significance for the EC East Subcatchment.

Data was obtained from SW to establish the total potable water imported into the subcatchment. Rainfall estimates were developed using long-term historic rainfall data at the nearest rain gauge at Sydney Airport.

The outflows and losses within the catchment include:

Outflows and losses related to the SW supply

- Leakage of potable water (7% of the supply)
- Consumption by residents (drinking, 1% of the supply)
- Garden and open space watering (4% of the supply)
- Wastewater (88% of the supply)

Outflows and losses related to rainfall in the subcatchment

- Stormwater runoff (66% of rainfall)
- Infiltration and evapotranspiration of stormwater (33% of rainfall)

The stormwater runoff and the infiltration/evapotranspiration losses were estimated by undertaking modelling of the subcatchment using the MUSIC software.

Details of the water balance for the subcatchment is presented in Table 4

Table 4: EC East Subcatchment Water Balance

Component	Measurement / estimation source	Volume (kL/year)
Rainfall	BoM rain gauge at Sydney Airport 1986 to 2006 in 6 minute intervals	1,460,000
Potable water imported to the subcatchment	SWC data for 2007/2008 + 8% loss	661,000
Potable water use measured in the catchment	SWC data for 2007/2008	612,000
Potable water leakage	Estimated flows that were lost prior to metering at individual premises (8%) based on SWC data for 2008	49,000
Consumed by residents	1.5% based on 2L/person/day (NHMRC/NRMMC, 2004) and 2 persons/dwelling (ABS, 2009)	9,000
Garden and open space watering	4% of potable water supplied	27,000
Infiltration and evapotranspiration	34% of rainfall. (Based on MUSIC modelling)	492,000
Stormwater runoff	67% of rainfall. (Based on MUSIC modelling)	968,000
Exfiltration and sewer overflows	Allow 15% for aging infrastructure.	86,000
Discharge to sewer	Measured as potable water inflow (consumption + watering)	576,000
Volume of sewage reaching ocean	Discharge minus leakage (80% of the supply volume)	490,000

Detailed analysis of the water balance and description of water usage within the EC East subcatchment is presented in APPENDIX B.

4.3 Stormwater Drainage

4.3.1 Overview

A detailed stormwater drainage study was undertaken as part of this process. The study established the likely runoff behaviour during rainfall events and helped to identify the stormwater related flooding issues in the subcatchment. The detailed stormwater drainage study report is presented in Volume 2 of this report.

The EC East Subcatchment, in general, is quite steep and is completely urbanised. The EC East Subcatchment can be broadly divided into three major subcatchments: one to the north, one to the east and one to the south (Figure F1, Appendix F). The Illawarra Railway line separates the northern and eastern subcatchments from the southern subcatchment. The EC East Subcatchment discharges in a westerly direction to Eastern Channel which then discharges to the Cooks River. Figure F1, Appendix F, illustrates the boundary of the EC East Subcatchment and the location of the northern, eastern and southern subcatchments within the catchment. Figure F2 presents the modelled terrain and the pit and pipe network

The northern subcatchment is 73.5 ha and is serviced by a pit and pipe network that extends into the north-eastern portion of the subcatchment and drains in a south-westerly direction towards Eastern Channel. There are two main trunk drains in the northern subcatchment The first commences in Ferndale St as two large diameter pipes, laid in parallel, which both drain along Camden St and into Edgeware Road. At the intersection of Alice St and Edgeware Road these parallel pipes converge into a single large culvert that runs down Murray St before discharging into Eastern Channel. The second main trunk drain also discharges to Eastern Channel; however, it commences at the intersection of Alice St and Edgeware Road and runs from Llewellyn St through Empire Lane to Victoria Road and then under the Marrickville Metro Shopping Centre. It is noted that this second main trunk is no longer connected to the catchment upstream of Alice St. This disconnection occurred in the late 1960s commensurate with the construction of the single large culvert that runs down Murray St.

The southern subcatchment is 38.9 ha and does not have a pit and pipe network in its upper reaches, however, there is a cluster of pit and pipes, at a natural low point, that act to collect and pipe runoff northward via a culvert under the Illawarra Railway line adjacent to the Bedwin Road railway bridge.

The eastern subcatchment is 18.9 ha and is located north of the Illawarra Railway line. Runoff from this catchment drains in a south-westerly direction toward the Bedwin Road bridge. A pit and pipe network exists from the middle reaches of this catchment; however, runoff from the majority of the catchment is transmitted via overland flow down various streets, predominantly Darley St and Lord St, to the low point at the corner of Railway Parade and Edgeware Road underneath the Bedwin Road railway bridge.

4.3.2 Drainage Issues

There are local drainage issues throughout the EC East Subcatchment identified by the modelling exercise described in Volume 2. The discussion of these issues is subdivided according to the respective subcatchment.

Northern Subcatchment

In the northern subcatchment, there is a drainage issue at the intersection of Alice St and Edgeware Road, which is a local low-point. Analysis indicates this intersection represents a low hazard during 2, 5 and 10 yr Average Recurrence Interval (ARI) events, however, it represents an intermediate hazard during the 100 yr event.

There are also drainage issues along Camden St and along Edgeware Road, which are high pedestrian traffic areas. The issue along Edgeware Road relates to the fact that there is no stormwater infrastructure along Edgeware Road between Sarah St and Camden St. Analysis indicates this area presents a high hazard in design flood events greater than 5 yr ARI. Drainage issues along Camden St relate to Camden St being a local low-point and analysis indicates that this represents a low hazard.

Hydraulic analysis of the stormwater infrastructure indicates that the upper parts of the northern subcatchment, at and above the intersection of Alice St and Edgeware Roads, has a capacity equivalent to a 5 yr ARI design flood event. The main trunk drainage lines (Murray St and Empire Lane Channel) have a level of service of equivalent to a 2 yr ARI and > 10 yr ARI capacity respectively. The drainage issue at the intersection of Alice St and Edgeware Road therefore relates to a capacity constraint of the main trunk line.

There is also a drainage issue at Pemell St, Sloane St and Fulham St in the locations that are not serviced by an overland flowpath. Analysis indicates that existing infrastructure (pit/pipe network) has a capacity of about 5 yr ARI. In excess of this level of service, stormwater ponds and modelling indicates a high hazard during a 100 yr ARI event.

Southern Subcatchment

In the southern subcatchment, there is a drainage issue at the corner of Campbell St and May St, which is a natural low point in the catchment. Runoff ponds at this intersection until it overtops the crest of May St and drains into Camdenville Detention Basin. Analysis indicates that the hydraulic hazard is low for 2, 5 and 10 yr ARI events and is intermediate during the 100 yr ARI design flood event. Modelling indicates that the 1200 mm pipe that runs northward to the Illawarra Railway is operating under outlet-control conditions. Accordingly, the inlet capacity of the pits at this intersection is not the cause of the observed issue.

There are drainage issues reported for Brown St and Florence St where there is currently no pit/pipe infrastructure.

There are also drainage issues identified in Goodsell St. These are discussed below in the summary of eastern catchment.

Eastern Subcatchment

In the eastern subcatchment, there are three drainage issues.

The first issue relates to surface overland flow along the upper part of John St/corner of Wells St where there is currently no stormwater infrastructure. Analysis indicates however that the flood hazard is low due to shallow depth, even up to the 100 yr ARI event.

The second issue is the hydraulic capacity of the existing infrastructure at the intersection of John St and Lord St where the existing infrastructure is overwhelmed in an approximate 1 yr ARI event and surface overland flow occurs along Lord St toward the underpass of the Bedwin Road railway bridge. Analysis indicates that the flood hazard at the intersection of John St and Lord St is low for 2 and 5 yr ARI event, however, approaches a high hazard in the 10 and 100 yr events.

The third issue relates to the capacity of the main culvert at the underpass. At the underpass, analysis indicates the existing culvert has a capacity of only approximately 1 yr ARI design flood event. Modelling indicates that the hydraulic hazard is low during 2, 5 and 10 yr events and is intermediate during the 100 yr event. The main culvert drains to Eastern Channel along Murray St, in a westerly direction, however it also receives inflow from the southern subcatchment via the 1200 mm pipe mentioned in the discussion of southern subcatchment. As well, the culvert receives inflow from the Goodsell St precinct. The contributing catchment to the culvert under the Bedwin Road railway bridge is therefore of the order of 58 ha and, accordingly, is a constraint to the hydraulic performance of the whole southern and eastern catchments.

4.4 Stormwater Quality

The stormwater quality in the EC East Subcatchment is primarily affected by the proportion of impervious areas and landuse within the subcatchment. Meteorological conditions such as rainfall patterns and evaporation rates also play an important role in determining the quality of stormwater leaving the subcatchment.

Stormwater quality in the EC East subcatchment is affected by a range of common urban contaminants, including gross pollutants, suspended solids, nutrients such as nitrogen and phosphorus, trace metals and other chemicals including hydrocarbons. All these contaminants are likely to impact on stormwater quality within the EC East subcatchment and hence the receiving waters of the Cooks River.

The total impervious area in the subcatchment is estimated to be 106 ha. The contribution of impervious surfaces from various land uses is presented in Figure 4.

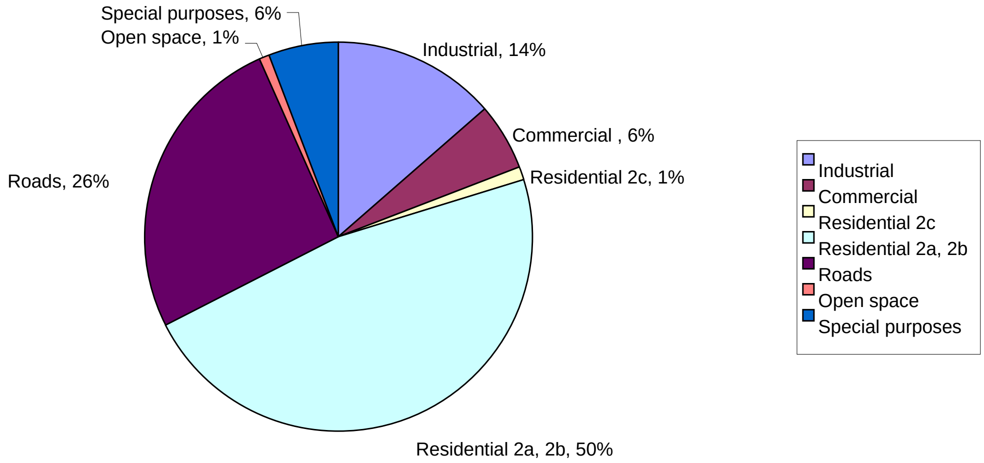

Figure 4: Land uses and contribution to catchment imperviousness

The industrial and commercial areas in the catchment have a high percentage of impervious surfaces, and account for 20% of the total impervious surfaces within the subcatchment. According to Figure 4, property zoned as Residential 2a and 2b accounts for nearly 50% of the total impervious surfaces within the subcatchment. Roads contribute a further 28 ha or 26% of the impervious surfaces.

4.5 Water Quality Modelling

A stormwater quality assessment was performed for the subcatchment using the MUSIC (Version 4) modelling software. This software is well established in the industry and has numerous applications throughout Australia and overseas. The model facilitates assessment of gross pollutants, suspended solids and nutrient loads generated within a catchment.

The modelled contaminant loads from the EC East subcatchment are presented in Table 5 below. The rainfall data (six minute interval) from the Sydney Airport gauge for the period 1986-2006 was used in the model.

The results in Table 5 assume that there are no major sewer overflows. The modelling does not take into account specific details of the drainage system in the subcatchment such as widespread use of street gutters rather than pipe drainage to convey stormwater. The impact of older dwellings with lead based paint and zinc coated roofs are also not taken into account. Lead and zinc contamination is often greater in catchments where buildings are over 100 years old (Fletcher et al, 2004).

The modelling results emphasise the critical importance of perviousness in determining the contaminant export from the catchment. The results indicate that residential areas and roads are the most significant contributors of stormwater contaminants based on the relative percentage of impervious surfaces associated with these landuses within the catchment. It is important that both these landuses be targeted in any effort to reduce total contaminant export from the catchment.

Table 5: Stormwater quality modelling results for the EC East subcatchment

Attribute	Land Use							
	Industrial	Commercial	Residential*		Roads	Open space	Special purposes	Total
			2c	2a, 2b				
Area (ha)	15	7	1	57	31	6	13	131
Flow (ML/yr)	130.5	60.2	8.2	427.5	260.4	19.2	66.3	972.3
Total Suspended Solids (kg/yr)	24,300	10,300	2,060	78,400	124,000	1,710	8,020	248,790
Total Phosphorus (kg/yr)	39	17	3	127	151	5	19	361
Total Nitrogen (kg/yr)	289	122	25	929	618	38	144	2,165
Gross Pollutants (kg/yr)	3,570	1,510	315	12,200	7,040	339	1,930	26,904

*Residential zone 2a is predominantly single dwelling residential development, 2b and 2c is multi unit housing and residential flat buildings

The yield per ha from various land uses in the subcatchment varies significantly. For example, 'open space' land use yields an estimated 274 kg/ha/yr of TSS, whereas from industrial areas it is estimated to be 1600 kg/ha/y and from roads 4039 kg/ha/yr. These contaminant export rates are close to those predicted by Fletcher et al (2004) for sites with similar rainfall and proportion of impervious surfaces in the subcatchment.

5.0 SUBCATCHMENT MANAGEMENT OPTIONS

As per the Council guidelines for Subcatchment Planning for sustainable water management, the context mapping undertaken for the EC East Subcatchment includes social, organisational and physical profiling tasks. The Council has already undertaken the social and the organisational profiling of the subcatchment. The results of social profiling are presented in this report together with the results of physical profiling.

As part of physical profiling of the subcatchment, a number of options were identified through community and stakeholder consultation to achieve the objectives of sustainable water management. These options include water re-use, water quality management and drainage management options.

The water re-use and water quality improvement options provide some benefit in managing the drainage issues in the subcatchment. However, these benefits are limited in improving the drainage issues and hence more comprehensive drainage options have been identified to improve management of overland stormwater flows and minimise the flood risk associated with these overland flows.

This report presents the water re-use, water quality improvement and drainage management options separately. Where options for these water management objectives are identified at the same location in the subcatchment, the pros and cons and any synergies associated with the implementation of these options are also discussed.

A preliminary list of various options was prepared and discussed with Council's Project Team and will be discussed with the Working Group. Modelling tools established for defining the physical profile of the subcatchment were used to assess the performance of these options. In general, the impact of these options on various components of the subcatchment water cycle was established. Preliminary cost estimates for implementing these options were also undertaken.

6.0 STORMWATER QUALITY MANAGEMENT AND WATER REUSE OPTIONS

A series of stormwater quality (SWQ) improvement and water reuse (WR) options were identified in the EC East subcatchment in order to reduce stormwater volumes and contaminant loads from the subcatchment. In addition, various WR options were identified to minimise the import of potable water into the subcatchment in line with the IUWM principles.

Water reuse options based on harvesting rainwater and stormwater also serve the purpose of improving stormwater quality in the subcatchment. In fact, stormwater reuse generally involves some level of treatment before it can be put to any fit-for-purpose use. Hence, both stormwater quality improvement and water reuse options are discussed together.

Various options were identified for the subcatchment, including:

- SWQ1 + WR: Rainwater tanks to allow substitution of stormwater for non-potable water needs within individual and multi unit dwellings;
- SWQ2 : A bioretention basin in Simpson Park to improve the quality of stormwater exiting the surrounding 10.3 ha catchment;
- SWQ3: A bioretention basin in TAFE Park to improve the quality of stormwater exiting the surrounding 3.8 ha catchment;
- SWQ4: A bioretention swale along the southern side of Pemell St, Newtown to improve the quality of stormwater exiting the surrounding 1.18 ha catchment;
- SWQ5: A bioretention swale along the northern side of Goodsell St, St Peters to improve the quality of stormwater exiting the surrounding 1.23 ha catchment;
- SWQ6: Rain gardens on redeveloping sites in the St Peters triangle area as part of the development control plan (DCP) for the locality;
- SWQ7 + WR: Stormwater collection tanks in Camdenville Park to collect stormwater for supply as irrigation water to Camdenville Park;
- SWQ8 + WR: Stormwater collection tanks in Camdenville Park to collect runoff from nearby factory roofs to supply irrigation water for Camdenville Park; and
- SWQ9 + WR: Adaptation of the existing Camdenville stormwater detention basin to collect and supply irrigation water to Camdenville Park.

MUSIC, Version 4, was used to estimate runoff volumes and contaminant loads for each scenario. The model also enabled estimates of system capital and operating costs. The effectiveness of the various options can be assessed using this program.

The model utilises six minute rainfall data from Sydney Airport for the period 1986 to 2006. It also uses long-term average evapotranspiration for the site.

In some instances there was a need for information such as water depth in ponds, available soil water content and the removal rate of trace metals, which is not retrievable from MUSIC. In these cases a daily time step program developed by Woodlots and Wetlands Pty Ltd was used.

The key features of each of the options, including costs, are summarised in the following section, and are described in detail in APPENDIX C.

6.1 SWQ1 + WR - Rainwater Tanks

The aim of investigating this option is to assess the feasibility and impact on the catchment water cycle of installing rainwater tanks for different proportions of dwellings in the catchment.

Substitution of mains water with the tank water reduces the demand for mains water while also reducing the runoff rate from urban areas. Reduction in runoff can reduce the extent of downstream erosion during storms. It also reduces the contaminant load being delivered to receiving water by the stormwater.

An additional benefit of having rainwater tanks is that tank owners develop an understanding of water usage. This can result in residents becoming more efficient water users.

The approach described in the following sections considers concerns with public safety with respect to water quality in an urban environment. It also examines issues such as limited roof catchment area and limited space for any water storage system.

6.1.1 Roof Water Quality

Studies carried out in Australia (Heyworth et al. 1999) have found no evidence of increase in disease using rainwater. In fact, evidence to the contrary (Heyworth et al. 2001) was found where the health of children in homes using rainwater tanks was better than those in homes reliant on town water supplies. This suggests that rainwater is generally safe for human consumption.

A study carried out for analysing chemical contamination from roof runoff in highly urbanised areas found that lead, manganese, nickel, zinc and hydrocarbon concentrations in the rainwater samples were consistently less than the guideline values cited in the Australian drinking water guidelines (South Australian Department of Human Services, unpublished results 1999–2002).

In Marrickville, some roofs could still have lead flashing as part of their roof plumbing system. Dissolution of this lead may increase lead concentration in the tank water and water from such tanks should not be used for drinking.

6.1.2 Current NSW Health Recommendations

NSW Health supports the use of rainwater tanks for non drinking water uses in areas where there is mains supply. These uses include toilet flushing, washing clothes or in water heating systems. It also supports tank water use in activities such as garden watering, car washing, filling swimming pools, spas and ornamental ponds and fire fighting (NSW Health, 2007).

NSW Health recommends the use of mains water supply for drinking and cooking.

6.1.3 Assumptions and Modelling Methodology – Single Dwelling

Total water use per day in a typical single dwelling was assumed to be 394 L. This volume was determined from data supplied for single dwellings by SWC (pers comm). It is less than the 558 L/day estimated for the Tennyson St catchment (Marrickville Council, pers comm). The 2006 Census data suggest that the EC East Subcatchment has a lower residential population density with more dwellings with one or two people in them compared to the Tennyson St catchment. Fewer people/ dwelling means there is less water use per dwelling.

Indicative volumes of water utilised in various parts of the average home are shown in Table 6.

Table 6: Estimated water usage/day in a typical single dwelling (Source: derived from SWC and ABS (2006) data).

Water use area	Volume/day
Kitchen	57 L
Shower	81 L
Bath and basins	32 L
Laundry	73 L
Toilets	118 L
Garden	32 L

The demand that could be supplied via a rain water tank was assumed to include the irrigation, the toilet and the hot water system. Hot water was considered to supply 50% of the water to the kitchen, bathroom and laundry, so the non-potable demand is 122 L/day {(57+32+81+73)*50%=122 L/day}.

The total rain water demand for internal use would be 122 L/day + 118 L/day (toilets) = 240 L/day.

This demand is likely to be the maximum as it assumes the rainwater line could be readily incorporated into the existing plumbing for the hot water system. This may not be feasible in all dwellings.

The anticipated irrigation demand is presented in Table 7. It is based on a 27 year daily time-step simulation. The calculated demand is for a well watered lawn. Details are presented in APPENDIX C.

Table 7: Anticipated irrigation demand each month in the average year for 'sunny' locations in Marrickville.

Month	J	F	M	A	M	J	J	A	S	O	N	D	Year
Irrig (mm)	148	119	109	0	0	0	0	0	95	119	129	152	871

The demand for irrigation will depend on weather conditions, the availability of suitable space and the interest of the residents. Assuming that 6% of water is used for irrigation, this would be sufficient to meet the irrigation demand for approximately 14 m^2 of land. This figure is consistent with observations made on garden areas of various properties during catchment inspection.

6.1.4 Water Capture and Usage Modelling – Single Dwelling

The volume of water captured and used was modelled using 27 years of daily rainfall for Sydney. Potential demand for rainwater was set at 240 L/day. Additionally some 14 m^2 of garden was watered.

The roof areas were assumed to be 25, 50, 75, 100, 150 and 150 m^2. Tank sizes examined were 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500 and 5000 L.

The results indicate that in the average year approximately 7 kL was used to water the gardens. This is equivalent to 500 mm/yr on 14 m^2. Indoor non-potable demand was 87.6 kL/year.

For a given rainwater tank, both the tank volume and roof catchment size impact on the volume of water that is utilised. There is little value in having a large tank if the catchment is small. Conversely a small tank attached to a large catchment is of limited value because it cannot contain the runoff volumes generated.

Figure 5 shows the combined impact of tank size and roof area on the annual yield of water.

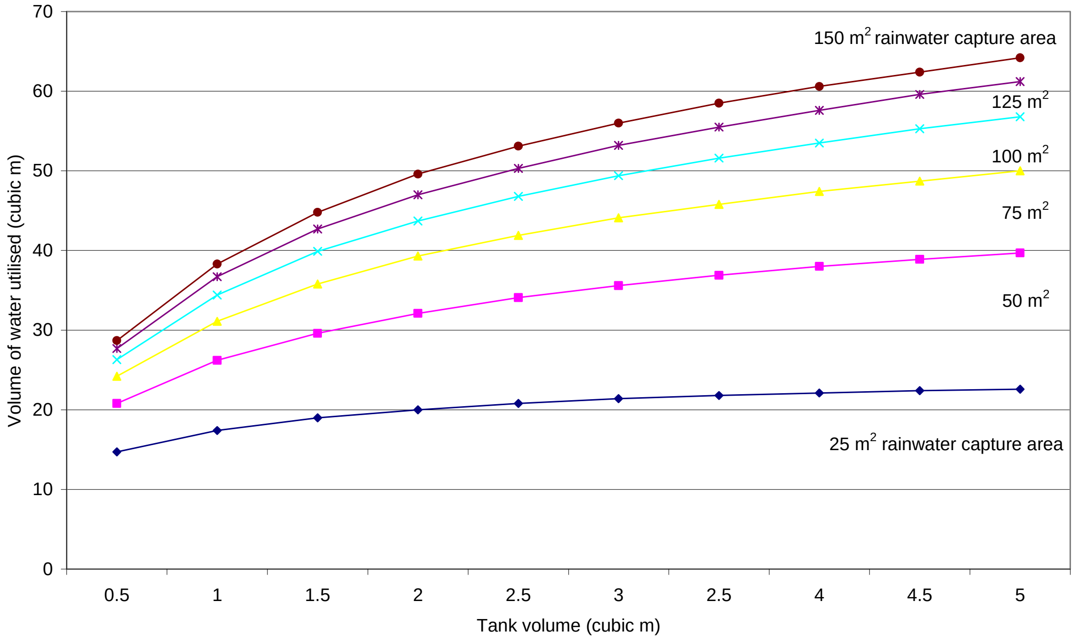

Figure 5: Relationships among combinations of rainwater tank volume (m^3), roof area (m^2) and volume of water utilised (m^3) in the average year (based on 27 year simulation).

Tank suppliers typically suggest a yield to storage ratio of 2 to 3. That is, the increase in volume delivered per year should be at least 2 to 3 times the increase in storage capacity. For example there should be an additional supply of at least 2 to 3 m^3/year for every additional m^3 of storage. Table 8 shows that by this criterion, a 1 to 1.5 m^3 tank would be sufficient for a home with a 25 m^2 catchment and up to 3 m^3 would be useful for a home with a 75 m^2 roof catchment.

Table 8: Increment of water yield in m^3/year for a range of roof areas and tank sizes. Assumed non-potable water use is 240 L/day. The shaded yield increments are at least three times the tank volume increment.

Tank volume m^3	25 m^2	50 m^2	75 m^2	100 m^2	125 m^2	150 m^2
1	2.7	5.4	6.9	8.1	9	9.6
1.5	1.6	3.4	4.7	5.5	6	6.5
2	1	2.5	3.5	3.8	4.3	4.8
2.5	0.8	2	2.6	3.1	3.3	3.5
3	0.6	1.5	2.2	2.6	2.9	2.9
3.5	0.4	1.3	1.7	2.2	2.3	2.5
4	0.3	1.1	1.6	1.9	2.1	2.1
4.5	0.3	0.9	1.3	1.8	2	2.
5	0.2	0.8	1.3	1.5	1.6	1.8

6.1.5 Catchment-wide Impacts of Using Rainwater Tanks

There are 17.2 ha of individual dwellings in the catchment. Modelling was undertaken to determine the impact of various levels of adoption of rainwater tanks within the EC East subcatchment. A roof area of 37.5 m^2 was assumed for a typical residence in the subcatchment. A tank size of 2.75 m^3 and a water demand of 240 L/day were used for the modelling purposes. The tank size used in the modelling is higher than the volume suggested for the 37.5 m^2 catchment in Table 8, but it allows for variation in resident numbers. This tank size is also typical of many tanks supplied to Sydney homes. Further modelling details and assumptions are presented in APPENDIX C. The impact of different percentages of dwellings utilising rainwater is summarised in Table 9.

Table 9: Impact of varying the percentage of individual dwellings on runoff volume and quality

Attribute	Units	% of homes with tanks						
		zero	10	20	40	60	80	All
Volume of runoff	ML/yr	133	126	120	106	93	80	67
Reduction in outflow/ha of single dwellings*	ML/yr	0	7	13	27	33	53	66
Mass of total suspended solids (TSS)	kg/yr	27300	26000	24600	20900	19400	15400	13700
Mass of Phosphorus	kg/yr	55	52	49	43	38	32	27
Mass of Nitrogen	kg/yr	377	358	339	308	268	228	191

* equivalent to likely reduction in potable water use (ML/yr)

Table 9 shows that 100% introduction of rainwater tanks halved the runoff volume from individual dwellings. A 100% uptake of rainwater tanks would reduce runoff volume to some 37% of rainfall. However, this is still higher than the 25% or 2.6 ML/ha/year anticipated under natural conditions (Fletcher, et al, 2004). The reason for this is that not all the impervious surfaces can be connected to rainwater tanks.

As expected, the reduction in runoff contributed by individual dwelling properties was proportional to the percentage of homes with tanks.

According to the Council records 37 rebates have been paid in the period between Sept 2008 and Sept 2009. This is equivalent to 0.1% of residences in the LGA. This slow rate of uptake suggests that it is reasonable to expect a maximum of 10 to 20% of homes would have tanks in the foreseeable future. Each 10% rise in the percentage of single dwellings with rainwater tanks reduces runoff from the 17.2 ha catchment by 6 to 7 ML/yr (see Table 9).

6.1.6 Application to the Multi-unit Dwellings

According to Council data there is approximately 40.2 ha of residential 2b zoning in the catchment, representing multi-unit dwellings. Connection of a rainwater supply system to the existing plumbing would be expensive in established multi-storey buildings. However approximately 9 to 12% land area associated with the multi-unit dwellings is covered with gardens of various types. This area could be irrigated with roof water. Modelling suggests that approximately 1.8 to 2 m^3 of storage is sufficient for the average medium density building. Approximately 14 ML of potable water could be substituted under these conditions if tanks were installed on all such properties.

6.1.7 Summary

The simulation examined substitution of rainwater for non potable uses in the home and in the garden. The average home was estimated to require 240 L of non potable water/day. A 37.5 m^2 roof catchment area would supply approximately 1/3 of the annual demand. There would be some 200 days in the average year when there was no water in the tank.

Total water savings of 70 ML or 12% of the estimated current potable supply to the catchment could be achieved by installation of at least 2.5 m^3 of rainwater tank capacity at every home and a tank of at least 1.8 m^3 capacity for every multi-unit dwelling.

As an additional benefit, the widespread installation of rainwater tanks would also reduce the mass of contaminants leaving the catchment.

Finally, there may be opportunities for industrial facilities to augment their water supply with stormwater runoff. This opportunity needs to be investigated on an individual site basis.

The likely issues to be encountered in implementing this option are:

- Encouraging a high a proportion of individual home owners to install adequate rainwater capture and reuse systems;
- Many of the dwellings are rented and both the site owners and the tenants would need an agreement for implementing this option; and
- High levels of lead are possible in the roof water due to old plumbing.

6.2 SWQ2 – Bioretention Basin at Simpson Park

Simpson Park is a significant community recreation resource within the suburb of St Peters. It is well vegetated and contains facilities for a range of activities. It is also in a lower part of the southern local catchment, with the gutters along its NE and SW boundaries (Lackey St and Campbell St respectively) conveying stormwater runoff from the western side of the Princes Hwy as well as Applebee St , St Peters St and portions of Florence St, Hutchinson St and Brown St . The catchment is 10.33 ha and has 63% of its surface as impervious.

The aim of this option is to use a bioretention basin to treat local runoff in order to reduce contamination load as well as peak runoff rates. A bioretention basin is a stormwater collection and filtration system which is normally installed in a lower part of the landscape. Water entering the system is allowed to percolate through a subsurface filtration media, eventually reaching subsurface drains. These drains convey the treated water to the regional stormwater system.

Simpson Park has also been identified as a potential site for a stormwater detention basin (to reduce peak flows). The effectiveness of this basin is discussed in Section 9.3.

Figure 6 shows the catchment. This catchment has industrial lands in the eastern portion and a mix of residential areas in the west. Figure 7 shows the drainage system details and the site of the proposed bioretention basin. The bund, proposed as part of the stormwater detention basin option, is also shown.

Water entering the park would be conveyed to the bioretention basin location shown in Figure 7. Some of the water would percolate through the basin floor and enter a slotted collection pipe that would connect to a drainage system sloping towards the Camdenville retention basin. There is sufficient grade to allow flow to the bioretention basin, provided the flow enters pipes installed towards the upper area of the park.

The maximum depth of water that could be contained was set at 0.2m. There were 350 m^2 of filter area and a surface area of 350 m^2. Figure 7 suggests that 350 m^2 is the largest area that can be contained in the park without removing trees. Details of the bioretention system are provided in APPENDIX C.

Figure 6: Simpson Park and its approximate catchment. The water management features are also shown

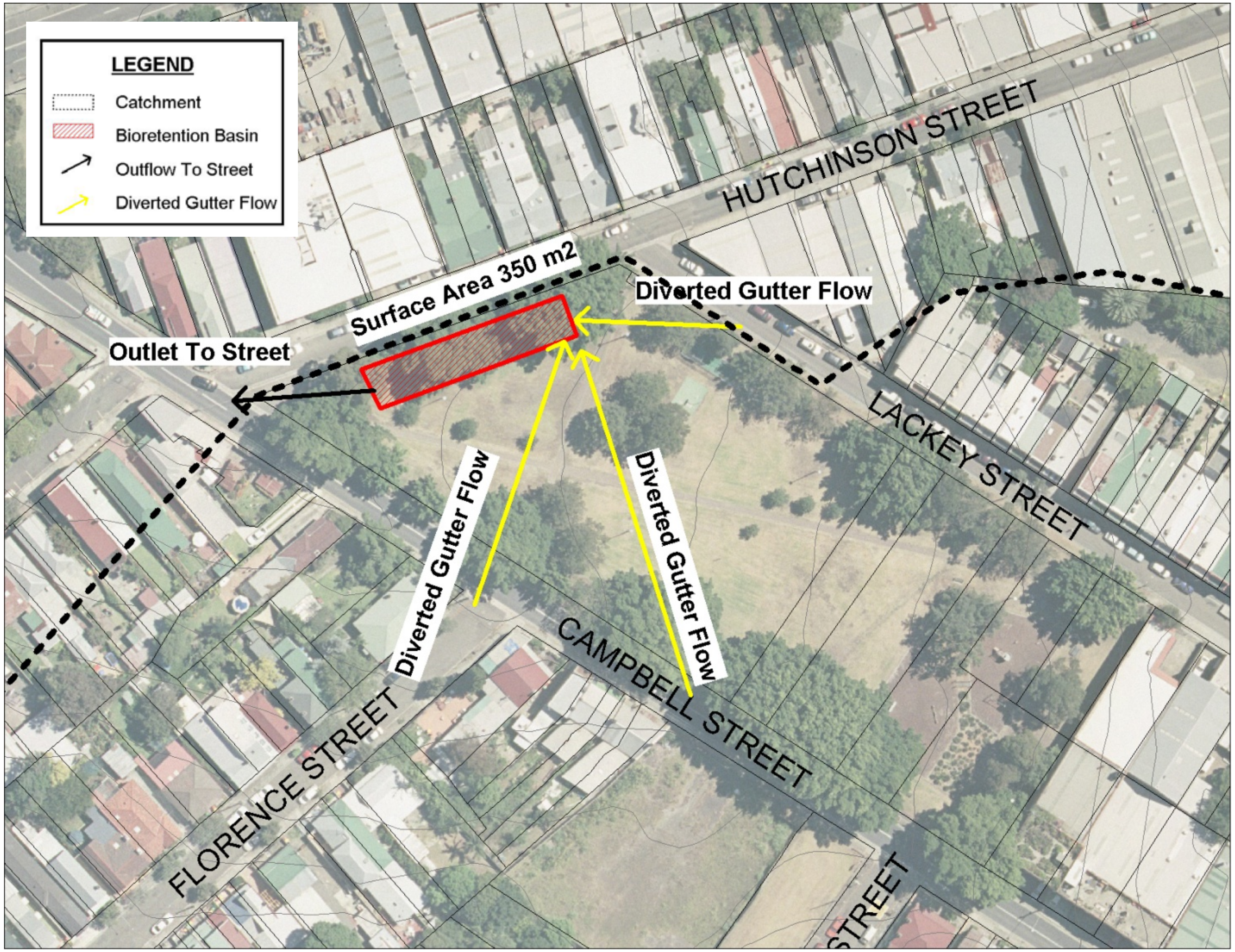

Figure 7: Street drainage surrounding Simpsons Park

6.2.1 Modelling of stormwater and contaminant loads

MUSIC version 4 was used for modelling the Simpson Park catchment. The urban default values were used for runoff percentages and event mean concentrations of contaminants.

Table 10 summarises the bioretention basin's performance. A 350 m^2 bioretention basin was used in the modelling as it was the largest that could reasonably fit onto the site without interfering with trees.

Table 10: Annual influx and export of stormwater and contaminant loads from a 350 m^2 bioretention basin in Simpson Park

Performance Indicator	Inflow	Outflow	% removal	BBCCI* Objectives
Flow (ML/yr)	68	65	5	Not listed
Total Suspended Solids (kg/yr)	13,600	4,420	68	75
Total Phosphorus (kg/yr)	27	13	53	50
Total Nitrogen (kg/yr)	192	144	25	35
Gross Pollutants (kg/yr)	1,970	1	100	Not listed

*Botany Bay Coastal Councils Initiative

The modelling results show that there is minimal impact on total flow volume/year. However, there have been major reductions in contaminant loads, with the proposed system close to achieving the Botany Bay Coastal Catchments Initiative (BBCCI) redevelopment objectives for reduction in TSS, nitrogen and phosphorus. The BBCCI lists the stormwater load objectives in terms of the percent reduction compared with that from conventional redevelopment sites.

An examination of the flow into and out of the bioretention basin indicated that 68 ML/year could enter the system. Approximately 1.3 ML would be lost via evapotranspiration and 2 ML by infiltration into the surrounding soil. Another 17.5 ML would be filtered, while 47.2 ML would simply overtop the basin and not be treated.

6.2.2 Cost

The costs for a 350 m^2 bioretention basin are shown below. The costing is based on estimated values in MUSIC Version 4.

Table 11: Cost summary for bioretention basin at Simpson Park

Life Cycle (yrs)	50
Acquisition Cost	$290,000
Annual Maintenance Cost	$19,000
Annual Establishment Cost	$0
Establishment Period (yrs)	0
Renewal/Adaptation Cost	$9,000
Renewal Period (yrs)	1
Decommissioning Cost	$94,000
Real Discount Rate (%)	5.5
Annual Inflation Rate (%)	2
Life Cycle Cost of Bioretention ($2010)	$800,000

6.2.3 Conclusions

Simpson Park has space for a shallow bioretention basin covering approximately 350 m^2. The proposed basin would markedly reduce peak flows but only for very frequent events ranging approximately to a 1 year ARI event. It would treat approximately a third of the catchment outflow, reducing TSS and phosphorus loads by percentages similar to the Interim Water Quality Objectives in the BBCCI.

The issues likely to be encountered in implementing this option include:

- Any redevelopment of public open space must have local community and Council input;
- The park is used by residents for a wide variety of recreational activities. The stormwater infrastructure should be designed to have minimal impact on the recreational value of the park;
- The public open space value of the park means that any pondage must be sufficiently shallow as to not be a drowning risk. The indicative maximum depth is 200 to 300 mm;
- The proposed bunding will result in water deeper than 300mm, at least during significant rain events. Areas where the depth exceeds 300 mm must be fenced; and
- The location of services may significantly impact on the cost of the proposal.

6.3 SWQ3 – Bioretention Basin at TAFE Park

The TAFE Park is a fenced dog exercise area to the immediate east of the TAFE campus on Edgeware Road. Figure 8 shows the park and its catchment. TAFE Park has 0.8 ha of open space. The catchment is 3.81 ha and has 64% of its surface as impervious. Figure 9 shows the park details with the surrounding street drainage.

The aim of this investigation is to examine the potential for use of a bioretention basin to treat local runoff to reduce contamination load as well as reducing peak runoff rates. A proportion of the water will infiltrate into the subsoil, further reducing contaminant loads exiting the catchment.

TAFE Park has also been identified as a potential site for a stormwater detention basin. The effectiveness of this basin is discussed in Section 9.4.

The local conditions at the park are shown in Figure 10 to Figure 12.

Figure 8: The TAFE Park and its catchment.

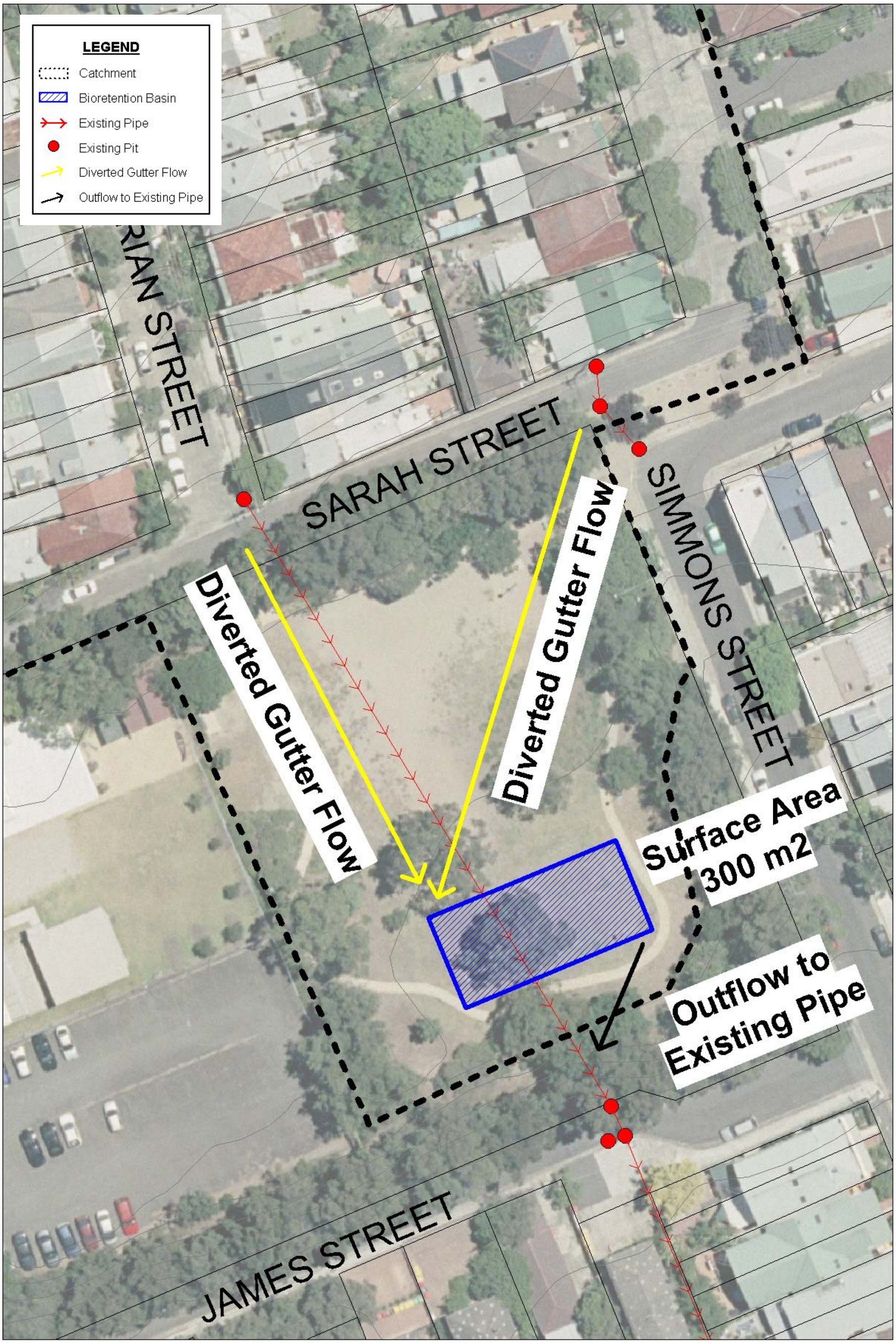

Figure 9: TAFE Park details including street drainage.

Figure 10: The TAFE Park is a major social and recreation site for local residents and their dogs.

Figure 11: TAFE Park is heavily used for dog exercising. Without irrigation to assist in maintaining a vigorous grass growth, it turns into a dust bowl in summer and a mud bog in winter. Shading is another critical issue.

Figure 12: Marian St drains directly towards the park.

6.3.1 Modelling of stormwater and contaminant loads

MUSIC version 4 was used for modelling the TAFE Park catchment. The urban default values were used for runoff percentages and event mean concentrations of contaminants.

The maximum depth of water that could be contained was set at 0.2m. There is 300 m^2 of filter area with a surface area of 300 m^2.

Table 12 summarises the modelling results.

Table 12: Performance of the infiltration system at TAFE Park (based on MUSIC modelling)

Component	Inflow	Outflow	Reduction %	BBCCI* Objectives
Flow (ML/yr)	25.4	22.4	12	Not listed
Total Suspended Solids (kg/yr)	4950	1190	76	75
Total Phosphorus (kg/yr)	10	4	60	50
Total Nitrogen (kg/yr)	72	48	33	35
Gross Pollutants (kg/yr)	734	4	100	Not listed

* Botany Bay Coastal Councils Initiative

The results show that the system reduces the outflow volume by 12%. It also reduces TSS and nitrogen loads to at least the extent recommended for BBCCI redevelopment objectives.

6.3.2 Costs

The estimated costs for a 300 m^2 bioretention basin are presented below. Table 13 shows the costing results.

Table 13: Cost summary for bioretention basin at TAFE Park

Life Cycle (yrs)	50
Capital Cost	$180,000
Annual Maintenance Cost	$14,000
Annual Establishment Cost	$0
Establishment Period (yrs)	0
Renewal/Adaptation Cost	$5,000
Renewal Period (yrs)	1
Decommissioning Cost	$80,000
Real Discount Rate (%)	5.5
Annual Inflation Rate (%)	2
Life cycle cost ($ 2010)	$500,000

6.3.3 Conclusions

The TAFE Park is extensively used for exercising dogs and other passive recreational activities. It is not on Council lands, but is leased to Council. Any stormwater management system would need to be agreed upon by TAFE administration. Changes to the park should not reduce the current recreational values of the site. The proposal involves a shallow dish design only 0.2 m deep and Is not likely to have a significant impact on use of the park. The park would be available for use by dogs and residents.

The proposed system will markedly reduce contaminant loads, exceeding the percentage reduction criteria of the Botany Bay Coastal Catchments Initiative redevelopment objectives. It will also reduce peak flows for very frequent events, approximately up to 1 year ARI.

The issues likely to be encountered in implementing this option include:

- The park is owned by TAFE. Any changes will need to be negotiated with TAFE administration;
- The park is used by residents for a wide variety of recreation. The stormwater infrastructure should be designed to have minimal impact on the recreational value of the park;
- The public open space value of the park means that any pondage must be sufficient shallow as to not be a drowning risk to children. The indicative maximum depth is 200 to 300mm; and
- The location of services may significantly impact on the cost of the proposal.

6.4 SWQ4 – Bioretention Swale at Pemell Street, Newtown

Pemell St, Newtown is one of the few streets in the catchment with a road width sufficient to enable installation of some Water Sensitive Urban Design (WSUD) features such as bioretention swales and rain gardens. The available street width offers the opportunity to install WSUD elements without changing the total number of car parking spaces. The catchment area is 1.18 ha with 63% imperviousness.

The purpose of the investigation is to identify opportunities to install WSUD features that assist in managing stormwater runoff rates and quality in an urban street.   Figure 13 shows the street and its surrounds.

The proposal is for a narrowing of Pemell St by 1 m to allow a 2.5 to 3 m wide swale to be installed on the southern side between Simmons St and Reiby St. The proposed bioretention swale has a surface area of 330 m^2. It has an extended detention depth of 0.15 m and a filter thickness of 0.5 m. It would be lined on the street side to minimise risk of seepage under the road base.

Figure 14 to Figure 16 provide details of some of the local street condition.

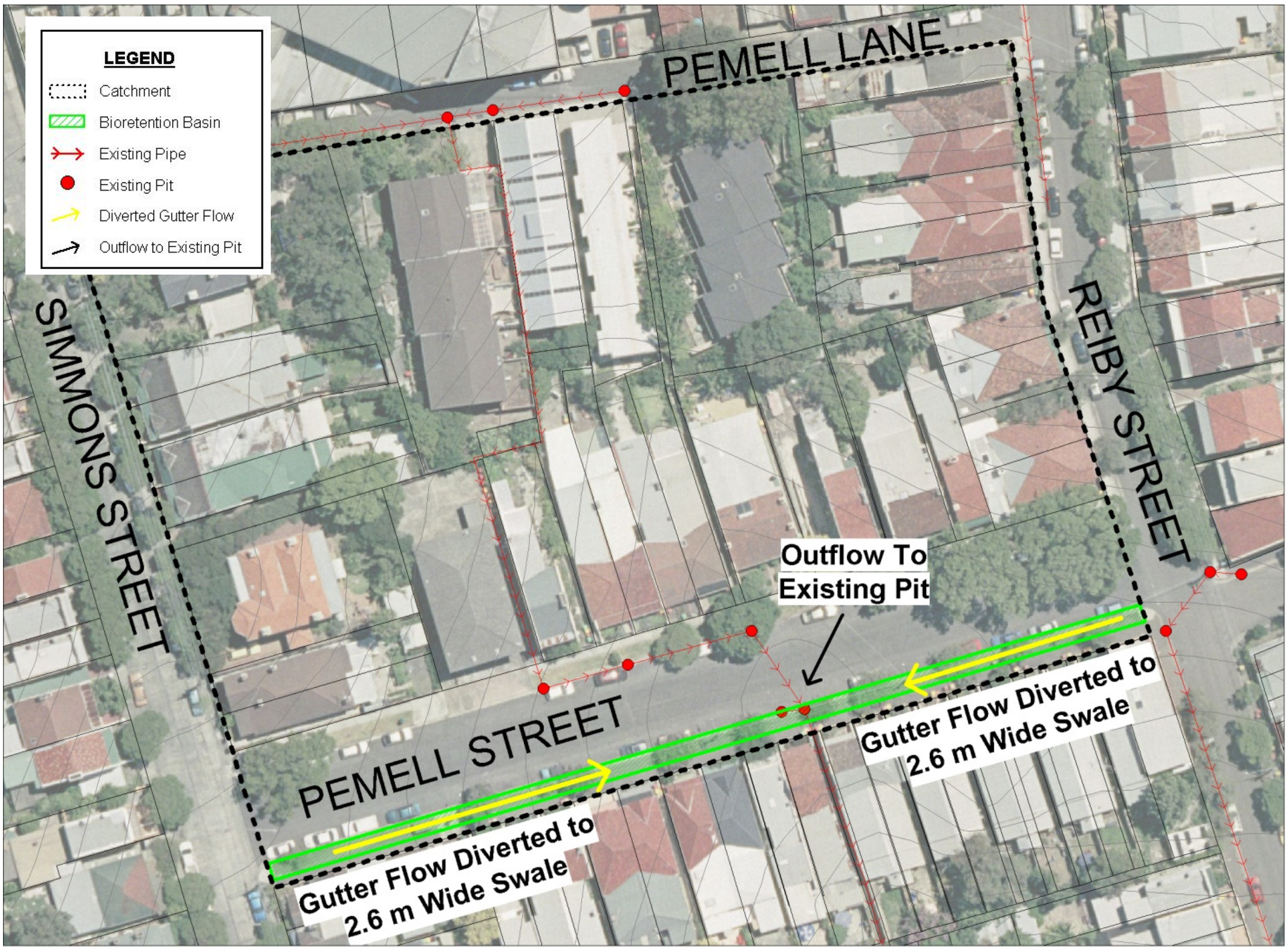

Figure 13: Pemell Street and surrounds. (Source: Dept Land)

Figure 14: Pemell Street is one of the few wide streets in the area. Its width from gutter to gutter is 12.7m.

Figure 15: The north side of Pemell Street has a grassed strip some 1.9m wide.

Figure 16: View of the southern side of Pemell St looking west towards Simmons St. The portion of the bitumen near the road could be converted to a swale system treating both local runoff and water diverted from Simmons St and Enmore Road.

The reasons for the swale location and configuration are:

- The south side of the street has only small trees. These can be incorporated into the design by installing the bioretention swale to the side of these saplings;
- The north side of the street has at least one large concrete apron interrupting the grassed verge. This would make the swale discontinuous, and require either a return of the water into the street gutter or some under concrete boring; and
- The swale will partly replace bitumen, increasing green areas on this side of the street.

6.4.1 Bioretention Swale Modelling

Table 14 shows the water and contaminant balance for the proposed bioretention swale.

Table 14: Performance from the proposed bioretention swale in Pemell St, Newtown.

Attribute	Inflow components	Outflow components	% reduction	BBCCI* objectives
Flow (ML/yr)	7.2	5.2	28	Not listed
Total Suspended Solids (kg/yr)	1,230	111	91	75
Total Phosphorus (kg/yr)	2.1	0.6	73	50
Total Nitrogen (kg/yr)	16.0	8.0	50	35
Gross Pollutants (kg/yr)	200	0	100	Not listed

* Botany Bay Coastal Councils Initiative

The proposed system reduces the outflow volume by 28%. The quantity of water treated could also be expressed as being the volume of water which is filtered through the system. On average 4.6 ML or 64% of the inflowing water is filtered by the time the stormwater reaches the outflow point.

The bioretention swale also reduces the contaminant yields by percentages that are greater than the BBCCI redevelopment water quality objectives.

The likely issues in implementing this option include:

- Interest and involvement of local residents;
- Location of services;
- The re-establishment of saplings that may be damaged during construction;
- The steepness of a portion of the swale length; and
- The need to link two swales coming in different directions to the pit at the centre of a sag in Pemell St.

6.4.2 Costs

Table 15 shows the anticipated costs of the bioretention swale. The establishment costs of $955/m^2$ are relatively high, but reflect the need to allow for adjustment of local designs to avoid services and to re-establish any saplings damaged by the bioretention swale installation. A life cycle of 50 years is assumed, but there will be a need for periodic renovation.

Table 15: Cost Summary for Bioretention Swale at Pemell Street

Life Cycle (yrs)	50
Capital Cost	$320,000
Annual Maintenance Cost	$20,000
Annual Establishment Cost	$0
Establishment Period (yrs)	0
Renewal/Adaptation Cost	$9,000
Renewal Period (yrs)	1
Decommissioning Cost	$140,000
Real Discount Rate (%)	5.5
Annual Inflation Rate (%)	2
Life Cycle Cost of Bioretention (2010$)	$800,000

6.4.3 Conclusions

Installing and adequately managing a 2.6m wide 130m long bioretention swale in Pemell St will result in marked reduction in peak outflows and contamination from this catchment. .

The system is expected to reduce TSS, P, N and gross pollutant mass by percentages that are greater than those used for BBCCI objectives.

The likely issues to be encountered in implementing this option are:

- The need for a positive interaction with local householders;
- The location of services;
- The reestablishment of the saplings currently on the site;
- The steepness of portion of the swale length; and
- The design would need to include appropriate access to the houses from the road.

6.5 SWQ5 – Bioretention Swale at Goodsell Street, St Peters

Goodsell Street, St Peters is the widest local street in the EC East Subcatchment. Its width provides opportunities to install WSUD features such as bioretention swales and rain gardens. Additionally there are significant redevelopment activities in the area as part of Council's urban renewal program. A Development Control Plan (DCP) is currently being prepared by the Council.

The purpose of the investigation is to identify opportunities to install WSUD features that assist in managing stormwater runoff rates and quality in an urban street. Three possible structural WSUD options were identified for Goodsell St:

- Install a bioretention swale on the northern side of the street;
- Encourage installation of rain gardens on the roofs of the high density housing at the eastern end of the street. (This should be part of the St Peters Triangle urban renewal); and
- Ensure any replacement of the factories at the eastern end of Goodsell St includes WSUD elements in new buildings. (This should be part of the St Peters Triangle urban renewal).

Figure 17 shows the catchment, which is 1.23 ha with 86% imperviousness. The bioretention swale would extend in a western direction towards Camdenville Oval for 125m from the traffic calming gardens to the western end of the street. The slight slope in the street suggests that the grades are suitable for installing a bioretention swale. The indicative width would be 1.8m, giving a total area of 225 m^2.

Figure 17 shows the prominent features around Goodsell Street. Figure 18 to Figure 20 provide local details of the Goodsell Street.

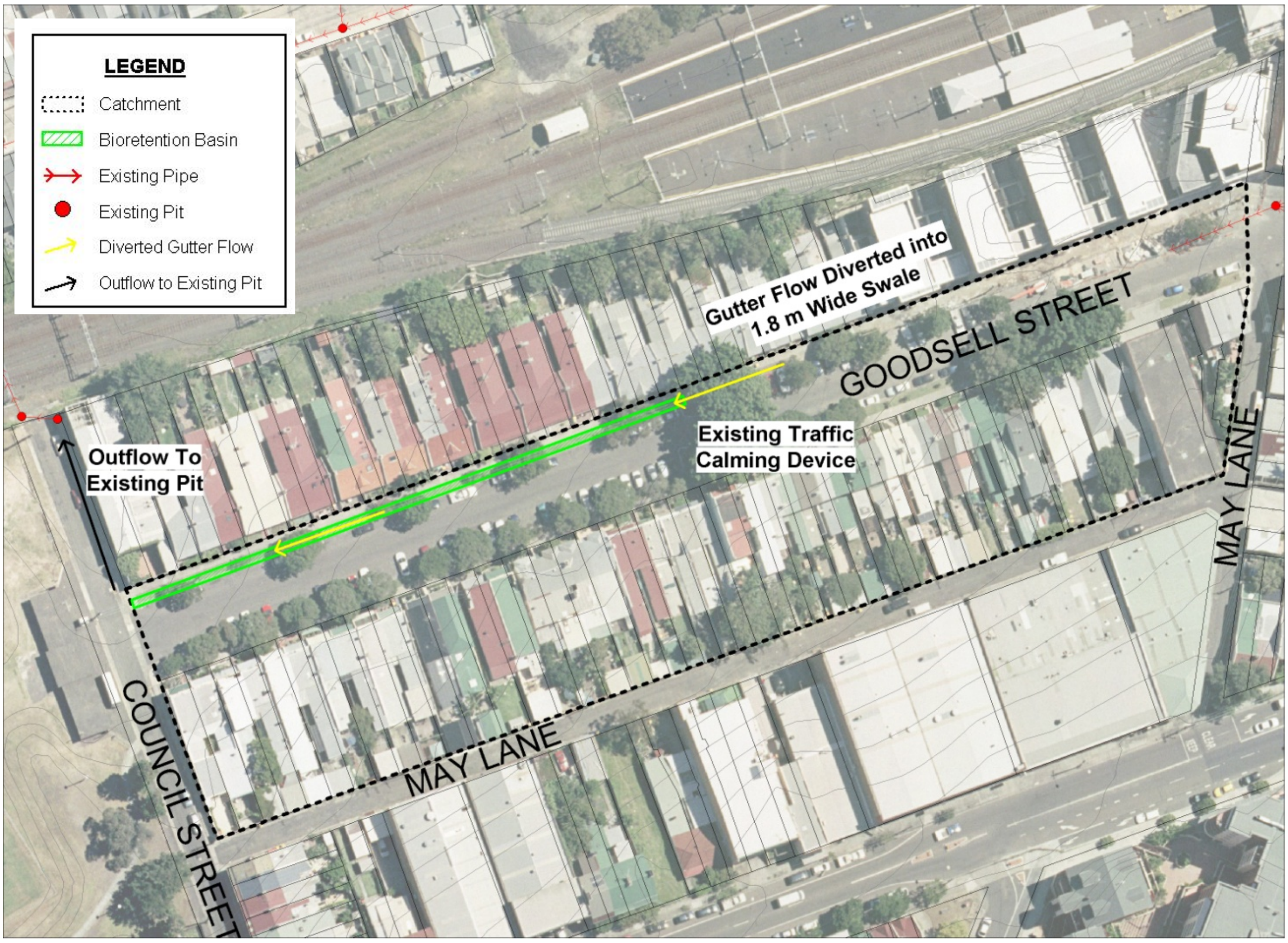

Figure 17: Goodsell St, its features and its catchment boundaries.

Figure 18: Much of Goodsell St has a mix of parallel and perpendicular parking. The grassed verges offer opportunity for WSUD features.

Figure 19: Verges can be converted to swales provided the levels are suitable.

Figure 20: Street gardens could be converted to rain gardens. It would require adjustment of levels to enable inflow of gutter water.

The reasons for the swale location and configuration are:

- The northern side of the street has fewer trees. These can be incorporated into the design; and
- The bioretention swale will partly replace bitumen, increasing the green area on this side of the street. It is designed to be the maximum dimensions that can fit into the site without creating a major change in access.

6.5.1 Bioretention swale modelling

Bioretention performance modelling was undertaken using MUSIC V4. Table 16 shows the effect of a bioretention swale.

Table 16: Annual influx and exit of stormwater and contaminant loads from a 250 m ^{2} bioretention swale in Goodsell St

Attribute	Inflow components	Outflow components	% reduction	BBCCI* objectives
Flow (ML/yr)	9.1	7.6	17	Not listed
Total Suspended Solids (kg/yr)	1660	246	85	75
Total Phosphorus (kg/yr)	2.7	1.0	64	50
Total Nitrogen (kg/yr)	21	13	38	35
Gross Pollutants (kg/yr)	244	0	100	Not listed

* Botany Bay Coastal Councils Initiative

The proposed system reduces the outflow volume by 17%. The quantity of water treated could also be expressed as being the volume of water which is filtered through the system. On average 4.2 ML or 46% of the inflowing water is filtered by the time the stormwater reaches the exit point.

There are also major reductions in contaminant loads, with the proposed system achieving the BBCCI redevelopment objectives for TSS, nitrogen and phosphorus.

The system is also expected to be an effective trap for gross pollutants.

6.5.2 Costs

Table 17 shows the anticipated costs of the bioretention swale. The establishment costs of $290/m^2 are relatively high, but reflect the need to allow for adjustment of local designs to avoid services and to re-establish the saplings which are already present in the street.

Table 17: Cost summary for the bioretention swale at Goodsell St

Cost estimate input	Assumed component
Life Cycle (yrs)	50
Capital Cost	$325,000
Annual Maintenance Cost	$20,000
Annual Establishment Cost	$0
Establishment Period (yrs)	0
Renewal/Adaptation Cost	$9,500
Renewal Period (yrs)	1
Decommissioning Cost	$145,000
Real Discount Rate (%)	5.5
Annual Inflation Rate (%)	2
Life Cycle Cost of Bioretention ($2010)	$820,000

6.5.3 Summary

It is feasible to install and manage a 1.8m wide 125 m long bioretention swale in Goodsell St.

The system is expected to reduce TSS, P, N and gross pollutant mass by percentages that are greater than those used for Botany Bay water quality objectives. It will also reduce the peak flows exiting the catchment by at least 10% in the typical year.

Cost estimates suggest that retrofitting a bioretention swale into a street will cost up to 10 times/unit of contaminant removed than would a similar structure in an open space such as a park.

The likely issue in implementing this option are:

- The need for a positive interaction with local householders;
- The location of services;
- The re-establishment of any saplings damaged by construction; and
- The presence of a street garden which prevents a continuous swale along the entire length of Goodsell St.

6.6 SWQ6 – Rain Gardens for Multi-unit Dwellings

This option involves installation of rain gardens on roofs or on the ground surrounding the new or redevelopment areas. The concept can be applied throughout the Marrickville Council area.

The aim of this study is to identify the feasibility, the costs and the potential benefits of installing rain gardens on redeveloping sites. Table 18 shows the effect of a 30 m^2 roof rain garden which receives runoff from the surrounding 100 m^2 of impervious surface. These gardens can either be on the roof or in sunny places on the ground.

Table 18: The effect of a 30 m^2 rain garden receiving runoff from 100 m^2 of impervious surface

Attribute	Influent	Effluent	% reduction	BBCCI* objectives
Flow (ML/yr)	0.090	0.088	2	Not listed
Total Suspended Solids (kg/yr)	16.80	3.28	81	75
Total Phosphorus (kg/yr)	0.027	0.011	59	50
Total Nitrogen (kg/yr)	0.21	0.12	42	35
Gross Pollutants (kg/yr)	2.410	0.000	100	Not listed

*Botany Bay Coastal Councils Initiative

The results show that while there is only a 2% reduction in the volume of runoff/year there is a major reduction in contaminant load The results suggest that rain gardens covering 20 to 25% of the site are very effective at reducing the export of contaminants in stormwater.

6.6.1 Post Industrial Development

The factories at the St Peters end of Goodsell St are being gradually replaced with high density housing. This provides the opportunity to install WSUD elements such as roof gardens. The discussion in the previous section identified the potential value of roof rain gardens in reducing contaminant yield from high density dwellings.

The main issues in implementing this option are:

- The cost of structural reinforcement needed on the roof to support the rain gardens;
- The interest in the developer in providing roof gardens; and
- The long term interest of site owners or residents in maintaining the gardens.

6.7 Camdenville Oval Options

Camdenville Oval is the largest open space available in the EC East Subcatchment. It provides an opportunity to manage both stormwater flooding as well as improve the stormwater quality in the subcatchment. A draft Masterplan for Camdenville Oval was prepared in 2006. This Masterplan included options for redevelopment of the current detention basin into a wetland that could also be used as an irrigation storage system.

Contaminated groundwater and gas production issues associated with the landfill buried under Camdenville Park have been identified (GHD, 2009). A Remediation Action Plan is currently being prepared. The remediation plan includes options to seal the floor of the basin and establish a gas management system.

The potential for using catchment runoff to irrigate the sports field has been examined. The effect of the irrigation on the stormwater volume and contaminant loads exiting the catchment has also been assessed. Based on this, three options are explored:

- Using a tank to capture street runoff {Option SWQ7 + WR};
- Using a tank to capture roof runoff {Option SWQ8 + WR}; and
- Using the Camdenville Oval basin both as a stormwater capture and remediation system, as well as a water storage system for the adjacent sports fields (the groundwater management issues would need to be addressed for this option to be acceptable) {Option SWQ9 + WR}.

6.8 SWQ7 + WR – Irrigate Camdenville Oval by Using Street Runoff from Camdenville Oval Catchment

This option involves capture of water from the streets of the Camdenville Catchment, storing it in tanks and using it to irrigate Camdenville Oval.

Figure 21 shows the location of the system. Whilst only 0.7 ha of catchment drains directly to the basin, there are some 25.4 ha of catchment that could drain to the Camdenville Park basin. Currently catchment drainage bypasses the detention basin, at least until flows exceed the present conveyance capacity of the drainage system (See stormwater drainage option R3).

Figure 21: The subcatchments which drain towards Camdenville Basin

Two tank sizes were considered for storage; 250 m^3 and 500 m^3. MUSIC modelling was used to assess the removal of water and contaminants from the stormwater system. The results are presented in Table 19.

Table 19: Effect of irrigation tank size on the volume of water irrigated and the contaminant load removed from the runoff

Component	Inflow from 25.4 ha catchment	Outflow (250 m^3 tank)	Outflow (500 m^3 tank)	% reduction (250 m^3 tank)	% reduction (500 m^3 tank)
Flow (ML/yr)	157	152	152	3	3
Total Suspended Solids (kg/yr)	29782	28731	28618	4	4
Total Phosphorus (kg/yr)	65	63	63	3	4
Total Nitrogen (kg/yr)	441	428	426	3	3
Gross Pollutants (kg/yr)	4910	0	0	100	100

The contaminant removal percentages are very small and do not vary greatly between the 250 and the 500 m^3 tanks.

The water balance modelling undertaken for the two tanks suggest that a 250 m^3 tank would be sufficient to supply water for much of the typical year. A 250 m^3 tank capturing a portion of runoff from a 25.4 ha catchment will meet 94% of the anticipated irrigation demand at Camdenville Oval. The remaining 6% could be met via top up from mains water.

The main issues in implementing this option are:

- The current drainage at the intersection of May St, Unwins Bridge Road Campbell Road and Bedwin Road needs to be modified to enable a portion of the stormwater to be captured; and
- The water needs to be of sufficient quality for safe irrigation of a public space with open access.

Further details of this option are presented in APPENDIX C.

6.8.1 Cost

The cost component of the MUSIC software and Rawlinsons (2010) were used to estimate the costs for installation and operating the storage tanks. Table 20 shows the cost summary for the proposed systems. Detailed cost estimates are presented in APPENDIX C.

Utilisation of captured runoff needs to be of sufficient quality for safe irrigation of public space with open access. The cost of disinfection is included in the analysis presented in Table 20.

Table 20: Cost summary for the various sizes of storage tanks for catchment runoff at Camdenville Oval.

Component	250 m^3	500 m^3
Life Cycle (yrs)	50	50
Capital Cost	\$345,000	\$390,000
Annual Maintenance Cost (includes electricity for pumps)	\$20,000	\$20,000

Component	250 m^3	500 m^3
Annual Establishment Cost	$0	0
Establishment Period (yrs)	0	0
Renewal/Adaptation Cost	$0	0
Renewal Period (yrs)	1	1
Decommissioning Cost	$10,000	$10,000
Real Discount Rate (%)	5.5	5.5
Annual Inflation Rate (%)	2	2
Life Cycle Cost ($2010)	$685,000	$730,000

6.9 SWQ8 + WR – Irrigate Camdenville Oval by Capturing Roof Runoff

There are a series of large factories to the south of Camdenville Oval. These factories have large roof areas and there is potential for capturing some of the roof runoff and using the water to irrigate Camdenville Oval.

The aim of this investigation is to identify the potential for using roof water from adjacent factories to irrigate the Camdenville Oval. Approximately 0.5 ha of roof area was available. The initial simulations examined a range of tank sizes. Table 21 shows the water balance components for 250, 500 and 1000 m^3 tanks.

Table 21: Effect of changing tank size on Camdenville Oval site water balance

Component	Units	250 m^3	500 m^3	1000 m^3
Rainfall	mm/y	1115		
Tank inflow	m^3/year	4517		
Volume/irrigation	mm/y	10	20	20
Irrigation (effective)-80% of volume actually applied	mm/y	141	197	281
Rainfall runoff from grass (assumes all irrigation water enters the soil)	mm/y	301		
Rainfall infiltration into topsoil	mm/y	846		
Percolation loss	mm/y	184	209	212
Grass transpiration	mm/y	768	803	869
Number of irrigations/year		19	14	18
Volume of water irrigated (80% efficient)	m^3	1766	2465	3500
Volume of water lost via bypassing or 'overtopping'	m^3	2752	2052	1017

The 250 m^3 tank in combination with a 0.5 ha roof catchment provided sufficient water for 20% of the 702 mm/yr irrigation demand. Only 39% of the water which was shed from the roofs (4517 m^3/yr) was utilised for irrigation. There was insufficient storage capacity to retain the other 2752 m^3. The result suggests that a larger tank size is needed. The 500 m^3 tank system met 28% of the irrigation demand. While a 1000 m^3 tank met 40% of the average total irrigation demand.

If a long term average irrigation of 500 mm/year is to be supplied, then the combination of a 0.5 ha catchment plus a 1000 m^3 tank, which supplies 281 mm of effective irrigation/year, would require a top-up of

219 mm or 1.75 ML/year of irrigation onto the 0.8 ha sportsground. If a 500 m^3 tank were installed it would supply 199 mm of effective irrigation, so another 301 mm of water or 3.6 ML/year would be required.

These differences are not large and it may be cheaper to have the 500 m^3 tank and rely on potable water supplies during extreme drought conditions.

Figure 22 presents the layout of this option. Table 22 presents results from the MUSIC modelling undertaken for this option.

Figure 22: Pipeline route and proposed tank locations.

Table 22: Effect of irrigation tank size on the volume of water irrigated and the contaminant load removed from the runoff

Component	Inflow	250 m^3 tank	500 m^3 tank	1000 m^3 tank	250 m^3 tank	500 m^3 tank	1000 m^3 tank	BBCCI* objectives
		Outflow			%reduction			
Flow (ML/yr)	4.35	1.62	1.03	0.61	63	76	86	Not listed
Total Suspended Solids (kg/yr)	955	216	130	61.3	77	87	94	75
Total Phosphorus (kg/yr)	1.87	0.521	0.309	0.163	72	83	91	50
Total Nitrogen (kg/yr)	9.12	3.26	2.07	1.21	64	77	87	35
Gross Pollutants (kg/yr)	118	0	0	0	100	100	100	Not listed

*Botany Bay Coastal Councils Initiative

The roof runoff was estimated at 4.35 ML/yr. The volume captured ranged from 63% of runoff for the 250 m^3 tank to 86% in the 1000 m^3 tank.

Depending on the tank size and contaminant type between 64 and 100% of the contaminant loads were removed from the stormwater flow which entered the tanks. All tank sizes resulted contaminant reductions greater than the BBCCI Water Quality Objectives for redeveloped areas.

The issues in implementing this option are :

- Obtaining factory owners' agreement to capture and utilise runoff;
- Transfer of the water from the factories to the sports fields; and
- The need for top up water during droughts.

6.9.1 Cost

The MUSIC package, Rawlinsons (2010) and past experience with similar projects were used to estimate the costs of the proposed system. The results are summarised in Table 23.

Table 23: Cost summary for the various sizes of storage tanks for roof runoff at Camdenville Oval

Component	250 m^3	500 m^3	1000 m^3
Capital Cost	$500,000	$555,000	$655,000
Annual Maintenance Cost	$15,000	$15,000	$15,000
Decommissioning Cost	$10,000	$10,000	$10000
Real Discount Rate (%)	5.5	5.5	5.5
Annual Inflation Rate (%)	2	2	2
Life Cycle Cost of Rainwater Tank ($2010)	$650,000	$810,000	$910,000

6.10 SWQ9 + WR – Use of Sealed Wetland in Camdenville Basin to Treat and Enable Reuse of Catchment Runoff

Currently runoff from the 25.4 ha Camdenville catchment is discharged into the SWC stormwater system. There is currently no arrangement in place for reducing the contaminant load exiting the area.

The objective of this investigation is to identify potential issues, benefits and costs associated with adapting the basin at Camdenville Oval to act as a stormwater treatment wetland as well as a reservoir to supply water to irrigate Camdenville Oval. A trace metal, zinc was included in the analysis as zinc was one of the contaminants exiting the groundwater at Camdenville Oval. The study aims included investigating the potential to use the basin to reduce trace metal export from the catchment.

Modelling results are summarised in Table 24.

Figure 23: Proposed layout of wetland system.

Table 24: Effect of using a wetland at Camdenville Oval to reduce mass balance and concentrations of two contaminants exiting the catchment

Attribute	unit	P	Zn
Contaminant mass in catchment runoff	kg/year	52	52
Contaminant mass into wetland	kg/year	47	47
Contaminant mass bypassing the wetland	kg/year	5	5
Contaminant mass in outflow exiting the wetland	kg/year	35	17
Contaminant mass in irrigation water	kg/year	0.57	0.05
Contaminant mass retained in wetland	kg/year	11.0	30.8
Concentration in wetland inflow	mg/L	0.36	0.36
Concentration in wetland outflow	mg/L	0.2144	0.091
Concentration in irrigation water	mg/L	0.107	0.013
Contaminant loading onto 0.8 ha of irrigated land	kg/year	0.84	0.10

According to data in Table 24, the mass of phosphorus exiting the wetland via overflows was approximately double that of zinc. The reason for this is that the removal rate of Zn in a wetland is greater than that of phosphorus; a larger quantity of zinc was therefore retained in the wetland.

Figure 24 shows the effect of the wetland in reducing zinc concentration in water either overtopping the wetland or being irrigated. The wetland has a major impact on zinc concentrations in outflowing water, with the concentrations being less than the ANZECC guidelines (2000) for either fresh or marine waters 80 to 90% of time. The concentration in the irrigation waters was typically even less, with the irrigation water meeting ANZECC Guidelines in over 95% of time.

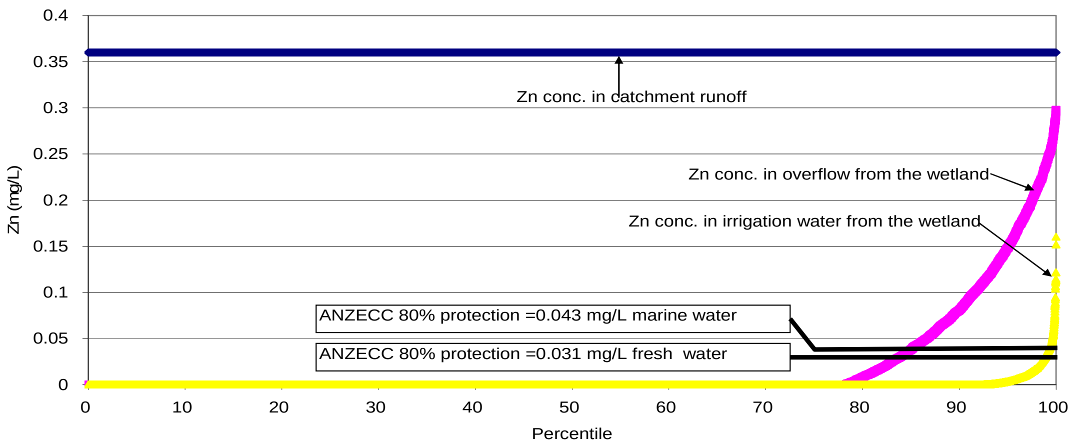

Figure 24: Percentile distribution of Zinc concentration (mg/L) in water exiting the 25.4 ha catchment, in overflow from the wetland and in irrigation water (mg/L).

The reason the irrigation water has less zinc concentration than overflowing water is that it is retained for a longer period than the overflows. The extra residence time allows for a higher rate of removal. These results suggest that the wetland could play a major role in removal of contaminant load from the catchment.

MUSIC modelling was used to assess the removal of other contaminants. Table 25 summarises the results.

Table 25: Combined effect of a wetland plus irrigation on the reduction in stormwater volumes and contaminant loads from the 25.4 ha catchment

Component	Flow (ML/Y)	TSS (kg/Y)	P (kg/Y)	N (kg/Y)	Gross pollutants (kg/Y)
Flow In	157	32141	64	450	4592
ET Loss	6	0	0	0	0
Infiltration Loss	0	0	0	0	0
Low Flow Bypass Out	0	0	0	0	0
High Flow Bypass Out	73	16847	31	212	1879
Weir Out	71	2338	10	119	0
Reuse Supplied	8	98	1	10	0
Reuse Requested	8	0	0	0	0
% Reuse Demand Met	100	0	0	0	0
% Load Reduction	9 (via irrigation)	40	36	26	59

Component	Flow (ML/Y)	TSS (kg/Y)	P (kg/Y)	N (kg/Y)	Gross pollutants (kg/Y)
Treated/ removed	85	12956	23	118	2713
% treated/removed	54	40	36	26	59

The average annual inflow to the wetland was 85 ML. Evapotranspiration accounted for 6 ML/yr while 73 ML/yr exited via overtopping and 8 ML/yr was utilised for irrigation. TSS, phosphorus and nitrogen loads were reduced by 40%, 36% and 25% respectively. Irrigation plus evapotranspiration reduced outflow by 9%, however 54% of the flow was either treated or removed.

The main issues in implementing this option are:

- Needs to be compatible with Camdenville Oval Master Plan and Remediation Action Plan;
- The interaction with groundwater needs to be managed to avoid contamination in other areas;
- The current drainage at the intersection of May St, Unwins Bridge Road Campbell Road and Bedwin Road needs to be modified to enable a portion of the stormwater to be captured;
- SWC needs to be involved in the decision making process; and
- The water needs to be of sufficient quality for safe irrigation of a public space with open access.

6.10.1 Cost

The cost software of the MUSIC program was used to estimate the cost for the wetland at Camdenville Oval. The sealing of the wetland plus weir construction, pumps and pipes were estimated from Rawlinsons (2010) plus our own experience. Table 26 shows the cost components for the proposed systems. Detailed cost estimates are presented in APPENDIX C.

Table 26: Cost summary for the development of Camdenville Oval Detention Basin as a stormwater quality and re-use wetland

Life Cycle (yrs)	50
Construction Cost	$680,000
Annual Maintenance Cost	$25,000
Annual Establishment Cost	$0
Establishment Period (yrs)	0
Renewal/Adaptation Cost	$11,000
Renewal Period (yrs)	1
Decommissioning Cost	$220,000
Real Discount Rate (%)	5.5
Annual Inflation Rate (%)	2
Life Cycle Cost of Pond (2010$)	$1,250,000

7.0 COMPARISON OF WATER QUALITY IMPROVEMENT AND WATER REUSE OPTIONS

Table 27 provides comparison of the performance of various stormwater quality improvement and water reuse options. These options vary greatly in scale and impact. The smallest one is “SWQ6 – Rain Gardens for Multi-unit Dwellings”, which involves a 30 m^2 rain garden treating a 100 m^2 of impervious surface. By contrast “SWQ9 + WR – Use of Sealed Wetland in Camdenville Basin to Treat and Enable Reuse of

Catchment Runoff" has a 25.4 ha catchment and a 0.7 ha wetland plus irrigation demand for the 0.8 ha sports field. However, if the treatment system is small, it will have minimal effect on the percentage reduction in loads. For example, "SWQ7 + WR – Irrigate Camdenville Oval by Using Street Runoff from Camdenville Oval Catchment", which involves 250 m^3 and 1000 m^3 tanks is primarily a re-use option.

Table 27 also demonstrates the importance of considering the volume of water that is either treated or removed. For example the option "SWQ9 + WR – Use of Sealed Wetland in Camdenville Basin to Treat and Enable Reuse of Catchment Runoff", reduced catchment outflow by 9%, however it treated 45% of the outflow, giving a removal or treatment rate of 54% for water from the 25.4 ha catchment.

The cost per unit of water and contaminant removed or treated is shown in Table 28. The costs of individual house tanks or rain gardens are not shown because their cost is extremely dependant on local conditions.

Option R9 – Optimization of Drainage at corner of Campbell St and May St is the cheapest option/ML of water removed. It is 2 to 3 times more cost effective than the other options. Options that include in-street bioretention swales such as SWQ4 – Bioretention Swale at Pemell Street, Newtown and SWQ5 – Bioretention Swale at Goodsell Street, St Peters or roof runoff plus irrigation systems such as SWQ8 + WR – Irrigate Camdenville Oval by Capturing Roof Runoff are the most expensive per unit of water removed. Option SWQ6 – Rain Gardens for Multi-unit Dwellings has, however, the highest cost per unit of water treated.

SWQ9 + WR – Use of Sealed Wetland in Camdenville Basin to Treat and Enable Reuse of Catchment Runoff is also the most cost effective when performance is expressed as $/unit contaminant removed. However, it has the highest capital cost. The main concern with option SWQ9 + WR – Use of Sealed Wetland in Camdenville Basin to Treat and Enable Reuse of Catchment Runoff is it's compatibility with the Masterplan and Remediation Action Plan for Camdenville Oval Detention Basin. Option SWQ2 – Bioretention Basin at Simpson Park is the next most cost efficient in terms of $/unit contaminant removed.

Table 27: Effectiveness of the stormwater quality improvement and water reuse options.

Option	SWQ1+WR	SWQ2	SWQ3	SWQ4	SWQ5	SWQ6+WR	SWQ7+WR	SWQ8+WR	SWQ9+WR
Name	Rainwater tanks	Simpson Park	TAFE Park	Pemmel St	Goodsell St	Redevelopment sites	Camdenville	Camdenville	Camdenville
Comments	Individual homes 20% uptake 3.44 ha	500 m^2 bioretention basin. 10.33 ha catchment, 63% impervious	300 m^2 bioretention basin. 3.81 ha catchment, 64% impervious	330 m^2 bioretention swale. 1.18 ha catchment, 63% impervious	225 m^2 bioretention swale. 1.23 ha catchment, 86% impervious	30% of site (roof/garden with rain gardens. Assume 30m^2, 100m^2 roof.	25.4 ha catchment 57% impervious 250 m^3 tank 0.8 ha irrigated	0.5 ha of roof area 500 m^3 tank 0.8 ha irrigated	25.4 ha catchment 57% impervious 0.7 ha wetland. Bypass at 0.125 m^3/sec
Reduction in outflow (ML/y)	13 (10%)	3 (5%)	3 (11%)	2.1 (28%)	1.5 (16%)	0.003 (2%)	5 (3%)	3.3 (75%)	14 (9%)
Treatment or reduction in outflow (ML/y)	13 (10%)	20.8 (31%)	15.8 (38%)	4.6 (64%)	4.2 (46%)	Same	Same	Same	85 (54%)
TSS reduction (kg/y) (% of sub-catchment outflow)	2,700 (11%)	9180 (68%)	3760 (76%)	1344 (90%)	1414 (85%)	13.5 (81%)	730 (3%)	825 (87%)	12956 (40%)
P reduction (kg/y)	6 (10%)	14 (53%)	6 (60%)	1.8 (71%)	1.7 (64%)	0.16 (59%)	2 (3%)	1.56 (83%	23 (36%)
N reduction (kg/y)	38 (9%)	48 (25%)	24 (33%)	9 (46%)	8 (38%)	0.9 (42%)	14 (3%)	7.05 (77%)	118 (25%)

Table 28: Cost efficiency of the stormwater quality improvement and water reuse options

Option	SWQ1 +WR	SWQ2	SWQ3	SWQ4	SWQ5	SWQ6	SWQ7+WR	SWQ8+WR	SWQ9+WR
Name	Rainwater tanks	Simpson Park	TAFE Park	Pemmel St	Goodsell St	Redevelopment Sites	Camdenville	Camdenville	Camdenville
Description	Rainwater tanks to allow substitution of stormwater for non potable water needs within individual and multi unit dwellings.	A bioretention basin in Simpson Park to improve the quality of stormwater exiting the surrounding 10.3 ha catchment	A bioretention basin in TAFE Park to improve the quality of stormwater exiting the surrounding 3.8 ha catchment	A bioretention swale along the southern side of Pemell St, Newtown to improve the quality of stormwater exiting the surrounding 1.18 ha catchment	A bioretention swale along the northern side of Goodsell St, St Peters to improve the quality of stormwater exiting the surrounding 1.23 ha catchment	Raingardens on redeveloping sites in the St Peters triangle area as part of the DCP for the locality	Stormwater collection tanks in Camdenville Park to collect catchment runoff and supply it as irrigation water to Camdenville Park	Stormwater collection tanks in Camdenville Park to collect runoff from nearby factory roofs to supply irrigation water for Camdenville Park	Adaptation of the existing Camdenville stormwater detention basin to collect and supply irrigation water to Camdenville Park
Comment	10% of individual dwellings	350 m^2 bioretention basin	200 m^2 bioretention basin	330 m^2 bioretention basin	225 m^2 bioretention swale	30 m^2 roof rain garden receiving from 100 m2 of roof	250 m^3 tank system	1000 m^3 tank system	24.5 ha catchment a 6680 m^2 basin, with 0.8 ha irrigation
Life Cycle (yrs)	25	50	50	50	50	50	50	50	50
Capital Cost	$1,145,000	$290,000	$180,000	$320,000	$325,000	$26,000	$345,000	$655,000	$680,000
Annual Maintenance Cost	$22,900	$19,000	$14,000	$20,000	$20,000	$4,200	$20,000	$15,000	$25,000
Annual Establishment Cost	$0	$0	$0	$0	$0	$0	$0	0	$0
Establishment Period (yrs)	0	0	0	0	0	0	0	0	0
Renewal/ Adaptation Cost	$0	$8,739	$5,084	$8,996	$9,208	$1,202	$0	0	$10,610
Renewal Period (yrs)	1	1	1	1	1	1	1	1	1
Decommissioning Cost	$51,525	$94,150	$78,238	$138,455	$141,709	$10,149	$10,000	$10,000	$218,083
Real Discount Rate (%)	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Annual Inflation Rate (%)	2	2	2	2	2	2	2	2	2
Life Cycle Cost ($2010)	$1,460,429	$760,412	$506,676	$800,515	$815,915	$117,523	$682,275	$906,422	$1,252,971
Equivalent Annual Payment Cost of the Asset ($2010/annum)	$58,417	$15,208	$10,134	$16,010	$16,318	$2,350	$13,645	$18,128	$25,059
Equivalent Annual Payment/ML of stormwater volume reduction/annum	$8,891	$5,243	$3,400	$7,925	$10,596	Not applicable	$2,608	$4,796	$1,772

Option	SWQ1 +WR	SWQ2	SWQ3	SWQ4	SWQ5	SWQ6	SWQ7+WR	SWQ8+WR	SWQ9+WR
Equivalent Annual Payment/ML of stormwater treated or supplied/annum	$7,518	$911	$1,057	$3,450	$3,813	$87,030	$2,608	$4,771	$850
Equivalent Annual Payment/kg Total Suspended Solids/annum	$42	$2	$3	$14	$12	$170	$19	$20	$2
Equivalent Annual Payment/kg Total Phosphorus/annum	$20,378	$1,209	$1,648	$10,679	$9,484	$147,812	$7,666	$10,620	$1,133
Equivalent Annual Payment/kg Total Nitrogen/annum	$3,128	$391	$422	$2,007	$2,075	$26,883	$990	$2,292	$209
Equivalent Annual Payment/kg Gross Pollutant/annum	$282	$8	$14	$80	$67	$976	$80	$154	$9

8.0 FLOOD MITIGATION OPTIONS

The flood risk in a catchment can be categorised into existing, future and residual risk. The existing risk relates to the existing developments on the flood prone land whereas the future risk relates to the development that would occur in the flood prone land in the future. The residual risk arises from the fact that unless flood management measures are designed for an extreme flood event, there is always a chance that these measures would be overwhelmed if the storm size exceeds the design criteria, resulting in adverse impact on the flood prone land.

Based on the above risk categories, the Floodplain Development Manual identifies the following three types of flood risk management measures:

- Flood Modification Measures –structural measures such as culvert enhancement, improvement in street drainage etc. for managing the existing and the future flood risk;
- Property Modification Measures - such as land use planning, development control plans, house raising etc. for managing the existing and the future flood risk; and
- Emergency Response Modification Measures – such as preparation of a Local Flood Plan, public awareness and education etc. to manage the residual risk.

The proposed flood modification measures are presented in Section 9.0 of the report. Discussion on property modification measures and emergency response modification measures is presented in Sections 10.0 and 11.0 respectively.

9.0 FLOOD MODIFICATION MEASURES

There are several drainage hotspots within the catchment that were targeted as part of the stormwater management option assessment.

Each of the management options were assessed using the TUFLOW hydraulic model and simulated for two storm event durations (30 minute and 60 minute) for the 2 yr, 5 yr, 20 yr, 100 yr and probable maximum flood (PMF) design flood events. The maximum modelled depth and maximum modelled hazard from either storm duration was then determined.

The modelled maximum depths and modelled maximum hazards were then compared to the base case, considering the same two storm event duration (30 minute and 60 minute), and the simulated impact presented as a difference plot.

The layout of each stormwater management option is presented in APPENDIX G with detailed long-sections for each pipe branch presented in APPENDIX F together with proposed pit inlet details.

It is noted that stormwater options that incorporate Camdenville Oval are currently constrained due to legacy below-ground site contamination issues within that detention basin.

The stormwater flooding management options included:

- Option R1 – Pit/pipe infrastructure in Railway Parade (Eastern Subcatchment): The option consists of duplication of the trunk drain (culvert) along Railway Parade to Eastern Channel, disconnection of some existing infrastructure and upgrade of other existing infrastructure, and installation of new pit and pipe network along John St above Darley St, within Lord St to Johns St and within Wells St;
- Option R2 – Pits/pipes infrastructure at Alice St (Northern Subcatchment): This option consists of installation of new pits on the western side of Alice St connected via a shallow box culvert to the open channel that runs through Empire Lane to the culvert under Marrickville Metro. It was identified that the hydraulic grade line of the main SWC

culvert is above ground surface at this intersection therefore not plausible to connect new pits to that culvert;

- Option R3 – Detention basin in Simpson Park (Southern Subcatchment): This option consists of installation of a detention basin into Simpson Park, installation of new pit and pipe infrastructure along Campbell St (throttled), within Florence St and within Brown St and along Lackey St, and installation of new infrastructure in Hutchinson St (diverted to Camdenville Oval via a new laneway between Hutchinson St to May St);

- Option R4 – Detention basin in TAFE Park (Northern subcatchment): This option consists of installation of a detention basin into the existing open space, upgrade of inlet capacity of existing infrastructure in Marion St, and installation of new infrastructure in Sarah St diverted into TAFE Park;

- Option R5 – Pit/pipe infrastructure in Sarah St (Northern subcatchment): This option consists installation of new infrastructure along Edgeware Road from Sarah St to Camden St;

- Option R6 – Overland flowpath in Sloane St (Northern subcatchment): This option consists of acquisition of existing properties to create an overland flowpath between Pemell St and Sloane St and between Fulham St and Margaret St, and installation of new pit/pipe infrastructure in Sloane St diverted (choked) to Reiby St;

- Option R7 – Pit/pipe infrastructure in Goodsell St (Southern subcatchment): This option consists of installation of new infrastructure along Goodsell St, May Lane and Council St connected to the culvert at the end of Council St that runs under the Illawarra Railway line. It is noted that this option will exacerbate drainage;

- Option R8 – Increase capacity of SWC Trunk Drainage (Northern subcatchment): This option consists of increasing the conveyance capacity of existing trunk drainage line to Eastern Channel by widening and/or adding additional barrels to the existing 2-barrel system downstream of Alice St and Edgeware Road intersection;

- Option R9 – Optimise drainage at the corner of Campbell St and May St (Southern subcatchment): This option consists of pit inlet grates (series) installed within roadway at the local trapped low-point to capture excess stormwater during intense rainfall events. These grated inlet pit series are diverted to Camdenville Oval through a new dedicated pipe drainage; and

- Option R10 – Expansion of Camdenville Oval Detention Basin (Southern subcatchment): This option is based on Option R3 (Detention Basin in Simpson Park), however, with trunk drainage lines maximised. This option also includes a 5400 m^3 expansion of Camdenville Oval.

The layout of each stormwater management option is presented in APPENDIX G with detailed long-sections for each pipe branch presented in APPENDIX F. Proposed pit inlet details are presented in APPENDIX E.

9.1 Option R1 – Railway Parade

This precinct is subject to intermediate and some high flood hazard areas during the 100 yr design flood event. It is also an area with regular drainage issues. It is expected that works will reduce the flood hazard; however, more recognisably for the community, the works would attempt to resolve the drainage hotspots at the intersection of John St and Lord St, along Lord St, and at the corner of Railway Parade and Edgeware Road which featured prominently in the community flood survey.

This approach includes:

- Extension of pit/pipe network up John St (900 mmØ) and into Wells St and then along Wells St (750 mmØ) until past Pearl St;
- Upgrade of existing pipe along John St (from 300 mmØ to 900 mmØ);
- Reconfiguration of pipe network at intersection of John St and Lord St to feed stormwater into new pipe in Lord St, between John St to midway along Lord St, (new pipe 1050 mmØ) rather than railway corridor;
- Upgrade of existing pipe in Lord St, from midway along Lord St to Edgeware Road (from 300 mmØ to 1050 mmØ), and increase in frequency of pits;
- Upgrade of existing pipe in Darley St (from 225 mmØ to 600 mmØ and 750 mmØ) and increase in frequency of pits;
- Upgrade of pipe in Edgeware Road from Wells St (from 225 mmØ to 750 mmØ) through to corner of Edgeware Road and Lord St (from 450 mmØ to 900 mmØ);
- Installation of new culvert (3 X 600 mmØ) from corner of Edgeware Road and Lord St to corner of Edgeware Road and Railway Parade;
- Installation of new culvert (2000 mmW x 1000 mmH) from corner of Edgeware Road and Railway Parade along Railway Parade to Murray St and then into Eastern Channel; and
- Construction of an embankment between Railcorp land and Railway Parade to prevent flow from Railcorp land (height of bund above existing ground level is approximately 0.5 m). Consultation with Railcorp will be required during detailed design.

The layout of this management option is presented in APPENDIX G (Figure G3). Detailed long-sections for this option are presented in APPENDIX F (Figure F1 to F4). Proposed pit inlet details are also presented in APPENDIX E.

9.1.1 Impact of Option R1

This option would involve extensive installation of new pipe/infrastructure along Lord St, Darley St and Wells St, as well as new infrastructure in John St into Wells St to Pearl Lane. Figure G4 presents the predicted impact on modelled maximum flood depths. Figure G5 presents the predicted impact on provisional hazard class (NSW Floodplain Manual).

As seen in Figure G4, there is a reduction of flood depth of about 5 cm throughout the eastern subcatchment in the 2 yr event, with a reduction of more than 15 cm at Railway Parade. The commensurate increase in flood level within Eastern Channel is about 5 cm. There is reduced benefit in the 100 yr event with the embankment installed between Railcorp land and Railway Parade leading to an increase in flood depth of more than 15 cm and overall reduction in flood level within eastern channel of between 0 cm and 5 cm. There is no increase in modelled flood depth in Eastern Channel during the 100 yr event.

As seen in *Figure G5*, there is no change to modelled hazard class since the eastern catchment is low hazard class during the 2 year event already. During the 100 yr event, the hazard class is reduced from high to intermediate in John St above Darley St.

There are several benefits associated with this option. These include a significant reduction of flood depth during the 2 year event at the corner of Railway Parade and Edgeware Road. That location is a reported drainage hotspot. Another benefit is the reduction in flood depth and hazard class in John St/Wells St, which is also a reported drainage hotspot. The cost of this option, however, is the prevention of runoff from Railcorp land entering Railway Parade, which leads to water ponding on the railway track side of the proposed embankment.

9.1.2 Staged Implementation of Option R1

The preliminary capital cost estimate for implementing this option is $2.9 million. This is an expensive option to implement and generally it is difficult for Council to secure funding for such projects. To overcome this issue, a progressive implementation of this option in a number of stages was considered. The staged implementation of this option would consist of:

Stage 1:

- Installation of new culvert (3 X 600 mmØ) from corner of Edgeware Road and Lord St to corner of Edgeware Road and Railway Parade;
- Installation of new culvert (2000 mmW x 1000 mmH) from corner of Edgeware Road and Railway Parade along Railway Parade to Murray St and then into Eastern Channel; and
- Construction of an embankment between Railcorp land and Railway Parade to prevent flow from Railcorp land (height of bund above existing ground level is approximately 0.5 m). Consultation with Railcorp will be required during detailed design.

Stage 2:

- Remainder of Option R1.

Staged implementation of this option provides Council the opportunity to progressively seek funding for its implementation. This staged implementation has not been modelled, however, cost estimates for Stage 1 have been prepared and are presented in APPENDIX D. The benefit of this option would accrue over various stages of implementation.

9.2 Option R2 – Alice St

This intersection is a local trapped low point in the catchment and is a drainage hotspot. Surface overland flow from the entire northeast section of the EC East Subcatchment arrives at this intersection. The intersection is a major intersection in terms of vehicular and pedestrian traffic and is subject to intermediate hazard during the 100 yr design flood event.

There is a major SWC culvert at this location that is operating at full capacity in the 5 yr ARI event; however, the hydraulic grade line (HGL) of this culvert is above ground surface, therefore it is not plausible to connect new pits to that culvert at this location. The management approach was therefore to install additional pits along Alice St that drain toward the Empire Lane Channel.

This approach included:

- Installation of new pits along the western side of Alice St connected via a shallow box culvert (600 mmW X 300 mmH) to existing infrastructure (P-EE162); and
- Upgrade of existing pipe between P-EE162 and P-EE161 (from 375 mmØ to 600 mmØ) and from P-EE161 to Empire Lane Channel (from 450 mmØ to 750 mmØ).

The layout of this management option is presented in APPENDIX G (Figure G6). Detailed long-sections of this option are presented in APPENDIX F (Figure F4). Proposed pit inlet details are also presented in APPENDIX E.

9.2.1 Impact of Option R2

This option involves installation of new pits at the intersection of Edgeware Road and Alice St, diverted to the existing Empire Lane Channel. Figure G7 presents the predicted impact on modelled flood depths and Figure G8 presents the predicted impact on provisional hazard class.

As seen in Figure G7, the predicted reduction in flood depth at the intersection of Alice St and Edgeware Road is up to 5 cm in the 2 yr event; however, the commensurate increase in flood depth in Empire Lane Channel is from 5 cm to 15 cm. This increase, however, does not result in overtopping of Empire Lane Channel at Marrickville Metro in the 2 yr event.

The modelled reduction in flood depth at the intersection of Alice St and Edgeware Road is about 2 cm in the 100 yr event because the conveyance capacity of the proposed drainage system is exceeded during less frequent events. In the 100 yr event, this option results in a 5 cm increase in modelled depth within the Empire Lane Channel and about a 2 cm increase in predicted flood depth outside of Marrickville Metro. It is noted that Empire Lane Channel already overtops in the 100 yr event.

As seen in Figure G8, there is no change in the predicted flood hazard class in the 2 yr or 100 yr event. The intersection of Alice St and Edgeware Road is already a low provisional hazard in 2 yr event and was intermediate hazard in the 100 yr event.

The reduction in flood depth of 5 cm during the 2 yr event will improve the serviceability of this intersection during more frequent events; however, the effectiveness of this management option is limited by the need to avoid significantly increasing flood depths in Empire Lane Channel. As expected, the benefit of proposed works during the 100 yr event is limited.

9.3 Option R3 – Simpson Park

This precinct is subject to regular drainage issues, namely the trapped local low point at the Town and Country Hotel; although provisional flood hazard in the 100 yr design flood event is only intermediate. There is currently no stormwater infrastructure up-gradient of this intersection.

This approach includes:

- Installation of detention storage system into Simpson Park (height of bund above existing ground level ranges from 0 m to 1.5 m; elevation of top of bund 8 mAHD). It is noted that outlet pipe (grated inlet connected to 225 mmØ pipe) is connected to new infrastructure running along Campbell St;
- Installation of pit/pipe network in Hutchinson St (pipe size ranging from 450 mmØ to 750 mmØ) which is diverted to Camdenville Oval via a new laneway connecting Hutchinson St to May St. The new laneway is a component of the St Peters Triangle Master Plan;
- Installation of pit/pipe network in Lackey St (pipe size ranging from 450 mmØ to 600 mmØ) which is diverted into Simpson Park;
- Installation of pit/pipe network along Campbell St from Church St to St Peters St, which is diverted into Simpson Park (pipe size ranging from 450 mmØ to 600 mmØ);
- Installation of pit/pipe network in Florence St (pipe size ranging from 450 mmØ to 525 mmØ) which is then diverted into Simpson Park. It is noted that there is no pit at the end of Florence St at Campbell St to avoid backflow from Simpson Park into Campbell St;
- Installation of 2 pits along Campbell St near corner of Florence St, connected to new infrastructure from Brown St;
- Installation of pit/pipe network in Brown St (pipe size 450 mmØ) which is connected to new infrastructure that will drain through existing open space outside of Town and Country Hotel. The draft St Peters Triangle Master Plan (Hassel Group, 2009) indicates that this open space is proposed to be retained; and
- Installation of multiple grated inlets at trapped local low-point outside of Town and Country Hotel draining via new pipe (600 mmØ [temporarily choked to 300 mmØ] and

then 750 mmØ) into Camdenville Oval. It is noted that pits L-ES110 and L-ES110A diverted into new pipe (750 mmØ).

The layout of this management option is presented in APPENDIX G (Figure G9). It is also noted that utilisation of Camdenville Oval as a detention basin has an operational cost associated with pumping out of detained runoff into the stormwater system following rainfall events. Detailed long-sections of this option are presented in APPENDIX F (Figure F5 to F7). Proposed pit inlet details are also presented in APPENDIX E.

9.3.1 Impact of Option R3

This option involves construction of a detention basin in Simpson Park as well as installation of new pit/pipe infrastructure throughout the southern subcatchment. The predicted impact on modelled flood levels is presented in Figure G10 and the predicted impact on provisional hazard class is presented in Figure G11.

As seen in Figure G10, this management option results in a predicted reduction of flood depth at the trapped low-point outside of the Town and Country Hotel of 5 cm in the 2 yr event and a reduction of 5 cm at the corner of Brown St and Campbell St. The predicted reduction in flood depth in Brown St and Florence St is about 2 cm in the 2 yr event. The predicted decrease in flood depth in Hutchinson St is between 2 and 5 cm. In the 100 yr event, the predicted reduction in flood depth outside of the Town and Country Hotel is about 7 cm and also about 7 cm at the corner of Brown St and Campbell St as well as in Camdenville Oval itself. The predicted decrease in flood depth in Hutchinson St is 2 to 5 cm in the 100 yr event. Model results indicate that changes in the southern catchment only have a local effect and do not result in changes to predicted flood depths elsewhere in the EC East subcatchment, as expected.

From Figure G11, there is only a minor change to hazard class along Campbell St in the 100 yr event. The detention basin, however, becomes high hazard during the 100 yr event due to the ponded depth.

There are several benefits associated with this management option, in particular helping to resolve the regularly recurring drainage problem outside of the Town and Country Hotel. This management option, as modelled, however, assumes the 600 mmØ pipe connecting the new pits installed on the eastern side of Campbell St at May St, is choked to 300 mmØ capacity so as to prevent increasing the frequency of inundation of Camdenville Oval. The cost of this option, however, is the reduction in amenity of Simpson Park because of its transformation into a detention storage in a flooding event. However, the loss of this amenity would be for short periods during flood events.

It is noted that the detention basin in Simpson Park reaches a maximum flood depth of 0.9 m in the 2 yr event (flood level is 7.15 mAHD) and 1.5 m in the 100 yr event (flood level is 7.85 mAHD). A bund level of 1.5 m above ground level at the corner of Hutchinson St and Campbell St may not be able to be implemented due to site constraints.

9.3.2 Staged Implementation of Option R3

The capital cost of implementing this option is approximately $1.6 million, which presents a significant funding constraint for implementing this option. As such, a staged implementation of this option is proposed as follows:

Stage 1:

- Installation of 1 pit on Hutchinson St at corner with Campbell St;
- Installation of 1 pit in Brown St (pipe size 450 mmØ) which is connected to new infrastructure that will drain through existing open space outside of Town and Country Hotel. The draft St Peters Triangle Master Plan (Hassel Group, 2009) indicates that this open space is proposed to be retained; and

- Installation of multiple grated inlets at trapped local low-point outside of Town and Country Hotel draining via new pipe (600 mmØ [temporarily choked to 300 mmØ] and then 750 mmØ) into Camdenville Oval. It is noted that pits L-ES110 and L-ES110A diverted into new pipe (750 mmØ).

Stage 2:

- Remainder of Option R3

This staged implementation has not been modelled, however, cost estimates for Stage 1 were prepared and are presented in APPENDIX D.

9.4 Option R4 – TAFE Park

This precinct is a reported drainage hotspot, however, is only subject to low flood hazard during the 100 yr event. Existing infrastructure at the corner of Sarah St and Simmons St acts to convey stormwater through the road divider at the location. There is no pit/pipe network along Simmons St.

This approach includes:

- Installation of a detention storage system into the park adjacent the TAFE (height of bund above existing ground level ranges from 0 m to 1 m; elevation of bund is 16.5 mAHD). Drainage pipe from detention basin (grated inlet connected to 225 mmØ) connected to existing pit P-EE127;
- Installation of grated inlets across Marian St via shallow box culvert (450 mmW X 150 mmH) to existing pit, P-EE242 (upgraded to triple-kerb inlet with grates); and
- Installation of a new pit at corner of Sarah St (north side of road divider) to drain the trapped corner at the end of Simmons St. Installation of grated inlets along Sarah St from that corner to existing pit, P-EE132 via a shallow box culvert (600 mmW X 200 mmH) and reconfiguration of existing pit, P-EE132, to divert stormwater into the detention basin (continuation of 600 mmW X 200 mmH box culvert).

The layout of this management option is presented in APPENDIX G (Figure G12). Detailed long-sections of this option are presented in APPENDIX F (Figure F7 to F8). Proposed pit inlet details are also presented in APPENDIX E.

9.4.1 Impact of Option R4

This option involved construction of a detention storage system in TAFE Park. *Figure G13* presents the predicted change to modelled flood depth associated with this management option and Figure G14 presents the predicted change to modelled flood hazard.

As shown in Figure G13, the predicted reduction in flood depth at Marian St ranges between 2 cm and 5 cm in the 2 yr event, however, there is a predicted increase in flood depth along James St of between 2 and 5 cm in the same event. This may result an increase in flood damages along James St, rather than a reduction. Analysis suggests this is caused by an interruption of the overland flow path from Sarah St toward Simmons St. The predicted reduction in flood depth in Camden St following installation of this detention basin is between 0 cm and 2 cm. In the 100 yr event, there is a 5 cm reduction in modelled flood depth in Camden St and a 2 to 5 cm reduction in flood depth in Alice St, Empire Lane Channel and Murray St.

From Figure G14, there is no predicted change in flood hazard during the 2 yr event since the precinct is already low hazard. There is also no reduction in flood hazard during the 100 yr event in this area.

There are mixed benefits of this management option. In the 100 yr event, there is a positive effect due to detention storage, however, in the 2 yr event there is limited utilization and, it is expected, negative effects due to interruption of surface overland flow from Sarah St into James St. James St is already susceptible to flooding due to its floor levels being at or below street level. Revision of this option to expand the available detention area appears limited since the adjacent area is a car park within the TAFE complex.

9.5 Option R5 – Sarah St

There is currently no pit/pipe infrastructure along Edgeware Road from Sarah St to Camden St. Stormwater captured upstream of Sarah St is currently discharged to the surface at the corner of Sarah St and Edgeware Road and travels along Edgeware Road to the corner of Camden St and Edgeware Road. This area is a reported drainage hotspot due to its high vehicular and pedestrian traffic levels. It is noted that Edgeware Road is subject to high hazard during the 100 yr design flood event due to water velocity.

This approach included:

- Installation of new pit/pipe network along Edgeware Road from Sarah St to Camden St (900 mmØ pipe connected to double-kerb inlets with grates);
- Installation of pit (double-kerb inlet with grate) at the corner of Lynch Ave and Edgeware Road, connected via new pipe under Edgeware Road (750 mmØ) to upgraded pit, L-EE245A;
- Upgrade of existing box culvert (450 mmW X 150 mmH) across Sarah St, from L-EE245A, to a 750 mmØ pipe; and
- Installation of a pit opposite Camden St, connected to the main SWC 72" pipe.

The layout of this management option is presented in APPENDIX G (Figure G15). Detailed long-sections of this option are presented in APPENDIX F (Figure F8). Proposed pit inlet details are also presented in APPENDIX F.

9.5.1 Impact of Option R5

This option consists of installation of new infrastructure from the corner of Sarah St and Edgeware Road to the corner of Camden St and Edgeware Road. *Figure G16* presents the predicted change in maximum modelled flood depth. *Figure G17* presents the predicted change in modelled flood hazard.

As shown in Figure G16, this management option leads to a predicted decrease of flood depth of 2 to 5 cm along Edgeware Road between Sarah St and Camden St in the 2 yr event. The predicted decrease in flood depth is 5 to 10 cm in the 100 yr event. Other areas that are predicted to experience a reduction in flood depth include the intersection of Alice St and Edgeware Road in both the 2 yr and 100 yr events. As well, Camden St is predicted to experience a reduction in flood depth of 5 to 10 cm in the 100 yr event. Model results indicate a 0 to 2 cm increase in flood depth in Eastern Channel in the 2 yr event and no predicted change in flood depth in Eastern Channel in the 100 yr event.

As seen in Figure G17, there is a minor reduction of flood hazard class in the 2 yr event and more extensive reduction in the 100 yr event. However, this management option does not appear to have alleviated this high velocity hazard area.

Model results indicate that there is a reasonable decrease in predicted flood depths along Edgeware Road in the 2 yr and 100 yr events associated with this management option, however, this option does not appear to resolve the high hazard categorization of Edgeware Road in this vicinity. Given this is an area of high pedestrian and vehicular traffic and is a reported drainage hotspot, application of this management option appears worthwhile. The 2 to 5 cm decrease in flood depth in the 2 yr event and the 5 cm decrease in the 100 yr event at the intersection of Alice St and Edgeware Road is noteworthy.

9.6 Option R6 – Sloane St, Enmore

Streets in this area are subject to high flood hazard during the 100 yr event due to ponded depth. There is currently no available overland flowpath and hydraulic capacity of existing infrastructure is only about 5 yr ARI. This option consists of property acquisition and new pit/pipe infrastructure.

This approach includes:

- Voluntary purchase acquisition of existing properties to create an overland flowpath between Pemell St and Sloane St and between Fulham St and Margaret St.
- The townhouse development on Sloane St was assumed to be unavailable for purchase.
- Installation of pit/pipe infrastructure in Sloane St (600 mmØ) to capture overland flow from Pemell St and transfer this to existing pit, P-EE155; and
- Ponded stormwater diverted to Reiby St via a new pit, R6-P02, connected to a 750 mmØ pipe. It is noted that new pipe in Reiby St is choked from 750 mmØ to 300 mmØ prior to connection to existing pit, P-EE35 so that those pits surcharge to ground surface.

The layout of this management option is presented in APPENDIX G (Figure G18). Detailed long-sections of this option are presented in APPENDIX F (Figure F8). Proposed pit inlet details are also presented in APPENDIX E.

9.6.1 Impact of Option R6

This option consists of establishment of overland flowpaths from Pemell St to Margaret St. Figure G19 presents the predicted change in flood depth and Figure G20 presents the predicted change in flood hazard. The location of the overland flow path is highlighted in Figure G18.

From Figure G19, the predicted change in flood depth is a reduction of more than 15 cm in Pemell St and Fulham St for the 2 yr event and a predicted increase of 5 cm in Sloane St and 5 to 10 cm in Margaret St. The predicted increase in Camden St is 2 to 5 cm in the 2 yr event. In the 100 yr event, the predicted changes in flood depth are significant. The predicted increase in flood depth along Camden St is 10 to 15 cm and is more than 5 cm in the Empire Lane Channel and 2 to 5 cm along Murray St.

From Figure G20, there is no predicted change in hazard class with respect to the 2 yr event. For the 100 yr event, the predicted change in flood hazard in Pemell St and Fulham St is a reduction of one hazard class; however, model results indicate there is an increase of two hazard classes along Ferndale St and increase of one hazard class in portions of Camden St, as a result of this management option.

At present Pemell St, Sloane St and Fulham St do not have active flowpaths and stormwater is predicted to pool at these trapped low-points, in rare events, until capacity is available to drain them. By relieving these trapped low-points, this management option, in effect, transfers the problem down-gradient to Camden St and further downstream. Accordingly, it is expected that there will be little overall improvement to predicted average annual flood damages by implementation of this option.

9.7 Option R7 – Goodsell St

There is currently no stormwater infrastructure in Goodsell St or May Lane. The precinct is low hazard during the 100 yr flood event. The north side (kerb and guttering exists) of Goodsell St, however, is quite low.

This approach consists of:

- Installation of new pit/pipe network along Goodsell St (pipe size ranging from 450 mmØ to 600 mmØ) connected to new pipe along Council St (pipe size 750 mmØ) connecting to existing pit, P-ES56);
- Connection of drainage from Princes Highway to new infrastructure in Goodsell St;
- Installation of pit/pipe network along May Lane (pipe size ranging from 450 mmØ to 525 mmØ);
- Installation of pit/pipe network along Council St (pipe size ranging from 450 mmØ to 750 mmØ; and
- Increased inlet capacity of pit at end of Council St, west side (P-ES57) to a double-kerb inlet with grates.

The layout of this management option is presented in APPENDIX G (Figure G21). Detailed long-sections of this option are presented in APPENDIX F (Figure F9 to F10). Proposed pit inlet details are also presented in APPENDIX E.

9.7.1 Impact of Option R7

Figure G22 presents the predicted change in maximum modelled flood depth and Figure G23 presents the predicted change in provisional flood hazard.

As seen in Figure G22, this management option results in a reduction of predicted flood depth along Goodsell St of 2 to 5 cm in the 2 yr event and 5 to 10 cm in the 100 yr event. A similar magnitude of reduction is predicted for May Lane. Model results for the 2 yr and 100 yr event indicate that the proposed pit/pipe infrastructure also leads to a reduction in surface overland flow along the south side of the railway track. As expected, entrainment of stormwater from Goodsell St that is diverted to the culvert on the north side of the railway track results in a 1 to 2 cm increase in predicted flood depth at the corner of Railway Parade and Edgeware Road in the 2 yr and 100 yr events.

As shown in Figure G23, there is no change in modelled flood hazard class in vicinity in the 2 yr event because the area was already low hazard. Model prediction suggests this management option would result in a reduction of one hazard class unit in the 100 yr along Goodsell St.

Model results indicate that this management option will result in a significant improvement in modelled flood depth in the 2 yr and 100 yr event along Goodsell St and May Lane, which are reported as areas with drainage issues. The cost of this option is a 1 to 2 cm increase in predicted flood level at the corner of Railway Parade and Edgeware Road, which is itself a drainage hotspot. The impact is, however, small and can be mitigated by implementing Option R1.

9.7.2 Staged Implementation of Option R7

The preliminary capital cost estimate for implementing this option is approximately $1.1 million. As with Option R1 and Option R3, this option can also be staged to overcome funding constraints.

Stage 1:

- Installation of pit/pipe network along Council St (pipe size ranging from 450 mmØ to 750 mmØ to existing pit (P-ES56) at end of Council St;
- Increased inlet capacity of pit at end of Council St, west side (P-ES57) to a double-kerb inlet with grates;

- Installation of a single pit at end of Goodsell St; and
- Installation of a single pit along May Lane (pipe size ranging from 450 mmØ to 525 mmØ).

Stage 2:

- Remainder of Option R7

This staged implementation has not been modelled, however, cost estimates for Stage 1 were prepared and are presented in APPENDIX D.

9.8 Option R8 – SWC Trunk Drain

There is a trunk drainage system owned and maintained by SWC that extends from the corner of Ferndale St and Margaret St, down Ferndale St and along Camden St into Edgeware Road and then down Murray St to Eastern Channel.

The current modelled hydraulic capacity of the lower section of this system, from Eastern Channel along Murray St, to Victoria Road is approximately 2 yr ARI. The rest of the system is modelled as running at full capacity in approximately the 5 yr event. There was therefore an opportunity to consider the impact of an increase in the hydraulic capacity of the trunk drain by widening the existing single culvert below Alice St to Victoria Rd and adding an additional barrel to the 2-barrel system below Victoria Road through to Eastern Channel. Accordingly, this stormwater management option considered a 50% increase in conveyance capacity from the corner of Edgeware Road and Alice St along Murray St to Eastern Channel. It is noted that there was not space available within the roadway along Camden St or above to allow further increase in the conveyance capacity.

The layout of this management option is presented in APPENDIX G (Figure G24). Detailed long-sections of this option are presented in APPENDIX F (Figure F11). Proposed pit inlet details are also presented in APPENDIX E.

9.8.1 Impact of Option R8

This management option consists of increase of the conveyance capacity of the main SWC culvert by 50%. Figure G25 present the predicted change in modelled flood depth and Figure G26 presents the predicted change in flood hazard class.

As shown in Figure G25, this management option results in a reduction of predicted flood depth of 5 cm in the 2 yr event in Murray St, just up-gradient of Eastern Channel. In the 100 yr event, there is a predicted 2 to 5 cm reduction in flood depth in Camden St, a 5 cm reduction in flood depth at the intersection of Alice St and Edgeware Road and a 5 cm predicted reduction in Victoria Road and along the upper part of Murray St. Commensurate with these improvements in predicted flood depth, there is a 2 to 3 cm increase in flood depth in Eastern Channel in the 2 yr event and a 1 to 2 cm increase in flood depth in Eastern Channel in the 100 yr event.

As seen in Figure G26, model simulations indicate that this management option does not result in a reduction in flood hazard in the 2 yr event, since the area is already low hydraulic hazard, although there is are a couple of patches of improvement of one hazard class in the 100 yr event along the upper part of Murray St.

Analysis suggests this option results in a general improvement in modelled flood depths within the northern catchment for the 100 yr event and local improvement along lower Murray St in the 2 yr event. It is, however, acknowledged that increasing the conveyance capacity of infrastructure within EC East subcatchment effectively transfers the problem out of the catchment via of increase in flood depths in Eastern Channel. Extensive consultation with SWC would be required if detailed design of this option is required.

9.9 Option R9 – Optimization of Drainage at corner of Campbell St and May St

The corner of Campbell St and May St has regular drainage issues because it is a local trapped low-point and the existing pit/pipe infrastructure at this location feeds into a 1200 mm pipe that underlies Bedwin Road which is subject to outlet control.

The objective of this management option therefore is to attempt to divert excess stormwater that ponds at this intersection into Camdenville Oval prior to it becoming a nuisance during more frequent storm events. It is not anticipated that this management solution will provide significant benefit during rare events such as the 10 yr or 100 yr events.

It is noted that this option is similar to the Stage 1 of Option R3 with the difference that Stage 1 of Option R3 would divert all stormwater at the corner of May and Campbell St into Camdenville Oval.

It is noted that this option is contingent on approval to discharge additional stormwater into Camdenville Oval due to current site contamination constraints at the detention basin.

The approach consists:

- Installation of row of grated inlets (3.6 m by 0.45 m) on either side of Campbell St, oriented parallel to Campbell St; and
- Installation of a new pipeline (2 x 900 mmØ) from western grated inlets through eastern grated inlets into open space and then diverted northward into Camdenville Oval.

It is noted that the location of the grated inlets inlets is to be within the roadway itself, rather than in the gutter, such that only excess stormwater is diverted to Camdenville Oval rather than runoff from every storm event.

The layout of this management option is presented in APPENDIX G (Figure G27). It is also noted that utilisation of Camdenville Oval as a detention basin has an operational cost associated with pumping out of detained runoff into the stormwater system following rainfall events. Detailed long-sections of this option are presented in APPENDIX F (Figure F14). Proposed pit inlet details are also presented in APPENDIX E.

9.9.1 Impact of Option R9

This management option consists of installation of new infrastructure to divert excess stormwater ponding at the corner of Campbell St and May St into Camdenville Oval. Figure G28 presents the predicted change in modelled flood depth and Figure G29 presents the predicted change in hazard class.

As shown in Figure G28, this management option results in a reduction of predicted flood depth of 10 cm at the low point at this intersection in the 2 yr event and a reduction of only 1 cm in modelled flood depth in the 100 yr event. The predicted increase in flood depth within Camdenville Oval is about 4 cm in the 2 yr event and less than 1 cm in the 100 yr event. The predicted increase in flood depth with the Camdenville Oval detention basin during the 2 yr event does not result in over-topping of the basin.

As seen in Figure G29, there is a minor reduction in flood hazard of overland flow at the entrance to Camdenville Oval during the 2 yr event. There is no change in flood hazard associated with the 100 yr event.

9.10 Option R10 – Expansion of Camdenville Oval Detention Basin

The southern subcatchment of EC East is subject to regular drainage issues, mostly related to the fact that there is no stormwater infrastructure up-gradient of the intersection of

Campbell St and May St. This management option considers the proposed stormwater infrastructure as outlined in Option R3, however, with trunk drainage lines maximized to divert stormwater into Camdenville Oval. This option also considers an expansion of Camdenville Oval detention basin itself. It is noted that below-ground contamination issues are currently a constraint on utilisation or expansion of Camdenville Oval as a detention basin. For the purpose of this modelling assessment, it was assumed that current low point was the lowest available elevation therefore storage capacity was expanded northward toward the Railway line. Base elevation was 3 mAHD with side slope of 1V:6H.

The approach consists of the layout presented for Option R3 (Section 9.3) with the following amendments. It is noted that new laneway between Hutchinson and May Lane is a component of the St Peters Triangle Redevelopment Master Plan:

- Increase diameter of pipe along Campbell St downstream of Florence St to intersection with Hutchinson St from 450 mmØ to 750 mmØ;
- Increase diameter of pipe from corner of Hutchinson St and Campbell St to intersection of Campbell St and Brown St from 600 mmØ to 2 x 750 mmØ;
- Increase diameter of pipe from corner of Brown St and Campbell St from 750 mmØ to 2 x 900 mmØ;
- Increase diameter of pipe under May St into Camdenville Oval from 750 mmØ to 3 x 900 mmØ;
- Increase diameter of pipes connecting proposed new pits on eastern side of Campbell St at corner with May St from 450 mmØ to 750 mmØ;
- Increase diameter of pipe connecting pit cluster on eastern side of Campbell St to pipe under May St from 600 mmØ (choked to 300 mm) to 2 x 900 mmØ;
- Increase length of new grated inlets from 5.4 m by 0.45 m to 10.8 m by 0.45 m; and
- The detention basin within Camdenville Oval has also been expanded by 5,400 m^3. The basin was extended northward at the current level of the basin floor.

The layout of this management option is presented in APPENDIX G (Figure G30). Detailed long-sections of this option are presented in APPENDIX F (Figure F12 to F14). Proposed pit inlet details are also presented in APPENDIX E.

9.10.1 Impact of Option R10

This management option consists of the installation of new pit/pipe infrastructure throughout the southern subcatchment and a new detention basin installed into Simpson Park as per Option R3; however, with the diameter of trunk drainage lines increased to maximalise diversion of stormwater into Camdenville Oval (expanded). The predicted impact on modelled flood levels is presented in Figure G31. The predicted change to hazard class is presented in Figure G32.

As shown in Figure G31, the predicted change in flood depth is a reduction at the intersection of Campbell St and May St of 5 cm in the 2 yr event and a reduction of 15 cm in the 100 yr event.

As seen in Figure G32, the predicted change in flood hazard is a minor reduction within Camdenville Oval itself during the 2 yr event due to slightly lower flood depths and essentially no change in flood hazard class during the 100 yr event.

As reported in Option R3, the detention basin in Simpson Park reaches a maximum flood depth of 0.9 m in the 2 yr event (head is 7.15 mAHD) and 1.5 m in the 100 yr event (head is 7.85 mAHD).

10.0 PROPERTY MODIFICATION MEASURES

Some of the commonly adopted property modification measures in a floodplain include:

- Effective land use planning and development controls;
- House raising;
- Voluntary purchase of flood affected properties; and
- Flood proofing of buildings.

The relevance of the above measures to the EC East Subcatchment is discussed below:

10.1 Land use Planning and Development Controls

In a developed area such as the EC East subcatchment, the most effective property modification measure is to have appropriate development controls to manage the flood risk. Currently, Marrickville Council's Development Control Plan (DCP) 30 is the relevant policy to control development in the floodplain. This policy is in the process of being amalgamated into a consolidated DCP for the Council. A draft of the consolidated DCP relevant to floodplain management was provided by Council for review.

A preliminary review of the draft policy was undertaken as part of this study. The review indicates that the policy covers a number of the floodplain issues and provides effective controls for development. However, issues and specific controls related to overland flooding can possibly be elaborated upon to provide clear guidance. This is particularly important for the EC East subcatchment where the majority of the flood affectation is due to overland flooding.

Planning controls can only be effective if due consideration is given to a number of factors including the type of development and the level of flood risk at the location of the development. For example, planning controls for a development in a low flood risk area will generally be not suitable in a high flood risk area. Similarly, the controls that are appropriate for say residential development in a low flood risk area may not be appropriate for the development of a critical facility in the same flood risk precinct.

Any development in the flood prone land would have elements of development that require flood-related planning considerations. The most common planning consideration in a flood prone area is the assignment of an appropriate floor level for the development. Other planning considerations include structural safety in a flood, car parking, boundary fencing, evacuation routes etc.

A matrix approach has been adopted in consideration of the above elements of planning in a flood prone area. This approach summarises the planning controls that are applicable to various types of developments in varying flood risk areas. The so-called Planning Matrix is presented in APPENDIX H. The planning controls presented in the Matrix have generally been adopted from "Georges River Floodplain Management Study and Plan" (Bewsher, 2004). Appropriate modifications have been made relevant to the EC East Subcatchment.

The Planning Matrix is based on the following general features of the EC East Subcatchment flood prone area:

- The intensity of development with high population density in the subcatchment generally warrants stringent development controls
- The high flood hazard at a number of locations in the subcatchment is primarily due to the high velocity even though the flow depths are shallow. There are some locations, however, that are high hazard due to ponded depth.

- Sensitivity of downstream receiving water environment requires stringent controls in handling materials within the development
- Lack of major flood modification measures requires the preparation of flood emergency response plans for various types of developments

Modelled flood hazards in the subcatchment are presented in Volume 2, Figures 8a to 8d and are discussed in Volume 2, Section 4.6.

10.1.1 Onsite Detention

Onsite detention (OSD) can play a role in flood management in the local EC East Subcatchment and wider Marrickville Valley catchment. Council currently has an OSD policy that restricts post development runoff to pre-development runoff, assuming pre-development state to be the natural state of the land. Details of this policy relevant to flood management can also be incorporated in the consolidated DCP. It is also noted that Sydney Water owns the major drainage infrastructure in the EC East Subcatchment. Any development impacting on this infrastructure would need to comply with SW guidelines for the provision of OSD.

The Council OSD policy was developed in 1999 and requires an update to reflect the current understanding and practice of OSD systems. In this regard, the updated Onsite Detention Handbook prepared by Parramatta River Catchment Trust can provide a useful guidance.

10.2 Voluntary Purchase of Flood affected Properties

Properties lying in high hazard flood areas, which have limited scope for improvement from proposed flood modification measures, may be considered for voluntary purchase. Such properties can then be demolished and the land rezoned to a flood compatible use such as a local park.

Unless undertaken on a large scale, voluntary purchase of flood affected properties would have a limited effect towards reducing the catchment wide flood risk in the EC East Subcatchment. Given the high property values in the Marrickville area, a large scale acquisition of properties is not likely to be economically viable.

10.3 House Raising

Most properties in the EC East subcatchment have slab-on-ground construction. This type of construction precludes the option of house raising of the flood affected properties due to prohibitive costs.

10.4 Flood Proofing of Buildings

Where residual flood risk is significant, flood proofing of the buildings is a useful measure to reduce the flood risk. Requirement for flood proofing for existing properties can be included in the consolidated DCP for Marrickville. This DCP would provide details of flood resistant materials and other measures that can be adopted.

Currently, the Council DCP 30 contains information about flood proofing of buildings. This information can be adopted for the consolidated DCP.

11.0 EMERGENCY RESPONSE MODIFICATION OPTIONS

Various measures that are generally adopted for response modification during a flood emergency include:

- Provision of flood warning systems
- Update of Local Flood Plan (a sub-plan of DISPLAN)
- Keeping SES up-to-date with the flood intelligence

- Public awareness and education
- Flood markers at flooding 'hotspots'

The relevance of the above measures to the EC East Subcatchment is discussed below:

11.1 Provision of a Flood Warning System

Flood warning systems are generally provided for areas where at least 6 hours of lead time is available before the arrival of a flood. This lead time is required to take appropriate actions before the onset of flooding. In the EC East Subcatchment, the typical time of flooding is of a short duration (1 to 2 hours) and falls in the category of so-called 'flash flooding'. A flood warning system, therefore, is not likely to be effective in this catchment.

SES has recently prepared a toolkit for businesses to manage flash flooding of the business premises. This toolkit is available on the SES website and can be downloaded free of charge. Businesses in the EC East Subcatchment should be encouraged to follow the guidelines provided in this toolkit.

SES is also undertaking research to develop warning systems for 'flash flooding' catchments. Guidelines from this research project, when available, may provide an opportunity for consideration of a warning system in the EC East Subcatchment.

11.2 Update of Local Flood Plan

The Local Flood Plan (LFP) forms part of the Marrickville Disaster Plan (DISPLAN). This Plan describes the mainstream flooding from Cooks River. The EC East subcatchment, however, is primarily affected by overland flooding resulting from the inadequate street drainage in the subcatchment.

The LFP does recognize the presence of overland flooding in the catchment but does not provide the necessary flood intelligence for the EC East subcatchment. The LFP therefore needs an update and description of flooding provided in the plan should include discussion on overland flow flooding in areas other than the Cooks River floodplain.

11.3 Provision of Flood Intelligence to SES

Flood intelligence (flood behaviour description, flood maps, etc.) is critical for the operation of SES during flood emergencies. The flood intelligence developed for the EC East Subcatchment should be made available to SES on a priority basis.

11.4 Public Awareness and Education

For developed areas such as EC East Subcatchment where large scale flood modification measures are difficult to implement and a significant residual flood risk is present, public education plays a critical role in managing flood risk.

Flood information needs to be provided to the community in an effective manner and the campaign for community awareness should be a regular feature of Council activities. This is particularly important for the EC East Subcatchment where a large flood event has not occurred for a long period and the community may have lost memory of the last flood and become less vigilant.

An effective method of public education is through the preparation of a FloodSafe brochure in association with the SES, and distribution of this brochure to the local residents.

Another effective method of public education is through the local schools, where information sessions can be held with the students and written information passed on to the students which can be shared with the rest of their families.

Local community groups can also be encouraged to participate in creating awareness of flooding in the subcatchment.

11.5 Flood Markers

Flood depth markers are provided to alert the public to the flood hazard at various hotspots in the catchment. The markers can also be used in flood data collection program. They may also act to more generally raise awareness of flood risk for flood affected communities and businesses in high hazard areas. EC East Subcatchment has a number of flooding hotspots where such markers can be provided.

Flood markers are recommended at the following locations within the EC East subcatchment:

- Campbell Street near the intersection with Brown Street
- May Street near the intersection with Campbell Street
- Camdenville Oval
- Intersection of Edgeware Road and Railway Parade
- Murray Street near Sydney Water channel
- Murray Street and Edinburgh Road intersection
- Murray Street and Smidmore Street intersection
- Alice Street and Edgeware Road intersection

11.6 Flood Data Collection

Collection of historic flood data within the flood prone areas is critical in improving the accuracy of flood behaviour modelling and therefore providing better flood risk management strategies. A data collection plan can be developed by Council whereby flood marks, flood behaviour observations (flow direction etc.) and interviews with the affected residents can be carried out after significant flood events. In addition, the rainfall data can be sourced from the relevant departments (Bureau of Meteorology, Sydney Water etc.) and archived for future update of the flood risk assessments.

12.0 FLOOD MITIGATION ECONOMIC ASSESSMENT

Based on the criteria presented in Section 13.0, various options for water management were assessed and ranked for comparison. For stormwater flooding management options, a benefit-cost analysis was also undertaken. This involved the estimation of capital and maintenance costs for the proposed works and the likely reduction in annual average damage (AAD) by undertaking these works.

12.1 Benefit-Cost Analysis

Preliminary cost estimates of the proposed options were prepared with the assistance of the Rawlinson *Building Cost Guide*. It should be noted that the costing for these options assume that no services (such as electricity, telephone, water, sewer etc) would need to be relocated. Details of cost items and assumed rates are presented in APPENDIX D.

A detailed analysis and design of the options would be required prior to implementation of these options. Detailed rates and quantities can also be derived at the detailed design stage.

The monetary benefit derived from each option is the reduction of AAD by implementation of the option. The hydraulic model results were processed for each option and compared with the existing conditions to estimate the reduction in damages for various design events. AAD was then derived as per the procedure described in Volume 2 – Flood Study.

All options results in reduction of AAD except for Option R9. However, this reduction needs to be offset against the costs of the option to achieve an economic benefit. This comparison is undertaken by estimating the benefit-cost ratio, which if greater than 1 signifies an economically viable option.

Table 29 provides a summary of the benefit-cost analysis undertaken for various options.

Table 29: Benefit-Cost analysis for stormwater management options

#	Description	Average Annual Damage	Reduction in AAD due to Option	NPV of Reduction in Annual Average Damage	Capital Cost	Maintenance Cost	NPV of Costs	Benefit Cost Ratio
BASE		$4,117,613	-	-	-	-	-	-
R1	Railway Parade	$4,020,278	$97,335	$1,343,293	$2,924,590	$146,230	$4,942,666	0.27
R2	Alice St	$4,110,601	$7,012	$96,770	$75,175	$3,759	$127,049	0.76
R3	Simpson Park	$4,078,368	$39,245	$541,608	$1,564,915	$78,246	$2,644,765	0.20
R4	TAFE Park	$4,127,870	-$10,257	-$141,552	$81,732	$4,087	$138,129	-1.02
R5	Sarah St	$4,107,077	$10,536	$145,398	$512,560	$25,628	$866,245	0.17
R6	Sloane St	$3,723,147	$394,466	$5,443,923	$3,569,441	$178,472	$6,032,488	0.90
R7	Goodsell St	$3,987,341	$130,271	$1,797,842	$1,124,227	$56,211	$1,899,985	0.95
R8	SWC Trunk Drain	$4,098,421	$19,191	$264,856	$2,241,116	$112,056	$3,787,569	0.07
R9	Campbell and May St	$4,117,613	$0	$0	$247,204	$12,360	$417,784	0.00
R10	Expansion CVO	$4,067,328	$50,285	$693,964	$3,133,271	$156,664	$5,295,344	0.13

The maintenance or recurrent cost of stormwater management options has been estimated to be 5% of the capital cost. The Net Present Value (NPV) has been calculated for a discount rate of 7% for a 50 year period.

The option Op R4 (TAFE Park) has a negative benefit-cost ratio because this option increases the AAD as compared to the existing conditions due to adverse downstream impacts by increasing the depth of flooding (along James St).

None of the options has benefit-cost ratio greater than 1. This implies that these options may not be economically viable. However, for Quadruple Bottom Line assessment, the social and environmental impacts of these options are also required to be considered in the assessment. These impacts have been estimated based on the criteria presented in Section 13.2 above. Details of the QBL assessment are presented in Section 13.3 below.

13.0 OPTION EVALUATION

13.1 Evaluation Criteria

The water management options identified in this study were evaluated using the Quadruple Bottom Line assessment involving economic, social, governance and environmental considerations. A number of criteria were identified for option assessment purposes. A summary of these criteria is provided in Table 30 below.

Table 30: Option Evaluation Criteria

Option Evaluation Criteria	Assessment
Economic:	
Costs of implementing the option, including life cycle costs	Cost estimate based on preliminary estimate of civil works
Economic benefits	As determined by reduction in Annual Average Damages (AAD)
Social:	
Compatible with community goals	Assessed against goals identified during community consultation
Downstream/adverse impacts	Comparison of flood levels with the existing conditions
Reduced hazard	Comparison with existing conditions
Reduced nuisance	Improved drainage or stormwater quality
Amenity	Impact on amenity
Environmental:	
Water savings	Amount of water reuse in the subcatchment
Reduced contaminant load to receiving waters	By comparison with the existing conditions
Impact of construction	Magnitude and extent of construction works
Land ownership	Based on Council landuse mapping
Compliance with local and state policies/plans	Check for any special requirements such as Controlled Activity Approval from the Office of Water
Supported by Council and other authorities	Approval requirements from Railcorp, RTA etc.

In addition to the above criteria, a technical criterion was also adopted where overall hydraulic improvement was considered. The hydraulic improvement was estimated from reduction in the number of flood affected properties.

The above criteria are varied in nature and can not be quantified in a single measure. A multi-criteria analysis has therefore been adopted to undertake qualitative as well as quantitative assessment to develop a single platform for option assessment.

Multi-criteria analysis is a flexible approach to option assessment and seeks to employ varied criteria compared with the conventional benefit-cost analysis. It also provides an opportunity for stakeholder participation at all levels and therefore the outcome of the analysis is a socially acceptable, environmentally sustainable and cost-effective list of water management options.

13.2 Option Scoring System

For undertaking the multi-criteria analysis, a scoring system was established based on the level of benefit that accrued from a specific option. The scoring system was established for all the option evaluation criteria as discussed above. Each criterion had a range of scores that provides a qualitative estimate for each option. The scoring range for each criterion is arbitrarily adopted to be +/- 2, with 0 being neutral or no impact. Details of the scoring system are presented in Table 31 below.

Table 31: Option Scoring Scheme

Criteria	Score				
	-2	-1	0	1	2
Cost of implementing the option, including operating costs	Extremely high (greater than $5 million)	High ($5 million - $2 million)	Moderate ($1 million - $2 million)	Low ($500,000 - $1 million)	Low (less than $500,000)
Monetary benefit/reduction in AAD	Any increase in AAD	-	No benefit	Decrease (up to $100,000)	Decrease (greater than $100,000)
Compatible with community goals	Non-compatible	Slightly compatible	Compatible	Highly compatible	Highly compatible with multiple goals being addressed
Downstream/adverse impacts	Negative impact (>15 cm increase in peak flood level at any location)[1]	Negative impact (>5 cm increase in average peak flood level at any location)[1]	Negligible improvement or only local improvement	Flood level decrease (>5 cm decrease in peak average flood level across the floodplain)	Flood level decrease (>15 cm decrease in peak average flood level across the floodplain)
Reduced hazard	Major hazard increase	Minor hazard increase	No impact	Minor hazard decrease	Major hazard decrease
Reduced nuisance	Major increase in nuisance	Minor increase in nuisance	No impact	Minor decrease in nuisance	Major decrease in nuisance
Amenity	Major decrease in amenity	Minor decrease in amenity	No impact	Minor increase in amenity	Major increase in amenity
Water savings	-	-	No impact	Minor water saving	Major water saving
Reduced contaminant load to receiving waters	Highly increased contaminant loads (greater than 10%)	Minor increase in contaminant loads (up to 10%)	No impact	Minor decrease in contaminant loads (up to 10%)	Major decrease in contaminant loads (greater than 10%)

Criteria	Score				
	-2	-1	0	1	2
Impact of construction on environment (including flora and fauna)	Major impact/loss of habitat	Minor impact with some loss of habitat	No impact	Minor Improvement	Major Improvement
Land ownership	-	Private	-	Public (other authorities)	Public (Council)
Compliance with local and state policies/plans	Complete incompliance	Partial incompliance	Neutral	Complies	Fully complies/encouraged in the policy
Supported by Council and other authorities	Unsupported	Partially unsupported	Neutral	Supported	Fully supported backed with policy direction

[1] Negative impact on flood level are excluded for detention basins.

It was assumed that each criterion had an equal weighting i.e. no extra weight is applied to any particular criteria for emphasis

13.3 Option Matrix (Quadruple Bottom Line Analysis)

A multi-criteria matrix was established to undertake the Quadruple Bottom Line analysis. For each option, a score was assigned for each criteria based on the modelling results where applicable and using judgement and experience for others. Each criterion was given equal weighting in the scoring.

The total score for each option was obtained and each option ranked for comparison purposes. Results of the analysis are presented in Table 32.

It is to be noted that the scoring system developed and as applied to the option assessment is subjective in nature and this should be borne in mind in evaluating the effectiveness of various options.

Table 32: Results of Multi-Criteria Analysis

Option Type*	Option #	Option Description	Capital Cost	Operating Cost[1]	NPV of Costs	NPV of Reduction in AAD	Benefit Cost Ratio	Multi-Criteria Analysis: Cost of implementing the option, including operating costs	Monetary benefit/reduction in AAD	Compatible with community goals	Downstream/adverse impacts	Reduced hazard	Reduced nuisance	Amenity	Water savings	Reduced contaminant load to receiving waters	Impact of construction on environment (including flora and fauna)	Land ownership	Compliance with local and state policies/plans	Supported by Council and other authorities	TOTAL SCORE	RANK
A	R1	New and upgraded pit/pipe network in John St into Wells St to Pearl Lane. New and upgraded pit/pipe network along Lord St. Upgraded pit/pipe network in Wells St and Darley St. New culvert along Murray St to Eastern Channel.	$2,924,590	$146,230	$4,942,666	$1,343,293	0.27	-1	2	1	1	0	2	0	0	0	0	2	0	-1	6	15
A	R2	New grated inlets at intersection of Alice St and Edgeware Road, diverted into Empire Lane Channel.	$75,175	$3,759	$127,049	$96,770	0.76	2	1	1	1	0	2	0	0	0	0	2	0	1	10	4
A,B,C	R3	Construction of detention basin in Simpson Park. New pit/pipe network in Lackey St, Campbell St, Florence St, Brown St. Reconfiguration of pits outside of Town and Country Hotel to divert to Camdenville Oval (choked).	$1,564,915	$78,246	$2,644,765	$541,608	0.20	-1	2	0	1	-1	2	-1	0	0	-1	2	0	0	3	21
A,B,C	R4	Construction of detention basin in TAFE Park. New pit/pipe network in Sarah St, diverted to TAFE Park. New grated inlets across Marian St, diverted to existing stormwater.	$81,732	$4,087	$138,129	-$141,552	-1.02	2	-2	-1	-1	0	1	-1	0	0	-1	1	0	-2	-4	23
A	R5	New pit/pipe network along Edgeware Road from Sarah St to Camden St. New pit/pipe at corner of Lynch Avenue and Edgeware Road.	$512,560	$25,628	$866,245	$145,398	0.17	1	2	1	1	0	1	1	0	0	0	2	0	0	9	9
A,B	R6	Acquisition of existing properties to create overland flow paths.	$3,569,441	$178,472	$6,032,488	$5,443,923	0.90	-2	2	0	-2	-1	-1	-1	0	0	0	-1	0	-1	-7	24
A	R7	Installation of new pit/pipe network along Goodsell St, May Lane and Council St.	$1,124,227	$56,211	$1,899,985	$1,797,842	0.95	0	2	1	1	0	1	0	0	0	0	2	0	-2	5	18
A	R8	Increase in conveyance capacity of main SWC culvert by 50%.	$2,241,116	$112,056	$3,787,569	$264,856	0.07	-1	2	0	0	0	1	0	0	0	0	1	0	0	3	21
A	R9	Drainage works at the corner of Campbell and May St	$247,204	$12,360	$417,784	$0	0.00	2	0	1	1	0	2	2	0	0	0	2	0	1	11	1

Option Type*	Option #	Option Description	Capital Cost	Operating Cost[1]	NPV of Costs	NPV of Reduction in AAD	Benefit Cost Ratio	Multi-Criteria Analysis														
								Cost of implementing the option, including operating costs	Monetary benefit/reduction in AAD	Compatible with community goals	Downstream/adverse impacts	Reduced hazard	Reduced nuisance	Amenity	Water savings	Reduced contaminant load to receiving waters	Impact of construction on environment (including flora and fauna)	Land ownership	Compliance with local and state policies/plans	Supported by Council and other authorities	TOTAL SCORE	RANK
A	R10	Based on option R3, however, with increased capacity of trunk drainage and expansion of available storage within Camdenville Oval detention basin.	$3,133,271	$156,664	$5,295,344	$693,964	0.13	-1	2	-1	2	0	2	0	0	0	0	2	-1	-1	4	20
D	NS1	Update OSD Policy	$10,000	$0	$10,000	N/A	N/A	2	N/A	2	1	0	1	1	0	1	0	-1	2	2	11	1
D	NS2	Update Local Flood Plan	$10,000	$0	$10,000	N/A	N/A	2	N/A	2	0	0	0	0	0	0	0	2	2	2	10	4
D	NS3	Public Awareness Campaign (in association with SES)	$20,000	$0	$20,000	N/A	N/A	2	N/A	2	0	2	0	0	0	1	0	0	2	2	11	1
D	NS4	Provision of Flood Markers (7)	$9,800	$490	$16,562	N/A	N/A	2	N/A	1	0	1	0	0	0	0	0	2	2	2	10	4
D	NS5	Flood Data Collection (per event)	$10,000	$0	$10,000	N/A	N/A	2	N/A	1	0	1	0	0	0	0	0	2	2	2	10	4
C	SWQ1 + WR	Rainwater tanks to allow substitution of stormwater for non-potable water needs	$1,145,000	$22,900	$1,411,867	N/A	N/A	0	N/A	2	0	0	0	1	2	0	0	-1	1	2	7	13
A,B	SWQ2	A bioretention basin in Simpson Park to improve water quality of surrounding 10.3 ha catchment.	$290,000	$19,000	$552,214	N/A	N/A	1	N/A	1	0	0	0	-1	0	2	1	2	0	0	6	15
A,B	SWQ3	A bioretention basin in TAFE Park to improve water quality of surrounding 3.8 ha catchment.	$180,000	$14,000	$373,210	N/A	N/A	2	N/A	1	0	0	1	1	0	2	1	1	0	-2	7	13
A,B	SWQ4	Construction of swale on southern side of Pemell St	$320,000	$20,000	$596,015	N/A	N/A	1	N/A	1	0	0	0	1	0	2	1	2	0	0	8	11
A,B	SWQ5	Construction of swale on northern side of Goodsell St	$325,000	$20,000	$601,015	N/A	N/A	1	N/A	1	0	0	0	1	0	2	1	2	0	0	8	11
B,C	SWQ6	Raingardens on redeveloping sites in the St Peters Triangle area as part of DCP	$26,000	$4,200	$83,963	N/A	N/A	2	N/A	2	0	0	0	1	1	1	1	-1	1	2	10	4
C	SWQ7 + WR	Stormwater collection tanks in Camdenville Oval to collect stormwater and supply it as irrigation water to Camdenville Park	$345,000	$20,000	$621,015	N/A	N/A	1	N/A	2	0	0	0	0	2	0	0	2	0	2	9	9

Option Type*	Option #	Option Description	Capital Cost	Operating Cost[1]	NPV of Costs	NPV of Reduction in AAD	Benefit Cost Ratio	Multi-Criteria Analysis														
								Cost of implementing the option, including operating costs	Monetary benefit/reduction in AAD	Compatible with community goals	Downstream/adverse impacts	Reduced hazard	Reduced nuisance	Amenity	Water savings	Reduced contaminant load to receiving waters	Impact of construction on environment (including flora and fauna)	Land ownership	Compliance with local and state policies/plans	Supported by Council and other authorities	TOTAL SCORE	RANK
C	SWQ8 + WR	Stormwater collection tanks in Camdenville Oval to collect roof runoff and supply it as irrigation water to Camdenville Park	$655,000	$15,000	$862,011	N/A	N/A	1	N/A	2	0	0	0	0	2	0	0	-1	0	1	5	18
A,B,C	SWQ9 + WR	Adaptation of existing Camdenville stormwater detention basin to collect and supply irrigation water to Camdenville Park	$680,000	$25,000	$1,025,019	N/A	N/A	0	N/A	1	0	0	0	1	2	2	2	2	-2	-2	6	15

^ Option types are: A Stormwater Quantity Management; B Stormwater Quality Management; C Water Re-Use; D Non-Structural Flood Risk Management Measure.

[1] Operating costs of stormwater management options are based on 5% of capital cost. Operating cost of stormwater quality options were defined individually.

14.0 CONCLUSIONS AND RECOMMENDATIONS

Sustainable water management in the EC East Subcatchment is a goal under Marrickville Council's Integrated Urban Water Management program. A collaborative planning approach was adopted to identify a number of water management options for the subcatchment. These options included stormwater quality improvement, water reuse and stormwater flooding management options. All options were analysed using the Quadruple Bottom Line assessment and ranked based an overall score for the social, environmental, governance and economic factors associated with these options.

The purpose of the subcatchment management plan is to provide a framework to Marrickville Council for implementation of these options.

After completing the analysis for various options a further evaluation was carried out to determine the suitability of implementing these options. In this regard, the Quadruple Bottom Line analysis presented in Table 32 and analysis of water quality and water reuse options presented in Table 27 and Table 28 was taken into account. In addition, any synergies (multiple benefits) in implementing various options were also considered.

The evaluation for various options is presented in the following sections. The stormwater flood management and water quality improvement/water reuse options are discussed together where likely synergies exist.

SWQ1 + WR - Rainwater Tanks

Rainwater tanks provide significant benefit in terms of reducing potable water demand and reducing the stormwater runoff volumes, and associated benefit of decreasing the net transport of contaminants out of the subcatchment, although this is minor. They also increase awareness and knowledge of sustainable water management in the community. Out of the 394 L/day demand for a single dwelling, rainwater tanks can provide up to 240 L/day. A tank size of 2.75 m^3 for a typical single dwellings and 2 m^3 for a typical multi-unit dwelling would provide the desired water utilisation.

An uptake of 10 to 20% of the households is likely in the short to medium term. However, the current uptake of rainwater tanks is not significant (0.13%) and further efforts are required to encourage the residents to take up this option.

SWQ2 + R3 – Bioretention Basin and Flood Detention Basin at Simpson Park

Simpson Park provides an opportunity to improve stormwater quality and locally establish a flood detention basin. A 350 m^2 bioretention basin at the Park would significantly improve the water quality (Table 27). The proposed stormwater network ultimately discharges to Camdenville Oval.

The cost for improving various water quality parameters such as TSS, N and P is higher than some of the other options.

Simpson Park also provide flood management benefits but has a low ranking among various options (Table 32). This also increases the flood hazard locally near the Park. This option would be suitable for implementation primarily for its water quality improvement benefits.

It is noted, however, that there are currently environmental constraints on the detention basin in Camdenville Oval due to site contamination issues. Utilisation of Camdenville Oval as a detention basin is also constrained due to operational costs associated with pumping out of detained runoff into the stormwater system following rainfall events.

The cost to partially implement this option (stormwater only) has been provided in APPENDIX D. However, this partial option was not modelled.

SWQ3 + R4 – Bioretention Basin and Flood Detention Basin at TAFE Park

TAFE Park is currently used as dog exercise area and has a poor vegetative cover. The Park presents an opportunity similar to Simpson Park for water quality improvement and flood detention. However a significant finding in the assessment for flood detention shows that there would be an increase in flooding in a downstream area of the subcatchment (along James St). This is a severe limitation of this option and as such the Park can not be recommended for flood detention purposes.

The water quality improvement efficiencies and cost for removing various contaminants is similar to Simpson Park (Table 27 and Table 28). However, due to negative flooding impact, TAFE Park option would rank lower than the Simpson Park.

SWQ4 + R6 – Bioretention Swale at Pemmel Street and Drainage Upgrade for Sloane Street

Pemmel Street is one of the widest streets in the subcatchment and provides an opportunity to install a bioretention swale along the street. The Sloane St drainage upgrade involves acquisition of properties between Pemmel St and Sloane St to create an overland flowpath. However, the drainage upgrade option has significant downstream impacts and therefore not worthy of further consideration.

Although the treatment efficiency of the bioretention swale is high, the cost for improving the water quality is also very high. In view of these limitations, this option may not be suitable for implementation in the subcatchment.

SWQ5 + R7 – Bioretention Swale and Drainage Upgrade at Goodsell Street

Goodsell St is also a wide street in the subcatchment and provides an opportunity for a bioretention swale. The proposed drainage upgrade includes upgrade along Goodsell St, May lane and Council St.

The drainage upgrade option provides significant benefits with a high benefit cost ratio and overall rating using the Quadruple Bottom Line analysis. However there is a small impact downstream near the Railway parade and Edgeware Rd intersection.

The water quality improvement is significant. However the cost of treatment is high.

This option can be considered for implementation in the subcatchment.

The cost to partially implement this option (stormwater only) has been provided in APPENDIX D.

SWQ6 – Rain Gardens at Redevelopment Sites

The rain gardens can be provided on the ground or on the rooves of multi-unit redevelopment sites. These rain gardens would typically range from 20 to 30 m^2. The runoff volume reduction is small but there is significant improvement in the runoff quality.

The provision of rain gardens can be offered as an option in the new DCP for the St Peters Triangle redevelopment. This option is therefore suitable for adoption for the EC East subcatchment.

SWQ7 + WR – Irrigation of Camdenville Oval using Street Runoff

A large part of the EC East Subcatchment drains into Camdenville Oval. A 250 m^3 tank would provide enough storage to meet 84% of the irrigation demand at the Oval. The water quality improvement is not significant and therefore the primary function of this option is to replace the potable water demand.

The average cost for replacing potable water is $2,608 ML/year, which is very attractive at the current potable water rates. In the Quadruple Bottom Line analysis, this option has one of the highest rankings outside of non-structural flood management measures. It is therefore suitable for implementation.

SWQ8 + WR – Irrigation of Camdenville Oval using Roof Runoff

This option envisages use of roof runoff from the factories to the west of Camdenville Oval. Due to small roof catchment, larger tank sizes are required for irrigation of the Oval. However, even with a tank size of 1000 m^3, the irrigation demand would be met for 40% of the time. For the remaining periods, top-up from the mains supply would be required.

This option is expensive to implement as compared to the irrigation option using street runoff. Other issues such as pipe laying across the Bedwin Rd or along the rail corridor and negotiations with the factory owners makes it less suitable for implementation.

SWQ9 + WR – Sealed Wetland in Camdenville Oval

Provision of a wetland in Camdenville Oval provides significant benefit in terms of stormwater quality improvement. It also provides a very cost-effective means of providing irrigation water for the Oval. However, Camdenville Oval is an old landfill site and currently under investigation for impacts on surrounding environment including landfill gas migration away from the site. Construction of a wetland, although sealed, would still be a major threat to enhancing the environmental impacts of the old landfill. Implementation of this option is therefore not recommended.

R2 – Drainage Upgrade at Alice St and Edgeware Rd Intersection

This involves street drainage upgrade at the intersection of Alice St and Edgeware Rd. The Quadruple Bottom Line analysis suggests that it is the second highest ranked option outside of non-structural flood measures. Given that the option has a reasonable benefit cost ratio and has reasonable scores in the Quadruple Bottom Line analysis, it is suitable for implementation.

R1 – Drainage Upgrade for Improvement of Railway Parade

This option involves extensive street drainage upgrade upstream of the Railway Parade including provision of a culvert along Murray St to the Eastern Channel. This option is ranked 15 out of the 24. The benefit cost ratio is low due to high capital cost. The option scores reasonably well for other criteria in the Quadruple Bottom Line analysis, however, due to high capital cost it will be difficult to implement.

This option can be suitable for implementation due to its widespread benefit within the subcatchment, however, may need to be implemented in stages. The cost to partially implement this option has been provided in APPENDIX D.

R9 – Drainage Upgrade at Corner of Campbell St and May St

This option involves diversion of ponded stormwater into Camdenville Oval during frequent rainfall events. Modelling indicates a reduction in ponded stormwater of more than 5 cm in the 2 yr event. However, this reduction is not sufficient to reduce flood damage of the effected property, Town and Country Hotel. The option, therefore, has no monetary benefit.

Although this option does not have a monetary benefit, a reduction in nuisance flooding due to ponded stormwater during events up to the 2 year event leads to this option having the highest rank for flood management purposes. This option may be considered for implementation, however, it is noted that there are currently environmental constraints on the detention basin in Camdenville Oval due to site contamination issues. It is noted, however, that utilisation of Camdenville Oval as a detention basin has an operational cost associated with pumping out of detained runoff into the stormwater system following rainfall events.

R10 – Drainage Upgrade of Southern Subcatchment and Expansion of Camdenville Oval

This option is based on Option R3, including Simpson Park detention basin, but also involves increased utilisation of Camdenville Oval by amplification of proposed trunk drainage system with the Southern Subcatchment, as well as expansion of Camdenville Oval itself. This option has a cost benefit ratio equivalent to option R3. This is because the benefit from the reduction in flood depth in the 100 yr event by expansion of Camdenville Oval detention basin is offset by increased capital cost.

This option remains suitable for implementation due to the potential of implementing a water quality improvement option in Simpson Park (SWQ3).

Property Modification and Emergency Response Modification Options

The Quadruple Bottom Line assessment of various property modification and response modification options highlights the high value of these options in managing the flood risk in the EC East Subcatchment. These options are generally suitable for highly developed catchments such as the EC East Subcatchment. The implementation cost for these options is low and although the monetary benefit cannot be assessed directly, the quadruple bottom line is very strong for these options. All those options presented in the Quadruple Bottom Line assessment are therefore suitable for implementation

Preferred Options

Based on the above discussion and Quadruple Bottom Line Assessment (Table 32), a preliminary recommendation is provided for implementation of the following options in the EC East Subcatchment:

- Update Council's OSD Policy
- Update Local Flood Plan in association with SES
- Public awareness campaign in association with SES
- Provision of flood markers
- Flood data collection
- Bioretention basin at Simpson Park
- Drainage upgrade at corner of Campbell St and May St
- Irrigation of Camdenville Oval using street runoff
- Rain gardens at redevelopment sites

The following options have significant benefits in terms of water quality improvement and/or flood management. These options can also be considered for implementation in the subcatchment:

- Rainwater tanks
- Drainage upgrade at Alice Street and Edgeware Road intersection
- Bioretention swale in Goodsell St
- Drainage upgrade for improvement of Railway Parade
- Bioretention swale in Pemell St

Bioretention basin in TAFE Park may be considered from water quality benefitis, however, TAFE Park is under NSW Department of Education ownership and appropriate consultation and permission from the Department would be required to pursue this option.

The recommendations provided above are preliminary and need to be reviewed by Council's Integrated Urban Water Management Group, the EC East Working Group and the Marrickville Council Floodplain Management Advisory Committee.

After review by Council, the plan will be finalised and recommended for implementation.

15.0 QUALIFICATIONS

This report has been prepared by Golder Associates for Marrickville Council and should not be used by a third party without prior approval from the Council.

The investigation procedures used in this study are based on industry standards and quality control procedures have been adopted in the preparation of this report. However, the investigative procedures, in particular the modelling used in the study depends on the quality of available data. Consequently, there will be a level of uncertainty in the study results which should be taken into account while interrogating and using the study results.

The results of the study are based on the following assumptions/conditions:

- Cost estimates for various options are preliminary. Detailed cost estimates should be prepared after the detailed design of these options;
- Flood damage analysis is based on the damage curve data produced by DECCW and is not specific for EC East Subcatchment;
- Hydraulic modelling of the drainage system is based on the data provided by the Council; and
- Study results should only be used for the purposes for which they were prepared.

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APPENDIX A

Community Consultation Report

GOLDER ASSOCIATES
for MARRICKVILLE COUNCIL

EASTERN CHANNEL EAST SUBCATCHMENT

Community Consultation Report

FINAL

MARCH 2010

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We would like to thank the following key people for contributing information and assisting with preparing this report.

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Habib Rehman

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Cooks River Sustainability Initiative

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Grateful thanks also to the Marrickville Council, Cooks River Sustainability Initiative and Golder Associates team who worked together to ensure the community consultation was a success.

Most importantly thanks are extended to the local school children, adults, school principals and other stakeholders who enthusiastically attended and contributed to the vision sessions and planning forums.

1 INTRODUCTION

1.1 Background

This report documents the process and outcomes of community consultation undertaken for the Eastern Channel East (EC EAST) Subcatchment Management Plan in early 2009.

Several documents produced for this project provided background information for and supported the consultation process. Such documents include "Planning Eastern Channel East Subcatchment" (Cooks River Sustainability Initiative and Marrickville Council, 2009) referred to as the "planning booklet", and relevant information placed on display boards at the visions sessions and planning forums.

1.2 Approach to community consultation

The approach taken to engaging the community in planning for sustainable water management in the EC East Subcatchment is known as "collaborative planning". This approach is documented in guidelines for community engagement in planning for sustainable water management in subcatchments prepared by Marrickville Council and Monash University (Marrickville Council, 2007). Collaborative planning has been successfully implemented by Marrickville Council in recent years in the Illawarra Road and other subcatchments in Marrickville local government area.

Essentially, collaborative planning involves the subcatchment community and government, non-government and private stakeholders working together in a collaborative and co-operative environment to create a vision, and develop realistic goals and actions to achieve the vision. The outcomes of a collaborative planning approach include greater commitment, transparency and accountability in making decisions and implementing actions.

1.3 Stakeholders

The Cooks River Sustainability Initiative and Sydney Water supported Marrickville Council and the consultant team in undertaking this project.

Collaborative planning for the EC EastT Subcatchment involved other people and organisations including residents, school students and principals, businesses and industries in the EC East Subcatchment.

1.4 Consultation process

Community consultation for the EC EAST Subcatchment was undertaken between March and May 2009 by Marrickville Council staff, Cooks River Sustainability Initiative (CRSI) staff, and the

Golder Associates consultant team. A Community Water Survey was undertaken in June 2008 by Marrickville Council and CRSI.

Three key stages in the community consultation undertaken for the EC East Subcatchment Management Plan were community water surveys, vision sessions, and planning forums. These aspects of community consultation are further outlined in Section 3.

2 SOCIAL PROFILE OF THE EC EAST SUBCATCHMENT

2.1 Introduction

The EC East Subcatchment is primarily residential, with a significant light and medium industrial area in the south-west and south-east, as well as commercial, retail, open space, community, educational and other landuses.

2.2 Residents and households

2.2.1 Total population

7,661 people in approximately 3,088 households live in the EC East Subcatchment (Australian Bureau of Statistics, 2006 Census of Population and Housing).

2.2.2 Residents

Country of birth and language

Most residents of the subcatchment were born in Australia. 31% of subcatchment residents were born overseas in a range of countries, particularly the United Kingdom (6%) and New Zealand (4%). A similar percentage (32%) of people in the Sydney Statistical Division (SSD) were born overseas. Key non-English languages spoken in homes in the subcatchment are Greek, Cantonese, and Portuguese.

Age

The age structure of the subcatchment population is dominated by people aged 25 to 44 years (49%). The SSD population is younger, with 30% of its population in the 25 to 44 years age group.

Education

The subcatchment population is educated and highly qualified compared to the SSD. Over one-third (36%) of subcatchment residents were attending an educational institution in 2006 in contrast to 24% of people in the SSD.

61% of subcatchment residents have a non-school qualification, including a bachelor degree or higher (33%) and an advanced diploma, diploma or certificate (26%). In comparison only 43% of SSD adults have a non-school qualification.

Religion

33% of subcatchment residents do not identify with a religion compared to 14% of people in the SSD. Of the residents in the subcatchment who identify with a religion, 18% are Catholic and 10% Anglican.

Employment

60% of the subcatchment population is in the active labour force which is similar to the SSD (61%). Of the active labour force in the subcatchment, 68% are employed full-time, 22% are employed part-time, and 4% are employed.

Travel to work

The main modes of travel to work by subcatchment workers are car (41% of workers), train (27%), bus (14%), walk (11%), and bicycle, motorcycle or scooter (6%). These results reflect the availability of public transport options in the St Peters/Newtown/Enmore area.

Mobility

The subcatchment population has a relatively high level of mobility compared to the SSD. 73% of subcatchment residents lived at the same address 1 year ago (compared to 79% in the SSD), and 43% of subcatchment residents lived at the same address 5 years ago (compared to 55% in the SSD). This relatively high level of mobility in the subcatchment poses challenges for long-term commitment of residents to catchment management initiatives.

2.2.3 Households and families

Household size

The majority (73%) of households in the subcatchment comprise 1 or 2 people.

Relationship

59% of adult residents in the subcatchment have never been married, while 27% of residents are married. Conversely a higher proportion of adults in the SSD are married (50%) while only 34% of adults in the SSD have never been married.

Family type

The EC East subcatchment has a lower proportion of children within families than the SSD. Most (54%) families in the subcatchment are couples with no children (compared to 33% in the SSD), and 22% of families are couples with children under 15 years (compared to 33% of families in the SSD).

Household income

The weekly income of households in the subcatchment is spread throughout the income range. The median weekly income of households in the subcatchment in 2006 is in the $1,000-$1,199 income band. This is consistent with the median household income of the SSD of $1,154.

2.2.4 Dwellings

Dwelling type

Residents in the subcatchment live in predominantly medium density dwellings as follows:

- 1, 2 or more storey semi, row, terrace or townhouse (57% of dwellings)
- 1,2, 3 or 4 storey flat, unit, apartment block (23%)
- Separate house (18%)
- House or flat attached to a shop (2%).

The medium density nature of the EC EAST is in strong contrast to the SSD, where 71% of dwellings are separate houses, 11% medium density dwellings, and 17% units/apartments.

Dwelling tenure

Dwellings in the subcatchment are almost evenly divided between owned/purchased and rented. 49% of dwellings in the subcatchment are fully owned (20%) or being purchased (29%), and 48% are rented privately (44%) or by the Housing Authority (4%). Home ownership is higher in the SSD, with 65% of households owning or purchasing their dwelling.

2.3 Workers

There is a concentration of light to medium industries in the south-west and south-East corners of the subcatchment. The range of industrial activities in these areas employ people in industries ranging from smash repairs, distribution centres and art studios.

2.4 Facilities and services in the subcatchment

2.4.1 Introduction

Residents and workers in the EC East Subcatchment have access to a wide range of community and welfare facilities, parks and reserves, public transport options, educational and performance facilities, commercial and retail, and places of worship.

2.4.2 Community and welfare facilities

Several community and welfare facilities operate in the subcatchment as set out below.

Tom Foster Community Care in Darley Street, Newtown provides a variety of community services to Marrickville residents.

Newtown Neighbourhood Centre provides services for people from disadvantaged and culturally and linguistically diverse (CALD) backgrounds.

Sydney City Mission operates a refuge for homeless men in Reiby Street, Enmore.

Our Place, a support and drop-in centre, is located in Enmore Road. Our place provides food, care, counselling, advocacy and outreach services to some of Sydney's most disadvantaged and marginalised citizens, many of them being homeless.

2.4.3 Parks and reserves

Parks and reserves catering for sport, play and active and informal recreation are located throughout the subcatchment. Key open spaces and recreational facilities include:

- Annette Kellerman Aquatic Centre in Enmore Park.
- sporting fields of Enmore Park, Camdenville Oval and Simpson Park.
- children's playgrounds in Enmore Park and Simpson Park (with picnic and barbecue area), Collyer Playground, Matt Hogan Reserve, Alice Street Playground, Darley Street Playground, Camdenville Park, Francis Street Playground, Salmon Playground.
- sports courts in Simpson Park.
- off-leash dog exercise area in Enmore TAFE Park.

2.4.4 Public transport

St Peters railway station is located in the subcatchment, while Newtown railway station is nearby.

Sydney Buses operate numerous bus routes linking the subcatchment with the Sydney CBD and other destinations.

2.4.5 Education

Four primary schools are located in the subcatchment: St Peters Public School, Camdenville Public School, Camdenville Primary Public School, and St Pius Catholic Primary School.

There are no secondary schools in the subcatchment. Secondary schools adjoining the subcatchment include Newtown Performing Arts High School on King Street in Newtown.

Tertiary education in design is available at Enmore TAFE in Edgware Road.

2.4.6 Performance spaces

Newtown Theatre is available for hire for rehearsals and performances. The theatre also co-ordinates acting classes.

2.4.7 Commercial and retail

King Street and Enmore Road host a wide variety of commercial, business and retail operators.

Marrickville Metro has a district/regional retail catchment.

Local corner stores serve residents' day-to-day needs.

2.4.8 Places of worship

Places of worship in the subcatchment include:

- St Peters Church Cooks River: Princes Highway, St Peters.
- St Pius: Edgware Road, Newtown.
- Friends of the Western Buddhist Order: Enmore Road, Newtown.
- Sydney Central Fijian: Metropolitan Road, Enmore.
- St Constantin and Helen: King Street, Newtown.

3 OUTCOMES OF CONSULTATION

3.1 Community Water Surveys

3.1.1 2008 survey

Introduction

To obtain preliminary information for the Subcatchment Management Plan for the EC EAST Subcatchment, Marrickville Council mailed a copy of a community water survey forms to 3,274 households in the EC East Subcatchment in June 2008. A copy of this survey form is included in Appendix A.

635 survey forms were returned, representing 19% of households in the catchment.

Characteristics of respondents

The characteristics of people who responded to the survey are set out in Table 3.1 below, and compared to the characteristics of the subcatchment population.

Table 3.1 Characteristics of people who responded to the Community Water Survey 2008

Characteristics		Survey respondents	Subcatchment population
Number		635	7,661
Gender	Male	33%	n/a
	Female	67%	
Origin	Australia	68%	69%
	UK	9%	6%
	NZ	4%	4%
	ATSI[1]	1%	
Language	Speak English at home	95%	86%
Education	University	31%	n/a
	Post-graduate	29%	
	TAFE/trade	14%	
Age	20-29 years	13%	n/a
	30-39 years	35%	
	40-49 years	24%	
	50-59 years	15%	
	60+ years	13%	
Household type	Couple no children	34%	n/a
	Couple with children	23%	
	Live alone	22%	
	Share with non-family	12%	

Table 3.1 Characteristics of people who responded to the Community Water Survey 2008 (cont.)

Characteristics		Survey respondents	Subcatchment population
Tenure type	Fully owned	43%	20%
	Purchased	28%	29%
	Rent–private	25%	44%
	Rent-public	3%	4%
Dwelling	Flat, unit, apartment	14%	23%
	Semi-detached/ terrace/ town house	63%	57%
	Separate house	23%	18%
	House/flat attached to shop/office	0%	2%
Time in current residence	0-1 yr	19%	
	1-10 yrs	56%	n/a
	11-20 yrs	14%	
	20+ yrs	12%	
Individual gross weekly income	$1,000 +	42%	n/a
	$400-999	37%	
	$1-399	17%	

1 Aboriginal or Torres Strait Islander descent
Source: Cooks River Sustainability Initiative (2009)

Knowledge of urban water systems

Respondents were asked questions about their knowledge of urban water systems.

They showed a high level of knowledge that rainwater in the street normally drains to the nearest waterway (75% correct); and that water from driveways, footpaths, other paved areas, roofs and gardens ends up in street drains (75%-92% correct). Up to 11% of respondents incorrectly thought that water from kitchen sinks, washing machines, showers and toilets ended up in street drains.

Most survey respondents (73%) underestimated their daily water use.

Behaviour

Current use of water storage or water saving devices by respondents at home is:

- water saving devices (81% of respondents) such as water saving showerheads, tap aerators, and toilet flush water savers.
- greywater reuse system (27%), mainly used to water the garden.
- rainwater tank (8%), mainly used to water the garden.

Receptivity to using rain and greywater

The survey respondents would be highly receptive to using filtered rainwater and treated recycled water particularly for non-contact uses such as watering the garden, flushing toilets, and washing the car. Using filtered rainwater and treated recycled water for uses involving skin contact, such as washing clothes and showering, was less supported. Direct contact with filtered rainwater and especially treated recycled water through cooking and drinking received very low support, although respondents would much prefer to cook with and drink filtered rainwater instead of treated recycled water.

Attitudes

The following statements reflect agreement of the majority of survey respondents:

- I would reduce my shower time by half to save limited water resources.
- Most people want to help improve the health of the waterway environment.

Statements which received neither majority agreement or disagreement are:

- Access to a healthy natural environment is more important than access to community facilities.
- My daily activities have little negative impact on the waterway environment.
- We should aim for the same waterway conditions as before the Europeans arrived over 200 years ago.

More survey respondents disagreed than agreed with the following statements:

- Jobs are more important than the environment.
- Government agencies should have the main responsibility for the waterway environment rather than the individual.
- Laws are more effective than education for protecting the waterway environment.

3.1.2 2009 Community Flood Survey

A survey form prepared by Golder Associates that built on the findings of the June 2008 survey was delivered to every residence in the EC East Subcatchment in March 2009. The response rate was approximately 7% (213 responses from approximately 3,000 surveys delivered). Questions on the survey form related to providing information about any experiences with stormwater ponding or overland flows. Main areas and street intersections of concern regarding flooding were identified. A detailed report on the results of this Community Flood Survey is presented in the Subcatchment Management Plan – Volume 1.

3.2 Vision sessions

The key objective of the vision sessions was to set a future vision for the Cooks River and the EC East Subcatchment to 2050.

Five vision sessions were held, involving three adult groups (18 people) and two primary school classes (49 children).

3.2.1 Adults

Introduction

The vision sessions involving 18 adult residents were held on 24 March, 2 April, and 12 May 2009.

Evaluation forms were completed by 15 of the 18 adult residents who participated in the vision sessions.

Characteristics of participants

The majority of participants in the vision workshops speak English, privately rent the dwelling they live in, are aged between 15 and 24 years, and are male.

Participants in the vision sessions

Sources of information about the vision sessions

Participants heard about the vision sessions either through word-of-mouth, from the local newspaper, the letter distributed to residences, or from information provided at the stall at Marrickville Metro.

Reasons for participating

Participants chose to participate in the vision workshop for several reasons, including to have a say about the future of and possibilities for water management, to be actively involved in local and community planning, to express concern for the sustainable future of the area, and because of an interest in the local environment and sustainability.

Information presented

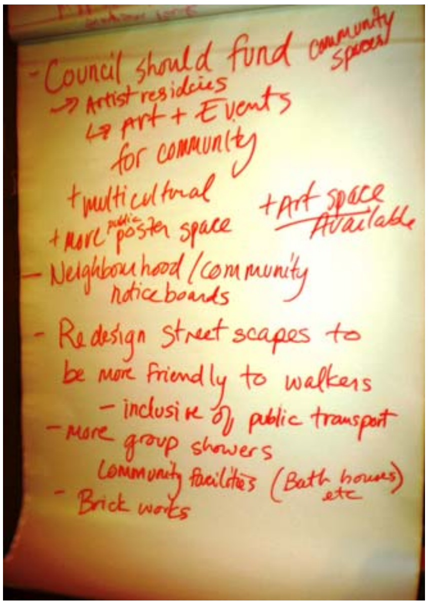
Information presented at the vision sessions to assist participants included background information for and goals of the CRSI OurRiver project, Marrickville Council's water management initiatives, and the planning booklet which contains information about the physical water catchment and socio-economic characteristics of the catchment's population.

Input from participants

Participants were asked to think about their use of and attitudes to water when they were a child, in the year 2000, and now.

Then participants were asked to think ahead to the year 2050 and their vision for water use and management in that year.

These ideas were then collated into a draft vision and goals for further discussion in the planning forums.



Satisfaction with the vision sessions

Participants were either very satisfied or satisfied with the vision workshop they attended. Reasons given for the high participant satisfaction with the vision sessions included that the session was:

- an opportunity for residents' opinions, ideas and vision to be asked for and heard.
- an opportunity for open discussion about new and current ideas.
- well structured, informative and helpful.
- well conducted and facilitated.
- entertaining, engaging, stimulating and inspiring.
- relaxed, enabling proper consultation.

The majority of participants would recommend the vision session to others, and felt confident discussing what was covered in the session with others.

Next steps

All participants in the vision sessions were invited to attend the subsequent planning forums.

Adults that had expressed an interest in the planning process but could not attend the vision sessions were sent an email with background information and were encouraged to attend the planning forums.

3.2.2 Children

Two school groups were consulted regarding their vision for water in general and the EC East subcatchment in particular as follows:

- Years 5/6 at St Peters Public School on 6 April 2009.

- Years 5/6 at Camdenville Public School on 8 April.

The children were asked about where water comes from and where it goes after use, and how they use water. The children thought ahead to the future and came up with ideas for sustainable water use and management, which they drew (see Figure 3.1), wrote or talked about.

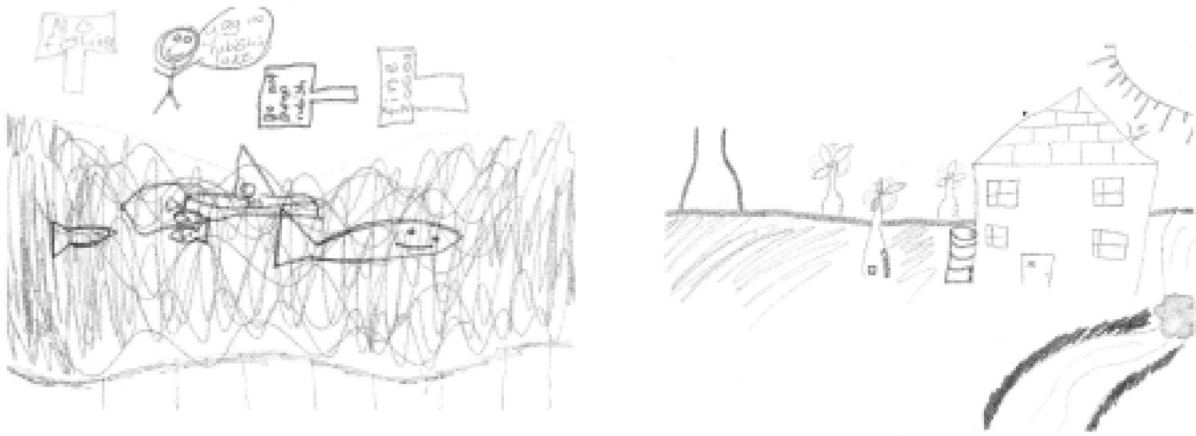


Figure 3.1 Examples of drawings of local school children about what water means to them

3.3 Planning forums

3.3.1 Introduction

Two planning forums were held at Camdenville Public School on Wednesday 20 May (Planning Forum 1) and Wednesday 27 May 2009 (Planning Forum 2, including attendance by a Marrickville Council Councillor).

Residents involved in the previous vision sessions, the principals of St Peters and Camdenville Public Schools, and a representative from Sydney Water attended the planning forums.

3.3.2 Planning forum 1

Agenda

The agenda for Planning Forum 1 was:

- Background to planning in the Marrickville subcatchments and to the Cooks River Sustainability Initiative role in subcatchment planning
- Purpose of Planning Forum 1
- Information about the EC East Subcatchment
- Explanation of the subcatchment planning approach and process
- Refine and agree on the 2050 vision
- Identify and discuss draft long-term goals to 2050 in groups
- Agreement of 2050 goals
- Introduction to Planning Forum 2 at which 2050 goals will be refined and interim goals to 2019 set.

2050 vision

The group refined the draft vision to agree on the 2050 vision, which is:

In 2050 we are happy, recognise our dependence on natural systems and we value water. We have a profound sense of achievement with respect to the changes to our subcatchment and lifestyles. We are leaders in sustainable practice and innovative design. Our society is active and engaged, and collaborative processes have influence beyond the subcatchment.

In 2050, a holistic approach is taken in the design, maintenance and improvement of the local natural and built environment. All new development is considerate of future generations, and water sensitive technologies are familiar, affordable and widely used.

2050 goals

Following on from the vision, small groups set long-term goals for the year 2050 in order to achieve the vision as follows.

The 2050 goals for the EC East Subcatchment are:

1 100% of the people understand and own the EC EAST subcatchment vision.

2 EC East has a reputation as a leader in sustainable practices.
3 Public streets and open spaces are co-managed by local people.
4 Public streets and open spaces have multiple functions and are retrofitted with water sensitive technologies.
5 100% of buildings meet a high level of sustainability standards.
6 Eastern Channel is naturalised.
7 99% of water is sourced from within the subcatchment and made fit for re-use / export:
   - only 1% of water is imported as potable water
   - only X% of water runs off to the Cooks River
8 Damaging flooding is eliminated through sustainable water management in the subcatchment.

The vision and the draft 2050 goals were sent to participants to help them prepare for the second planning forum one week later.

3.3.3 Planning forum 2

The agenda for Planning Forum 2 included:

- ❒ Purpose of the planning forum
- ❒ Recap of discussions at Planning Forum 1

- ❒ Decide on the draft EC East Subcatchment 2050 goals
- ❒ Create draft EC East Subcatchment 2019 goals
- ❒ Agreeing on the 2019 goals
- ❒ What happens next?

The 2019 goals relating to the 2050 goals and the vision are outlined in Table 4.1 below.

Evaluation of planning forums

The feedback from people that attended the planning forums was similar to the evaluation by participants in the vision sessions, in that the planning forums were interesting, informative, and gave the community an opportunity to influence local planning.

3.4 Next steps

Following the Planning Forums, residents in the EC East Subcatchment were invited to join the EC East Subcatchment Working Group. The Group will work with Council and the Cooks River Sustainability Initiative (CRSI) to further develop the actions for the Draft EC East Subcatchment Management Plan. Once the Management Plan is completed, the Group will continue to give feedback to and help Marrickville Council carry out the actions in the Management Plan.

4 VISION AND GOALS FOR EC EAST SUBCATCHMENT

Table 4.1 below sets out the vision and draft goals for 2050 and 2019 for the EC East Subcatchment developed through community consultation.

Table 4.1 Vision and draft goals for 2050 and 2019 for the EC East Subcatchment

Vision	**2050 Goals**		**2019 Interim Goals**
In 2050 we are happy, recognise our dependence on natural systems and we value water. We have a profound sense of achievement with respect to the changes to our subcatchment and lifestyles. We are leaders in sustainable practice and innovative design. Our society is active and engaged, and collaborative processes have influence beyond the subcatchment.	1	100% of the people understand and own the EC EAST subcatchment vision and goals	70% of people are aware of and understand the vision and goals.
			Permanent public and commercial community bodies (e.g. schools and businesses) own and promote the vision.
			50% of people are actively involved in at least one of the actions contributing to the 2050 goals.
	2	EC East has a reputation as a leader in sustainable practices.	2019 goals not defined
	3	Public streets and open spaces are co-managed by local people.	2019 goals not defined
In 2050, a holistic approach is taken in the design, maintenance and improvement of the local natural and built environment. All new development is considerate of future generations, and water sensitive technologies are familiar, affordable and widely used.	4	Public streets and open spaces have multiple functions and are retrofitted with water sensitive technologies.	A minimum of five WSUDs have been built in the EC East subcatchment, for example Marrickville Metro retrofitted to harvest rainwater, and bioretention ponds.
			All spaces retrofitted with WSUD are built as open classrooms that showcase innovations, multiple functions with scope to be replicated on small and large scales.
	5	100% of the new buildings meet a high	Policy for new development on water use, recycling and site permeability

Vision	**2050 Goals**		**2019 Interim Goals**
Our waterways, wetlands and green spaces are thriving urban ecosystems that support cultural activities, recreation or local food production		level of sustainability standards.	with an aim of at least 50% of water from rainwater and greywater is reused within the catchment.
			Permanent incentives to enable policies to be adopted by all stakeholders without discouraging growth, including rebates for sustainable measures and promotion of local businesses that are adopting environmental methods.
	6	Eastern Channel is naturalised.	2019 goals not defined
	7	99% of water is sourced from within the subcatchment and made fit for re-use / export: a) only 25% of water runs off the sub-catchment into the Cooks River b) potable water is only used for essential purposes.	30% of water is sourced from within the subcatchment and made fit for re-use.
			Only 50% of water runs off the subcatchment and into the Cooks River (assumed natural conditions)
			10% of potable water is used for essential purposes (consumption)
	8	Stormwater flooding is minimised through sustainable water management in the subcatchment	2019 goals not defined

References

Cooks River Sustainability Initiative and Marrickville Council (2009) *Planning Eastern Channel East Subcatchment*.

Marrickville Council and Monash University (2007) *Subcatchment Planning for Sustainable Water Management: Guidelines for Councils*.

APPENDIX A

Community Water Survey form

4. Please indicate on a scale of 1 (strongly agree) to 5 (strongly disagree) how much you agree with the following statements.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	2	3	4	5

a. Jobs are more important than the environment.				
1	2	3	4	5
b. Access to a healthy natural environment, e.g. parks and waterways, is more important than access to community facilities, e.g. libraries, shops and restaurants.				
1	2	3	4	5
c. My daily activities have little negative impact on the waterway environment.				
1	2	3	4	5
d. Government agencies should be mainly responsible for the waterway environment rather than the individual.				
1	2	3	4	5
e. We should aim for the same waterway conditions as before the Europeans arrived more than 200 years ago.				
1	2	3	4	5
f. I would reduce my shower time by half to save limited water resources.				
1	2	3	4	5
g. Most people want to help improve the health of the waterway environment.				
1	2	3	4	5
h. Laws are more effective than education for protecting the waterway environment.				
1	2	3	4	5

5. Do you have a rainwater tank?

☐ Yes ☐ No

***If yes*, how many litres is your tank?** ___________

How do you use the water? ___________________

____

6. Do you reuse greywater?

☐ Yes ☐ No

***If yes*, how do you use the water?**

____

____

7. Do you have any water saving devices? (e.g. showerheads, tap aerators, toilet water flush saver)

☐ Yes ☐ No

8.

a. If you collect(ed) and filtered <u>rainwater</u> from your roof in a tank, what would you consider using it for?	b. If you collected wastewater from your kitchen, laundry and shower, and treated it to reuse on your property, what would you use it for?
(Please tick ☑ all that apply)	*(Please tick ☑ all that apply)*
☐ Cooking	☐ Cooking
☐ Drinking	☐ Drinking
☐ Showering	☐ Showering
☐ Washing clothes	☐ Washing clothes
☐ Flushing the toilet	☐ Flushing the toilet
☐ Washing the car	☐ Washing the car
☐ Watering the garden	☐ Watering the garden
☐ Nothing	☐ Nothing

9. What major improvement to Marrickville's environment do you want to see in the next 20 years?

____

____

Thank you!

Anonymity and Confidentiality

All the information you provide will be treated as strictly **confidential**, and will not be sold or disclosed to any third parties. No individuals, households or businesses will be identifiable in any report or data collection.

June 2008

OurRiver

cooks river sustainability initiative

Community Water Survey

Marrickville Subcatchments

EASTERN CHANNEL 1 EAST

Return by 30 June 2008 to be in the draw to win a dinner for 2!

www.marrickville.nsw.gov.au / 93352222

Section A

About you

This information is to make sure we hear from a good cross section of people in your area.

Please Tick ☑ the best answer to the following questions.

1. I am:

☐ Male ☐ Female

2. Age:

☐ 18-19 yrs	☐ 50-59 yrs
☐ 20- 29 yrs	☐ 60-75 yrs
☐ 30-39 yrs	☐ 75+ yrs
☐ 40-49 yrs	

3. I have lived in this residence for ______ years.

4. I live in a:

☐ Separate house	☐ Flat, unit or apartment
☐ Semi-detached, terrace or townhouse	☐ Other (*specify*)

5. ______ (*number*) people live in this residence.

6. My household is made up of:

☐ Single person living alone	☐ One parent with child(ren) at home
☐ Couple with children at home	☐ Adult living with parents
☐ Couple with no children at home	☐ Extended family household
☐ Share accommodation with non-family	☐ Other (*specify*)

7. My home is:

☐ Fully owned (owner occupied)
☐ Being purchased
☐ Rented privately
☐ Rented from Public Housing
☐ Other (Specify ____________________

8. I am:

☐ Working ***full-time***	☐ Not working
☐ Working ***part-time*** or ***casual***	☐ Student ☐ Retired
☐ Self-employed ☐ Unemployed	☐ Other (*specify*)

9. My individual weekly income before tax is.

☐ Negative / Nil income	☐ $600 - $799
☐ $1-$199	☐ $800 - $999
☐ $200 - $399	☐ $1,000 - $1,499
☐ $400 - $599	☐ $1,500 or more

10. I am from Aboriginal or Torres Strait Islander Descent.

☐ Yes ☐ No

11. I was born in (*country*) _________________ .

12. I speak _____________ (*name of language*) at home.

13. The highest level of education I have completed is:

☐ Some schooling	☐ Advanced Diploma
☐ High School – Year 10	☐ University Degree
☐ High School – Year 12	☐ Postgraduate Qualification
☐ TAFE or Trade Certificate/Diploma	☐ Other (please specify) ____________________

(If you are from another state or country, tick ☑ the equivalent educational level.)

Section B

Some of the following questions refer to the '*waterway environment*'. **The waterway environment is all forms of natural and urban surface water, such as stormwater drains and channels, gullies, canals, streams, rivers, lakes, harbours, seawater and oceans.**

Questions 1-3 are measuring general knowledge about urban water. **Please do not** try to find the answers, simply answer them the best you can.

Tick ☑ the best answer to all questions below.

1. In Marrickville, the rainwater in the street drains normally goes: *(Tick ☑ one only)*

☐ To the sewerage system
☐ To the nearest waterway (Cooks River, Alexandra Canal, Sydney Harbour)
☐ Directly into the sea
☐ Other: ______________________________

2. From the list below, which would normally end up in the street drains? *(Tick ☑ all that apply)*

Water from:

☐ the kitchen sink ☐ the washing machine
☐ the shower ☐ driveways, footpaths
☐ the toilets ☐ other paved areas
☐ excess water from the garden ☐ rainwater from the roof

3. On average, how many litres of water does a typical Marrickville household use per day? *(Tick ☑ one only)*

(One milk carton equals one litre of water.)

☐ 0-100 litres ☐ 300-400 litres
☐ 100-200 litres ☐ 400-500 litres
☐ 200-300 litres ☐ more than 500 litres

APPENDIX B

Water Balance Assessment

1.0 EC EAST SUBCATCHMENT WATER BALANCE

The water cycle in the EC East subcatchment is quantified by estimating the water balance for the subcatchment. It provides an opportunity to highlight potential drinking water savings through rainwater and stormwater harvesting. It also provides an indication of the likely quality of the stormwater leaving the subcatchment.

The water balance analysis requires estimation of water inflows and outflows or losses within the subcatchment. These elements of the water balance are presented below:

1.1 Inflows to the Subcatchment

Rainfall:

Rainfall was obtained for 6 minute and daily totals for Sydney Airport (Data source BOM 1986 to 2006). The mean annual rainfall over this 20 year interval was 1115 mm.

The subcatchment area is 131 ha; therefore the total volume of rain falling in the average year was 1,460,000 kL/year.

Mains water supply:

The total annual mains supply to the catchment since early 2007/08 was 612,375 kL (SWC pers comm). That is, SWC supply provides the equivalent of approximately 30% of the total water delivered to the subcatchment (rainfall plus water mains).

Figure 1 shows the percentage distribution of different water uses according to landuse in the catchment. Single residences have the highest water usage, accounting for 75% of mains water use in the most recent available 12 month period (from April 2007 to March 2008). However this landuse type is also the largest in the catchment.

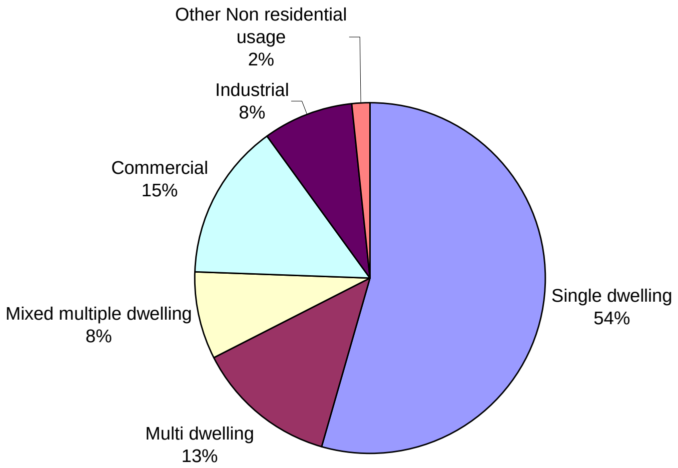


Figure 1: Percentage consumption of water in the catchment by various landuses (Source: SWC)

Figure 2 shows the mains water supply to different landuses each quarter since 1999.

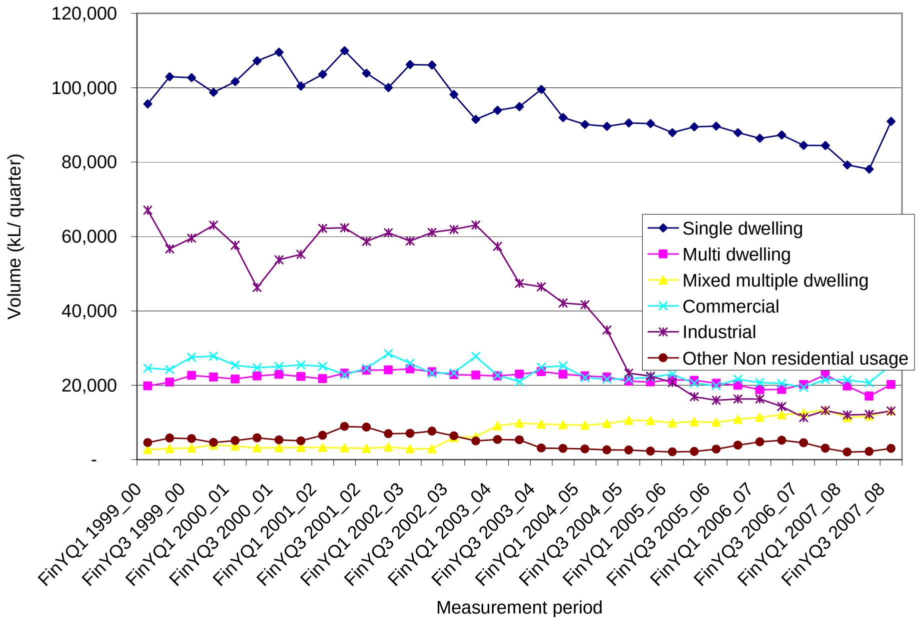


Figure 2: Water use per quarter by different land uses. Based on quarterly data since 1999 (Data source: SWC).

Potable water use in residential single dwellings has fallen by some 20% in the past decade. Water usage is higher in the second and third quarters of each financial year during the period to 2002/03. These second and third quarters include the October to March period when hot weather would result in increased demand for garden and lawn watering. Water restrictions since 2003 has led to lower water usage in this period, so there is usually less seasonal fluctuation in water use in recent years (SWC, 2008).

Usage by industrial sites has also fallen significantly; with usage in 1999/2000 being 246,365 kL/y compared with 50,555 kL/y in the period since 2006-07. This is a major change. It would reflect a combination of landuse change and more conservative attitude to water use.

The average water usage per single family unit dwelling is 394 L/day, or some 159 L/day. Figure 3 shows the distribution of water uses within typical single dwellings.

Toilets and bathrooms are the main areas of usage. Human consumption is typically 2 L/day (NHMRC/NRMMC, 2004). This is 1 to 1.5% of the volume supplied to individual homes. Garden usage of 8% is equivalent to 32 L/day.

Toilet utilise some 30% of the water supply to individual homes. This is high compared with other parts of Sydney and reflects the age of the homes and the widespread use of single flush toilets.

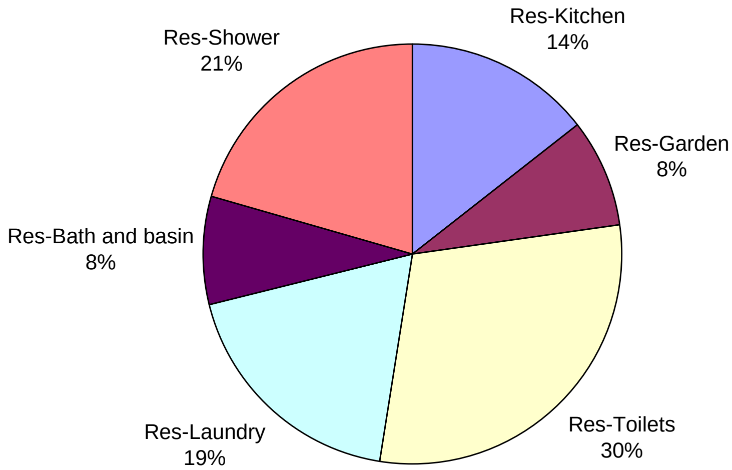


Figure 3: Water use per quarter by different land uses. Based on quarterly data since 1999 (Data source: SWC).

Groundwater:

According to DWE records there are some licensed bores in the catchment. However the underlying rock is largely shale overlying Hawkesbury Sandstone. There will be limited water from the shales and water at depth is likely to be saline at least in some areas.

Groundwater is not a significant water source in this subcatchment (Timms et al, 2004).

1.2 Outflow and Losses from the Subcatchment

1.2.1 Outflow and losses related to the mains supply

Garden usage:

It was assumed that 8% of water supplied to single dwellings was used for irrigation. In 2007/08, some 332,741 kL was supplied to homes, 8% of this is 26,619 kL or 4% of total water supplied to the catchment

Drinking:

It was assumed that 1.5% of the water was used for drinking.

Mains water supply leakage:

SWC annual report for 2008 states that the annual loss from main leakage across the Sydney and Illawarra Network was 8%. This loss may be even higher for older pipes in the catchment, however 8% was used as it is the SWC documented rate. Conversely some of the leakage will occur between the water treatment plants and the Marrickville LGA. The proportion of loss from pipes within the LGA is not known but it is assumed to be a maximum of 8%.

Sewage:

The sewerage system is a significant export mechanism in most urban catchments. Information on typical individual dwellings suggests sewage flows of 115 to 140 L/person/day depending on the extent of water conservation devices such as dual flush toilets and front loading washing machines (Standards Australia, 2000). These flow rates/person would result in flows of between 230 L/day for a dwelling with 2 people and conservative water use to 560 L/day for dwellings with standard fixtures and 4 residents. (The 2006 census reported that the average household had 2.48 people in it (ABS website)).

The sewer flows will also include stormwater infiltration and illegal connections of stormwater pipes. Exfiltration of sewage to the surrounding soil and surcharges can also occur. The losses from these pathways vary with sewer age, installation quality, soil type and subsoil moisture conditions. A typical older urban catchment will have around 15% loss of sewage between dwellings and ocean outfall.

Wastewater discharge to Malabar sewage treatment plant is estimated at 584,000 kL or 95% of the supplied water.

1.2.2 Outflows and losses related to rainfall

Stormwater:

Stormwater export from the catchment is at the end of a series of pathways leading from collection to exit from the catchment. Classical rainfall and runoff analysis concentrates on peak flow (this is essential in order to determine flood heights). However in catchment water and nutrient balance studies the total volume is important.

The process of stormwater generation depends on:

- Rainfall
- Surface storage
- Runoff to impervious surfaces in pipes and drains
- Runoff to stormwater collection devices-tanks, rain gardens, soak-a-ways, bio retention systems and regional detention systems, e.g at Camdenville Park.
- Percolation into the surface layer
- Percolation from the surface horizon into subsoil below root zone
- Percolation to the groundwater
- Evaporative losses
- Reuse from rainwater tanks and storage

Additional exports from the catchment can occur from activities such as over irrigation and washing down of premises. These flows can go to stormwater system.

Estimation of evaporation and evapotranspiration losses is discussed below:

***Evaporation*:**

The BoM site at Sydney Airport provides the evaporation data. Note that this site has unusually high evaporation rate compared with sites such as at Observatory Hill, Sydney. Local conditions e.g. the nearness to a large area of runway concrete or the presence of a large body of water nearby, can markedly influence pan evaporation.

In the current catchment, the high proportion of roofs and paving suggests that the pan evaporation data from Sydney Airport (1756 mm/y) is more representative of the Marrickville Catchment than the evaporation rate for Observatory Hill which is given as 1069 mm/y.

An additional reason for using evaporation from Sydney Airport is that evaporation rates at Observatory Hill were only measured between 1955 and 1966. This is too short a period to accurately estimate long term averages.

Evapotranspiration:

Potential evapotranspiration is commonly calculated by multiplying the pan evaporation with the crop factor. However much of the existing vegetation in the subcatchment is surrounded by buildings and other infrastructure, and consequently the vegetation is in shade, and protected from winds, for much of the time. The microclimate will therefore result in significantly less than the expected evapotranspiration. A recent study initiated by Sydney Water Corporation suggested that the crop factor for plants adjacent to typical high density home sites could be less than 50% of plants exposed to full sunlight. Obviously reducing the transpiration by 50% has a major impact on the catchment water balance.

Modelling for stormwater estimation:

MUSIC ® was used to model runoff and contaminant generation from different landuses in the catchment. MUSIC is a stormwater management program developed by the Cooperative research Centre for Catchment Hydrology. The data used was 6 minute rainfall from 1986 to 2006. This interval was selected as it is the longest continuous period of record. According to this model 978 ML of the 1460 ML/year of rainfall exits the catchment as runoff.

The estimate of pervious and impervious areas is critical to stormwater modelling. Pervious surfaces are critical as they enable water to penetrate the soil. The percentages of different surfaces were established via walking each street in the catchment noting the extent of gardens and by using Google Earth® to enable measurement of green areas within individual sites. An estimated 75% of the 131 ha catchment is impervious. Figure 4 to Figure 7 provide an overview of the subcatchment features that have been modelled.

Figure 4: School grounds such as Camdenville Public School provide significant open space areas. (Image source Google Earth ®).

Figure 5: View over Marrickville Metro Shopping Centre and surrounding lands. The shopping centre and the industrial lands have <5% pervious surface. The significant open spaces include school grounds and lands adjacent to the railway. (Image source Google Earth ®

Figure 6: Portion of the catchment centred on the TAFE. The dog exercise area in the upper right hand side of the image is in very poor condition. Most homes have little or no vegetation. (Image source Google Earth ®).

Figure 7: Aerial image of northern portion of catchment. Note lack of 'greenery' behind the commercial strip along Enmore Rd. Street trees are the most obvious vegetation among the residential areas.

Individual homes typically have zero to 20m sq of garden in the frontyard and zero to 40 msq in the back yard. (Image source: Google Earth ®).

Groundwater flow

Some of the infiltrated water reaches the groundwater. The catchment has a slight grade and consequently water reaching the groundwater table is likely to move along the gradient towards the exit area of the catchment. The rate of movement will be very slow, but over the long term the water will be delivered from the catchment. Ultimately the catchment has to be in long term equilibrium (Timms et al, 2004).

1.3 Water Balance

The measured rainfall and water supply data were combined with estimates of usage and losses to establish a catchment water cycle. The components are given below in Table 1.

Table 1: EC East subcatchment water balance components

Component	Measurement/ estimation source	Volume (kL/year)
Rainfall	BoM Sydney Airport 1986 to 2006 in 6 minute intervals	1,460,000
Potable water imported to catchment	SWC data for 2007/2008 +8% loss	661,000
Potable water use measured in the catchment	SWC data for 2007/2008	612,000
Potable water leakage	Estimated flows that were lost prior to metering at individual premises (8%) based on SWC data for 2008	49,000
Consumed by residents	1.5% based on 2L/person/day	9,000

Component	Measurement/ estimation source	Volume (kL/year)
	(NHMRC/NRMMC,2004) and 2 persons/dwelling (ABS, 2009)	
Garden and open space watering	4% of potable water suppled	27,000
Infiltration and evapotranspiration	34% of rainfall. Based on MUSIC Modelling	492,000
Stormwater runoff	67% of rainfall. Based on MUSIC Modelling	968,000
Exfiltration and sewer overflows	Allow 15% for the aging infrastructure.	86,000
Discharge to sewer	Measured potable water inflow-(consumption + watering)	576,000
Volume of sewage reaching ocean	Discharge minus leakage (80% of the supply volume)	490,000

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APPENDIX C

Detailed Analysis of Water Quality Improvement and Water Reuse Options

Table of Contents

TABLES

FIGURES

1.0 STORMWATER QUANTITY AND QUALITY

1.1 Overview

The EC East Subcatchment of Marrickville covers 131 ha, 75% of which is impervious. The runoff rate was calculated as being 978 ML/year. The contaminant loads produced in this catchment were calculated using MUSIC software incorporating 6 minute rainfall data from Sydney Airport from 1986 to 2006.

Table 1 shows the average, contaminant load generated and the generation rate/ha for the various land use categories.

Table 1: Average Catchment Contaminant Generation Rates

Land Use	Industrial	Commercial	Residential		Roads	Open space	Special Purposes	Total
			High density (2c)	Low & medium density (2a, 2b)				
Area (ha)	15	7	1	57	31	6	13	131
Flow (ML/ha/yr)	8.7	8.6	8.2	7.5	8.4	3.2	5.1	50
Total Suspended Solids (kg/yr)	24,300	10,300	2,060	78,400	124,000	1,710	8,020	248,790
Total Phosphorus (kg/yr)	39	17	3	127	151	5	19	361
Total Nitrogen (kg/yr)	289	122	25	929	618	38	144	2,165
Gross Pollutants (kg/yr)	3,570	1,510	315	12,200	7,040	339	1,930	26,904
Total Suspended Solids (kg/ha/yr)	1,600	1,583	1,477	1,364	4,039	274	594	1,899
Total Phosphorus (kg/ha/yr)	2.6	2.6	2.4	2.2	4.9	0.8	1.4	2.8
Total Nitrogen (kg/ha/yr)	19.0	18.7	17.8	16.2	20.1	6.1	10.7	17
Gross Pollutants (kg/ha/yr)	235	232	226	212	229	54	143	205

The results above assume there are no major sewer overflows and it does not take into account catchment peculiarities such as widespread use of street gutters rather than pipework to convey stormflows. The impact of older dwelling with lead based paint and zinc coated roofs are also not taken into account. However they are discussed when site specific conditions warrant their investigation.

The yield per ha from EC East Subcatchment land uses vary greatly. For example, 'open space' land use yields an estimated 274 kg/ha/y of TSS. TSS yield from industrial areas is estimated at 1600 kg/ha/y, while roads yield an estimated 4039 kg/ha/y. The contaminant export rates are close to those predicted by Fletcher et al (2004) for sites with similar rainfall and % imperviousness.

The results emphasise the critical importance of perviousness in determining the contaminant export from the catchment.

The results also show that the main contaminant sources in the catchment are residential areas and roads. This reflects the relatively high proportion of the catchment covered with these land uses and the substantial contaminant yield per ha of these land uses.

1.2 Potential for reducing contaminant exports from the catchment

The Botany Bay Coastal Council Initiative (BBCCI) sets water quality objects for infill development within the upper Cooks River. Whilst these targets are not being applied to the Cooks River Estuary, all Councils in the catchment agreed to use 45% total N load reduction as a target. This figure is incorporated into Table 2 below.

Since 1995 the CRC for Catchment Hydrology has developed a series of best practice management targets for contaminant removal from stormwater. These targets have been incorporated in the various Stormwater Management Plans (e.g. Woodlots and Wetlands, 1999). Table 2 shows the estimated current contaminant export rate. It also shows the potential reduction due to best practice management throughout the catchment.

Table 2: Current contaminant export rate, proposed targets and potential export rates.

Contaminant	Estimated annual contaminant load (kg/y)	BBCCI* Targets for new redevelopments (% reduction)	Target contaminant load (kg/y)
Total Phosphorus (kg/yr)	361	50	182
Total Nitrogen (kg/yr)	2,165	35	1,407
Total Suspended Solids (kg/yr)	249,000	75	62,250
Gross Pollutants (kg/yr)	269,000	90	26,900

* Botany Bay Coastal Council Initiative

It is noted that many of the best practice management activities and devices are expensive to install and operate, especially in a highly urbanised catchment. Nevertheless there are numerous opportunities to improve stormwater quality in this catchment.

1.3 Pollutants and impervious surfaces

Many of the industrial and commercial areas in the catchment have almost 100% impervious surface (see portions of Figure 4). Figure 1 shows the area of impervious surfaces in each of the seven land use categories. Residential zones 2a and 2b contain almost half the 106 ha of impervious surface in the catchment. Roads contribute a further 28 ha or 26% of the impervious surface in the catchment.

These results indicate that residential areas and roads are the most important sources of stormwater and therefore of contaminants (Fletcher, et al, 2004). It is important that both these landuses be targeted in any effort to reduce total contaminant export from the catchment.

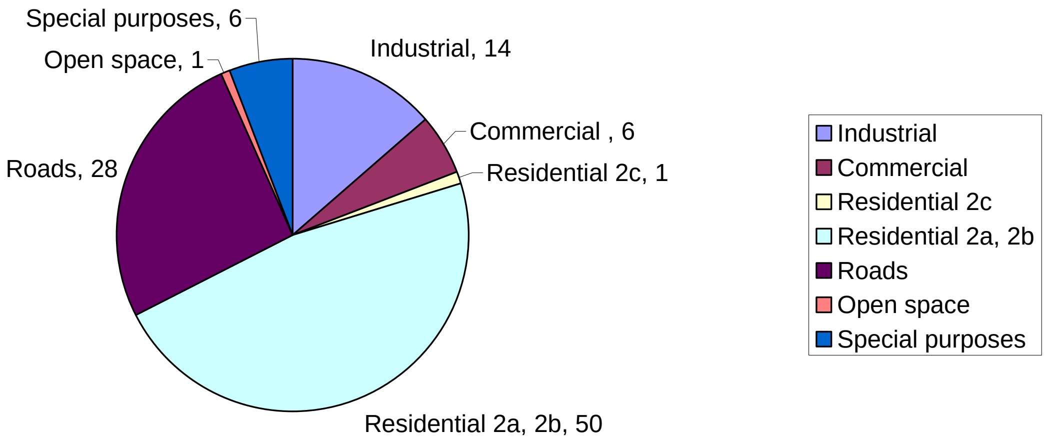

Figure 1: Area (ha) of imperviousness within each land use category

2.0 WATER QUALITY MANAGEMENT AND WATER REUSE OPTIONS

The section above quantified the catchment water balance and the likely contaminant yields.

A number of stormwater management options were developed to identify the feasibility of managing stormwater within in the catchment in order to reduce stormwater volumes and contaminant loads in addition to identifying opportunities for re-use. These options were:

(WR stands for 'Water Reuse' and SWQ stands for 'Stormwater Quality' in the following text)

1. SWQ1 + WR: Rainwater tanks to allow substitution of stormwater for non potable water needs within individual and multi unit dwellings.
2. SWQ2: A bioretention basin in Simpson Park to improve the quality of stormwater exiting the surrounding 10.3 ha catchment
3. SWQ3: 1A bioretention basin in TAFE Park to improve the quality of stormwater exiting the surrounding 3.8 ha catchment
4. SWQ4: A bioretention swale along the southern side of Pemell St, Newtown to improve the quality of stormwater exiting the surrounding 1.18 ha catchment
5. SWQ5: A bioretention swale along the northern side of Goodsell St, St Peters to improve the quality of stormwater exiting the surrounding 1.23 ha catchment
6. SWQ6: Rain gardens on redeveloping sites in the St Peters triangle area as part of the DCP for the locality
7. SWQ7 + WR: Stormwater collection tanks in Camdenville Park to collect catchment runoff and supply it as irrigation water to Camdenville Park
8. SWQ8 + WR: Stormwater collection tanks in Camdenville Park to collect runoff from nearby factory roofs to supply irrigation water for Camdenville Park
9. SWQ9 + WR: Adaptation of the existing Camdenville stormwater detention basin to collect and supply irrigation water to Camdenville Park

2.1 MUSIC modelling of stormwater

A stormwater modelling package, MUSIC Version 4, was used to estimate runoff volumes and contaminant loads in each investigation. The effectiveness of the various options can be assessed using this program. The model also enabled estimation of the costs for the proposed water quality improvement system costs.

The model utilises 6 minute pluviograph information from Sydney Airport for the period 1986 to 2006. It also uses long term average evapotranspiration for the site. Default contaminant concentrations, as provided in the MUSIC package, were used in the modelling of various options. The MUSIC package allows calculation of cost per unit of stormwater treated and contaminant removal. Installation and operation costs of various options were based on estimates from Rawlinsons (2010) and on information provided by Council. Detailed cost estimates for each option are presented in Section 4.0

In some instances there was a need for information such as water depth in ponds, available soil water content and the removal rate of trace metals, which is not retrievable from MUSIC. In these cases a daily time step program developed by Woodlots and Wetlands Pty Ltd was used.

The section below summarises the key features of each of the options.

2.2 SWQ1 + WR - Rainwater Tanks

The aim of investigating this option is to assess the feasibility and impact on the catchment water cycle of installing rainwater tanks for different proportions of dwellings in the catchment.

The EC East Subcatchment receives an estimated 612,000 kL (612 ML) of potable water from SWC per year. Average annual rainfall onto the catchment is some 1,460,000 kL/y, which is more than twice the potable demand.

Residents consume approximately 1% of the supplied potable water. Another 13% is used for cooking and other kitchen activities. In theory, it should be possible to supply the remaining 86% as non potable water provided it is fit for a variety of non drinking purposes such as toilet flushing, irrigation and laundry. There may also be opportunities for individual industrial enterprises to substitute rainwater for water supplied by Sydney Water Corporation (SWC). Current Health Department recommendations list the acceptable uses of tank-water in urban areas (NSW Health website).

The approach taken below considers concerns with public safety with respect to water quality in an urban environment. It also examines issues such as limited roof catchment area and limited space for any water storage system.

2.2.1 Current NSW Health Recommendations

NSW Health supports the use of rainwater tanks in urban areas for non-drinking uses. These uses include toilet flushing, washing clothes or in water heating systems. It also supports tank water use in activities such as garden watering, car washing, filling swimming pools, spas and ornamental ponds, and fire fighting (NSW Health, 2007).

NSW Health recommends that people use the mains water supply for drinking and cooking.

2.2.2 Reasons for Using Rainwater

Substitution of mains water with the tank water reduces the demand for mains water. It also reduces the runoff rate from urban areas. Reduction in runoff can reduce the extent of downstream erosion during storms. It also reduces the contaminant load being delivered to receiving water by the stormwater.

An additional major benefit of having a rainwater tank is that the tank owners develop an understanding of water usage. This can result in residents becoming more efficient water users.

2.2.3 Water quality

Tank rainwater can contain organisms referred to as opportunistic pathogens such as *Aeromonas spp*. and *Pseudomonas aeruginosa*. However, except for severely immuno-compromised persons, these organisms are not considered to represent a significant risk through normal uses of drinking water supplies (WHO 2002). In the current catchment it is proposed to only use the water for non potable uses. This leaves rainwater usage for purposes such as irrigation, toilets and hot water needs in the home.

Microbial contamination is normally measured by testing for *Escherichia coli (E. coli*), or alternatively thermotolerant coliforms. Thermotolerant coliforms or *E. coli* have been commonly identified in domestic tanks. This implies that enteric pathogens could often be present in rainwater tanks. However, when specific pathogens do occur, the number is usually extremely low and insufficient to cause infection (Australian Government, 2004).

There is no evidence in Australia to show that use of rainwater increases disease (Heyworth et al. 1999). In fact Hayworth at al, (2001), found evidence that the health of children in homes using rainwater tanks was better than those in homes reliant on town water supplies. This occurred even when the tank maintenance level were poor. The likely reason why there is little evidence of health impacts from drinking rainwater captured off roofs with contamination such as bird faeces present is that the microflora in bird faeces are non infective to humans (Australian Government, 2004). This suggests that rainwater is generally safe for non consumptive usage.

Dead animals, especially large ones such as possums and cats, will definitely impact on tank water quality. It is essential that tanks be screened to prevent animal entry to the tank. Similarly, mosquitoes can be adequately addressed by suitable screening of the tank.

Chemical contamination of roofs and rainwater has been examined in several highly urbanised areas (Australian Government, 2004). Testing of rainwater from household tanks near industrial precincts was undertaken as part of investigations into impacts of lead, manganese, nickel, zinc and hydrocarbon concentrations in rainwater samples. The concentrations were consistently less than the guideline values cited in the Australian drinking water guidelines (South Australian Department of Human Services, unpublished results 1999–2002).

In Marrickville, some roofs could still have lead flushing as part of their roof plumbing system. Dissolution of this lead may increase lead concentration in the tank water and water from such tanks should certainly not be used for drinking (Kus, et al, 2010).

2.2.4 Assumptions and modelling methodology to determine potential usage of rainwater

The initial inputs and assumptions to determine the likely volumes of water used for various purposes are shown below. Figure 2, from unpublished Marrickville Council data, shows the estimated water use distribution within the typical single dwelling.

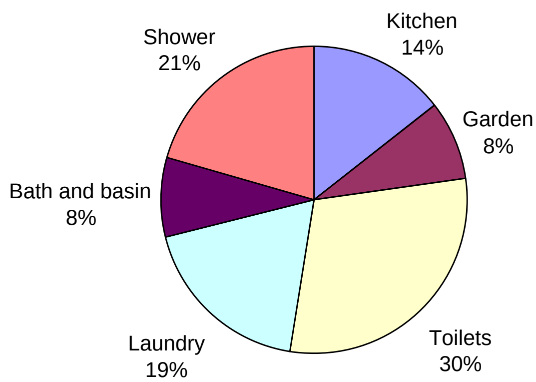

Figure 2: Percent distribution of potable water use in the typical single dwelling within the catchment (Source: Marrickville Council, 2008)

Total water use/day in the typical single dwelling was assumed to be 394 L. This volume was determined from data supplied for single dwellings by SWC (pers. comm.). It is less than the 558 L/day estimated for the Tennyson St Catchment (Marrickville Council, pers. comm.). The 2006 census data suggest that the EC East Subcatchment has more dwellings with 1 or 2 people in them. This would reduce water use per dwelling.

The volumes of water utilised in various parts of the average home are shown in Table 3.

Table 3: Estimated water usage/day in various parts of the average home (Source: derived from SWC (pers comm) and Australian Census (2006) data).

Water use area	Volume/day (L)
Kitchen	57
Shower	81
Bath and basins	32
Laundry	73
Toilets	118
Garden	32

The actual water use figures for individual homes will vary considerably with the number and type of residents. For example a home with several small children and a full time carer would use considerably more water than a home where the two occupants work away from home 5 days a week. Water use will therefore vary between individual dwellings, dwelling types and even catchments within the LGA depending on lifestyles, number of inhabitants, proportion of rental properties, age and conditions of dwellings and space available for outdoor activities such as gardening.

Additionally, the volumes are based on moderate water conservation appliances and practices. Increased water conservation is likely to significantly reduce water demand in laundries, showers and toilets.

In the analyses below, the demand that could be supplied via a rain water tank was assumed to be for irrigation, the toilet and the hot water system. Hot water was considered to supply 50% of the water to the kitchen, bathroom and laundry, so the non potable demand is calculated as (57+32+81+73)*50%=122L/day.

The total rain water demand for internal use would be 122+118 (toilets) = 240L/day.

This rainwater demand likely to be the maximum as it assumes the rainwater line could be readily plumbed into the inflow point of the hot water system. This may not be feasible in all dwellings.

The anticipated irrigation demand is shown in Table 4. It is based on a 27 year daily time-step simulation. The assumed irrigation figure of 870 mm is higher than Marrickville Council figure of 600 mm/year for irrigation of typical ovals. (The figure of 870 mm is based on the likely demand for a well watered lawn in highly urbanised areas of Sydney). The actual volume of water used for irrigation will vary significantly among individual dwelling depending on the residents' interests. People interested in their garden tend to over water, especially if they are using 'free' water.

Table 4: Anticipated maximum likely irrigation demand in mm each month in the average year for 'sunny' locations in Marrickville.

Month	J	F	M	A	M	J	J	A	S	O	N	D	Year
Irrig (mm)	148	119	109	0	0	0	0	0	95	119	129	152	871

The demand for irrigation will depend on weather conditions, the availability of suitable space, the exposure and extent of shading and the interest of the residents. Assuming that 6% of the rainwater is used for irrigation, this would be sufficient to meet the irrigation demand for approximately 14 m^2 of land. This figure is consistent with observations made on garden areas of various properties during catchment inspection.

An examination of individual home sites using Google Maps® showed that roof area in the catchment varies markedly. Many of the terrace homes have relatively small roof areas of around 50 m^2. Additionally there is almost no room at the front of the home to install a tank. Therefore rainwater draining off the front gutter is lost to the street drainage system. The semi detached homes generally have larger roof areas, typically between 80 and 115 m^2.

Most homes have considerable areas of their back yard under a combination of translucent roof material and hard surface such as concrete. This means that a very high proportion of rainfall will runoff the site.

2.2.5 Water capture and usage modelling

The volume of water captured and used was modelled using 27 years of daily rainfall for Sydney. Potential demand for rainwater was set at 240L/day. Additionally some 14 m^2 of garden was assumed to be irrigated.

The roof areas were assumed to be 25, 50, 75, 100, 150 and 150 m^2. Tank sizes examined were 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500 and 5000 L.

Results

In the average year some 7 kL was used to water the gardens. This is equivalent to 500 mm/y on 14 m^2. This is less than the maximum of 871 mm indicated in table 4, but is realistic considering the range of light conditions and residents' interest in gardening. Indoor non-potable demand was 87.6 kL/year. Table 5 shows the percentage of demand of 394 L/day that is met for a range of tank sizes and roof catchment areas.

Table 5: The percentage of total water supply based on 394 L/day demand which can be met via rainwater.

Tank volume m^3	25 m^2	50 m^2	75 m^2	100 m^2	125 m^2	150 m^2
0.5	10	15	17	18	19	20
1	12	18	22	24	26	27
1.5	13	21	25	28	30	31
2	14	22	27	30	33	35
2.5	15	24	29	33	35	37
3	15	25	31	34	37	39
2.5	15	26	32	36	39	41
4	15	26	33	37	40	42
4.5	16	27	34	39	42	44
5	16	28	35	40	43	45

It is obvious that both tank volume and roof catchment size impact on the percent of water supplied. There is little value in having a large tank if the catchment is small. Conversely a small tank attached to a large catchment is of limited value because it cannot contain the runoff volumes generated.

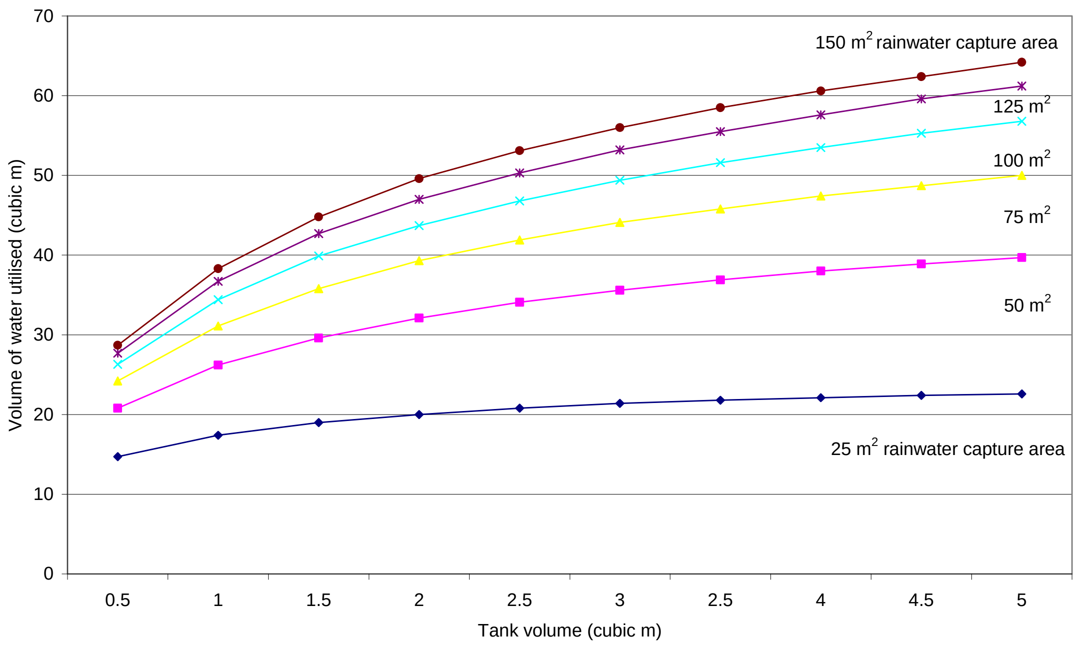

Figure 3: Relationships among combinations of rainwater tank volume (m^3), roof area (m^2) and volume of water utilised (m^3) in the average year based on a 27 year daily time step simulation.

Figure 3 shows similar trends to those in Table 5. Firstly if the roof area is relatively small, there is little benefit in increasing the tank size. However the rate of increase in water available for use/year in the home also decreases as the roof area increases. The reason for this is that the larger roof catchment increases flow to the tank, but the volume stored is limited by tank size.

Tank suppliers typically suggest a yield to storage ratio of 2 to 3. That is, the increase in volume delivered per year should be at least 2 to 3 times the increase in storage capacity. For example there should be an additional supply of at least 2 to 3 m^3/year for every additional m^3 of storage.

Table 6: Increment of water yield, expressed as the m^3 of rainwater stored/ m^3 of tank volume/year for a range of roof areas and tank sizes. Assumed non potable water use is 240 L/day. The shaded yield increments are at least 2 to 3 times the tank volume increment.

Tank volume m^3	25 m^2	50 m^2	75 m^2	100 m^2	125 m^2	150 m^2
1	2.7	5.4	6.9	8.1	9	9.6
1.5	1.6	3.4	4.7	5.5	6	6.5
2	1	2.5	3.5	3.8	4.3	4.8
2.5	0.8	2	2.6	3.1	3.3	3.5
3	0.6	1.5	2.2	2.6	2.9	2.9
3.5	0.4	1.3	1.7	2.2	2.3	2.5
4	0.3	1.1	1.6	1.9	2.1	2.1
4.5	0.3	0.9	1.3	1.8	2	2.1
5	0.2	0.8	1.3	1.5	1.6	1.8

Table 6 shows that by this criterion, a 1 to 1.5 m^3 tank would be sufficient for a home with a 25 m^2 catchment, up to 3 m^3 would be useful for a home with a 75 m^2 roof catchment. A 3 m^3 tank would be useful for a home with a 75 m^2 roof catchment.

2.2.6 Conditions for the 'average' home

Google Earth ® was used to identify typical roof areas and yard dimensions. The results were used to establish typical sizes. The areas of roof and yards in individual sites was used to extend the results from an individual home to a catchment wide impact

The 'average' home was assumed to require 240L/day of non potable water. The effective roof catchment for rainfall runoff is estimated to be between 25 and 50 m^2, which is 1/3 to 2/3 of the typical allotment area. In many cases portion of the rear of the allotment was covered with translucent roofing, so that the total impervious surface would be around 80%. It was not possible to determine the potential for connecting the informal roofing to tanks, so it was assumed that only the home roof could be considered as 'catchment' for the tanks.

Allowing for inefficiencies in drainage it was assumed that the 'average' home has 37.5 m^2 of roof catchment. The 'average' allotment was 75 m^2 and 15 m^2 of this area was pervious with an average of 14 m^2 being irrigated.

2.2.7 Methodology for establishing catchment based impacts of rainwater tanks.

MUSIC version 4 was used to establish the catchment based impacts of changing the number of rainwater tanks in the catchment. Modelling was based on 6 minute rainfall data for the period 1986 to 2006.

The inputs assumed:

- 2292 single dwellings
- Average area 75 m^2/ allotment
- The total area 17.2 ha
- 37.5 m^2 of the average roof could drain to a rainwater tank

- 60% of the remaining 37.5 m^2 consisted of impervious surfaces (22.5m^2)
- The tank was 2.75 m^3 in volume. This is higher than the volume suggested for the 37.5 m^2 catchment in table 6, but it allows for variation in resident numbers. It is typical of many tanks supplied to Sydney homes (pers comm).
- Internal non-potable demand was 240L/day
- Demand for garden watering averaged 32 L/day. This was weighted depending on maximum potential evapotranspiration minus rainfall.
- The total roof catchment area draining to tanks = the assumed average area (37.5 m2)*number of dwellings or 2292*37.5 = 8.595 ha.
- A 6 minute time step was used over the period 6.7.86 to 2.3.2006
- The default values for MUSIC Urban areas were used to estimate contaminant yield.
- Rainfall for the simulation period was 1061 mm/year while the evaporation was 1772 mm/year. (Note this is based on evaporation at Sydney Airport, which is in a high density urban area similar to Marrickville)
- Assuming an average tank volume of 2.75 m^3, the total tank volume =number of dwellings (2292)* proportion of dwellings with tanks*2.75.

Results

Annual runoff from the 17.2 ha of individual dwellings was 773 mm or some 73% of rainfall. This is a very high percentage, and reflects the fact that on average 80% of the allotments surfaces were impervious.

Table 7 shows that 100% introduction of rainwater tanks halved the runoff volume from individual dwellings. A 100% uptake of rainwater tanks would reduce runoff volume to some 37% of rainfall. However, this is still higher than the 25% or 2.6 ML/ha/year anticipated under natural conditions (Fletcher, et al, 2004). The reason for this is that not all the impervious surfaces can be connected to rainwater tanks.

Table 7: Effect on outflow and contaminant load of varying the percentage of individual dwellings having 2.75 m^3 rainwater tanks. Total area was 17.2 ha

Attribute	Units	% of homes with tanks						
		zero	10	20	40	60	80	All
Volume of runoff	ML/y	133	126	120	106	93	80	67
Reduction in outflow/ha of single dwellings	ML/y	0	7	13	27	33	53	66
Mass of total suspended solids (TSS)	kg/y	27300	26000	24600	20900	19400	15400	13700
Mass of Phosphorus	kg/y	55	52	49	43	38	32	27
Mass of Nitrogen	kg/y	377	358	339	308	268	228	191
Mass of gross pollutants	kg/y	3670	3460	3250	2840	2430	2010	1600

As expected, the reduction in runoff was proportional to the percentage of homes with tanks. Note that this comment refers to individual dwellings. Up to 30% of the catchment is covered with roads and other impervious surfaces.

The results can readily be adjusted to examine changes in the ground area covered by individual dwellings. For example, Table 8 shows the effect on runoff and contaminant load/ha of this type of dwelling.

Table 8: Effect of varying the percentage of individual dwellings having 2.75 m^3 rainwater tanks on yield of water and contaminant load/ha of individual dwellings.

Attribute	Units	% of homes with tanks						
		Zero	10	20	40	60	80	All
Volume of tanks/ha of housing	kL/ha	0	37	73	147	220	293	367
Volume of flow	ML/ha/y	7.7	7.3	7.0	6.2	5.4	4.7	3.9
Mass of total suspended solids (TSS)	kg/ha/y	1506	1512	1430	1215	1128	895	797
Mass of Phosphorus	kg/ha/y	3.2	3.0	2.8	2.5	2.2	1.8	1.6
Mass of Nitrogen	kg/ha/y	22.7	20.8	19.7	17.9	15.6	13.3	11.1
Mass of gross pollutants	kg/ha/y	213	201	189	165	141	117	93

This information can be applied to predicting responses from precinct levels down to individual home sites.

The impact of the tanks can also be assessed via expression such as m^3 of storage/ha. Assuming an average area of 75 m^2/allotment and an average of 2.75 m^3/tank for each dwelling, there would be 367 m^3/ha of rainwater storage capacity. Note that this only concerns single dwellings, not the surrounding roads, etc.

The results above show there is potential for significant reduction in stormwater volumes and contaminant loads through the introduction of rainwater tanks.

Additionally, the use of rainwater has the potential to reduce the current inflow from Sydney Water of 612 ML/year by approximately 66 ML/year if all dwellings had rainwater tanks. This is equivalent to a 10% reduction in potable water demand in the catchment.

According to Council records 37 rebates have been paid in the period Sept 2008 to Sept 2009. This is equivalent to 0.13% of residences in the LGA. This slow rate of uptake suggests that it is reasonable to expect a maximum of 10 to 20% of homes would have tanks in the foreseeable future. Each 10% rise in the percentage of single dwellings with rainwater tanks reduced runoff from the 17.2 ha catchment by 6 to 7 ML/year (see Table 7).

2.2.8 Application to multi apartment dwellings

The 17.2 ha of single dwelling represents some 7.6% of the catchment area, and while a 66 ML/y reduction in runoff rate from the 17.2 ha is a substantial volume of water, it is only 11% of the total supplied by SWC.

According to council data there is some 40.2 ha of residential 2b zoning in the catchment. Connection of a second supply system would be expensive in established multistorey dwellings. Consequently the analyses below concentrated on external uses of the rainwater.

An examination of satellite images suggests that some 9 to 12% land area associated with units is covered with gardens of various types. This area could be watered with captured runoff.

The assumptions used in the analysis are shown below:

- There are 40.2 ha of land dedicated to units, apartments and flats.
- The median site area of multi story unit allotment is 981 m^2
- The 981 m^2 includes a median of 91 m^2 of ‘green’ area (7% pervious)
- There are an estimated 410 units, apartments and flats in the catchment.
- Irrigation demand was set at 50% of potential because of the extensive shading around each building.

- The 50% of demand was 436 mm/year
- The maximum water required was 16.3 ML/year.

Table 9 shows the effect of changing the tank volume on the quantity of water use for irrigation. The rainwater storage capacity was initially set at 367 kL/ha. This is the rainwater storage volume/ha for 100% of individual home sites having rainwater tanks (Table 8).

Table 9: Effect of changing storage volume per ha on the volume of water utilised for irrigation among flats, units and apartments. Assumes 7% perviousness and irrigation demand of 436 mm/year.

Attributes	units	Inflow	Outflow with 367 kL/ha rainwater storage	184 kL/ha storage	36.7 kL/ha storage	18.3 kL/ha storage
Flow	ML/y	516	500	500	501	502
TSS	kg/y	92500	86,500	87,900	89,400	89,800
Phosphorus	kg/y	209	198	201	202	203
Nitrogen	kg/y	1550	1480	1490	1500	1510
Gross pollutants	kg/y	1273	0	0	0	

The different storage capacities have little impact, so even 18.3 kL/ha is sufficient.

The 18.3 kL/ha of rainwater storage would mean there would be approximately 1.8 m^3 of rainwater storage/ building allotment. The data in table 9 suggests this is all that is required if the water is only used for irrigation.

2.2.9 Summary

The simulations examined substitution of rainwater for non potable uses in the home and in the garden. The typical individual dwelling was estimated to require 240 L of non potable water/day. A 37.5 m^2 roof catchment area would supply approximately 1/3 of the annual demand. There would be some 200 days in the average year when there was no water in the tank.

There were 2292 individual homes sites in the catchment. Installation of rainwater tanks of at least 2.75 m^3 capacity on individual home allotments reduced stormwater runoff rate by 0.65 ML/year for every 1% of homes having the tanks. Therefore a 10% installation and usage rate would reduce runoff by 6 to 7 ML/y. This is equivalent to some 0.6% of the catchment requirement for potable water.

A similar approach was undertaken for medium and high density housing. However water demand was based on only supplying irrigation water to the typical 7% of the property covered in gardens. The shaded conditions created by the close building were estimated to reduce evapotranspiration by 50% to 436 mm/year. Around 1.8 to 2 m^3 of storage is sufficient for the average medium density building. Approximately 14 ML of potable water could be substituted under these conditions if tanks were installed on all properties.

Total water savings of 70 ML or 12% of the estimated current potable supply to the catchment could be achieved by installation of at least 2.5 m^3 of rainwater tank capacity at every home and a tank of at least 1.8 m^3 capacity for every multi-story dwelling.

The widespread installation of rainwater tanks would also reduce the mass of contaminants exiting the catchment. For example a 20% adoption of tanks in single dwellings would reduce runoff volume by 13ML/year, with a 2.7 t/year reduction in TSS, a 6 kg/year reduction in phosphorus and a 38 kg/year reduction in nitrogen.

Finally there may be opportunities for factories to utilise stormwater runoff. This opportunity needs to be investigated on an individual site basis.

2.2.10 Issues

The key issue is convincing a high a proportion of individual home owners to install adequate rainwater capture and reuse systems. Many of the dwellings are rented and both the site owners and the tenants need to agree on cost sharing.

2.3 SWQ2 - Bioretention Basin at Simpson Park

Simpson Park is a significant community recreation resource within the suburb of St Peters. It is well vegetated and contains facilities for a range of activities. It is also in a lower part of a local catchment, with the gutters along its NE and SW boundaries (Lackey St and Campbell St respectively) conveying stormwater runoff from the western side of the Princes Hwy as well as Applebee St , St Peters St and portions of Florence St, Hutchinson St and Brown St.

The aim of this investigation is to examine the potential for use of a bioretention basin to treat local runoff to reduce contamination load as well as reducing peak runoff rates. A bioretention basin is a stormwater collection and filtration system which is normally installed in a lower part of the landscape. Water entering the system is allowed to percolate through a subsurface filtration media, eventually reaching subsurface drains. These drains convey the treated water to the regional stormwater system. During intense rain events, the basin will fill up and overtop. The excess water may be detained by a local detention basin.

Figure 6 presents an idealised design for bioretention basin and Figure 7 presents a typical cross-section.

Simpson Park has been identified as a potential site for a stormwater detention basin (flood management option R3-Simpsons Park) and as such overflow from the bioretention basin would be accommodated in the detention basin storage.

2.3.1 Local conditions

Simpson Park and the adjacent footpaths have 1 ha of grassed area. A number of subcatchments drain towards the park. The water is then conveyed via gutters towards Camdenville Detention basin. The catchment is 10.33 ha and has 63% of its surface impervious.

Figure 4 shows the catchment. This catchment has industrial lands in the eastern portion and a mix of residential areas in the west. Figure 5 shows the drainage system details and the site of the proposed bioretention basin. The bund along the lower portions of the park is also shown. This bund creates a detention basin and is proposed as part of the flood management options.

Figure 8 to Figure 14 present the local conditions and the environs of Simpson Park.

Figure 4: Simpson Park and its catchments.

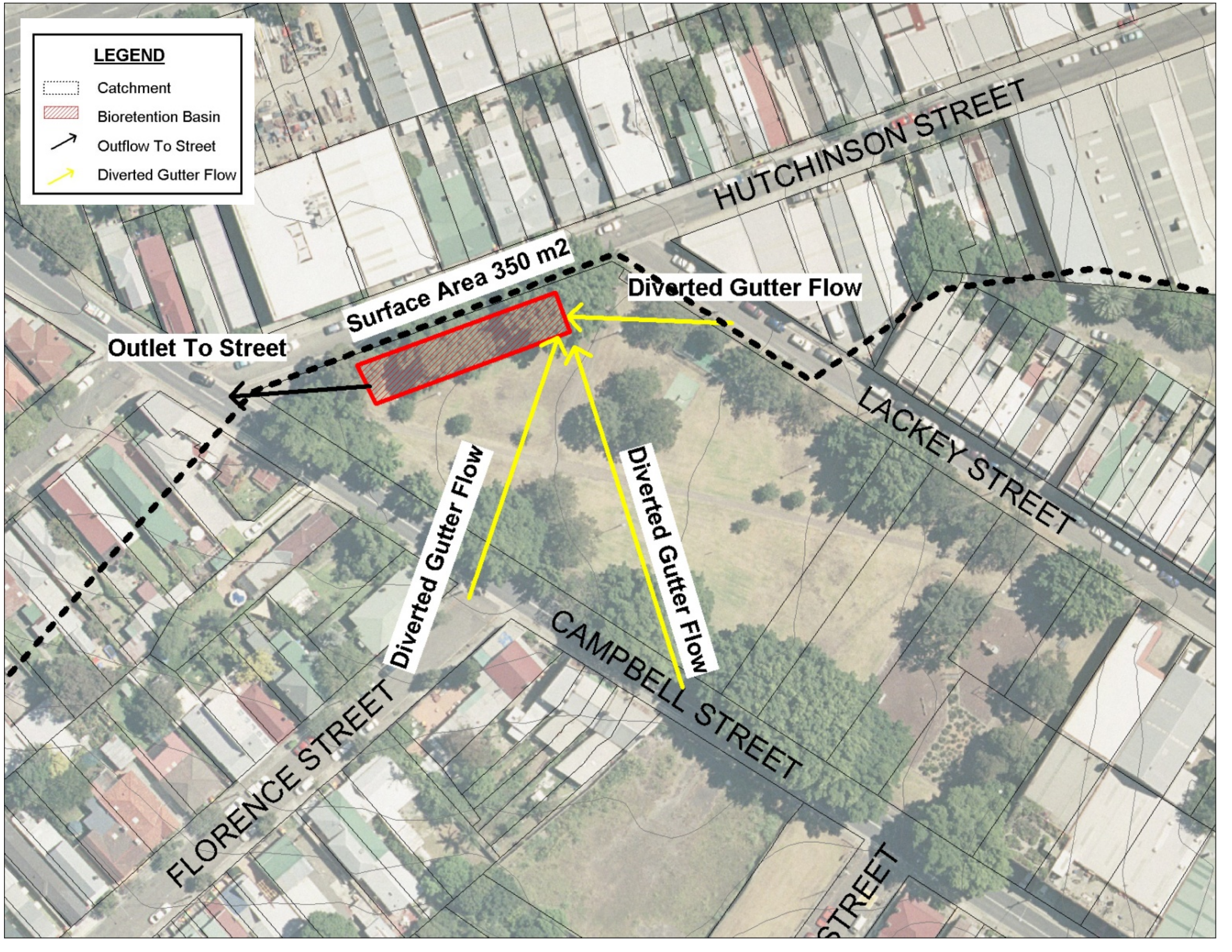

Figure 5: Simpson Park and site of proposed bioretention basin.

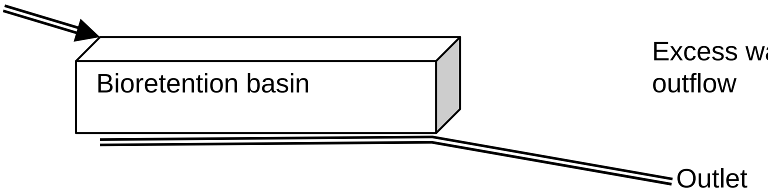

Figure 6: Idealised design for the bioretention basin.

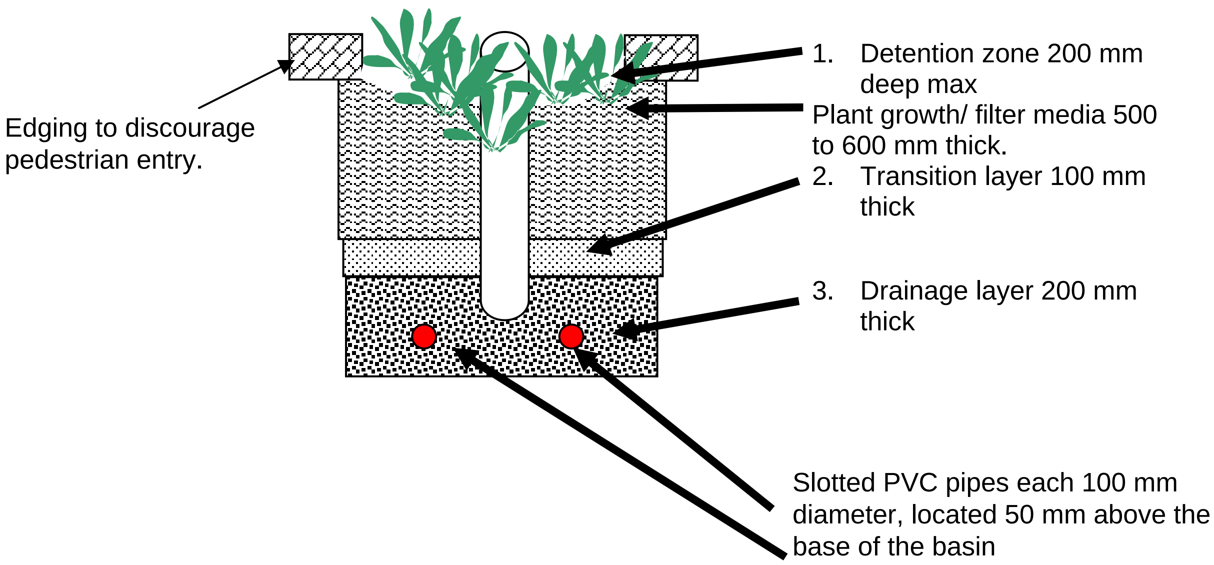

Figure 7: Cross section of typical bioretention basin. Indicative depth is 1.05 m.

Figure 8: The park is well vegetated with a combination of mature trees and grass.

Figure 9: The gutters on the north and south sides of the park convey local runoff.

Figure 10: The park is used for a wide variety of activities. However there is enough space to install a 350 m^2 bioretention basin. This basin would have a ponded depth of 0.2 m and have sloping sides.

Figure 11: Stormwater is currently conveyed in gutters parallel to the park boundaries. Ideally the gutter on the left hand side of the picture would also be connected to drain into Simpson Park.

Figure 12: This open space and the surrounding buildings drain to the park via a lane way off Lackey St.

Figure 13: Both Lackey Street and Applebee Street drain to the park

Figure 14: Portions of St Peters St, Florence St and Church St drain towards the park.

The area marked on Figure 4 and shown in Figure 12 is an open space, enclosed by buildings and currently used for parking purposes. Establishing a stormwater detention system in this area was also examined. However the area is near the top of the catchment so any detention system would have minimal impact on runoff rates exiting the catchment.

2.3.2 Conceptual design

Runoff water from the surrounding catchment flows along gutters on either side of the roads adjacent to Simpson Park. Flow could be conveyed from one side of Lackey St and Campbell St and drained to the northern end of Simpson Park. There is sufficient grade to allow flow to the bioretention basin, provided the flow enters pipes installed towards the upper area of the park.

Water entering the park would be conveyed to the bioretention basin shown in Figure 5. The maximum ponded depth is 0.2 m. Some of the water would percolate through the basin floor and enter a slotted collection pipe which would connect to a drainage system sloping towards the Camdenville Oval detention basin.

2.3.3 Modelling of stormwater and contaminant loads

MUSIC version 4 was used for modelling the Simpson Park catchment. The urban default values were used for runoff percentages and event mean concentrations of contaminants.

The maximum depth of water that could be contained was set at 0.2 m. The filter area was set to 350 m^2. Figure 5 suggests that 350 m^2 is the largest area that can be contained in the park without removing trees.

The filter area was 0.5 m deep and had a saturated hydraulic conductivity of 36 mm/hr. It is a conservative rate to allow for some blockages in the longer term. The basin was not lined and had an exfiltration rate of 1 mm/hr.

2.3.4 Hydrological balance and contaminant removal

Table 10 summarises the basins' performance.

Table 10: Annual influx and exit of stormwater and contaminant loads from a 350 m^2 bioretention basin in Simpson Park.

Treatment train performance	Inflow	Outflow	% removal	BBWQI Targets for new redevelopments (% reduction)
Flow (ML/yr)	68	65	4	Not listed
Total Suspended Solids (kg/yr)	13,300	5,220	61	75
Total Phosphorus (kg/yr)	27	14	47	50
Total Nitrogen (kg/yr)	190	151	21	35
Gross Pollutants (kg/yr)	1,970	1	100	Not listed

It is obvious that there is minimal impact on total flow volume/year. An examination of the flow into and out of the bioretention basin indicated that 68 ML/year could enter the system. Some 0.9 ML would be lost via evapotranspiration and 2 ML by infiltration into the surrounding soil. Another 14 ML would be filtered/year, while 51 ML would simply overtop the basin and not be treated. Figure 15 shows the inflow and outflow rates for the highest 0.2%ile of time in a typical rainfall year. It is obvious that the bioretention basin reduces the peak outflow rate at least for flows in an average rainfall year. There were, however, major reductions in contaminant loads, with the proposed system approaching the BBCCI redevelopment objectives for TSS and phosphorus.

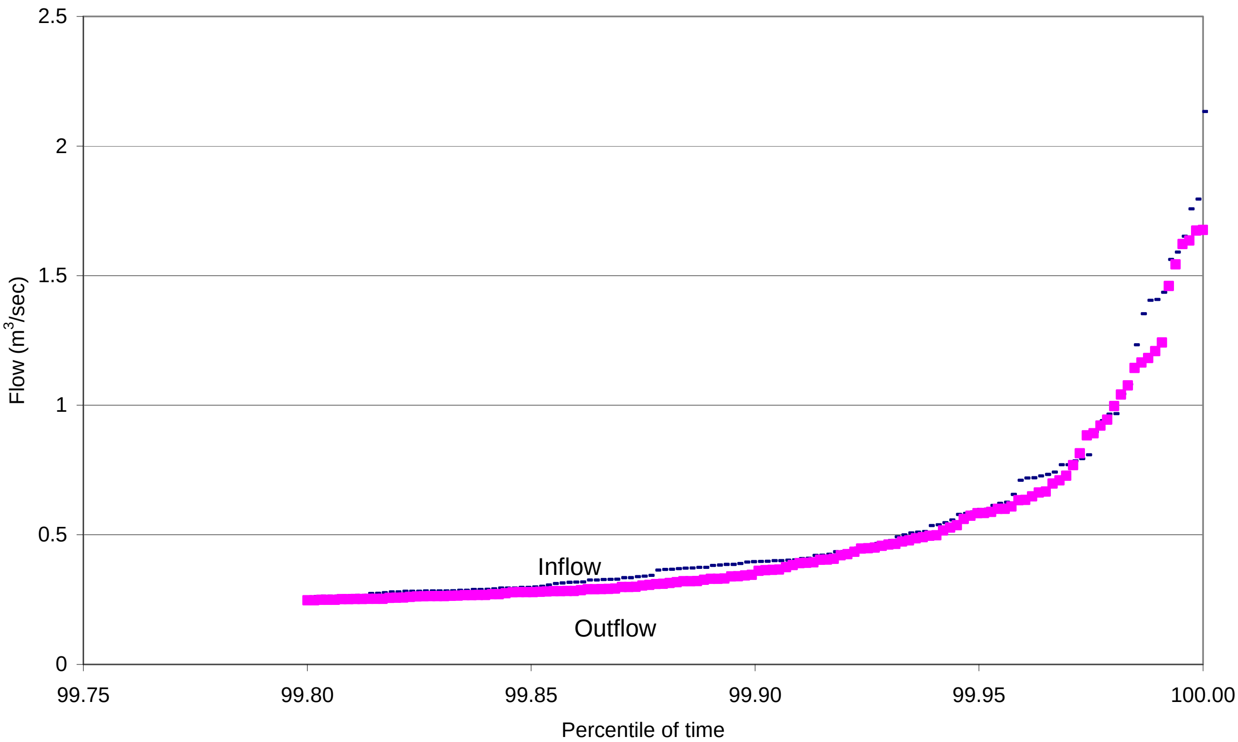

Figure 15: Inflow and outflow rates for the highest 0.2%ile of time in a typical year.

The greatest percentage reduction occurs above the 99.95%ile in an average rainfall year. The maximum 6 minute inflow over the typical year was 2.13m^3/sec, while the outflow was 1.68 m^3/sec. That is there was a 21% lower peak flow due to the bioretention basin.

Table 11 shows that over the 20 year simulation the proposed system reduces the maximum inflow by 16%. That is, the basin markedly reduces the peak flow at least for low to moderate rain events.

The flood retardation benefits of using Simpson Park are discussed in flood management option, R3-Simpsons Park.

Table 11: Statistical comparison of inflow and outflow rates in m^3 /sec.

Flow (m^3/sec)	mean	standard deviation	median	maximum	minimum	10 percentile	90 percentile
Inflow	0.0022	0.0235	0.00	2.8000	0.00	0.00	0.0007
Outflow	0.0021	0.0212	0.00	2.3600	0.00	0.00	0.0028

2.3.5 Estimated Costs

The costs for a 350 m^2 bioretention basin are shown below.

Table 12: Capital and operating costs for the 350 m^2 bioretention basin.

Life Cycle (yrs)	50
Acquisition Cost	$290,000
Annual Maintenance Cost	$19,000
Annual Establishment Cost	$0
Establishment Period (yrs)	0
Renewal/Adaptation Cost	$9,000
Renewal Period (yrs)	1
Decommissioning Cost	$94,000
Real Discount Rate (%)	5.5
Annual Inflation Rate (%)	2
Life Cycle Cost of Bioretention ($2010)	$800,000

The annualised cost per unit of water or contaminant removed provides a way of comparing the cost verses benefits of different stormwater management devices. Costs are highly dependant on local conditions, however they do provide an initial cost estimate. Costs can be expressed as per unit of water or contaminant removed. They can also be expressed as per unit of water treated. Table 13 shows the system performance components expressed as the cost per unit of water or contaminant removed.

Table 13: Cost per unit of stormwater treated/ irrigated or contaminant removed.

System Performance Component	Cost per unit of water or contaminant
Equivalent Annual Payment Cost of the Asset (2010	$15,208

System Performance Component	Cost per unit of water or contaminant
$/annum)	
Equivalent Annual Payment/ML of flow reduction /annum	$5,243
Equivalent Annual Payment/ML of flow treated or removed /annum	$911
Equivalent Annual Payment/kg Total Suspended Solids/annum	$2
Equivalent Annual Payment/kg Total Phosphorus/annum	$1,209
Equivalent Annual Payment/kg Total Nitrogen/annum	$391
Equivalent Annual Payment/kg Gross Pollutant/annum	$8

2.3.6 Conclusions

Simpson Park has space for a shallow bioretention basin covering approximately 350 m^2. The proposed basin would markedly reduce peak flows at least in average rainfall year but would not alleviate flood problems. It would treat approximately a third of the catchment outflow, reducing TSS and phosphorus loads by percentages similar to the BBCCI targets.

The flood study component of the report suggests that a bund could be placed around the lower portion of Simpson Park to create a detention basin. The bund would increase the water depth and detention time. Both these features would decrease the peak flows and increase contaminant mass removed from the stormwater.

2.3.7 Issues

- Any redevelopment of public open space must have local community input.
- The park is used by residents for a wide variety of recreational activities. The stormwater infrastructure should be designed to have minimal impact on the recreational value of the park.
- The public open space value of the park means that any pondage must be sufficient shallow as to not be a drowning risk to children. The indicative maximum depth is 200 to 300 mm.
- The proposed use as a detention basin will result in water deeper than 300 mm, at least during significant rain events. Areas where the depth exceeds 300 mm must be fenced.
- Dial Before You Dig information requests indicates that there are no Sydney Water or UECOMM services within the park itself. Confirmation of the location of local electrical services (Energy Australia) and local gas supply services (Jemena) will be required during detailed design.
- The western portion of the park is noted as being part of a future arterial road. This would cause major changes to the bioretention basin. However it also could be used to treat runoff during construction.

2.4 SWQ3 – Bioretention Basin at TAFE Park

The TAFE Park is a fenced dog exercise area to the immediate east of the TAFE campus on Edgeware Road. The park is leased to Council who is responsible for its maintainance. Figure 16 shows the park.

The aim of this investigation is to examine the potential for use of a bioretention basin to treat local runoff to reduce contamination load as well as reducing peak runoff rates.

TAFE Park has also been identified as a potential site for a stormwater detention basin. The effectiveness of this basin is discussed in section in water management option, R4.

2.4.1 Local conditions

TAFE Park has 0.8 ha of open space. A number of subcatchments drain towards the park. These include runoff from Marian and Simmons St as well as from the park itself. It is important to include as much park runoff as possible: The use of the park as a dog exercise area means that there would be a large contaminant load from dog excreta. The catchment is 3.81 ha and has 64% of its surface impervious.

Figure 16: The TAFE Park is a major social and recreation site for local residents and their dogs.

Figure 17: The park is so heavily used by dogs that and turns into a dust bowl in summer and a mud bath in winter.

Figure 18: Marian St drains directly towards the park.

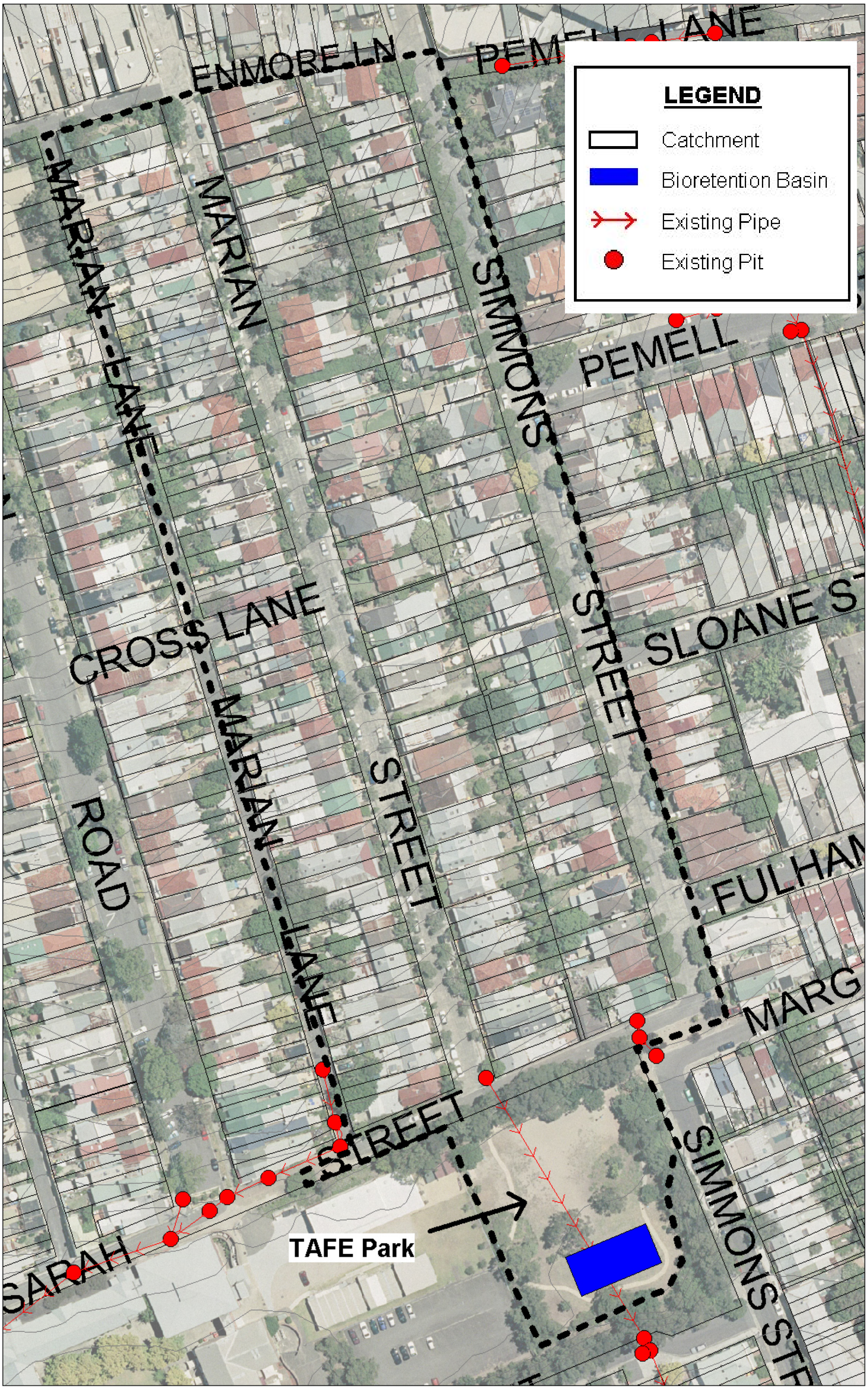

Figure 19: The TAFE Park and its catchment.

Runoff water from the catchment is conveyed via gutter flow towards to TAFE Park. Gully pits along the south side of Sarah St, will be used to collect runoff from Marian St and Simmons St catchments and convey a proportion of flows into the bioretention basin.

2.4.2 Modelling of stormwater and contaminant loads

MUSIC version 4 was used for modelling the TAFE Park catchment. A 300 m^2 basin was selected because this size could readily fit into the park with minimal impact on park use.

The maximum depth of water that could be contained was set at 0.2 m. The modelling assumed a 300 m^2 of filter area and a 300 m^2 of surface area.

The filter area was 0.5m deep and a saturated hydraulic conductivity of 36 mm/hr was assumed. This value is conservative to allow for some blockages in the longer term. The basin was not lined and had an exfiltration rate of 1 mm/hr. Default concentration for Total Suspended Solids (TSS), nitrogen (N), phosphorus (P) and gross pollutants were used in the modelling.

2.4.3 Hydrological balance and contaminant removal

Table 14 shows the water and contaminant balance resulting from the 300 m^2 bioretention basin.

Table 14: Performance of the bioretention basin at TAFE Park (based on MUSIC modelling)

Component	Inflow	Outflow	Reduction %	BBCCI* Targets (% reduction)
Flow (ML/yr)	25.4	22.4	12	Not listed
Total Suspended Solids (kg/yr)	4950	1190	76	75
Total Phosphorus (kg/yr)	10	4	60	50
Total Nitrogen (kg/yr)	72	48	33	35
Gross Pollutants (kg/yr)	734	4	100	Not listed

* Botany Bay Coastal Councils Initiative

The results show that the system reduces outflow volume by 12%. It also reduces TSS and nitrogen loads to the BBCCI targets.

Figure 20 shows that the inflow rates are consistently higher than the outflow rates. The differences are typically less than 10% for the same percentiles. However the results suggest that the bioretention basin does reduce the peak flow rates at least for small to medium flows. The system is designed to allow bypass of higher flows.

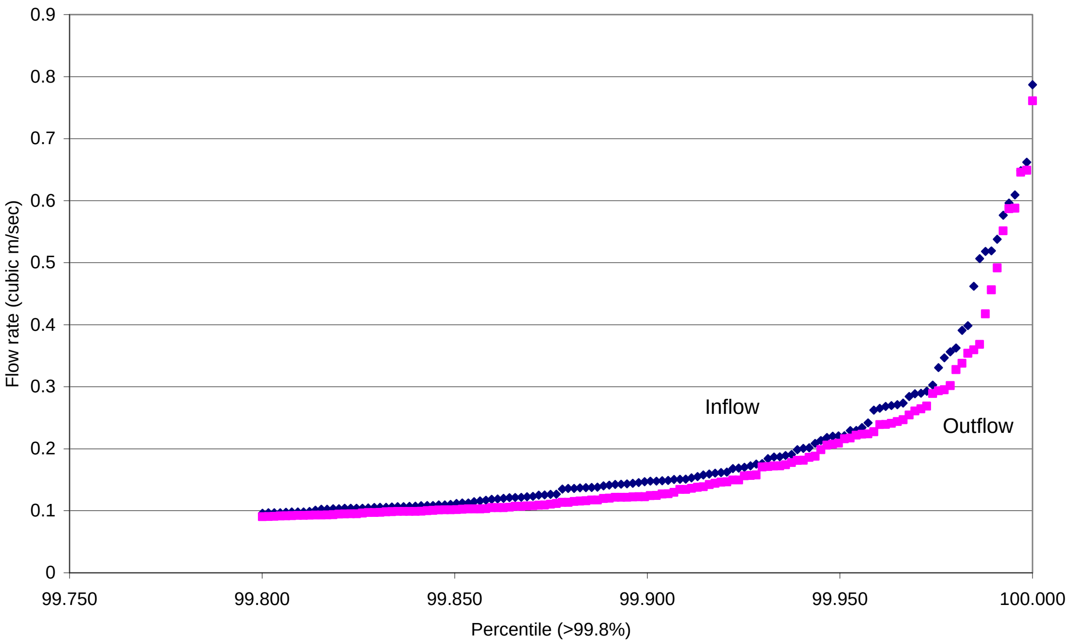

Figure 20: Inflow and outflow rates for the highest 0.2%ile of time in a typical year.

2.4.4 Estimated Costs

The estimated costs for a 300 m^2 bioretention area are presented below

Table 15: Capital and operating costs for the bioretention basin at TAFE park

Life Cycle (yrs)	50
Capital Cost	$180,000
Annual Maintenance Cost	$14,000
Annual Establishment Cost	$0
Establishment Period (yrs)	0
Renewal/Adaptation Cost	$5,000
Renewal Period (yrs)	1
Decommissioning Cost	$80,000
Real Discount Rate (%)	5.5
Annual Inflation Rate (%)	2
Life cycle cost ($ 2010)	$500,000

The cost per unit of water or contaminant removed provides a way of comparing the cost verses benefits of different stormwater management devices. Costs are highly dependent on local conditions. However Table 15 does provide a preliminary cost estimate.

Costs can be expressed as per unit of water or contaminant removed. They can also be expressed as per unit of water treated.

Table 16: Cost per unit of stormwater treated/ irrigated or contaminant removed

System Performance Component	Cost per unit of water or contaminant removed
Equivalent Annual Payment Cost of the Asset (2010$/annum)	$10,134
Equivalent Annual Payment/ML of flow treated or removed /annum	$3,400
Equivalent Annual Payment/ML of flow reduction /annum	$1,057
Equivalent Annual Payment/kg Total Suspended Solids/annum	$3
Equivalent Annual Payment/kg Total Phosphorus/annum	$1,648
Equivalent Annual Payment/kg Total Nitrogen/annum	$422
Equivalent Annual Payment/kg Gross Pollutant/annum	$14

2.4.5 Conclusions

The TAFE Park has extremely heavy use for exercising dogs and other passive recreational activities. It is not on Council lands, but is leased to Council. Any stormwater management system would need to be agreed upon by TAFE administration. Changes to the park should not reduce the current recreational values of the site.

The proposed system will markedly reduce contaminant loads, exceeding the percentage reduction criteria of the Botany Bay redevelopment objectives. It will also reduce peak loads.

2.4.6 Issues

- The park is owned by TAFE, but managed by Council. Any changes will need to be negotiated with TAFE administration.
- The park is used by residents for a wide variety of recreation. The stormwater infrastructure should be designed to have minimal impact on the recreational value of the park.
- The public open space value of the park means that any pondage must be shallow as to not be a drowning risk to people. The indicative maximum water depth is 200 to 300 mm.
- DBYD enquiry indicates that there is a major Sydney Water supply line at considerable depth under TAFE Park; therefore, should this option proceed then structural requirements will need be addressed, if any. Electrical transmission lines are also noted along Simmons St (adjacent the park).

2.5 SWQ4 – Bioretention Swale at Pemell Street, Newtown

2.5.1 Background and aim of investigation

Pemell St in Newtown is one of the few streets in the catchment with a road width sufficient to enable installation of some Water Sensitive Urban Design (WSUD) features such as bioretention swales and rain gardens.

The purpose of the investigation is to identify opportunities to install WSUD features that assist in managing stormwater runoff rates and quality in an urban street.

Figure 21 shows the street and its surrounds.

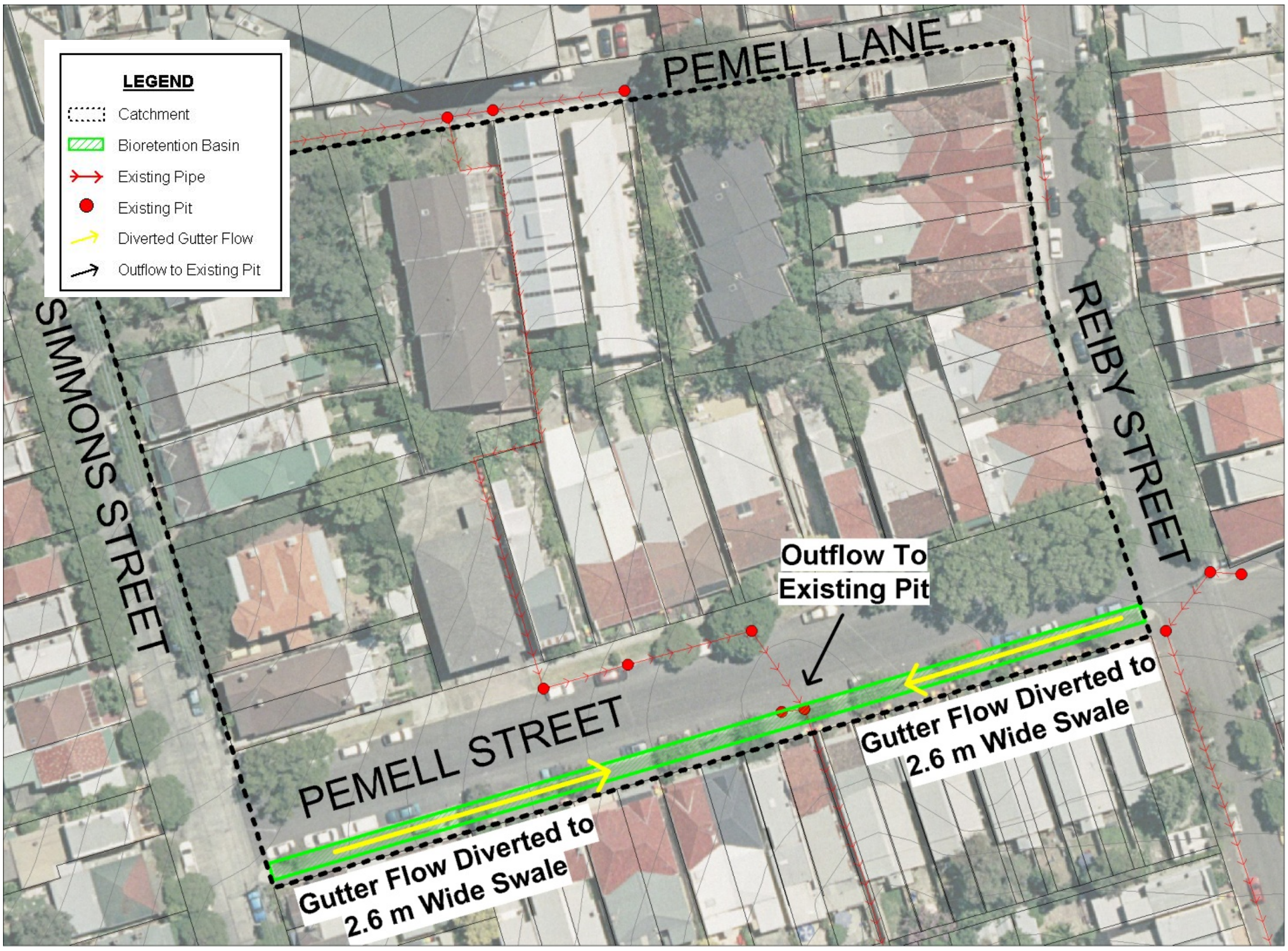

Figure 21: Pemell St and surrounds. The catchment area draining to the bioretention swale is shown together with the stormwater pit.

Figure 22: Pemell Street is one of the few wide streets in the area. Its width from gutter to gutter is 12.7m.

Figure 23: The north side of Pemell Street has a grassed strip some 1.9m wide.

Figure 24: View of the southern side of Pemell St looking west towards Simmons St. Portion of the bitumen near the road could be converted to a bioretention swale system treating both local runoff and water diverted from Simmons St and Reiby St.

2.5.2 Concept design

The width of Pemell St offers the opportunity to install WSUD elements without changing the total number of car parking spaces.

The street has a distinct 'sag' in it approximately 90m from its western end. West of this point it has a grade of 6 to 7%. Use of swales in this area would require grade controls to prevent erosion. The levels are sufficient to allow installation of the proposed bioretention swale. The site is also subject to a proposed stormwater quantity management option, R4.

The proposal is for a narrowing of Pemell St by 1 m to allow a 2.5 to 3m wide swale to be installed on the southern side between Simmons St and Reiby St.

The approach is presented in Figure 25 and Figure 26.

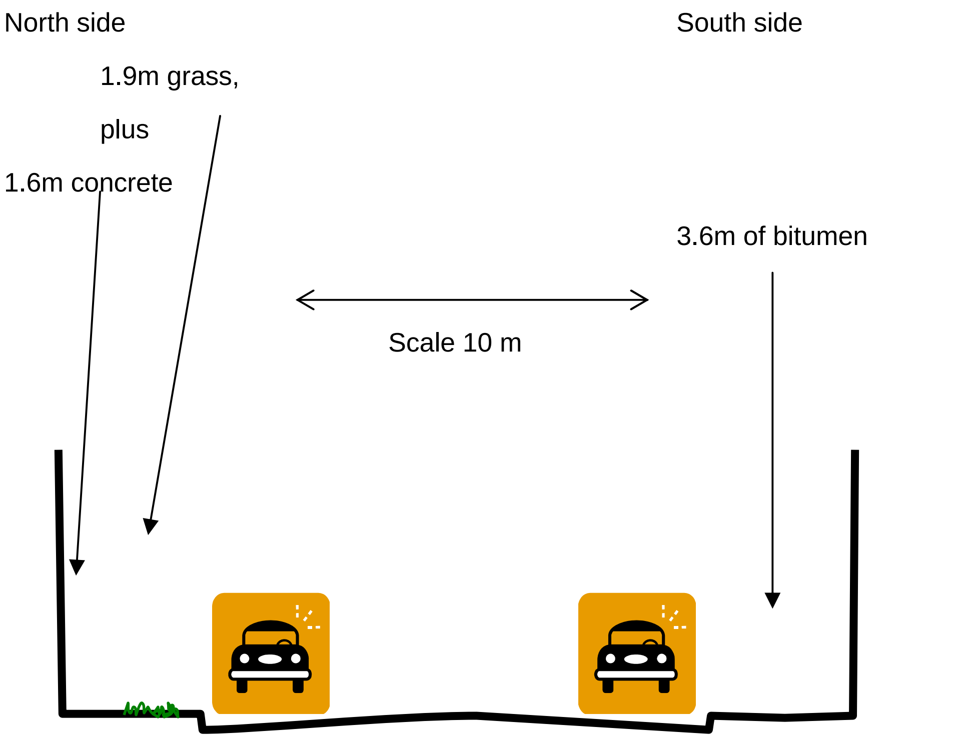

Figure 25: The current situation looking east towards Reiby and Don St. There are 3.5 to 3.6m of space between the gutters and fences.

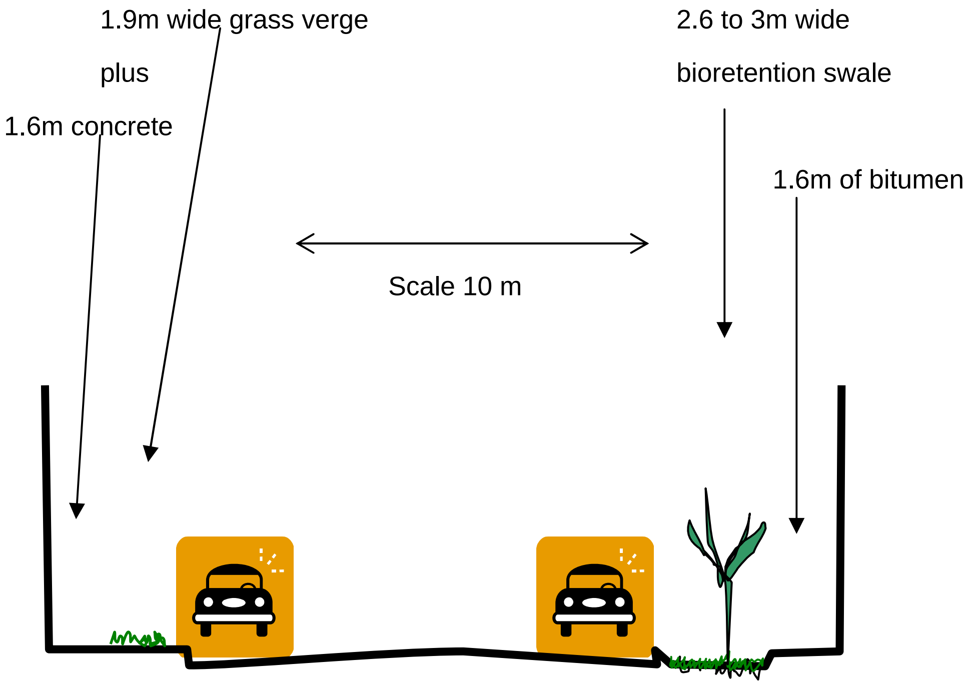

Figure 26: The installed bioretention swale on the southern side of the street.

Water flowing down the gutter on the east side of Simmons St will be diverted into the southern side of Pemell St, entering the bioretention swale at the western end of Pemell St. The bioretention swale will extend in an easterly direction to a pit located in the centre of a sag in Pemell St. A second bioretention swale will extend along the southern side of Pemell St, conveying runoff from the eastern end of Pemell St plus some flow from the western side of Reiby St. The street levels seem suitable for this proposal. Additionally the use of a bioretention swale will increase the effective drainage width of Pemell St, reducing flood risk from moderate storms.

The reasons for the swale location and configuration are:

- The south side of the street has only small trees. These can be incorporated into the design by installing the bioretention swale to the side of these saplings.
- The north side of the street has at least one large concrete apron interrupting the grassed verge. This would make the swale discontinuous, and require either a return of the water into the street gutter or some under concrete boring.
- The swale will partly replace bitumen, increasing green areas on this side of the street.

2.5.3 Design components

The catchment area is 1.18 ha with 63% imperviousness.

The bioretention swale has a surface area of 330 m^2. It has an extended detention depth of 0.15m and a filter thickness of 0.5m. It would be lined on the street side to minimise risk of seepage under the road base.

Figure 27 shows a cross section of a typical bioretention swale.

m

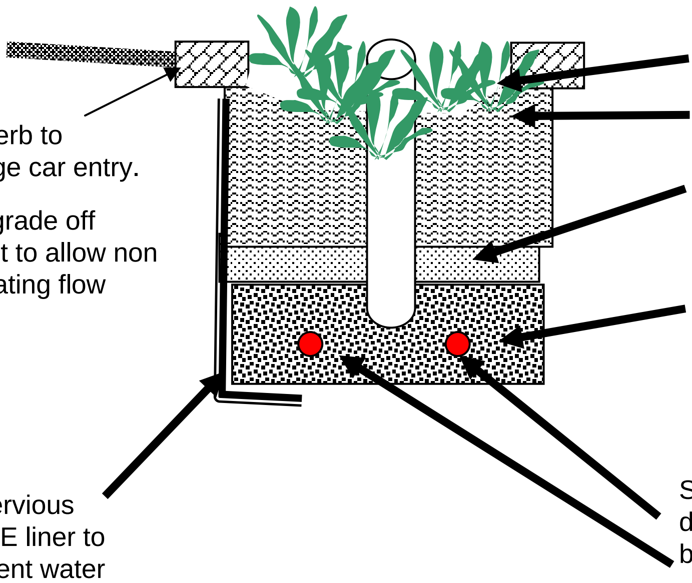

Figure 27: Cross section of typical bioretention swale. Indicative width is 2 m. Indicative depth is 1.05 m.

Inlet system

A mechanism is needed to enable inflow of stormwater from the road whilst minimising pedestrian and vehicle access. Typically this can be done with a series on inlet cuts set at the rate of 50 to 70 mm of 'open slot' every 500 mm of kerb. Figure 28 illustrates the inlet arrangement.

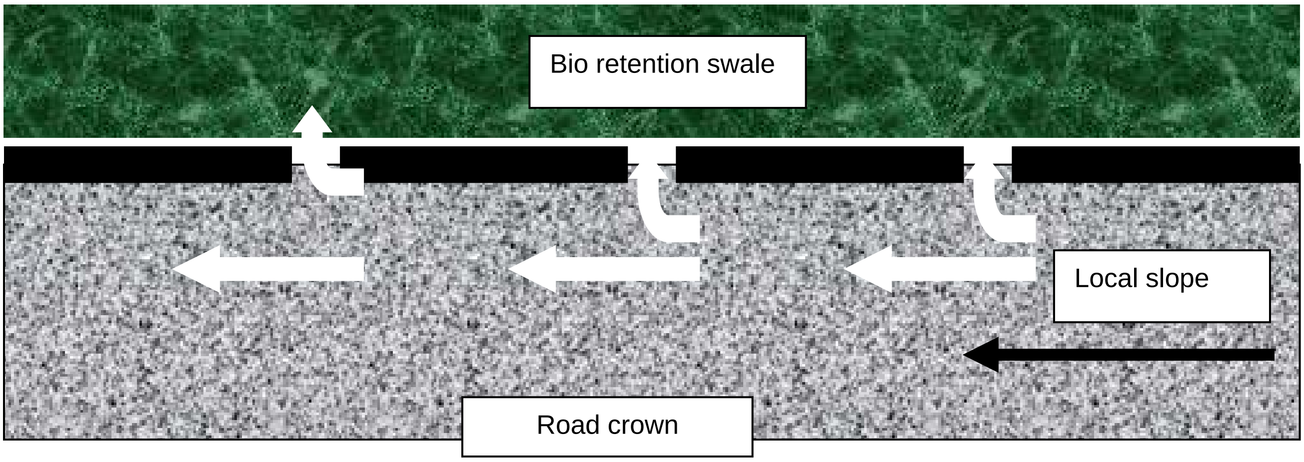

Figure 28: Inflow arrangements to the planted area. There are 500 mm long concrete stops with 50 to 70 mm gaps between each one.

Grade controls

Grade controls are needed to enable temporary ponding during rain events. An indicative grade control is shown below in Figure 29. This will detain water and allow portion of the water to enter the pipe connecting to the drainage line below the swale. The ponding of water upstream of the grade control will facilitate percolation into the media.

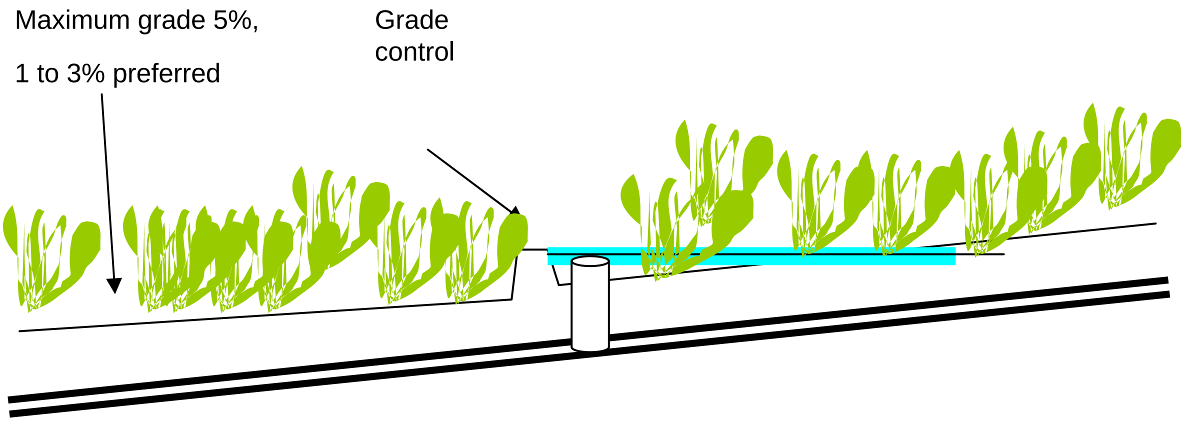

Figure 29: Grade control arrangements. Figure 27 provides details

The top of the surcharge cylinder or pit should be 50mm below the level of the nearest entry gap between the bollards. The surcharge pit should be immediately upslope of any grade control. The crest of the grade control should be 50mm below the level of the nearest entry gap between the bollards.

The suggested maximum grade is 5%. Parts of the street are steeper than this grade. Large rocks on the swale base will be required to reduce runoff velocity in the steeper areas.

The substrate materials

The proposed materials are listed below, and presented conceptually in Figure 27.

i) Detention zone — Grades from edge at 2:1 (H:V) to 200 mm maximum storage

ii) Plant growth/ filter media — 500 to 700 mm-of sandy loam

iii) Transition layer — 100 mm of coarse sand

iv) Drainage layer — 150 to 200 mm of 5mm gravel

Vegetation

Plantings of *Carex appressa* at 4 stems/ m^2 is recommended.

2.5.4 Bioretention swale modelling

Table 17 shows the water and contaminant balance for the proposed bioretention swale in Pemell St Newtown.

Table 17: Annual influx and exit of stormwater and contaminant loads from a 330 m^2 bioretention swale in Pemell St

Attribute	Inflow components	Outflow components	% reduction	BBCCI Targets (% reduction)
Flow (ML/yr)	7.2	5.2	28	Not listed
Total Suspended Solids (kg/yr)	1,230	111	91	75
Total Phosphorus (kg/yr)	2.1	0.6	73	50
Total Nitrogen (kg/yr)	16.0	8.0	50	35
Gross Pollutants (kg/yr)	200	0	100	Not listed

The proposed system reduces outflow volume by 28%. The quantity of water treated could also be expressed as being the volume of water which is filtered through the system. On average 4.6 ML or 64% of the inflowing water is filtered by the time the stormwater reaches the exit point.

However if the analysis was based on water removed from the system then the ‘treatment’ applies to only 2 ML/y, which is the difference between inflow and outflow in the average year.

The bioretention swale also reduces the contaminant yields by percentages that are greater than the Botany Bay redevelopment water quality objectives.

The system reduces nitrogen mass by 50%. The nitrogen removal process requires a combination of denitrification (gaseous loss from wet soil) and plant uptake and removal. The nitrogen removal rate will be much less if either of these processes are less than expected.

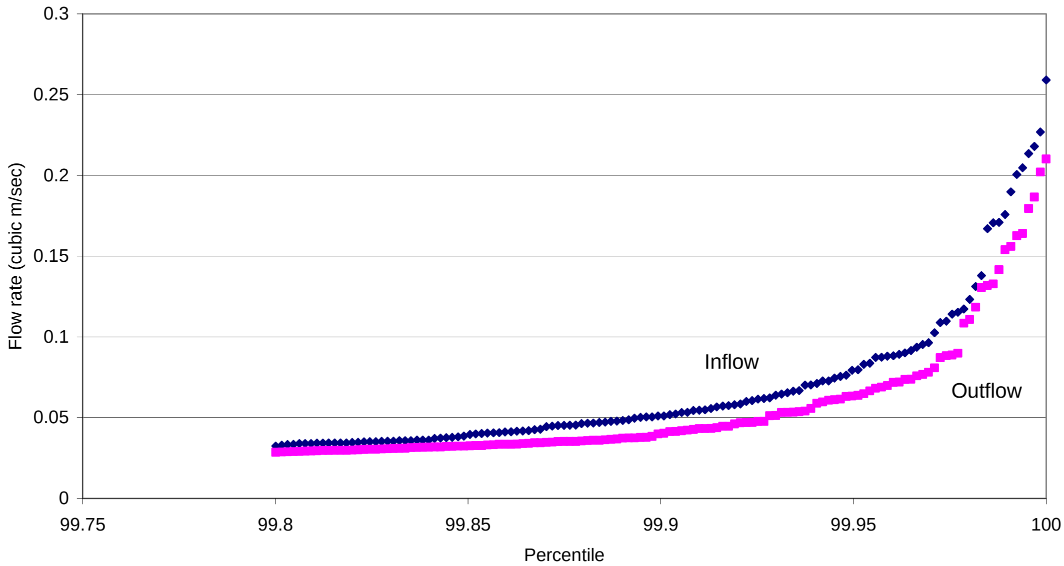

Figure 30: Percentile exceedence of inflows and outflow rates for a bioretention swale in Pemell St for a typical year based on 6 minute time steps.

Figure 30 shows a comparison between inflow and outflow rates for the 99.8 to 100% exceedence values between 1986 and 1987. Differences of at least 10% occur at the highest flow rates in the 12 month simulation period.

2.5.5 Bioretention swale costs

Table 18 shows the anticipated costs of the bioretention swale. The establishment costs of $\$955/m^2$ are relatively high, but reflect the need to allow for adjustment of local designs to avoid services and to re-establish any saplings damaged by the bioretention swale installation. A life cycle of 50 years is assumed, but there will be a need for periodic renovation.

Table 18: Capital and operating costs for the bioretention system.

Life Cycle (yrs)	**50**
Capital Cost	$320,000
Annual Maintenance Cost	$20,000
Annual Establishment Cost	$0
Establishment Period (yrs)	0
Renewal/Adaptation Cost	$9,000
Renewal Period (yrs)	1
Decommissioning Cost	$140,000
Real Discount Rate (%)	5.5
Annual Inflation Rate (%)	2
Life Cycle Cost of Bioretention (2010$)	$800,000

The performance per unit cost was calculated for the mass of each of the measured attributes that is removed from the stormwater flow.

Table 19: Cost per unit of stormwater treated/ irrigated or contaminant removed.

System performance component	Cost per unit of water or contaminant removed
Equivalent Annual Payment Cost of the Asset (2010$/annum)	$16,010
Equivalent Annual Payment/ML of stormwater treated or removed/annum	$7,925
Equivalent Annual Payment/ML of stormwater removed/annum	$3,450
Equivalent Annual Payment/kg Total Suspended Solids/annum	$14
Equivalent Annual Payment/kg Total Phosphorus/annum	$10,679
Equivalent Annual Payment/kg Total Nitrogen/annum	$2,007
Equivalent Annual Payment/kg Gross Pollutant/annum	$80

2.5.6 Conclusions

Installing and adequately managing a 2.6 m wide 130 m long bioretention swale in Pemell St will result in marked reduction in peak outflows and contamination from this catchment. .

The system is expected to reduce TSS, P, N and gross pollutant mass by percentages that are greater than those used for Botany Bay redevelopment objectives. It will also reduce the peak flows exiting the catchment during a typical year by at least 10%.

2.5.7 Issues

The main issues are:

- Interest and involvement of local residents
- Access to individual homes
- Location of services
- The re-establishment of saplings that may be damaged during construction
- The steepness of portion of the swale length.
- The need to link two swales coming in from different directions to the pit at the centre of a sag in Pemell St.

2.6 SWQ5 – Bioretention Swale in Goodsell Street, St Peters

2.6.1 Background and aim of investigation

Goodsell Street, St Peters is the widest local street in the local area. Its width means there are opportunities to install WSUD features such as bioretention swales and rain gardens.

The purpose of the investigation is to identify opportunities to install WSUD features that assist in managing stormwater runoff rates and quality in an urban street.

Figure 31 shows the catchment. The catchment is 1.23 ha, with 86% imperviousness. Note however, that the catchment size may vary depending on direction of flows from individual roofs. The catchment area is based on drainage diagrams which are shown in Figure 31.

Goodsell St catchment is to the immediate south of the Illawarra Railway line. The eastern end contains multistorey home units and factories. The western end contains numerous single storey dwellings. Figure 32 to Figure 37 show components of the Goodell Catchment and its drainage features.

As part of Council's urban renewal program a new Development Control Plan (DCP) is being prepared for the St Peters Triangle – the area bounded by Goodsell St, Princess Hwy, Campbell St and May St.

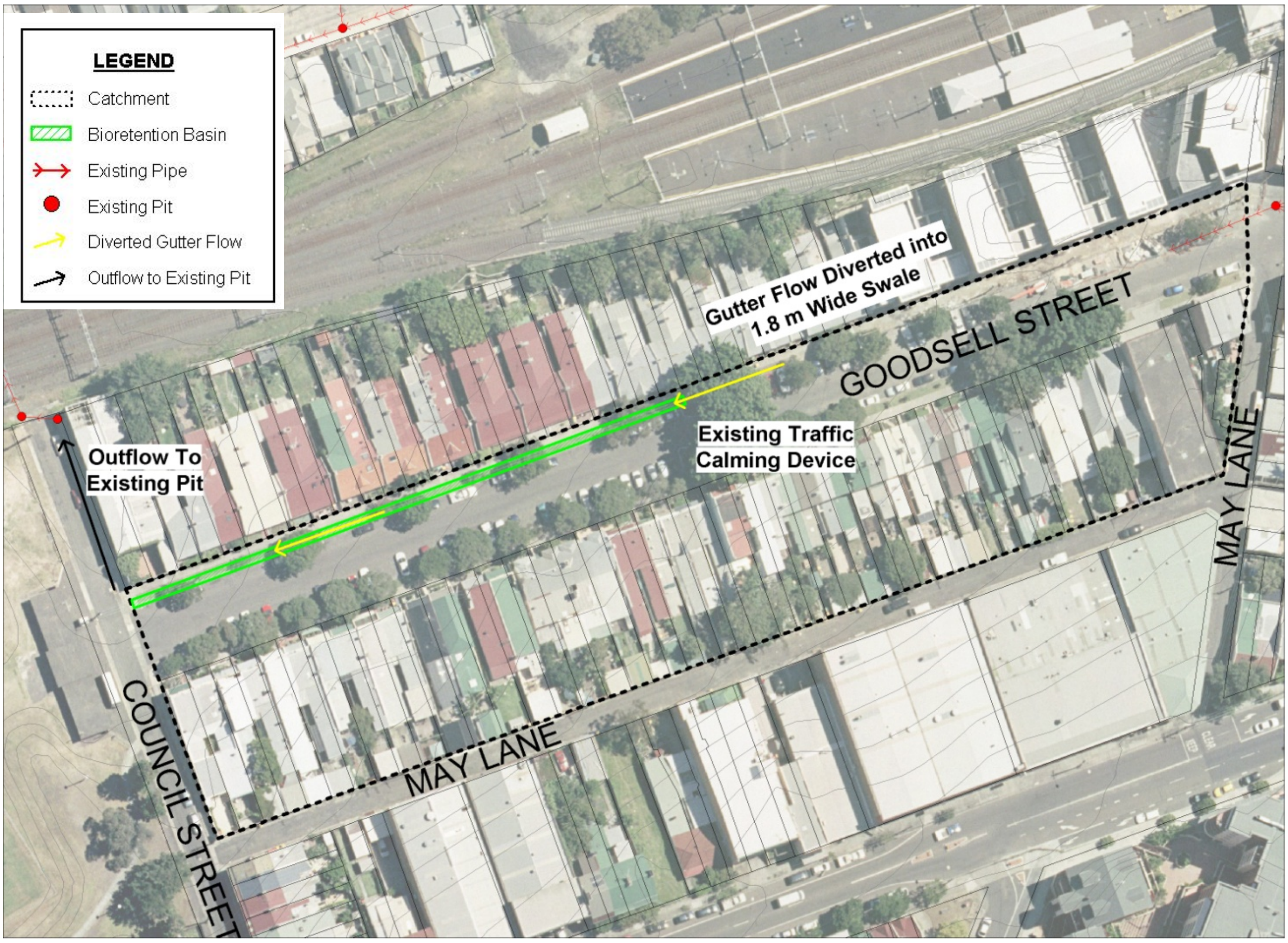

Figure 31: Goodsell Street, its features and the catchment boundary with bioretention swale on the north side of road.

Figure 32: The eastern end of Goodsell St has high density housing and some industrial sites. There is little room to install WSUD features, except possibly rain gardens on the roofs.

Figure 33: Much of Goodsell St has a mix of parallel and perpendicular parking. The grassed verges offer opportunity for WSUD features.

Figure 34: Verges can be converted to swales. Established trees are an issue, especially on the southern side of the street.

Figure 35: Runoff from homes to the street can be treated via bioretention swales established within grass verges. It would require capture of outflows which are currently conveyed to the gutter via domestic pipes.

Figure 36: Street gardens could be converted to rain gardens. It would require significant adjustment of levels to enable inflow and discharge of gutter water into the garden.

Figure 37: Gutter pits at the south west end of Goodsell St join north sloping pipes and convey water towards the railway line. There is potential for capturing and reusing this water on Camdenville Oval.

2.6.2 Concept Plan

As part of Council's Urban Renewal Program a new DCP is being prepared for the St Peters triangle. This area is bounded by Goodsell St, Princes Hwy, Campbell St and May St.   The DCP will emphasise water sensitive design wherever practical.

Figure 38 shows a typical cross section of the south side of the western portion of Goodsell St.

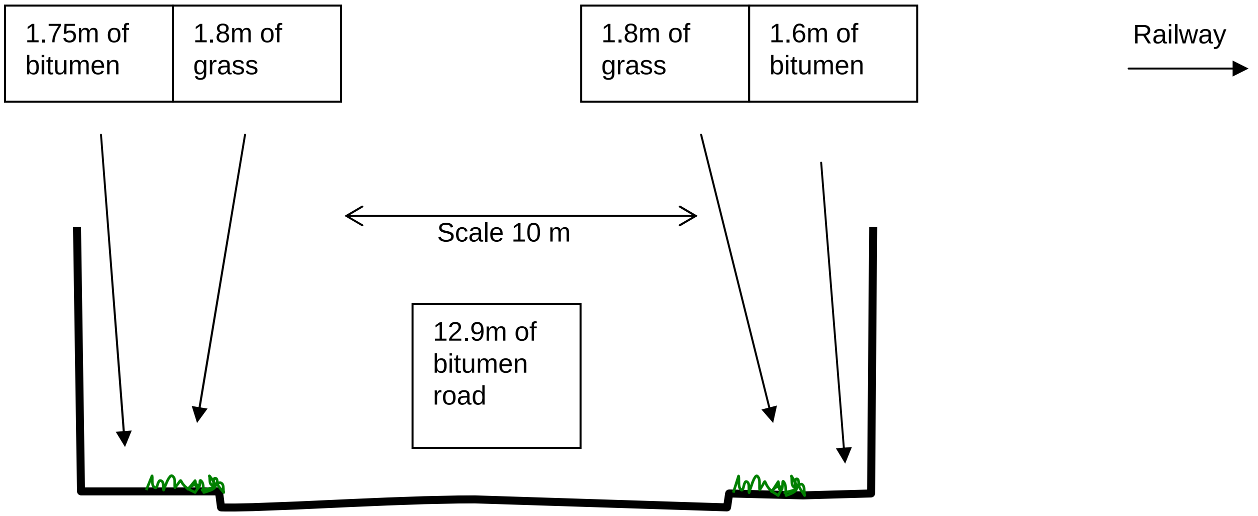

Figure 38: The current configuration looking west towards Camdenville Park.

There are at least five possible structural WSUD options for Goodsell St:

- Install a bioretention swale on the northern side of the street
- Install rain gardens in the traffic calming gardens established approximately half way along the street
- Capture and reuse street runoff from the gully pits at the western end of the street. Use the water to irrigate portion of Camdenville Oval.
- Encourage installation of rain gardens on the roofs of the high density housing at the eastern end of the street. (This should be part of the new St Peters Triangle DCP).
- Ensure any replacement of the factories at the eastern end of Goodsell St includes WSUD elements in new buildings. (This should be part of the St Peters Triangle DCP).

An initial inspection suggested that installing rain gardens in the traffic calming gardens established approximately half way along the street would be difficult because of differences in local levels. No further assessment of this option was made.

Capture and reuse street runoff from the gully pits at the western end of the street would not be necessary if the options to irrigate the fields with water from the southern portion of the park were developed. No further assessment of this option was made. However it should be considered if the development of the Camdenville Basin does not proceed.

2.6.3 Concept design

The northern (railway side) of the street is the more suitable for a bioretention swale as it has fewer established trees. Saplings can be readily incorporated into the design, but large, established trees make construction difficult.

The bioretention swale would extend in a western direction towards Camdenville Oval for 125m from the traffic calming gardens to the western end of the street. The slight slope in the street means grades are suitable for installing a bioretention swale.

The indicative width would be 1.8m, giving a total area of 225 m^2.

The bioretention filter area was 0.5m deep and had a saturated hydraulic conductivity of 36 mm/hr. The basin was not lined and had an exfiltration rate of 2 mm/hr.

The bioretention swale design had similar specification to that proposed for Pemell St. See Figure 27 through Figure 29.

The bioretention swale will partly replace bitumen, increasing green area on the northern side of the street. The bioretention swale is designed to be the maximum dimensions which can fit into the site without creating a major change in access.

2.6.4 Bioretention swale modelling

Bioretention performance modelling was undertaken using MUSIC V4. Table 20 shows the effect of a bioretention swale.

Table 20: Annual influx and exit of stormwater and contaminant loads from a 250 m^2 bioretention swale in Goodsell St.

Attribute	Inflow components	Outflow components	% reduction	BBCCI Targets (% reduction)
Flow (ML/yr)	9.1	7.6	17	Not listed
Total Suspended Solids (kg/yr)	1660	246	85	75
Total Phosphorus (kg/yr)	2.7	1.0	64	50
Total Nitrogen (kg/yr)	21	13	38	35
Gross Pollutants (kg/yr)	244	0	100	Not listed

The proposed system reduces outflow volume by 17%. The quantity of water treated could also be expressed as being the volume of water which is filtered through the system. On average 4.2 ML or 46% of the inflowing water is filtered by the time the stormwater reaches the exit point.

However if the analysis was based on water removed from the system then the ‘treatment’ applies to only 1.5 ML/y, which is the difference between inflow and outflow in the average year.

The modelling indicated that there would be major reductions in contaminant loads, with the proposed system achieving the Botany Bay redevelopment objectives for TSS, nitrogen and phosphorus.

The combination of plant filtration plus filtration through the media will be very effective at removing TSS and P. Nitrogen removal is relatively lower, and initially the system could even gain N via mineralisation of organic matter.

The system is expected to be an effective trap for gross pollutants.

2.6.5 Bioretention swale costs

Table 21 shows the anticipated costs of the bioretention swale. The establishment costs of \$290/m^2 are relatively high, but reflect the need to allow for adjustment of local designs to avoid services and to re-establish the saplings which are already present in the street.

The performance per unit cost was calculated for the mass of each of the measured attributes that is removed from the stormwater flow.

A life cycle of 50 years is assumed, but there will be a need for periodic renovation.

Table 21: Capital and operating costs for the bioretention system.

Cost estimate input	Assumed component
Life Cycle (yrs)	50
Capital Cost	$325,000
Annual Maintenance Cost	$20,000
Annual Establishment Cost	$0
Establishment Period (yrs)	0
Renewal/Adaptation Cost	$9,500
Renewal Period (yrs)	1
Decommissioning Cost	$145,000
Real Discount Rate (%)	5.5
Annual Inflation Rate (%)	2
Life Cycle Cost of Bioretention ($2010)	$820,000

Table 22: Cost per unit of stormwater treated/ irrigated or contaminant removed.

System performance component	Cost per unit of water or contaminant removed
Equivalent Annual Payment Cost of the Asset (2010$/annum)	$16,318
Equivalent Annual Payment/ML of stormwater treated or removed/annum	$10596
Equivalent Annual Payment/ML of stormwater removed/annum	$3813
Equivalent Annual Payment/kg Total Suspended Solids/annum	$12
Equivalent Annual Payment/kg Total Phosphorus/annum	$9,484
Equivalent Annual Payment/kg Total Nitrogen/annum	$2,075
Equivalent Annual Payment/kg Gross Pollutant/annum	$67

2.6.6 Conclusions

It is feasible to install and manage a 1.8m wide 125m long bioretention swale in Goodsell St.

The system is expected to reduce TSS, P, N and gross pollutant mass by percentages that are greater than those used for Botany Bay water quality objectives. It will also reduce the peak flows exiting the catchment by at least 10% in the typical year.

It is noted that the cost per unit of contaminant removed is 6 or more times higher for Goodsell St than for public recreation areas such as Simpson Park. For example the cost for TSS removal is $12/kg for the Goodsell St rain bioretention system compared with $2/kg for Simpson Park. This reflects the additional cost of retrofitting facilities within an existing streetscape.

2.6.7 Issues

The main issues are:

- The need for a positive interaction with local householders
- Maintenance of access for local householders
- The location of services
- The re-establishment of any saplings damaged by construction
- The presence of a street garden which prevents a continuous swale along the entire length of Goodsell St.

2.7 SWQ6 – Rain gardens for Multi-unit Dwellings

The factories at the St Peters end of Goodsell St are being gradually replaced with high density housing. This provides the opportunity to install WSUD elements such as rain gardens. The high density of development suggests that these apartments have virtually no pervious area. Whilst it would be structurally difficult to install rain gardens on existing buildings, it is possible for the St Peters Triangle DCP to require use of rain gardens to create the desired area of imperviousness, say 30% on the site. The rain gardens would also provide some insulation and cooling for the buildings.

The aim of this study is to identify the feasibility, the costs and the potential benefits of installing rain gardens on redeveloping sites.

2.7.1 Modelling Analysis

Table 23 shows the effect of a 30 m^2 rain garden which receives runoff from the surrounding 100 m^2 of impervious surface. It assumes that this garden is installed as part of construction of a new building.

Table 23: The effect of a 30 m^2 rain garden receiving runoff from 100 m^2 of impervious surface.

Attribute	Inflow components	Outflow components	% reduction	BBCCI Targets for new redevelopments (% reduction)
Flow (ML/yr)	0.090	0.088	2	Not listed
Total Suspended Solids (kg/yr)	16.80	3.28	81	75
Total Phosphorus (kg/yr)	0.027	0.011	59	50
Total Nitrogen (kg/yr)	0.21	0.12	42	35
Gross Pollutants (kg/yr)	2.410	0.000	100	Not listed

The results show that while there is only a 2% fall in the volume of runoff/year there is a major reduction in contaminant load The results suggest that rain gardens covering 30% of the site are very effective at reducing export of contaminants in stormwater. These gardens can be either on the roof or in sunny places on the ground.

The cost of rain gardens will vary significantly with locality. For example they would be relatively expensive compared with street bioretention systems if the rain garden was located on a roof which required additional structural support.

The costs are so variable that it is likely to be misleading to provide an indicative figure. The cost/ unit of stormwater quality improvement is likely to be higher than for large scale system in public parks.

2.7.2 Conclusions

There is potential to install rain gardens of roof of new and even recently constructed apartments. If the cost of such installation were too high then developers could be encouraged to contribute to nearby stormwater treatment facilities, for example bioretention swales along streets fronting the development.

2.7.3 Issues

The main issues are:

- The cost of structural reinforcement needed on the roof to support the rain gardens (rain gardens on land surrounding the building may be more economic).
- The interest in the developer in providing rain gardens
- The long term interest of site owners or residents in maintaining the gardens.

3.0 CAMDENVILLE OVAL OPTIONS

3.1 Background and aim of investigation

Camdenville Oval is the largest open space available in the EC East subcatchment. It provides an opportunity to manage both stormwater flooding as well as improve the stormwater quality in the subcatchment. However contaminated groundwater and gas production issues associated with the landfill buried under Camdenville Park have been identified. Until these issues are addressed, it is not advisable to create a permanent store of water within the Camdenville Basin.

This section examines the potential for using catchment runoff to irrigate the sports field. It also assesses the effect of the irrigation on the stormwater volume and contaminant loads exiting the catchment.

Two scenarios are explored:

- The first one involves using a tank to capture and utilise runoff. This runoff could be derived from nearby roofs or from the street runoff.
- The second scenario uses the current basin both as a stormwater capture and remediation system, as well as a water storage system for the adjacent sports fields. (The groundwater management issues would need to be addressed for this option to be acceptable).

Based on the above scenarios, three options for identified for stormwater management. These options are discussed in the following sections.

3.2 SWQ7 + WR – Irrigate Camdenville Oval by Using Street Runoff from Camdenville Oval Catchment

This option involves capture of stormwater from the streets of the Camdenville Catchment, storing it in tanks and using it to irrigate Camdenville Oval. Currently the oval is irrigated by the potable water. The proposed option can significantly reduce the consumption of potable water for irrigation purposes at the Oval.

3.2.1 Quality of inner city stormwater and its management implications

Sydney stormwater characteristics have been intensively studied as part of sewer overflow management investigations by SWC. The results are documented in the Catchment Stormwater Management Plans sponsored by the EPA in the late 1990s. These studies demonstrated the large contaminant loads in the inner city runoff.

In several studies the investigations examined trace metals as well as the major contaminants such as N and P.

In one detailed investigation of road runoff the trace metal concentrations exceeded the ANZECC guideline concentrations for aquatic ecosystem protection by several orders of magnitude (ANZECC, 2000a). Table 24 contains typical results.

Table 24: Runoff water quality in ug/L from five Sydney roads near Mascot (Source: Batley et al, 1998)[1]. The ANZECC (2000a) sediment trigger values for protection of 80% of species are also shown.

Statistical component	Pb ug/L	Cu ug/L	Zn ug/L	Fe mg/L	Mn ug/L	Cd ug/L
Median-site 1	67	18	71	1.0	23	2
Median-site 2	235	189	1060	2.7	272	10
Median-site 3	152	87	401	2.4	115	3
Median-site 4	130	140	891	1.5	234	3
Median-site 5	62	18	131	0.2	35	2
Mean	146	109	606	1.9	161	4.5
ANZECC (2000) Guideline for protection of 80% of freshwater species	9.4	2.5	31	NA[2]	3600	0.8

[1] These roads were all near Mascot Airport, so some of the contamination could be due to fuel dumping by airplanes.[2]NA Concentrations Not Available

There is an obvious environmental advantage if these contaminant loads can be reduced. Studies by the CRC for Catchment Hydrology (Fletcher, et al, 2004), showed that on a catchment basis, contaminant load in runoff was proportional to runoff volume. There was little evidence that the contaminant concentration falls with the duration of runoff events. This observation suggests that activities and structures which reduce the volume of stormwater exiting the catchment will also reduce the contaminant load exiting the catchment.

Irrigation of stormwater offers one way of reducing the volume of stormwater exiting the catchment. However, it also raises the issue of human and environmental safety. This issue is site dependent and is discussed below.

Substitution of runoff for mains water obviously reduces the demand for mains water. It also reduces the peak stormwater runoff rate from urban areas. Reduction in peak runoff rates can reduce the extent of downstream flooding and erosion during storms. It also reduces the contaminant load being delivered to receiving water by the storm flows. Fletcher, et al, (2004) reported that the trace metal concentrations in the runoff can be sufficiently high so as to inhibit aquatic biota. Stormwater quality treatment should aim to reduce trace metal concentrations to non toxic concentrations.

3.2.2 Issues associated with using runoff to irrigate Camdenville Oval

An examination of the Camdenville site and the surrounding catchment identified a series of issues which need to be addressed to ensure the feasibility of the stormwater capture and reuse on the ovals. These are listed and discussed in Table 25.

Table 25: Issues and responses associated with using runoff to irrigate Camdenville Oval.

Issue/limitations	Response
A small catchment (approximately 0.7 ha) drains directly to Camdenville basin.	The basin is over 3000 to 4000 m^2, depending on water depth. It can markedly reduce contaminant loads for catchments of 10 or more ha (Fletcher, et al, 2004). The drainage system could be modified so that a higher stormwater volume is delivered to the basin. This would increase the value of the basin in managing stormwater.

Issue/limitations	Response
The basin has a combination of upwelling contaminated groundwater and gas escape.	There is the potential to use a sealant such as Elcoseal X2000 to separate ground and surface water. This would prevent contaminated groundwater entering the wetland through its base. An indicative total cost is \$30/ m^2 or \$120,000 for a 4000 m^2 surface. This would enable treatment of the stormwater and irrigation without the need for a large irrigation tank.
Much of the flow in the current stormwater delivery system bypasses the basin.	The inflow could be adjusted to allow a higher proportion of runoff to enter the basin. A pump station say 10 m^3 capacity could be inserted into the floor of the basin and used to collect inflow. The water would then be pumped up to the irrigation tank from this pump station.
Flooding is already an issue for the basin. Adding additional flows to the basin during rain events will exacerbate the problem.	Install the irrigation tank within the Camdenville basin area and irrigate Use Camdenville Basin for initial storage of water and irrigate directly from the basin Arrange diversion structures so that the inflow is reduced once the basin is full.
There may be insufficient storage capacity to enable irrigation during extended periods of dry weather.	• Source water from as large a catchment as possible • Install as large a storage tank as possible • Rely on Sydney Water supplies to top up during drought

The issues and the responses above were taken into account when developing a concept plan.

3.2.3 Conceptual design

This option involves capture of stormwater from the streets of the Camdenville Catchment, storing it in tanks and using it to irrigate Camdenville Oval. Currently the oval has limited irrigation, relying on potable water.

Figure 39 shows the location of the system. Whilst only 0.7 ha of catchment drains directly to the basin, there are some 25.4 ha of catchment which could drain to the Camdenville Basin. This includes the 10.33 ha area which drains towards Simpson Park. Runoff from this area could reach Camdenville Basin provided the drainage system was reconfigured.

Installation of the Simpson Park bioretention basin (SWQ2) would reduce flow to Camdenville, however in the analysis below it was assumed that Option SWQ2 was not implemented.

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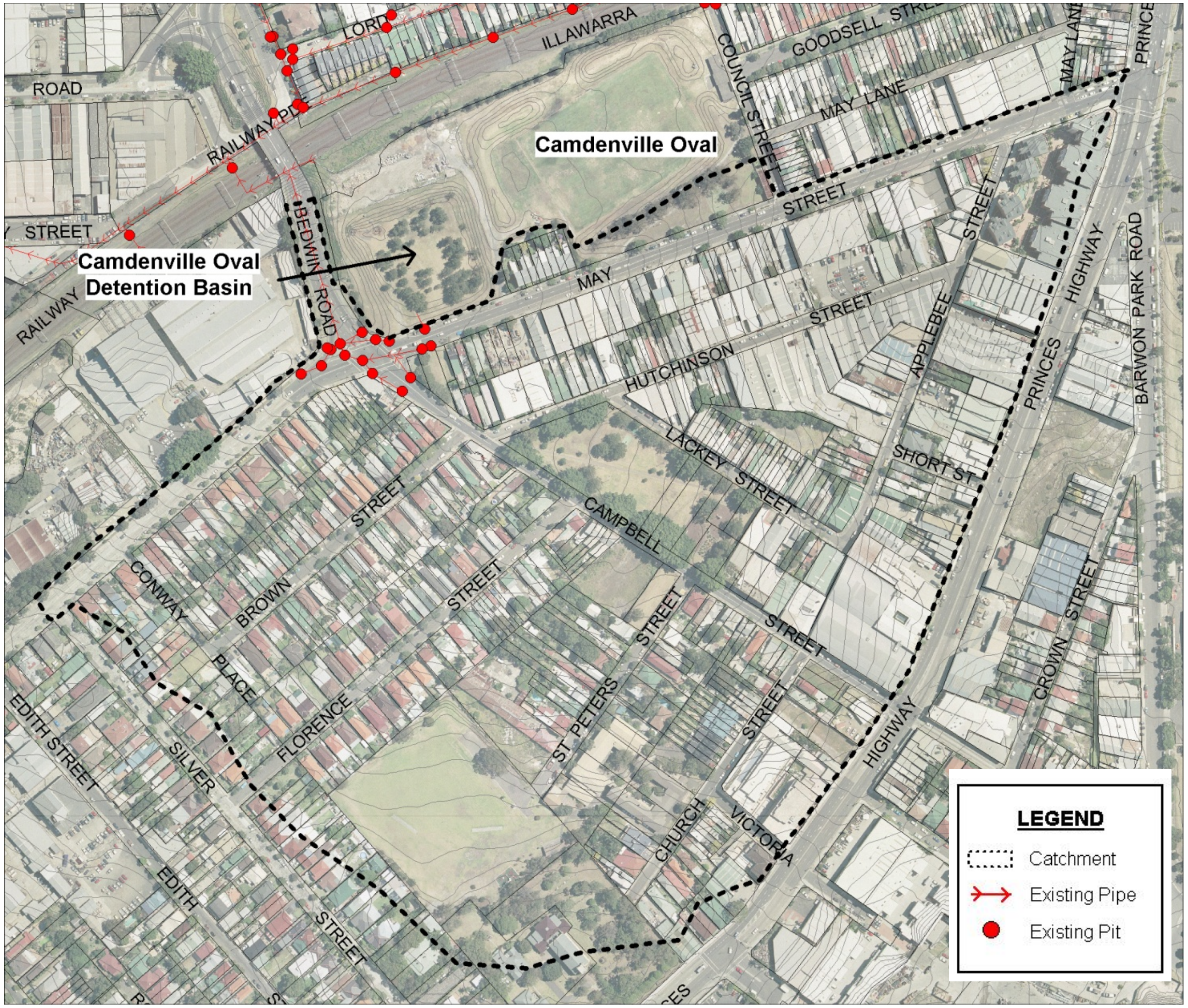

Figure 39: The subcatchments which drain towards Camdenville Basin.

Figure 40: The proposed layout of the capture, storage and supply system.

3.2.4 Storage tank

Due to the potential for contamination from groundwater, it is currently proposed to use a tank to retain stormwater for reuse on the Camdenville Oval. The location of the storage tank should be protected from vandals, but be as close to the irrigated areas as possible. Figure 40 indicates the suggested location for the tank.

The ideal volume of water in storage will depend on both supply and irrigation demand. Cost is also an obvious factor:

3.2.5 Irrigation system

The soccer ground was 0.8 ha in area. However it is not possible to apply water exactly to the target root zone. Some water irrigates unintended areas, some is directly intercepted by leaves, and some areas receive excess water and this water is lost via percolation below the root zone. An irrigation efficiency of 80% was assumed. In practice this means that in order to meet the plant water demand an additional 20% of water is applied.

There is already an existing tank on Camdenville Park. However this tank is less than 20 m^3 and is designed to act as a buffer system rather than a storage system.

3.2.6 Water balance methodology and assumptions

Input data

A daily time step water balance model was created by Woodlots and Wetlands. The runoff coefficient was derived from Fletcher, et al, 2004). The inputs and assumptions are shown in Table 26.

Table 26: Input data to the Camdenville Oval water balance model.

Component	units	Value	Comment
Rainfall	mm/y	1115	Daily rainfall at Sydney Airport from 1954 to 2009
Evaporation	mm/y	1756	>30 years of daily pan evaporation at Sydney Airport
Crop factor		0.7	
Catchment area	ha	25.4	Includes all runoff from the catchment
Irrigation area	ha	0.8	
Irrigation efficiency		80%	80% of the applied water is available for root uptake.
Catchment runoff	m^3/y	143,382	Mix of roof, grass and roads
Max daily runoff to basin	m^3/d	31,405	Inflow max set at 6680 m^3/day
Max pumped to irrigation tank	m^3/y	33,838	Max to irrigation tank set at 500 m^3/day
Rainfall runoff from pervious surfaces	mm/y	436	Initial loss of 5mm then 41% runoff of rainfall in excess of the first 5 mm.
Assumed water holding capacity	mm	57	A moderately structured loam with a 0.3m root depth and no impedance layer. Water in excess of 57 mm either runs off or percolates below the root zone.

Model variables

Site water balance is:

- (Rainfall + irrigation) - (runoff + percolation + evapotranspiration) = Zero.

It was assumed that all the irrigation water infiltrated the soil.

The irrigation system was 80% efficient. In practice this means that a 20mm irrigation would deliver 16 mm to the root zone, while a 10mm irrigation would deliver 8 mm to the root zone.

Rainfall runoff was attenuated over 3 days, so there is opportunity for excess water to contribute to evapotranspiration in this period.

The model assumes that the field will be irrigated once the irrigation trigger point is reached. The irrigation rule was 20 mm of irrigation (16 mm addition to the soil water content) once the available water content fell below 28 mm for the simulation using a 500 m^3 tank. The 250 m^3 tank utilised 10 mm of irrigation (8 mm addition to the soil water content) once the available water content fell below 28 mm. The exception to this would obviously be if there was no water in the storage tank. Potable water would be required if irrigation was considered essential at this time.

3.2.7 Water Balance Results

Use of a 250 or 500 m^3 irrigation tank in conjunction with a 25.4 ha catchment

The simulations examined two irrigation tank sizes. Table 27 shows the water balance components for 250 and 500 m^3 tanks.

Table 27: Effect of changing tank size on site water balance.

Component	Units	250 m^3 tank	500 m^3 tank
Rainfall	mm	1115	
Volume/irrigation	mm	10	20
Irrigation (effective)	mm	388	569
Rainfall runoff (assumes no irrigation water runs off)	mm	425	
Rainfall infiltration into topsoil	mm	860	
Percolation loss	mm	213	252
Grass transpiration	mm	977	1102
Number of irrigations/year		48	35
Volume of water irrigated (80% efficient)	m^3	4810	7119

The 250 m^3 tank provides sufficient water for 48 irrigations/year of 10mm each. Allowing for 80% efficiency the effective irrigation was 388 mm. Based on 80% delivery efficiency, the irrigation system supplied 4.8 ML/year.

The 500 m^3 tank enabled an average of 35, 20mm irrigations/year, of which 16 mm/irrigation were considered effective. The system delivered an effective 569 mm of irrigation/year. The total irrigation volume was 7.1 ML/year. The estimated evapotranspiration of the grass was 1102 mm or 67% of the pan evaporation. Assuming a crop factor of 0.7 when water supply is unlimited, the maximum water requirement would be 1206 mm, of which 702 mm would need to be met via irrigation.

Table 27 shows that the 500 m^3 tank system has higher percolation losses and more evapotranspiration. This is due to the higher average soil moisture content under this system.

Rainfall is obviously episodic, so supplying an average of 81% of the plant's maximum water needs (569/702) means that the grass will be moisture stressed at least in some times during the average year. Figure 41 shows that there are extensive periods when the soil water availability is below 50% the field capacity value of 28 mm. Grass would be stressed at these times.

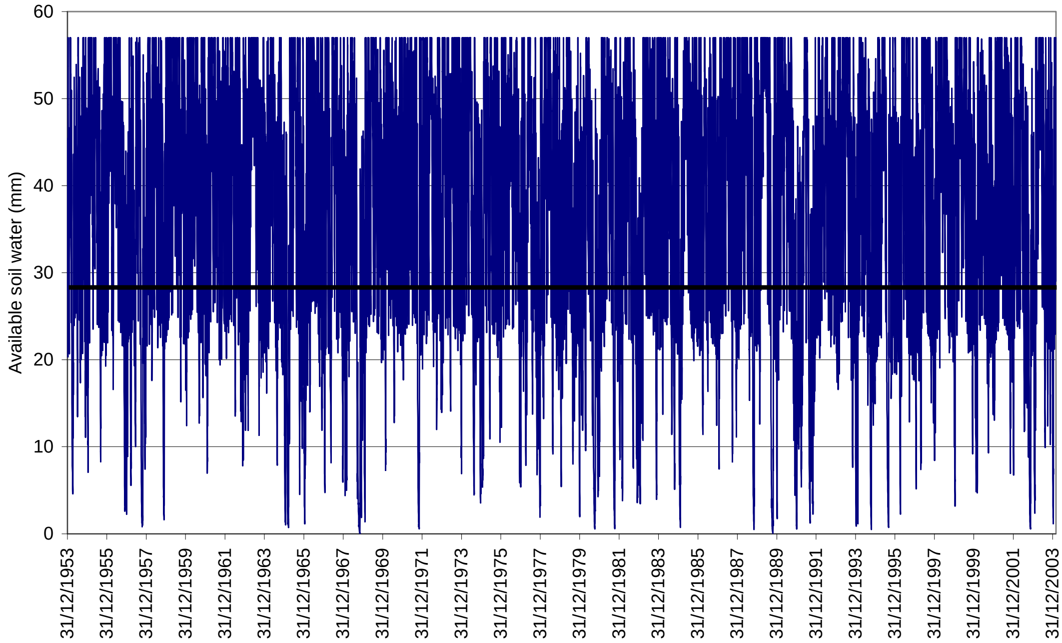

Figure 41: Available soil water content (mm) each day since 1954. Assumes 25.4 ha catchment and a 500 m3 storage tank. The 50% of field capacity (28 mm) is shown by a dark line. Plant growth in soils between 50 and 100% of field capacity is not normally restricted by moisture availability.

It is obvious that the 500 m^3 tank can supply sufficient water to ensure there is minimal plant moisture stress for much of the time. Top up may be required during droughts.

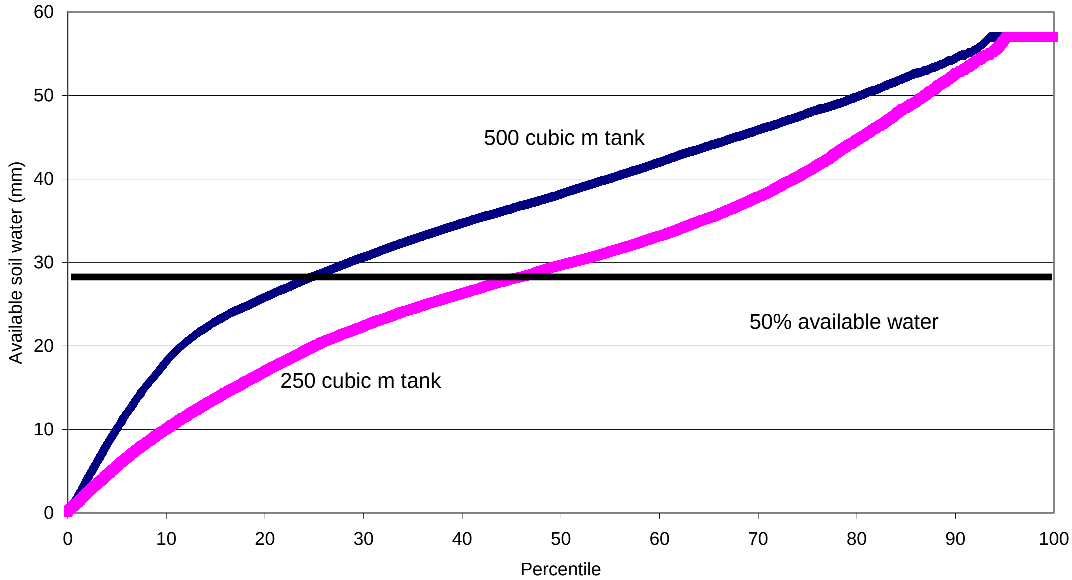

Figure 42: Percentile distribution of available soil water content for the 250 m3 and 500 m3 tank systems. Based on a 25.4 ha catchment.

The 500 m^3 tank system resulted in the soil water content being above 50% of field capacity in 38% of time while the 250 m^3 tank system resulted in the available soil water content being above 50% of field capacity in 18% of time. These differences are physiologically significant and the grass would be showing markedly more stress in the 250 m^3 tank system. However this could be addressed by top up from Sydney Water mains.

The 500 m^3 tank system obviously works well and could readily provide sufficient irrigation water for Camdenville Oval. The 250 m^3 tank would also provide significant quantities of water. The 500 m^3 tank system is preferable, but costs more than the 250 m^3 system. The costs are examined below.

3.2.8 Use of MUSIC simulations to assess contaminant removal

MUSIC modelling was used to assess the removal of water and contaminants from the stormwater system.

Table 28: Effect of irrigation tank size on the volume of water irrigated and the contaminant load removed from the runoff.

Component	Inflow from 25.4 ha catchment	Outflow (250 m^3 tank)	Outflow (500 m^3 tank)	% reduction (250 m^3 tank)	% reduction (500 m^3 tank)
Flow (ML/yr)	157	152	152	3	3
Total Suspended Solids (kg/yr)	29782	28731	28618	4	4
Total Phosphorus (kg/yr)	65	63	63	3	4
Total Nitrogen (kg/yr)	441	428	426	3	3
Gross Pollutants (kg/yr)	4910	0	0	100	100

The contaminant removal percentages are very small, reflecting sedimentation in the tanks, and do not vary greatly between the 250 and the 500 m^3 tanks. There is also little difference in the mass of contaminants discharged from the catchment. The reason for this is that both the 250 m^3 tank system and the 500 m^3 tank system use only a few percent of the water. In practice the vast majority of the catchment outflow would by pass the tanks.

The results suggest there is little value in increasing the tank size beyond 250 m^3. The 250 m^3 tank system supplied 94% of demand compared with 98% of demand via the 500 m^3 tank system. That is both tank sizes meet almost all the irrigation demand.

The results suggest that a 250 m^3 tank would be sufficient to supply water for much of the typical year. Occasional irrigation using potable water would ensure that the park could be adequately maintained for a variety of sporting events.

The options to treat a higher proportion of the catchment runoff is discussed below.

3.2.9 Estimated Costs

The cost software of the MUSIC program was used to estimate the costs per unit of water and contaminant removed. Table 29 shows the cost components for the proposed systems. These are based on our own experience, Council's data and Rawlinsons, (2010).

Table 29: Cost components for the various sizes of tanks.

Component	250 m^3	500 m^3
Life Cycle (yrs)	50	50
Capital Cost	$345,000	$390,000
Annual Maintenance Cost (includes electricity for pumps)	$20,000	$20,000
Annual Establishment Cost	$0	0
Establishment Period (yrs)	0	0
Renewal/Adaptation Cost	$0	0
Renewal Period (yrs)	1	1
Decommissioning Cost	$10,000	$10,000
Real Discount Rate (%)	5.5	5.5
Annual Inflation Rate (%)	2	2
Life Cycle Cost ($2010)	$685,000	$730,000

Table 30 shows the annual cost per unit of water utilised or contaminant removed.

Table 30: Cost per unit of stormwater treated/ irrigated or contaminant removed.

Cost per unit of water or contaminant removal	250 m^3 tank	500 m^3 tank
Equivalent Annual Payment Cost of the Asset (2010$/annum)	$13,645	$14,551
Equivalent Annual Payment/ML of irrigated water/annum	$2,608	$2,646
Equivalent Annual Payment/kg Total Suspended Solids/annum	$19	$17
Equivalent Annual Payment/kg Total Phosphorus/annum	$7,666	$7,700
Equivalent Annual Payment/kg Total Nitrogen/annum	$990	$676

The cost per unit of water or contaminant removed is slightly lower for the 250 m^3 tank.

The 250 m^3 tank system supplied 5.2 of the 5.6 ML anticipated irrigation requirement. Assuming mains water costs $1000/ML, the annual cost of meeting the demand would be an additional $400/year.

The 500 m^3 tank system met 5.5 of the 5.6 ML anticipated irrigation requirement. Assuming mains water costs $1000/ML, the annual cost of meeting the demand would be an additional $100/year.

A 250 m^3 tank system seems to meet irrigation demand for most of the time.

3.2.10 Conclusions

A 250 m^3 tank capturing a portion of runoff from a 25.4 ha catchment will meet 94% of the anticipated irrigation demand at Camdenville Oval. The remaining 6% could be met via top up from mains water.

3.2.11 Issues

The main issues are:

- The current drainage at the intersection of May St, Unwins Bridge Road Campbell Road and Bedwin Road needs to be modified to enable a portion of the stormwater to be captured. This is discussed in the flood management section of the current report.
- The water needs to be of sufficient quality for safe irrigation of a public space with open access. The cost of disinfection is included in the cost analysis presented in Table 30.

3.3 SWQ8 + WR – Irrigate Camdenville Oval by Capturing Roof Runoff

There is a series of large factories to the south of Camdenville Oval. These factories have large roof areas and there is potential for capturing some of the roof runoff and using the water to irrigate Camdenville Oval.

The aim of this investigation is to identify the potential for using roof water from adjacent factories to irrigate the Camdenville Oval.

3.3.1 Reasons for using roof runoff

Stormwater runoff from older inner city areas can be contaminated with an array of trace metals and persistent toxicants such as dieldrin. Additionally there can be issues such as sewer overflows and surcharges from ECE catchment pipes which are over 100 years old. In these situations it would be advantageous to irrigate high contact sports areas with roof water rather than street runoff (Duncan, 1999).

Substitution of roof runoff for mains water reduces the demand for mains water. It also reduces the runoff rate from urban areas. Reduction in runoff can reduce the extent of downstream erosion during storms. It also reduces the contaminant load being delivered to receiving water by the stormflows.

3.3.2 Quality of roof runoff from industrial areas and its implications

Chemical contamination of roofs and rainwater has been examined in several highly urbanised areas (Australian Government, 2004). In Adelaide, testing of rainwater from household tanks near industrial precincts was undertaken as part of two investigations into impacts of contaminants associated with local emissions. Lead, manganese, nickel, zinc and hydrocarbon concentrations in the rainwater samples were consistently less than the guideline values cited in the Australian drinking water guidelines (South Australian Department of Human Services, unpublished results 1999–2002). This suggests that the water would be suitable for irrigation.

3.3.3 Issues associated with using runoff from the surrounding roofs to irrigate Camdenville Oval

An examination of the site and the surrounding catchment identified a series of issues which need to be addressed to ensure the feasibility of the proposed system. These are listed and discussed in Table 31.

Table 31: Issues and responses associated with using roof runoff to irrigate Camdenville Oval

Issue	Response
Simpler to manage runoff from a few large roofs rather than a large number of small ones	Use the roofs from large factories bounded by Unwins Bridge Road, the railway line and Bedwin Road.
Factory owners' interest in supplying roof runoff	Simpler to have a few large factories. May need to offer necessary incentive such as gutter and downpipe replacement
Water needs to be conveyed to Camdenville Park	Bore under Unwins Bridge Road. However the potential for interference with existing services and the cost of boring need consideration.

	Alternatively obtain permission to pipe along railway easement.
Use of Camdenville Basin for initial storage of water: Flooding is already an issue for the basin. Adding additional flows during rain events will exacerbate the problem.	Construct water storage tanks on private land adjacent to factories. Issues then become owner willingness, tank maintenance and cost of pumping OR Install the irrigation tank within the Camdenville area and irrigate directly from it. Overtopping could be directed to the main drainage system near the railway line rather than into the Camdenville Basin.
Having sufficient storage to supply the irrigation during dry periods	• Have as large a roof catchment as possible • Have as large a storage tank as possible • Rely on Sydney Water supplies in drought

The issues and the responses above were taken into account when developing a concept plan.

3.3.4 Conceptual design

Figure 43 shows the location and potential layout of the system. Various options for pipeline and tank locations and are also shown on this image.

Roof area

Approximately 0.5 ha of roof area was available on the factories on the other side of Bedwin Bridge Road to the Camdenville detention basin. Additional factory roof area is nearby, but it is less usable, being smaller and more isolated.

Storage tanks

The location of the storage tank should be close to the irrigated areas. Power should also be readily available.

The ideal volume of water in storage will depend on both supply and irrigation demand.

Irrigation system

The soccer ground is 0.8 ha in area. An irrigation efficiency of 80% was assumed.

3.3.5 Water balance methodology and assumptions

Input data

A daily time step water balance model was created using the Woodlots and Wetlands template. The components are shown in Table 32.

Table 32: Input data to the model for roof runoff study.

Component	units	Component	Comment
Catchment area	ha	0.5	Nearby factory roofs
Irrigation area	ha	0.8	
Roof runoff	m^3/y	5207	Calculated as being an initial loss of 1mm then 90% efficiency

Model variables

The roof runoff/ irrigation model assumes that the field will be irrigated once the irrigation trigger point is reached. The irrigation rule was 20 mm of irrigation once the available water content fell below 28 mm. The exception to this would obviously be if there was no water in the storage tank. An initial examination of the results indicated that a 250 m^3 tank would be very inefficient if irrigation only occurred when there was 200 m^3 of water in it. It was therefore decided to operate the 250 m^3 tank simulation on 10mm/irrigation.

Plant water use (evapotranspiration) as assumed to be 70% of pan evaporation until soil water content fell below 28 mm[1]. This was equivalent to 50% of the available water content of the turf root zone. The rate of evapotranspiration as a percentage of the pan evaporation fell linearly from 100% to zero as the available soil water content fell from 50% to zero.

[1] The crop factor is dependant on grass species and season. 0.8 of pan evaporation is used for vigorous grasses. Assuming irrigation when available soil water falls to 50%, some 774 mm/year is required. If the crop factor was assumed to be 0.7, the irrigation demand would be 639 mm. A crop factor of 0.6 would require 500 mm while a crop factor of 0.5 would require some 365 mm of irrigation. Turf watered using the 0.5 crop factor criteria would be under moisture stress for much of the year.

Figure 43: Pipeline route and proposed tank locations.

3.3.6 Water Balance Results

Use of a 250, 500 or 1000 m^3 irrigation tank and 0.5 ha roof catchment

The initial simulations examined a range of tank sizes. Table 33 shows the water balance components for 250, 500 and 1000 m^3 tanks.

Table 33: Effect of changing tank size on site water balance.

Component	Units	250 m^3	500 m^3	1000 m^3
Rainfall	mm/y	1115		
Tank inflow	m^3/year	4517		
Volume/irrigation	mm/y	10	20	20
Irrigation (effective)-80% of volume actually applied	mm/y	141	197	281
Rainfall runoff from grass (assumes all irrigation water enters the soil)	mm/y	301		
Rainfall infiltration into topsoil	mm/y	846		
Percolation loss	mm/y	184	209	212
Grass transpiration	mm/y	768	803	869
Number of irrigations/year		19	14	18
Volume of water irrigated (80% efficient)	m^3	1766	2465	3500
Volume of water lost via bypassing or 'overtopping'	m^3	2752	2052	1017

The 250 m^3 tank in combination with a 0.5 ha roof catchment provided sufficient water for 19 irrigations of 10mm each. Allowing for 80% efficiency the effective irrigation was 141 mm. This is 20% of the anticipated 702 mm/year irrigation demand. Only 39% of the available water which was shed from the roofs (4517 m^3/ year) was utilised for irrigation. There was insufficient storage capacity to retain the other 2752 m^3. The result suggests that a larger tank size is needed.

The combination of a 0.5 ha roof catchment and a 500 m^3 tank enabled an average of 14 irrigations/year, delivering an effective 197 mm of water. The estimated evapotranspiration of the grass was 803 mm or 50% of the pan evaporation. Assuming a crop factor of 0.7 when water supply is unlimited, the maximum water requirement would be 1229 mm, of which 702 mm would need to be met via irrigation. The 500 m^3 tank system met 28% (197 mm supplied/702 mm demand) of the irrigation demand.

The combination of a 0.5 ha roof catchment and a 1000 m^3 tank enabled an average of 18 irrigations/year, delivering an effective 281 mm of water. This is 40% of the average total irrigation demand.

Rainfall is obviously episodic, so supplying an average of 22% of the plant's maximum water needs (197/877) means that the grass will be moisture stressed at some times during the average year. Figure 44 shows that there are extensive periods when the soil water availability is low. Grass would be stressed at these times.

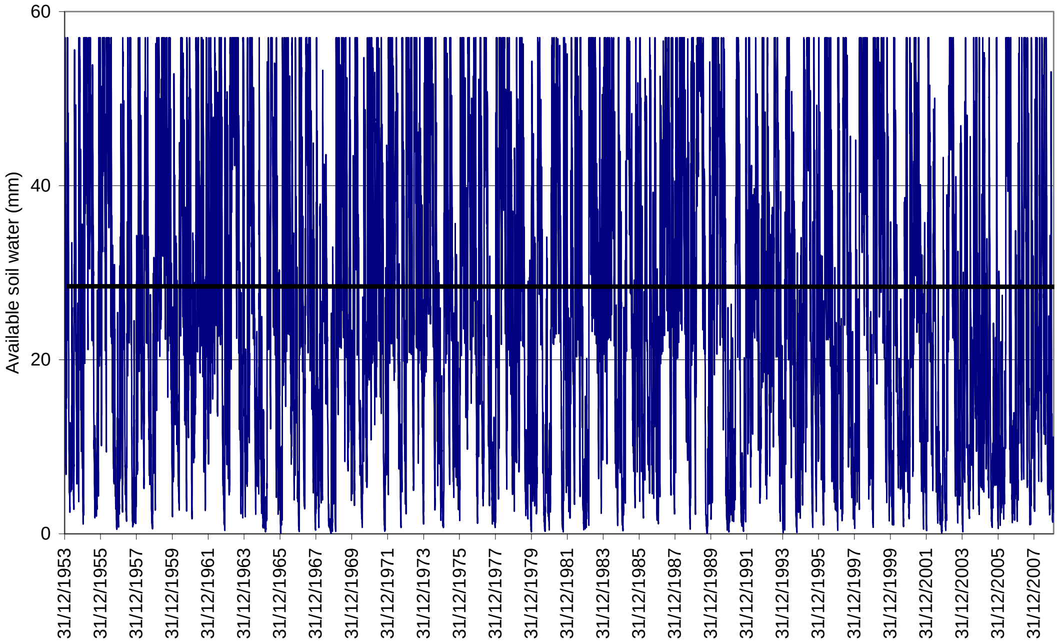

Figure 44: Available soil water (mm) each day assuming 0.5 ha of roof and 500 m3 tank. 50% of field capacity (28 mm) is marked as a thick line.

An average 77% of the roof runoff was utilised in the 1000 m^3 tank system. The annual 'turnover' in the tank was 3.5 times. Approximately 23% of the potential water was lost via overtopping.

Percolation increased by 3 mm as the tank size increased from 500 to 1000 m^3. The soil moisture content results suggest that the soil is not being over irrigated.

Effect of storage volumes on soil water availability

Figure 45 shows the percentile distribution of volume of water in storage for three tank sizes. The minimum irrigation volume trigger was set at 200 m^3. In the 500 m^3 tank scenario the volume was less than this trigger in 62% of time. In the 1000 m^3 tank scenario this occurred in 46% of time. That is, the additional tank capacity enabled irrigation for an extra 16% of time.

Figure 45 compares the soil water regimes when water is supplied from a 250, a 500 or a 1000 m^3 tank. The soils are at 100% of holding capacity in 4 to 5% of time. All three scenarios have periods when there is less than 10 mm available water. The 50% of the soil water holding capacity is commonly taken as being the moisture level at which moisture stress commences. The 250 m^3 tank simulation has soil available water content less than 50% in 62% of time. In 55% of time the 500 m^3 simulation is less than this value, while the 1000 m^3 tank simulation is below the 50% moisture line in 48% of time. Obviously increasing tank volume resulted in reduced plant moisture stress. The extent to which plant moisture stress is acceptable depends on the uses of the irrigation area. If the park is used simply for local games and passive recreation then a higher degree moisture stress can be tolerated. Conversely if the field is used for semi professional games the appearance and usability of the surface becomes more important.

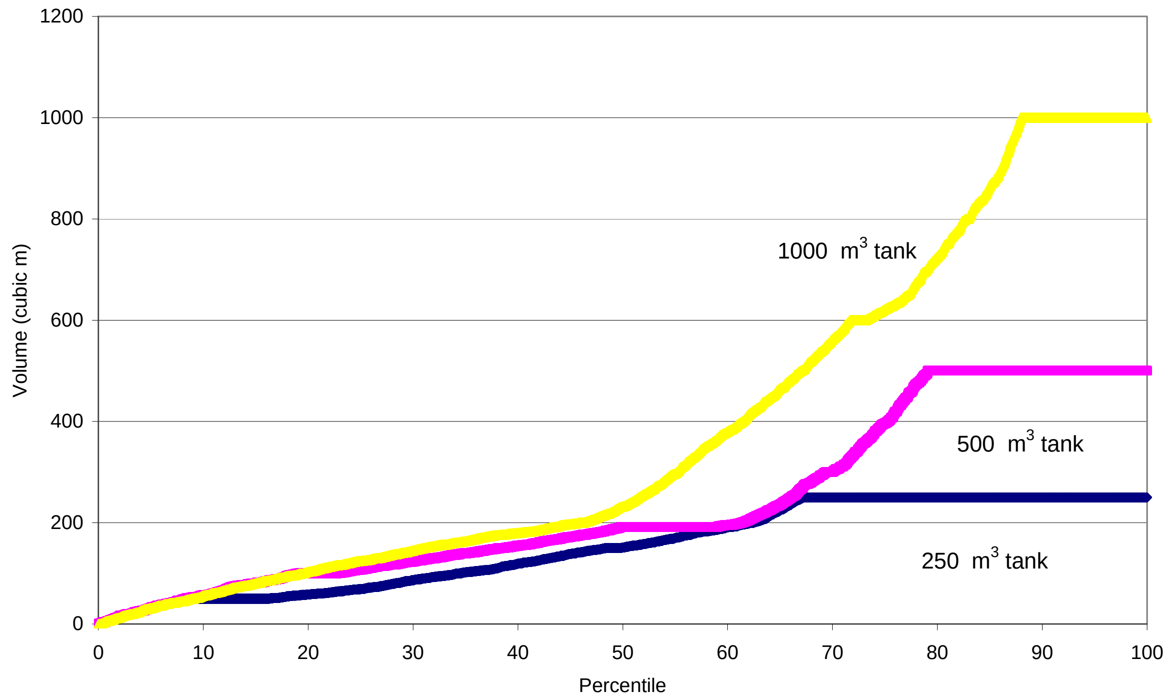

Figure 45: Percentile distribution of volume of water in storage for three tank sizes.

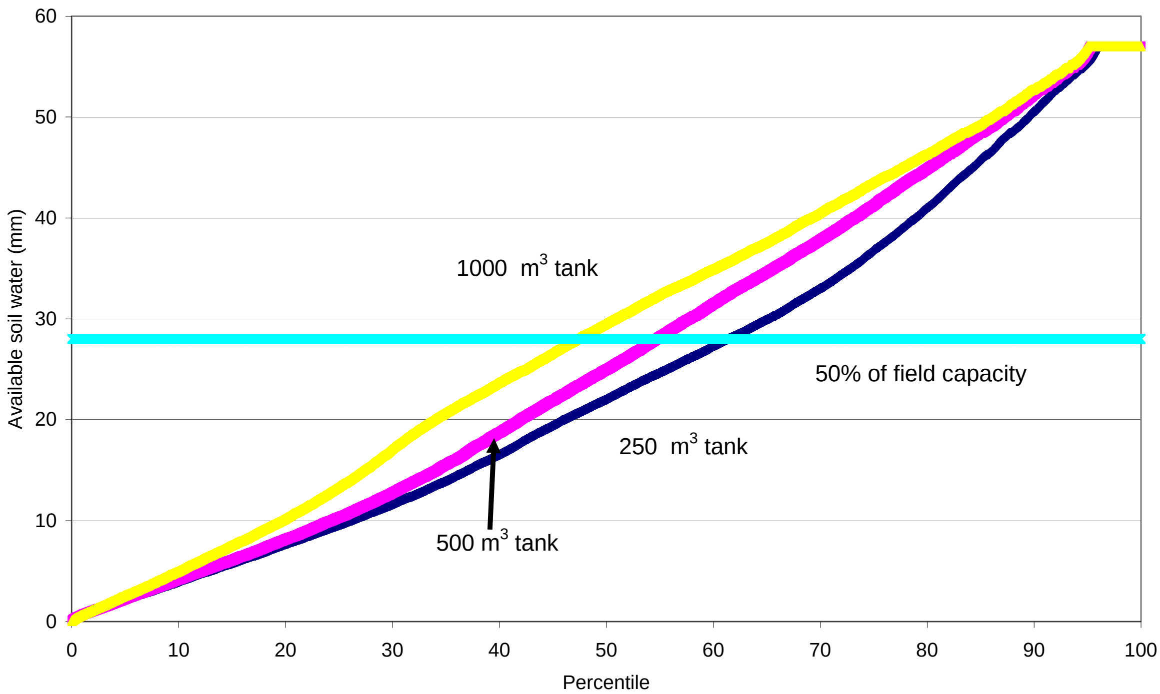

Figure 46: The effect of 250, 500 or 1000 m^3 irrigation tanks on the percentile distribution of available soil water.

If a long term average irrigation of 500 mm/year is to be maintained, then the combination of a 0.5 ha catchment plus a 1000 m^3 tank, which supplies 281 mm of effective irrigation/year, would require a top-up of 219 mm or 1.75 ML/year of irrigation onto the 0.8 ha sportsground. If a 500 m^3 tank were installed it would supply 199 mm of effective irrigation, so another 301 mm of water or 3.6 ML/year would be required.

Depending on Council resources it may be an option to increase irrigation on the high usage portions of the field and reduce irrigation elsewhere.

3.3.7 Performance based on MUSIC simulations

Performance was also estimated using the MUSIC software. Table 34 summarises the performance of the proposed system. Tank sizes of 250, 500 and 1000 m^3 were compared. The catchment was 0.5 ha of impervious factory roof. The irrigation demand of the 0.8 ha sports field was set at 640 mm (which assumes a crop factor of 0.7).

Table 34: Effect of irrigation tank size on the volume of water irrigated and the contaminant load removed from the runoff.

Component	Inflow	250 m^3 tank	500 m^3 tank	1000 m^3 tank	250 m^3 tank	500 m^3 tank	1000 m^3 tank	BBCCI Targets for new redevelopments (% reduction)
		Outflow			%reduction in flow or contaminant load			
Flow (ML/yr)	4.35	1.62	1.03	0.61	63	76	86	Not listed
Total Suspended Solids (kg/yr)	955	216	130	61.3	77	87	94	75
Total Phosphorus (kg/yr)	1.87	0.521	0.309	0.163	72	83	91	50
Total Nitrogen (kg/yr)	9.12	3.26	2.07	1.21	64	77	87	35
Gross Pollutants (kg/yr)	118	0	0	0	100	100	100	Not listed

The roof runoff was estimated at 4.35 ML/year. The volume captured ranged from 63% of runoff for the 250 m^3 tank to 86% in the 1000 m^3 tank.

Depending on the tank size and contaminant type between 64 and 100% of the contaminant loads were removed from the stormwater flow which entered the tanks. All tank sizes resulted contaminant reductions greater than the Botany Bay Water Quality Objectives for redeveloped areas.

Table 35 shows the effect of tank volume on the water and phosphorus balance for the irrigation system.

Table 35: Effect of tank volume on the water and phosphorus balance for the irrigation system.

Tank volume	250 m^3	500 m^3	1000 m^3	250 m^3	500 m^3	1000 m^3
Component	Flow (ML/yr)			Total Phosphorus (kg/yr)		
Flow In	4.35			1.9		
Overflow/bypassed	1.62	1.03	0.61	0.6	0.3	0.2
Reuse Supplied	2.7	3.3	3.8	0.4	0.5	0.6
Reuse Requested	6.4			Not applicable		
% Reuse Demand Met	43	53	60	NA	NA	NA

Table 35 shows that the volume of water bypassing or overflowing the tanks decreases markedly as the tank size increases from 250 to 1000 m^3. The increased tank size allows the percentage demand met to increase from 43 to 60%. The analysis also shows the P load in the stormwater is reduced as the tank size increases.

Supplying irrigation water costs Council money as well as using a valuable resource instead of using stormwater as a substitute. However the cost/ML of water needs to be considered.

3.3.8 Estimated Costs

The MUSIC package was used to estimate the costs of the proposed system. The results are summarised in Table 36.

Table 36: Cost components for the various sizes of tanks.

Component	250 m^3	500 m^3	1000 m^3
Capital Cost	$500,000	$555,000	$655,000
Annual Maintenance Cost	$15,000	$15,000	$15,000
Decommissioning Cost	$10,000	$10,000	$10000
Real Discount Rate (%)	5.5	5.5	5.5
Annual Inflation Rate (%)	2	2	2
Life Cycle Cost of Rainwater Tank ($2010)	$650,000	$810,000	$910,000

The system was assumed to last 50 years. The cost of the irrigation system was not included as there is already an irrigation system on site. The main difference in costs is the cost of the tank.

Table 37shows the costs per unit of water or contaminant used for irrigation.

Table 37: Cost per unit of stormwater treated/ irrigated or contaminant removed[1].

Component	250 m^3	500 m^3	1000 m^3
Equivalent Annual Payment Cost of the Asset (2010$/annum)	$13,000	$16,172	$18,128
Equivalent Annual Payment/ML of stormwater irrigated/annum	$4,745	$4,842	$4,771
Equivalent Annual Payment/kg Total Suspended Solids/annum	$17	$19	$20
Equivalent Annual Payment/kg Total Phosphorus/annum	$9,647	$10,613	$10,620
Equivalent Annual Payment/kg Total Nitrogen/annum	$2,229	$2,298	$2,292
Equivalent Annual Payment/kg Gross Pollutant/annum	$111	$138	$150

[1.] Note that all gross pollutants entering the stormwater system were assumed to have been retained on grates before entering the tanks.

The results show that the water substitution costs an average of $4800/ML. This is more than treble the current cost of potable water. However the system has additional benefits in that the peak outflow rates are reduced. Minimum cost/unit of contaminant removed occurs for the 500 m^3 tank.

3.3.9 Conclusions

The combination of a 0.5 ha roof catchment and 500 or 1000 m^3 of irrigation storage can supply significant quantities of irrigation water. The main advantage of the larger tank is that it supplies more water in the midrange situation. If 10% of available water (5.7 mm still available) indicates severe moisture stress, then severe stress occurs in 11% of the time for the 1000 m^3 simulation and 14% of time for the 500 m^3 simulation.

The additional tank capacity of the 1000 m^3 tank compared with the 500 m^3 tank resulted in sufficient water for irrigation for an extra 12% of time.

The 500 m^3 tank system reduced catchment runoff by 3.3 ML while the 1000 m^3 system reduced catchment runoff by some 3.8 ML.

These differences are not large and it may be simpler to have the 500 m^3 tank and rely on potable water supplies during extreme drought conditions.

3.4 SWQ9 + WR – Use of Sealed Wetland in Camdenville Basin to Treat and Enable Reuse of Catchment Runoff

3.4.1 Overview

Currently runoff from the 25.4 ha Camdenville catchment is discharged into the SWC stormwater system. There is no mechanism available for reducing the contaminant load exiting the area.

It is recognised that there is a risk of influencing the distribution and discharge of landfill leachate and gases if the base of the Camdenville detention basin is sealed. However the potential benefits of having a 'permanent' wetland in the basin are likely to be substantial. For example a basin will allow significant water quality improvement.

Additionally the use of a relatively large wetland offers the opportunity to treat a significant volume of stormwater. Wetlands are efficient at removing trace metals such as zinc. Zinc is likely to be a major contaminant in catchments such as Camdenville, where zinc coated roofs are common (Duncan, 1999).

Initial modelling of the wetland performance with respect to removal of contaminant loads including zinc was undertaken.

The objective of this investigation is to identify potential issues, benefits and costs associated with adapting the Camdenville Basin to act as a stormwater treatment wetland as well as a reservoir to supply water to irrigate Camdenville Park.

3.4.2 Modelling inputs

The basin was assumed to have a full water level of 0.5m. The basin would contain approximately 3340 m^3 of water. The maximum daily inflow to the basin was set at 6680 m^3, or double the maximum storage volume. The catchment area was set at 25.4 ha. A daily time step model, developed by Woodlots and Wetlands, was used with daily rainfall and evaporation for the period 1954 to 2009 at Sydney airport. Figure 47 shows the conceptual flow paths with proposed layout presented in Figure 48.

The estimated concentrations of P and zinc (Zn) in stormwater were 0.355 mg/L and 0.36 mg/L respectively (from Fletcher, et al, 2004). Zinc was selected as it is a major contaminant from areas with zinc coated roofs. Additionally it is toxic to aquatic biota at low concentrations, but would have minimal impact on irrigated vegetation at the anticipated concentrations

Zinc removal rates were derived from a range of publications, with the North American Wetland Data base being the primary source.

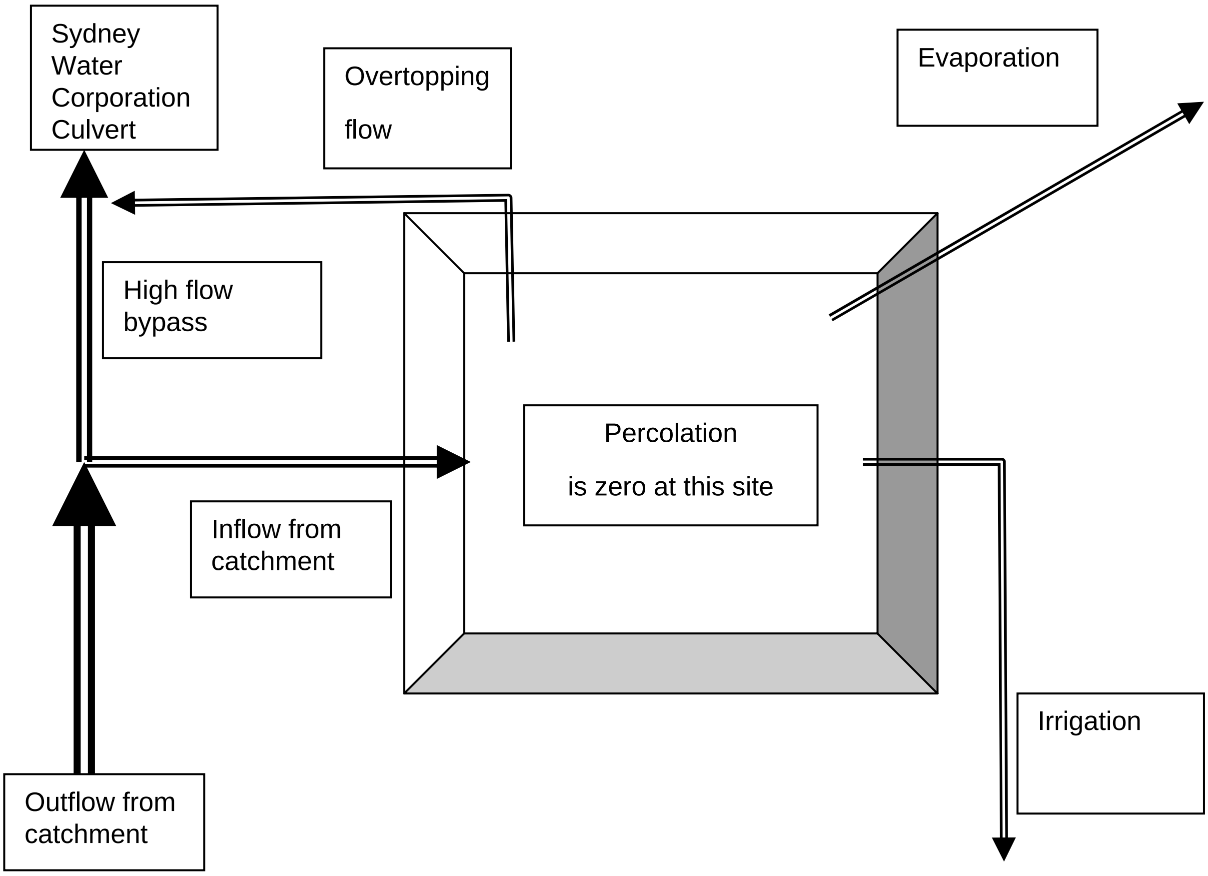

Figure 47: Conceptual drawing of the wetland water pathways.

Figure 48: Proposed layout of wetland system.

3.4.3 Modelling results

Table 38 summarises the modelling results.

Table 38: Effect of using a wetland at Camdenville Park to reduce mass balance and concentrations of two contaminants exiting the catchment.

Attribute	Unit	P	Zn
Contaminant mass in catchment runoff	kg/year	52	52
Contaminant mass into wetland	kg/year	47	47
Contaminant mass bypassing the wetland	kg/year	5	5
Contaminant mass in outflow exiting the wetland	kg/year	35	17
Contaminant mass in irrigation water	kg/year	0.57	0.05
Contaminant mass retained in wetland	kg/year	11.0	30.8
Concentration in wetland inflow	mg/L	0.36	0.36
Concentration in wetland outflow	mg/L	0.2144	0.091
Concentration in irrigation water	mg/L	0.107	0.013
Contaminant loading onto 0.8 ha of irrigated land	kg/year	0.84	0.10

Setting the inlet throttle at 6680 m^3/day resulted in some 9% of the runoff flowing directly to the stormwater drainage system. That is, the model assumed that approximately 91% of the catchment runoff entered the wetland.

According to the data in Table 38, the mass of P exiting the wetland via overflows was approximately double that of zinc. The reason for this is that the removal rate of Zn in a wetland is greater than that of P. A larger quantity of zinc was therefore retained in the wetland.

Figure 49 shows the effect of the wetland in reducing zinc concentration in water either overtopping the wetland or being irrigated. The wetland has a major impact on zinc concentrations in outflowing water, with the concentrations being less than the ANZECC guidelines (2000) for either fresh or marine waters in 80 to 90% of time. The concentration in the irrigation waters was typically even less, with the irrigation water meeting ANZECC Guidelines in over 95% of time.

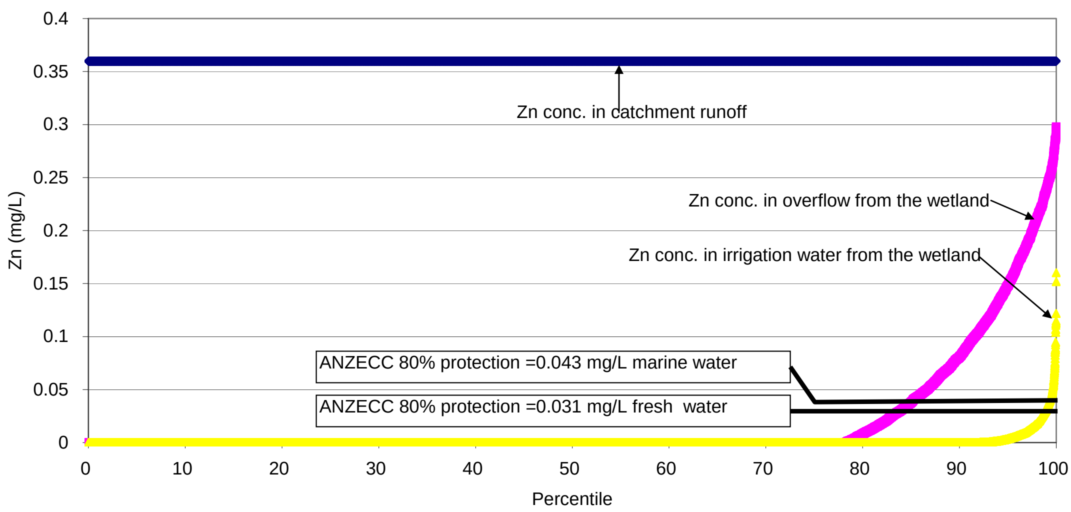

Figure 49: Percentile distribution of Zinc concentration (mg/L) in water exiting the 25.4 ha catchment, in overflow from the wetland and in irrigation water (mg/L).

The reason the irrigation water has less zinc concentration than overflowing water is that it is retained for a longer period than the overflows. The extra residence time allow for a higher % removal. These results suggest that the wetland could play a major role in removal of contaminant loads from the stormwater.

MUSIC modelling was used to assess the removal of other contaminants. Table 39 summarises the results.

Table 39: Combined effect of a wetland plus irrigation on the reduction in stormwater volumes and contaminant loads[2].

Component	Flow (ML/Y)	TSS (kg/Y)	P (kg/Y)	N (kg/Y)	Gross pollutants (kg/Y)
Flow In	157	32141	64	450	4592
ET Loss	6	0	0	0	0
Infiltration Loss	0	0	0	0	0
Low Flow Bypass Out	0	0	0	0	0
High Flow Bypass Out	73	16847	31	212	1879

Component	Flow (ML/Y)	TSS (kg/Y)	P (kg/Y)	N (kg/Y)	Gross pollutants (kg/Y)
Weir Out	71	2338	10	119	0
Reuse Supplied	8	98	1	10	0
Reuse Requested	8	0	0	0	0
% Reuse Demand Met	100	0	0	0	0
% Load Reduction	9 (via irrigation)	40	36	26	59
Treated/ removed	85	12956	23	118	2713
% treated/removed	54	40	36	26	59

2. Wetland area 6680 m^2, 0.5m deep. Irrigation area 0.8 ha. The high flow bypass was 0.125 m^3/sec.

The average annual inflow to the wetland was 85 ML. Evapotranspiration accounted for 6 ML/y while 73 ML/y exited via overtopping and 8 ML/was utilised for irrigation. TSS, P and N loads were reduced by 40%, 36% and 25% respectively. Irrigation plus evapotranspiration reduced outflow by 9%, however 54% of the flow was either treated or removed.

3.4.4 Estimated Costs

The cost software of the MUSIC program and Rawlinsons (2010) were used to estimate the costs per unit of water and contaminant removed. Table 40 shows the cost components for the proposed system. Table 41 shows the costs per unit of water or contaminant removed.

Table 40: Cost components for the development of Camdenville Basin as a stormwater quality and reuse wetland.

Life Cycle (yrs)	50
Construction Cost	$680,000
Annual Maintenance Cost	$25,000
Annual Establishment Cost	$0
Establishment Period (yrs)	0
Renewal/Adaptation Cost	$11,000
Renewal Period (yrs)	1
Decommissioning Cost	$220,000
Real Discount Rate (%)	5.5
Annual Inflation Rate (%)	2
Life Cycle Cost of Pond (2010$)	$1,250,000

Table 41: Cost per unit of stormwater treated or contaminant removed.

Equivalent Annual Payment Cost of the Asset (2010$/annum)	**$25,059**
Equivalent Annual Payment/ML of water removed/annum	$1772
Equivalent Annual Payment/ML of water removed or treated/annum	$850
Equivalent Annual Payment/kg Total Suspended Solids/annum	$2
Equivalent Annual Payment/kg Total Phosphorus/annum	$1,133
Equivalent Annual Payment/kg Total Nitrogen/annum	$209
Equivalent Annual Payment/kg Gross Pollutant/annum	$9

3.4.5 Conclusions

The creation of a 'permanent' wetland in the current Camdenville Basin results in over 100 ML/year of stormwater being treated. The cost of this treatment/ML is significantly less than the cost /unit treatment of small bioretention systems in established streets.

Additionally the system provides all the irrigation requirements for Camdenville Oval. Approximately 40% of the TSS, 36% of the P and 25% of the N load of the 25.4 ha catchment has been removed by this combination of a wetland plus an irrigation system. The system treated 54% of the catchment outflow.

Creating a 'permanent' wetland does create significant environmental issues relating to landfill leachate and gas management. However there is potential to substantially reduce contaminant yield from this portion of the subcatchment. This approach may become more important if SWC commenced to charge for the contaminated liquid being pumped out of the basin at present.

3.4.6 Issues

The main issues are:

- The interaction with groundwater needs to be managed to avoid contamination in other areas
- The current drainage at the intersection of May St, Unwins Bridge Road Campbell Road and Bedwin Road needs to be modified to enable a portion of the stormwater to be captured. This is discussed in detail in the flood management section of the current report.
- SWC needs to be involved in the decision making process
- The water needs to be of sufficient quality for safe irrigation of a public space with open access. The cost of disinfection is included in table 33.

4.0 COSTS AND COST PER UNIT OF STORMWATER TREATED OR CONTAMIANT REMOVED

Capital and estimated operational costs were derived from our own experiences, form Council data and from Rawlinsons (2010). The costs were then used to calculate Net Present Value and annualised costs per unit of benefit. The approach was used for each of the major on ground works. The costs for individual household rainwater tanks were not included as the exceptions

The tables below show the estimated capital costs for each major option.

4.1 SWQ1 + WR - Rainwater Tanks

Tank installation, backflow prevention and plumbing to toilets, hot water system and gardens allow $5000/existing dwelling. Note that this is high compared with installation during construction.

4.1.1 SWQ2 – Bioretention Basin at Simpson Park

Costs are based on a 350 m^2 bioretention basin.

Table 42: Estimated Costs for SWQ2 – Bioretention Basin at Simpson Park

Component	Unit	Price data source	Rate	Quantity	Cost ($2010)
Preliminaries					
Survey, geotechnical, services and other investigations	LS (Lump sum)	Own data	$40,000	1	$40,000
Detailed design	LS	Own data	$20,000	1	$20,000
Review of Environmental factors, including community consultation	LS	Own data	$20,000	1	$20,000
Permits	LS	Own data	$5,000	1	$5,000
Dilapidation survey (works only within park and Council gutters)	LS	Own data	$5,000	1	$5,000
Establishment					
Mobilisation, OH&S, site office & facilities	LS	Own data	$2,000	1	$2,000
Sediment and erosion control plan and measures	LS	Own data	$3,000	1	$3,000
Traffic management	LS	Own data	$5,000	1	$5,000
Site clearance for works			350 + 300 m^2 surrounds and pipes line locations		
Above ground structures	LS	Own data	$2,000	1	$2,000
Removing/ modifying existing structures-gutter inlet system	LS	Own data	$2,000	2	$4,000
Excavation of trench					
Soil	m^3	Rawlinsons	$54.10	120	$6,492
Pipes-375 mm ID	m	Rawlinsons	$156	120	$18,720
Back filling of trench	m^3	Rawlinsons	$184.90	120	$22,188
Restore surface and replace turf	m^2	Rawlinsons	$10.00	240	$2,400
Installation of bioretention basin					
Excavate soil (500 mm deep*350m^2 area)	m^3	Council	$78.75	175	$13,781
Install 90 mm ID slotted UPVC collection pipes on base	m	Council	$26	120	$3,150
Install drainage layer graded 3 mm D_{50} 150 mm thick	m^3	Council	$40	52.5	$2,100
Install 100 mm thick coarse sand transition layer	m^3	Council	$40	35	$1,400
Supply and spread 50mm topsoil. Smooth join to local surfaces	m^2	Council	$32	17.5	$560
Supply and plant vegetation	m^2	Council	$35	350	$12,250
Connect percolate collection pipes to 150 mm ID pipe, drain to collection point, connect into pit. Include connections	m	Rawlinsons	$50	70	$3,500

Component	Unit	Price data source	Rate	Quantity	Cost ($2010)
Disposal of excavated soil (load and haul to 10 km)	m^3	Council	$32	175	$5,600
Tipping fees	t	Council	$17	228	$3,876
Others					
Project management (10%)					$19,814
Contingency (20%)					$39,628
Subtotal					$261,460
GST					$ 26,146
Total					$287,606

4.2 SWQ3 – Bioretention Basin at TAFE Park

Costs are based on a 300 m^2 bioretention basin.

Table 43: Estimated Costs for SWQ3 – Bioretention Basin at TAFE Park

Component	Unit	Price data source	Rate	Quantity	Cost ($2010)
Preliminaries					
Survey, geotechnical, services and other investigations	LS (Lump sum)	Own data	$10,000	1	$10,000
Detailed design	LS	Own data	$15,000	1	$15,000
Review of Environmental factors, including community consultation	LS	Own data	$20,000	1	$20,000
Permits	LS	Own data	$5,000	1	$5,000
Dilapidation survey (works only within park and Council gutters)	LS	Own data	$5,000	1	$5,000
Establishment					
Mobilisation, OH&S, site office & facilities	LS	Own data	$2,000	1	$2,000
Sediment and erosion control plan and measures	LS	Own data	$3,000	1	$3,000
Traffic management	LS	Own data	$5,000	1	$5,000
Site clearance for works					
Above ground structures	LS	Own data	$3,000	1	$3,000
Removing/ modifying existing structures-gutter inlet system	LS	Own data	$2,000	2	$4,000
Excavation of trench					
Soil	m^3	Rawlinsons	$54.10	50	$2,705
Pipes-375 mm ID	m	Rawlinsons	$156	50	$7,800
Back filling of trench	m^3	Rawlinsons	$184.90	50	$9,245
Restore surface and replace turf	m^2	Rawlinsons	$10.00	100	$1,000
Installation of bioretention basin					
Excavate soil (700 mm deep*300m^2 area)	m^3	Council	$78.75	140	$11,025
Install 90 mm ID slotted UPVC collection pipes on base	m	Council	$26	50	$1,313
Install drainage layer graded 3 mm D_{50} 400 mm thick	m^3	Council	$40	80	$3,200
Install 100 mm thick coarse sand transition layer	m^3	Council	$40	20	$800
Supply and spread 250 mm topsoil. Smooth join to local surfaces	m^2	Council	$32	30	$960
Supply and plant vegetation	m^2	Council	$35	200	$7,000
Connect percolate collection pipes to 150 mm ID pipe, drain to collection point, connect into pit. Include connections	m	Rawlinsons	$50	10	$500
Disposal of excavated soil (load and haul to 10 km)	m^3	Council	$32	140	$4,480

Component	Unit	Price data source	Rate	Quantity	Cost ($2010)
Tipping fees	t	Council	$17	196	$3,332
Others					
Project management (10%)					$12,203
Contingency (20%)					$24,406
Subtotal					$161,968
GST					$16,197
Total					$178,165

4.3 SWQ4 – Bioretention Swale at Pemell Street, Newtown

Costs are based on a 330 m^2 bioretention swale.

Table 44: Estimated Costs for SWQ4 – Bioretention Swale in Pemell St, Newtown

Component	Unit	Price data source	Rate	Quantity	Cost ($2010)
Preliminaries					
Survey, geotechnical, services and other investigations	LS (Lump sum)	Own data	$10,000	1	$10,000
Detailed design	LS	Own data	$15,000	1	$15,000
Review of Environmental factors, including community consultation	LS	Own data	$15,000	1	$15,000
Permits	LS	Own data	$5,000	1	$5,000
Dilapidation survey (Council gutters, foot paths and potential impacts of private fences and other structures)	LS	Own data	$10,000	1	$10,000
Establishment					
Mobilisation, OH&S, site office & facilities	LS	Own data	$2,000	1	$2,000
Sediment and erosion control plan and measures	LS	Own data	$3,000	1	$3,000
Traffic management	LS	Own data	$5,000	1	$5,000
Site clearance for works			330 m^2 surrounds and pipes line locations		
Above ground structures	LS	Own data	$3,000	1	$3,000
Removing/ modifying existing structures- gutter inlet system	LS	Own data	$5,000	1	$5,000
Excavation of bioretention trench					
Break up and remove concrete paths	m^2	Own data	$64.46	250	$16,115
Remove, cut inlets and replace kerb	m	Council	$100.00	125	$12,500
Place bollards to prevent vehicle access to swale	m	Council	$125.00	125	$15,625
Excavate soil (1m deep*330m^2 area)	m^3	Council	$78.75	330	$25,988
Installation of bioretention swale (filter area 250 m^2-125 m^2. Disturbance area 330 m^2)					
Supply and install liner on road side of trench	m		$30	125	$3,750
Install 90 mm ID slotted UPVC collection pipes on base	m	Council	$26	125	$3,281
Install drainage layer graded 5 mm D_{50} 400 mm thick	m^3	Council	$40	100	$4,000
Install 100 mm thick coarse sand transition layer	m^3	Council	$40	25	$1,000
Supply and spread 250 mm topsoil. Grade to bollards	m^2	Council	$32	62.5	$2,000

Supply and plant vegetation	m^2	Council	$35	250	$8,750
Connect percolate collection pipes to 100mm ID pipe, drain to collection point, connect into pit. Include connections	m	Rawlinsons	$50	250	$12,500
Install access over swale for each pair of dwellings	LS	Own	$1,000	10	$10,000
Adapt current roof drainage from each dwelling to enter swale	LS	Own	$800	20	$16,000
Disposal of excavated soil (load and haul to 10 km)	m^3	Council	$32	350	$11,200
Tipping fees	t	Council	$17	350	$5,950
Others					
Project management (10%)		Own			$21,571
Contingency (20%)		Own			$43,142
Subtotal					$286,371
GST					$28,637
Total					$315,009

4.4 SWQ5 – Bioretention Swale at Goodsell Street, St Peters

Costs are based on a 225 m^2 bioretention swale.

Table 45: Estimated costs for SWQ5 – Bioretention Swale in Goodsell St, St Peters

Component	Unit	Price data source	Rate	Quantity	Cost ($2010)
Preliminaries					
Survey, geotechnical, services and other investigations	LS (Lump sum)	Own data	$15,000	1	$15,000
Detailed design	LS	Own data	$15,000	1	$15,000
Review of Environmental factors, including community consultation	LS	Own data	$15,000	1	$15,000
Permits	LS	Own data	$5,000	1	$5,000
Dilapidation survey (Council gutters, foot paths and potential impacts of private fences and other structures)	LS	Own data	$20,000	1	$20,000
Establishment					
Mobilisation, OH&S, site office & facilities	LS	Own data	$2,000	1	$2,000
Sediment and erosion control plan and measures	LS	Own data	$3,000	1	$3,000
Traffic management	LS	Own data	$5,000	1	$5,000
Site clearance for works	364 m^2 surrounds and pipes line locations				
Above ground structures	LS	Own data	$3,000	1	$3,000
Removing/ modifying existing structures- gutter inlet system	LS	Own data	$5,000	1	$5,000
Adapt design around traffic calming area	LS	Own data	$5,000	1	$5,000
Excavation of bioretention trench					
Break up and remove concrete paths	m^2	Own data	$64.46	0 (none)	$0
Remove, cut inlets and replace kerb	m	Council	$100.00	125	$12,500
Place bollards to prevent vehicle access to swale	m	Council	$125.00	125	$15,625
Excavate soil (1m deep*(1.8*125 m^2 area)	m^3	Council	$78.75	225	$17,719
Installation of bioretention swale (filter area 225 msq-125m*1.8m. Disturbance area 330 m^2)					
Supply and install liner on road side of trench	m		$30	125	$3,750
Install 90 mm ID slotted UPVC collection pipes on base	m	Council	$26	125	$3,281
Install drainage layer graded 3 mm D_{50} 400 mm thick	m^3	Council	$40	90	$3,600
Install 100 mm thick coarse sand transition layer	m^3	Council	$40	22.5	$900
Supply and spread 250 mm topsoil. Grade to bollards	m^2	Council	$32	56.25	$1,800

Component	Unit	Price data source	Rate	Quantity	Cost ($2010)
Supply and plant vegetation	m^2	Council	$35	225	$7,875
Connect percolate collection pipes to 100mm ID pipe, drain to collection point, connect into pit. Include connections	m	Rawlinsons	$50	225	$11,250
Install access over swale for each pair of dwellings	LS	Own data	$1,000	16	$16,000
Adapt current roof drainage from each dwelling to enter swale	LS	Own data	$800	32	$25,600
Disposal of excavated soil (load and haul to 10 km)	m^3	Council	$32	225	$7,200
Tipping fees	t	Council	$17	315	$5,355
Others					
Project management (10%)					$22,546
Contingency (20%)					$45,091
Subtotal					$293,092
GST					$29,309
Total					$322,401

4.5 SWQ6 – Rain Gardens for Multi-unit Dwellings

The costs are based on the assumption that 100 m^2 of roof drains into a 30 m^2 rain garden. The rain garden in on the roof, so the cost/ m^2 (\$1000/ m^2) is higher than the cost for a garden at ground level (\$200/ m^2). MUSIC default value is \$25,898 for a 30 m^2 roof rain garden. This figure was used in the cost assessment.

4.6 SWQ7 + WR – Irrigate Camdenville Oval by Using Street Runoff from Camdenville Oval Catchment

The table below contains costs for a 250 m^3 tank system

Table 46: Estimated Costs for SWQ7 + WR – Irrigate Camdenville Oval using Street Runoff (250 m^3 tank)

Component	Unit	Price data source	Rate	Quantity	Cost ($2010)
Preliminaries					
Survey, geotechnical, services and other investigations	LS	Own data	$5,000	1	$5,000
Detailed design	LS	Own data	$5,000	1	$5,000
Review of Environmental factors, including community consultation	LS	Own data	$5,000	1	$5,000
Permits	LS	Own data	$5,000	1	$5,000
Dilapidation survey (works only within park and Council gutters)	LS	Own data	$5,000	1	$5,000
Establishment					
Mobilisation, OH&S, site office & facilities	LS	Own data	$2,000	1	$2,000
Sediment and erosion control plan and measures	LS	Own data	$3,000	1	$3,000
Traffic management	LS	Own data	$0	1	$0
Site clearance for works					
Above ground structures	LS	Own data	$3,000	1	$3,000
Removing/ modifying existing structures- inlet system to basin (included in stormwater flow study	LS	Own data	$0	2	$0
Excavation for pipework					
Soil excavation from kerb to sump tank	m^3	Rawlinsons	$54.10	20	$1,084
Soil excavation from sump tank to irrigation storage tank	m^3	Rawlinsons	$54.10	90	$4,869
Soil excavation from irrigation storage tank to irrigation system		Rawlinsons	Rawlinsons	180	$9,738
Back filling of trenches	m^3	Rawlinsons	$184.90	87	$16,086
Returf/ make good to original surfaces	m^2	Rawlinsons	$30.00	145	$4,350
Tanks					
Sump tank to collect runoff	m^3	Own data	LS	1	$7,000
Irrigation tank 250 m3		Rawlinsons		250	$69,900
Pipes, pumps and water treatment					
Electrical connection-extremely dependant on site configuration design	LS		$40,700	1	$40,700
Pipes-375 mm ID from stormwater pit (by others) to sump	m	Rawlinsons	$156	20	$3,120
Pipes-100mm ID from sump to irrigation tank	m	Rawlinsons	$49.00	90	$4,410

Component	Unit	Price data source	Rate	Quantity	Cost ($2010)
Pipes-150 mm ID from irrigation tank to irrigation mains	m	Rawlinsons	$87.00	180	$15,660
Pump from sump to irrigation tank (10L/sec flow)		Rawlinsons	$6,000	1	$6,000
Pump from sump to irrigation tank (35L/sec, 35m head)		Rawlinsons	$13,200	1	$13,200
Disinfection system (chlorination)		Own data	$8,000	1	$8,000
Others					
Project management (10%)					$23,712
Contingency (20%)					$52,166
Subtotal					$312,995
GST					$31,299
					$344,294

The table below contains costs for a 500 m^3 tank system

Table 47: Estimated Costs for SWQ7 + WR – Irrigate Camdenville Oval using Street Runoff (500 m^3 tank)

Component	Unit	Price data source	Rate	Quantity	Cost ($2010)
Preliminaries					
Survey, geotechnical, services and other investigations	LS	Own data	$5,000	1	$5,000
Detailed design	LS	Own data	$5,000	1	$5,000
Review of Environmental factors, including community consultation	LS	Own data	$5,000	1	$5,000
Permits	LS	Own data	$5,000	1	$5,000
Dilapidation survey (works only within park and Council gutters)	LS	Own data	$5,000	1	$5,000
Establishment					
Mobilisation, OH&S, site office & facilities	LS	Own data	$2,000	1	$2,000
Sediment and erosion control plan and measures	LS	Own data	$3,000	1	$3,000
Traffic management	LS	Own data	$0	1	$0
Site clearance for works		Own data			
Above ground structures	LS	Own data	$3,000	1	$3,000
Removing/ modifying existing structures- inlet system to basin (included in stormwater flow study	LS	Own data	$0	2	$0
Excavation for pipework					
Soil excavation from kerb to sump tank	m^3	Rawlinsons	$54.10	20	$1,082

Component	Unit	Price data source	Rate	Quantity	Cost ($2010)
Soil excavation from sump tank to irrigation storage tank	m^3	Rawlinsons	$54.10	90	$4,869
Soil excavation from irrigation storage tank to irrigation system		Rawlinsons	Rawlinsons	180	$9,738
Back filling of trenches	m^3	Rawlinsons	$184.90	87	$16,086
Returf/ make good to original surfaces	m^2	Rawlinsons	$30.00	145	$4,350
Tanks					
Sump tank to collect runoff	m^3	Own experience	LS	1	$7,000
Irrigation tank 500 m3		Rawlinsons		500	$110,900
Pipes, pumps and water treatment					
Electrical connection-extremely dependant on site configuration design	LS		$35,000	1	$35,000
Pipes-375 mm ID from stormwater pit (by others) to sump	m	Rawlinsons	$156	20	$3,120
Pipes-100mm ID from sump to irrigation tank	m	Rawlinsons	$49.00	90	$4,410
Pipes-150 mm ID from irrigation tank to irrigation mains	m	Rawlinsons	$87.00	180	$15,660
Pump from sump to irrigation tank (10L/sec flow)		Rawlinsons	$6,000	1	$6,000
Pump from irrigation tank to irrigation system (35L/sec, 35m head)		Rawlinsons	$13,200	1	$13,200
Disinfection system (chlorination)			$8,000	1	$8,000
Others					
Project management (10%)					$27,242
Contingency (20%)					$54,483
Subtotal					$354,140
GST					$35,414
Total					$389,554

4.7 SWQ8 + WR – Irrigate Camdenville Oval by Capturing Roof Runoff

The cost components for three tank sizes are shown below.

Table 48: Estimated Costs of SWQ8 + WR – Irrigate Camdenville Oval using Roof Runoff

Component	Unit	Price data source	Rate	Quantity	Cost ($2010) 250 m^3	Cost ($2010) 500 m^3	Cost ($2010) 1000 m^3
Preliminaries							
Survey, geotechnical, services and other investigations	LS		$40,000	1	$40,000	$40,000	$40,000
Detailed design	LS	Own data	$20,000	1	$20,000	$20,000	$20,000
Review of Environmental factors, including consultation with factory owners	LS	Own data	$20,000	1	$20,000	$20,000	$20,000
Permits	LS	Own data	$5,000	1	$5,000	$5,000	$5,000
Dilapidation survey (works on roofs, under road & within park)	LS	Own data	$20,000	1	$20,000	$20,000	$20,000
Establishment							
Mobilisation, OH&S, site office & facilities	LS	Own data	$2,000	1	$2,000	$2,000	$2,000
Sediment and erosion control plan and measures	LS	Own data	$3,000	1	$3,000	$3,000	$3,000
Traffic management	LS	Own data	$5,000	1	$5,000	$5,000	$5,000
Site clearance for works							
Above ground structures	LS	Own data	$5,000	1	$5,000	$5,000	$5,000
Connection of roof guttering to drainage system							
Removing/ modifying existing structures-gutter inlet system	LS	Own data	$15,000	1	$15,000	$15,000	$15,000
Collection tank adjacent to factory (91 m^3)	LS	Rawlinsons	$10,000	1	$10,000	$10,000	$10,000

Component	Unit	Price data source	Rate	Quantity	Cost ($2010) 250 m^3	Cost ($2010) 500 m^3	Cost ($2010) 1000 m^3
Excavation for pipework							
Soil excavation from factory roofs to collection tank	m	Rawlinsons	$54.10	40	$2,164	$2,164	$2,164
Soil excavation from collection tank to irrigation storage tank (including under Bedwin Rd	m	Rawlinsons	$200.00	90	$18,000	$18,000	$18,000
Soil excavation from irrigation storage tank to irrigation system	m	Rawlinsons	$54.10	180	$9,738	$9,738	$9,738
Returf/ make good to original surfaces	m^2	Rawlinsons	$30.00	145	$4,350	$4,350	$4,350
Pumps and pipes							
Irrigation tank 250, 500 or 1000 m3	LS	Rawlinsons		1	$69,900	$110,900	$179,300
Pump from sump to irrigation tank (10L/sec flow)		Rawlinsons	$6,000	1	$6,000	$6,000	$6,000
Pipes-125 mm ID under Bedwin Rd to south of Camdenville detention ponds.	m	Rawlinsons	$98	80	$7,840	$7,840	$7,840
Pump from sump to irrigation tank (10L/sec flow)		Rawlinsons	$6,000	1	$6,000	$6,000	$6,000
Pump from irrigation tank to irrigation system (35L/sec, 35m head)		Rawlinsons	$13,200	1	$13,200	$13,200	$13,200
Pipe from irrigation tank to irrigation area plus connections (class 12, 150 mm)	m	Rawlinsons	$138	234	$32,292	$32,292	$32,292
Disinfection system (chlorination)			$8,000	1	$8,000	$8,000	$8,000
Back filling of trench	m^3		$184.90	120	$22,188	$22,188	$22,188
Restore surface and replace turf	m^2		$10.00	240	$2,400	$2,400	$2,400

Component	Unit	Price data source	Rate	Quantity	Cost ($2010) 250 m³	Cost ($2010) 500 m³	Cost ($2010) 1000 m³
Others							
Project management (10%)					$34,707	$38,807	$45,647
Contingency (20%)					$69,414	$77,614	$91,294
Subtotal					$451,194	$504,494	$593,414
GST					$45,119	$50,449	$59,341
Total					$496,313	$554,943	$652,755

4.8 SWQ9 + WR – Use of Sealed Wetland in Camdenville Basin to Treat and Enable Reuse of Catchment Runoff

Assumes a 25.4 ha catchment draining to a 6680 m^2 basin, with irrigation onto a 0.8 ha sports area.

Table 49: Estimated Costs for SWQ9 + WR – Use of Sealed Wetland in Camdenville Basin to Treat and Enable Reuse of Catchment Runoff

Component	Unit	Price data source	Rate	Quantity	Cost ($2010)
Preliminaries					
Survey, geotechnical, services and other investigations	LS (Lump sum)	Own data	$40,000	1	$40,000
Detailed design	LS	Own data	$20,000	1	$20,000
Review of Environmental factors, including community consultation	LS	Own data	$20,000	1	$20,000
Permits	LS	Own data	$5,000	1	$5,000
Dilapidation survey (works only within park and Council gutters)	LS	Own data	$5,000	1	$5,000
Establishment					
Mobilisation, OH&S, site office & facilities	LS	Own data	$2,000	1	$2,000
Sediment and erosion control plan and measures	LS	Own data	$3,000	1	$3,000
Traffic management	LS	Own data	$5,000	1	$5,000
Site contaminant assessment	LS	Own data	$7,000	1	$7,000
Site clearance for works					
Above ground structures	LS	Own data	$3,000	1	$3,000
Removing/ modifying existing structures-gutter inlet system	LS	Own data	$2,000	2	$4,000
Levelling of site		Rawlinsons	$3	6600	$21,120
Mulch existing vegetation and retain	LS	Own data	$2,000		$2,000
Construction					
Weir wall-reinforced cement+ rockfill	LS	Own data	$20,000.00	1	$20,000
excavate and retain 0.2m topsoil (assumes suitable for reuse on site)		Own data	$23.30	1320	$30,756
Sump tank	m^3	Own data	LS	1	$7,000
Install bentonite sealing blanket	m^2	Own data	$20.00	6600	$132,000
Return surface 0.2m of topsoil		Own data	$10.00	1320	$13,200
Plant to aquatic macrophytes	m^2	Own data	$12.00	6600	$79,200
Install irrigation buffer tank (48 m^3)	LS	Rawlinsons		1	$7,450
Pipes-100mm ID from sump to irrigation tank	m	Rawlinsons	$49.00	90	$4,410
Pipes-150 mm ID from irrigation tank to irrigation mains	m	Rawlinsons	$87.00	180	$15,660
Pump from sump to irrigation tank (10L/sec flow)		Rawlinsons	$6,000	1	$6,000
Pump from sump to irrigation tank (35L/sec, 35m head)		Rawlinsons	$13,200	1	$13,200

Component	Unit	Price data source	Rate	Quantity	Cost ($2010)
Disinfection system (chlorination)		Own data	$8,000	1	$8,000
Others					
Project management (10%)					$47,400
Contingency (20%)					$94,799
Subtotal					$616,195
GST					$61,619
Total					$677,814

Summary of costs

Option	SWQ1 +WR	SWQ2	SWQ3	SWQ4	SWQ5	SWQ6	SWQ7+WR	SWQ8+WR	SWQ9+WR
Cost component	Rainwater tanks to allow substitution of stormwater for non potable water needs within individual and multi unit dwellings.	A bioretention basin in Simpson Park to improve the quality of stormwater exiting the surrounding 10.3 ha catchment	A bioretention basin in TAFE Park to improve the quality of stormwater exiting the surrounding 3.8 ha catchment	A bioretention swale along the southern side of Pemell St, Newtown to improve the quality of stormwater exiting the surrounding 1.18 ha catchment	A bioretention swale along the northern side of Goodsell St, St Peters to improve the quality of stormwater exiting the surrounding 1.23 ha catchment	Raingardens on redeveloping sites in the St Peters triangle area as part of the DCP for the locality	Stormwater collection tanks in Camdenville Park to collect catchment runoff and supply it as irrigation water to Camdenville Park	Stormwater collection tanks in Camdenville Park to collect runoff from nearby factory roofs to supply irrigation water for Camdenville Park	Adaptation of the existing Camdenville stormwater detention basin to collect and supply irrigation water to Camdenville Park
Comment	10% of individual dwellings	350 m^2 bioretention basin	200 m^2 bioretention basin	330 m^2 bioretention basin	225 m^2 bioretention swale	30 m^2 roof rain garden receiving from 100 m2 of roof	250 m^3 tank system	1000 m^3 tank system	24.5 ha catchment a 6680 m^2 basin, with 0.8 ha irrigation
Life Cycle (yrs)	25	50	50	50	50	50	50	50	50
Acquisition Cost	$1,145,000	$287,606	$178,000	$315,000	$322,401	$25,898	$344,294	$652,755	$677,814
Annual Maintenance Cost	$22,900	$18,932	$14,093	$19,239	$19,489	$4,193	$20,000	$15,000	$22,605
Annual Establishment Cost	$0	$0	$0	$0	$0	$0	$0	0	$0
Establishment Period (yrs)	0	0	0	0	0	0	0	0	0
Renewal/Adaptation Cost	$0	$8,739	$5,084	$8,996	$9,208	$1,202	$0	0	$10,610
Renewal Period (yrs)	1	1	1	1	1	1	1	1	1
Decommissioning Cost	$51,525	$94,150	$78,238	$138,455	$141,709	$10,149	$10,000	$10,000	$218,083
Real Discount Rate (%)	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Annual Inflation Rate (%)	2	2	2	2	2	2	2	2	2

Life Cycle Cost ($2010)	$1,460,429	$760,412	$506,676	$800,515	$815,915	$117,523	$682,275	$906,422	$1,252,971
Equivalent Annual Payment Cost of the Asset ($2010/annum)	$58,417	$15,208	$10,134	$16,010	$16,318	$2,350	$13,645	$18,128	$25,059
Equivalent Annual Payment/ML of stormwater volume reduction/annum	$8,891	$5,243	$3,400	$7,925	$10,596	Not applicable	$2,608	$4,796	$1,772
Equivalent Annual Payment/ML of stormwater treated or supplied/annum	$7,518	$911	$1,057	$3,450	$3,813	$87,030	$2,608	$4,771	$850
Equivalent Annual Payment/kg Total Suspended Solids/annum	$42	$2	$3	$14	$12	$170	$19	$20	$2
Equivalent Annual Payment/kg Total Phosphorus/annum	$20,378	$1,209	$1,648	$10,679	$9,484	$147,812	$7,666	$10,620	$1,133
Equivalent Annual Payment/kg Total Nitrogen/annum	$3,128	$391	$422	$2,007	$2,075	$26,883	$990	$2,292	$209
Equivalent Annual Payment/kg Gross Pollutant/annum	$282	$8	$14	$80	$67	$976	$80	$154	$9

The comparison of cost per unit of water utilised or treated and the cost per unit of contaminant removed shows that Option 8 is the most cost efficient. Option 2 is the next most cost efficient

APPENDIX D

Water Management Options – Cost Estimates

Culvert/Pipe and Pit Laying				Unit	Price from Rawlinson 2007	Rate	Quantity	Cost
1	**Preliminaries**							
	1.1	Survey, geotechnical and other investigations		LS		20,000.00	1.00	20,000.00
	1.2	Detailed design		LS		100,000.00	1.00	100,000.00
	1.3	Review of environmental factors		LS		7,500.00	1.00	7,500.00
	1.4	Permits		LS		5,000.00	1.00	5,000.00
	1.5	Dilapidation survey		LS		30,000.00	1.00	30,000.00
2	**Establishment**							
	2.1	Mobilisation, OH&S and site camp		LS		6,000.00	1.00	6,000.00
	2.2	Erosion and sediment control measures		LS		7,500.00	1.00	7,500.00
	2.3	Traffic management		LS		20,000.00	1.00	20,000.00
	2.4	Site clearance for works		m2			2,030.79	-
		2.4.1	Above ground structures and trees	LS		10,000.00	1.00	10,000.00
		2.4.2	Cable location	LS		5,000.00	1.00	5,000.00
	2.5	Removing existing structures				-		-
		2.5.1	Pits	Item		200.00	10.00	2,000.00
		2.5.2	Culverts	m		50.00	610.60	30,530.00
	2.6	Diversion channel, if required		LS		10,000.00	1.00	10,000.00
3	**Excavation of trench**			**m3**			**3,292.15**	**-**
	3.1	Soil		m3	37.50	48.15	2,445.99	117,774.42
	3.2	Road surface		m3		-	846.16	-
		3.2.1	Breakup and remove reinforced concrete ground slab 100mm thick	m2	50.20	64.46	-	-
		3.2.2	Breakup and remove bitumen paving with basecourse under	m2	2.95	3.79	1,692.33	6,410.20
	3.3	Shoring boxes						
		3.3.1	< 1m deep	m2	-	-	-	-
		3.3.2	1 - 3m deep	m2	29.70	38.13	4,357.21	166,161.47
		3.3.3	> 3m deep	m2	35.64	45.76	-	-

4	**Culvert/pipe supply and installation**							
	4.1	Pipes						
		4.1.1	1000 x 2000	m	1,300.00	1,669.20	195.00	325,494.00
		4.1.2	d1050	m	790.50	1,015.00	282.50	286,738.07
		4.1.3	d900	m	580.00	744.72	235.20	175,158.14
		4.1.4	d750	m	405.00	520.02	246.70	128,288.93
		4.1.5	d600	m	285.00	365.94	267.00	97,705.98
		4.1.6	d450	m	200.00	256.80	37.70	9,681.36
		4.1.7	d375	m	150.00	192.60	17.90	3,447.54
		4.1.8	d300	m	118.00	151.51	43.10	6,530.17
	4.6	Backfilling of trench by suitable materials (stabilised sand)		m3	144.00	184.90	1,866.50	345,107.96
5	**Stormwater Pit**							
	5.1	Kerb inlets with grates (900x600x600) - heavy duty		Item	385.00	494.34	31.00	15,324.54
	5.2	Manholes (900 x 900 x 1200)		Item	1,275.00	1,637.10	5.00	8,185.50
6	**Re-establishing the road surface**							
	6.1	Basecourse		m2	19.75	25.36	1,692.33	42,915.72
	6.2	Asphalt		m2	26.10	33.51	1,692.33	56,713.94
	6.3	Kerb and gutter (600x225)		m	125.00	160.50	-	-
7	**Disposal of excavation materials**							
	7.1	Soil		t	53.00	68.05	4,402.78	299,618.12
	7.2	Road materials		t	95.00	121.98	2,115.41	258,037.56
8	**Others**							
	8.1	Project Management (10%)						204,516.79
	8.2	Contingency (20%)						409,033.59
	Subtotal							**2,658,718.31**
	GST							**265,871.83**
	TOTAL							**2,924,590.14**

Op R1- Railway Parade (Partial)			Unit	Price from Rawlinson 2007	Rate	Quantity	Cost
1	**Preliminaries**						
	1.1	Survey, geotechnical and other investigations	LS		12,500.00	1.00	12,500.00
	1.2	Detailed design	LS		40,000.00	1.00	40,000.00
	1.3	Review of environmental factors	LS		7,500.00	1.00	7,500.00
	1.4	Permits	LS		5,000.00	1.00	5,000.00
	1.5	Dilapidation survey	LS		15,000.00	1.00	15,000.00
2	**Establishment**						
	2.1	Mobilisation, OH&S and site camp	LS		2,000.00	1.00	2,000.00
	2.2	Erosion and sediment control measures	LS		3,500.00	1.00	3,500.00
	2.3	Traffic management	LS		10,000.00	1.00	10,000.00
	2.4	Site clearance for works	m2			756.85	-
		2.4.1 Above ground structures and trees	LS		4,000.00	1.00	4,000.00
		2.4.2 Cable location	LS		2,500.00	1.00	2,500.00
	2.5	Removing existing structures			-		-
		2.5.1 Pits	Item		200.00	2.00	400.00
		2.5.2 Culverts	m		50.00	29.50	1,475.00
	2.6	Diversion channel, if required	LS		10,000.00	1.00	10,000.00
3	**Excavation of trench**		**m3**			**1,370.34**	**-**
	3.1	Soil	m3	37.50	48.15	1,054.98	50,797.37
	3.2	Road surface	m3		-	315.35	-
		3.2.1 Breakup and remove reinforced concrete ground slab 100mm thick	m2	50.20	64.46	-	-
		3.2.2 Breakup and remove bitumen paving with basecourse under	m2	2.95	3.79	630.71	2,389.00
	3.3	Shoring boxes					
		3.3.1 < 1m deep	m2	-	-	-	-
		3.3.2 1 - 3m deep	m2	29.70	38.13	968.11	36,918.74
		3.3.3 > 3m deep	m2	35.64	45.76	-	-
4	**Culvert/pipe supply and installation**						
	4.1	Pipes					
		4.1.1 1000 x 2000	m	1,300.00	1,669.20	195.00	325,494.00
		4.1.2 d1050	m	790.50	1,015.00	-	-

Management Option R1 (Partial)

		4.1.3	d900	m	580.00	744.72	-	-
		4.1.4	d750	m	405.00	520.02	-	-
		4.1.5	d600	m	285.00	365.94	29.60	10,831.82
		4.1.6	d450	m	200.00	256.80	-	-
		4.1.7	d375	m	150.00	192.60	-	-
		4.1.8	d300	m	118.00	151.51	-	-
	4.6	Backfilling of trench by suitable materials (stabilised sand)		m3	144.00	184.90	833.21	154,057.02
5	**Stormwater Pit**							
	5.1	Kerb inlets with grates (900x600x600) - heavy duty		Item	385.00	494.34	1.00	494.34
	5.2	Manholes (900 x 900 x 1200)		Item	1,275.00	1,637.10	1.00	1,637.10
6	**Re-establishing the road surface**							
	6.1	Basecourse		m2	19.75	25.36	630.71	15,994.12
	6.2	Asphalt		m2	26.10	33.51	630.71	21,136.54
	6.3	Kerb and gutter (600x225)		m	125.00	160.50	-	-
7	**Disposal of excavation materials**							
	7.1	Soil		t	53.00	68.05	1,898.97	129,228.50
	7.2	Road materials		t	95.00	121.98	788.39	96,167.20
8	**Others**							
	8.1	Project Management (10%)						73,362.51
	8.2	Contingency (20%)						146,725.01
	Subtotal							**953,712.57**
	GST							**95,371.26**
	TOTAL							**1,049,083.83**

				Unit	Price from Rawlinson 2007	Rate	Quantity	Cost
Culvert/Pipe and Pit Laying								
1	**Preliminaries**							
	1.1	Survey, geotechnical and other investigations		LS		5,000.00	1.00	5,000.00
	1.2	Detailed design		LS		5,000.00	1.00	5,000.00
	1.3	Review of environmental factors		LS		1,000.00	1.00	1,000.00
	1.4	Permits		LS		1,000.00	1.00	1,000.00
	1.5	Dilapidation survey		LS		500.00	1.00	500.00
2	**Establishment**							
	2.1	Mobilisation, OH&S and site camp		LS		500.00	1.00	500.00
	2.2	Erosion and sediment control measures		LS		1,000.00	1.00	1,000.00
	2.3	Traffic management		LS		1,000.00	1.00	1,000.00
	2.4	Site clearance for works		m2			72.60	-
		2.4.1	Above ground structures and trees			1,000.00	1.00	1,000.00
		2.4.2	Cable location	LS		1,000.00	1.00	1,000.00
	2.5	Removing existing structures						-
		2.5.1	Pits	Item		200.00	-	-
		2.5.2	Culverts	m		50.00	9.90	495.00
	2.6	Diversion channel, if required		LS		-	-	-
3	**Excavation of trench**			**m3**			36.63	
	3.1	Soil		m3	37.5	48.15	6.38	307.00
	3.2	Road surface		m3			30.25	
		3.2.1	Breakup and remove reinforced concrete ground slab 100mm thick	m2	50.2	64.46	-	-
		3.2.2	Breakup and remove bitumen paving with basecourse under	m2	2.95	3.79	60.50	229.16
	3.3	Shoring boxes				-		
		3.3.1	< 1m deep	m2	0	-	63.69	-
		3.3.2	1 - 3m deep	m2	29.7	38.13	-	-
		3.3.3	> 3m deep	m2	35.64	45.76	-	-

4	**Culvert/pipe supply and installation**							
	4.1	Pipes						
		4.1.1	300 x 600	m	352.8	453.00	30.70	13,906.95
		4.1.2	d750	m	405	520.02	9.90	5,148.20
		4.1.3	d600	m	285	365.94	2.10	768.47
	4.6	Backfilling of trench by suitable materials (stabilised sand)		m3	144	184.90	26.17	4,839.63
						-		
5	**Stormwater Pit**							
	5.1	Kerb inlets with grates (900x600x600) - heavy duty		Item	385	494.34	3.00	1,483.02
	5.2	Manholes		Item		-	-	-
6	**Re-establishing the road surface**					-		
	6.1	Basecourse		m2	19.75	25.36	60.50	1,534.23
	6.2	Asphalt		m2	26.1	33.51	60.50	2,027.51
	6.3	Kerb and gutter (600x225)		m	125	160.50	30.10	4,831.05
7	**Disposal of excavation materials**							
	7.1	Soil		t	53	68.05	11.48	781.00
	7.2	Road materials		t	95	121.98	75.63	9,224.80
8	**Others**							
	8.1	Project Management (10%)						5,257.02
	8.2	Contingency (20%)						10,514.05
	Subtotal							**68,341.30**
	GST							**6,834.13**
	TOTAL							**75,175.43**

Culvert/Pipe and Pit Laying				Unit	Price from Rawlinson 2007	Rate	Quantity	Cost
1	**Preliminaries**							
	1.1	Survey, geotechnical and other investigations		LS		20,000.00	1.00	20,000.00
	1.2	Detailed design		LS		100,000.00	1.00	100,000.00
	1.3	Review of environmental factors		LS		7,500.00	1.00	7,500.00
	1.4	Permits		LS		5,000.00	1.00	5,000.00
	1.5	Dilapidation survey		LS		30,000.00	2.00	60,000.00
2	**Establishment**							
	2.1	Mobilisation, OH&S and site camp		LS		6,000.00	1.00	6,000.00
	2.2	Erosion and sediment control measures		LS		7,500.00	1.00	7,500.00
	2.3	Traffic management		LS		20,000.00	1.00	20,000.00
	2.4	Site clearance for works		m2			1,390.47	-
		2.4.1	Above ground structures and trees	LS		10,000.00	1.00	10,000.00
		2.4.2	Cable location	LS		5,000.00	1.00	5,000.00
	2.5	Removing existing structures				-		-
		2.5.1	Pits	Item		200.00	3.00	600.00
		2.5.2	Culverts	m		50.00	-	-
	2.6	Diversion channel, if required		LS		10,000.00	1.00	10,000.00
3	**Excavation of trench**			m3			1,563.58	**-**
	3.1	Soil		m3	37.5	48.15	984.22	47,389.99
	3.2	Road surface		m3		-	579.36	-
		3.2.1	Breakup and remove reinforced concrete ground slab 100mm thick	m2	50.2	64.46	-	-
		3.2.2	Breakup and remove bitumen paving with basecourse under	m2	2.95	3.79	1,158.73	4,389.03
	3.3	Shoring boxes				-		
		3.3.1	< 1m deep	m2	0	-	16.82	-
		3.3.2	1 - 3m deep	m2	29.7	38.13	2,845.46	108,511.07
		3.3.3	> 3m deep	m2	35.64	45.76	-	-

4	**Culvert/pipe supply and installation**							
	4.1	Pipes						
		4.1.1	d750	m	405	520.02	237.05	123,270.74
		4.1.2	d600	m	285	365.94	171.90	62,905.09
		4.1.3	d525	m	235	301.74	269.60	81,349.10
		4.1.4	d450	m	200	256.80	390.40	100,254.72
		4.1.5	d225	m	105.6	135.59	18.90	2,562.66
	4.6	Backfilling of trench by suitable materials (stabilised sand)		m3	144	184.90	1,174.00	217,068.70
5	**Stormwater Pit**							
	5.1	Kerb inlets with grates (900x600x600) - heavy duty		Item	385	494.34	39.00	19,279.26
	5.2	Pit with grate (600x600x600)		Item	980	1,258.32	6.00	7,549.92
	5.3	Manholes		Item		-	-	-
6	**Re-establishing the road surface**							
	6.1	Basecourse		m2	19.75	25.36	1,158.73	29,384.21
	6.2	Asphalt		m2	26.1	33.51	1,158.73	38,831.79
	6.3	Kerb and gutter (600x225)		m	125	160.50	-	-
7	**Disposal of excavation materials**							
	7.1	Soil		t	53	68.05	1,771.59	120,560.13
	7.2	Road materials		t	95	121.98	1,448.41	176,677.20
8	**Others**							
	8.1	Project Management (10%)						109,434.63
	8.2	Contingency (20%)						218,869.25
	Subtotal							**1,422,650.15**
	GST							**142,265.02**
	TOTAL							**1,564,915.17**

Op R3 - Simpson Park (Partial)			Unit	Price from Rawlinson 2007	Rate	Quantity	Cost
1	**Preliminaries**						
	1.1	Survey, geotechnical and other investigations	LS		12,500.00	1.00	12,500.00
	1.2	Detailed design	LS		40,000.00	1.00	40,000.00
	1.3	Review of environmental factors	LS		7,500.00	1.00	7,500.00
	1.4	Permits	LS		5,000.00	1.00	5,000.00
	1.5	Dilapidation survey	LS		15,000.00	2.00	30,000.00
2	**Establishment**						
	2.1	Mobilisation, OH&S and site camp	LS		2,000.00	1.00	2,000.00
	2.2	Erosion and sediment control measures	LS		3,500.00	1.00	3,500.00
	2.3	Traffic management	LS		10,000.00	1.00	10,000.00
	2.4	Site clearance for works	m2			413.86	-
		2.4.1 Above ground structures and trees	LS		4,000.00	1.00	4,000.00
		2.4.2 Cable location	LS		2,500.00	1.00	2,500.00
	2.5	Removing existing structures			-		-
		2.5.1 Pits	Item		200.00	3.00	600.00
		2.5.2 Culverts	m		50.00	-	-
	2.6	Diversion channel, if required	LS		10,000.00		-
3	**Excavation of trench**		m3			295.00	**-**
	3.1	Soil	m3	37.5	48.15	122.56	5,901.11
	3.2	Road surface	m3		-	172.44	-
		3.2.1 Breakup and remove reinforced concrete ground slab 100mm thick	m2	50.2	64.46	-	-
		3.2.2 Breakup and remove bitumen paving with basecourse under	m2	2.95	3.79	344.88	1,306.34
	3.3	Shoring boxes			-		
		3.3.1 < 1m deep	m2	0	-	16.82	-
		3.3.2 1 - 3m deep	m2	29.7	38.13	525.57	20,042.66
		3.3.3 > 3m deep	m2	35.64	45.76	-	-
4	**Culvert/pipe supply and installation**						
	4.1	Pipes					
		4.1.1 d750	m	405	520.02	79.90	41,549.60
		4.1.2 d600	m	285	365.94	42.30	15,479.26

		4.1.3	d525	m	235	301.74	-	-
		4.1.4	d450	m	200	256.80	185.80	47,713.44
		4.1.5	d225	m	105.6	135.59	18.90	2,562.66
	4.6	Backfilling of trench by suitable materials (stabilised sand)		m3	144	184.90	181.09	33,482.69
5	**Stormwater Pit**							
	5.1	Kerb inlets with grates (900x600x600) - heavy duty		Item	385	494.34	10.00	4,943.40
	5.2	Pit with grate (600x600x600)		Item	980	1,258.32	2.00	2,516.64
	5.3	Manholes		Item		-	-	-
6	**Re-establishing the road surface**							
	6.1	Basecourse		m2	19.75	25.36	344.88	8,745.81
	6.2	Asphalt		m2	26.1	33.51	344.88	11,557.76
	6.3	Kerb and gutter (600x225)		m	125	160.50	-	-
7	**Disposal of excavation materials**							
	7.1	Soil		t	53	68.05	220.60	15,012.43
	7.2	Road materials		t	95	121.98	431.10	52,585.58
8	**Others**							
	8.1	Project Management (10%)						31,340.14
	8.2	Contingency (20%)						62,680.27
	Subtotal							**407,421.77**
	GST							**40,742.18**
	TOTAL							**448,163.95**

				Unit	Price from Rawlinson 2007	Rate	Quantity	Cost
Culvert/Pipe and Pit Laying								
1	**Preliminaries**							
	1.1	Survey, geotechnical and other investigations		LS		2,000.00	1.00	2,000.00
	1.2	Detailed design		LS		3,000.00	1.00	3,000.00
	1.3	Review of environmental factors		LS		1,000.00	1.00	1,000.00
	1.4	Permits		LS		1,000.00	1.00	1,000.00
	1.5	Dilapidation survey		LS		-	-	-
2	**Establishment**							
	2.1	Mobilisation, OH&S and site camp		LS		-	-	-
	2.2	Erosion and sediment control measures		LS		1,000.00	1.00	1,000.00
	2.3	Traffic management		LS		1,000.00	1.00	1,000.00
	2.4	Site clearance for works		m2			60.32	-
		2.4.1	Above ground structures and trees	LS		3,000.00	1.00	3,000.00
		2.4.2	Cable location	LS		1,000.00	1.00	1,000.00
	2.5	Removing existing structures				-		-
		2.5.1	Pits	Item		200	1.00	200.00
		2.5.2	Culverts	m		50	-	-
	2.6	Diversion channel, if required		Item		-	-	-
3	**Excavation of trench**			**m3**			**54.36**	**-**
	3.1	Soil		m3	37.5	48.15	29.23	1,407.45
	3.2	Road surface		m3		-	25.13	-
		3.2.1	Breakup and remove reinforced concrete ground slab 100mm thick	m2	50.2	64.46	-	-
		3.2.2	Breakup and remove bitumen paving with basecourse under	m2	2.95	3.79	50.27	190.41
	3.3	Shoring boxes				-		
		3.3.1	< 1m deep	m2	0	-	71.76	-
		3.3.2	1 - 3m deep	m2	29.7	38.13	-	-

		3.3.3	> 3m deep	m2	35.64	45.76	-	-
4	**Culvert/pipe supply and installation**					-		-
	4.1	Pipes						
		4.1.1	600 x 225	m	350	449.40	42.20	18,964.68
		4.1.2	450 x 150	m	290	372.36	7.95	2,960.26
		4.1.3	d 225	m	105.6	135.59	19.65	2,664.35
	4.6	Backfilling of trench by suitable materials (stabilised sand)		m3	144	184.90	24.33	4,497.92
5	**Stormwater Pit**							
	5.1	Kerb inlets with grates (900x600x600) - heavy duty		Item	385	494.34	3.00	1,483.02
	5.2	Pit with grate (450x450x600)		Item	820	1,052.88	5.00	5,264.40
	5.3	Manholes		Item		-	-	-
	5.4							
6	**Re-establishing the road surface**							
	6.1	Basecourse		m2	19.75	25.36	50.27	1,274.75
	6.2	Asphalt		m2	26.1	33.51	50.27	1,684.60
	6.3	Kerb and gutter (600x225)		m	125	160.50	22.20	3,563.10
7	**Disposal of excavation materials**							
	7.1	Soil		t	53	68.05	52.61	3,580.55
	7.2	Road materials		t	95	121.98	62.84	7,664.61
8	**Others**							
	8.1	Project Management (10%)						5,715.49
	8.2	Contingency (20%)						11,430.99
	Subtotal							**74,301.42**
	GST							**7,430.14**
	TOTAL							**81,731.56**

Culvert/Pipe and Pit Laying								
			Unit	Price from Rawlinson 2007	Rate	Quantity	Cost
1	**Preliminaries**						
	1.1	Survey, geotechnical and other investigations	LS		20,000.00	1.00	20,000.00
	1.2	Detailed design	LS		50,000.00	1.00	50,000.00
	1.3	Review of environmental factors	LS		7,500.00	1.00	7,500.00
	1.4	Permits	LS		5,000.00	1.00	5,000.00
	1.5	Dilapidation survey	LS		15,000.00	1.00	15,000.00
2	**Establishment**						
	2.1	Mobilisation, OH&S and site camp	LS		2,000.00	1.00	2,000.00
	2.2	Erosion and sediment control measures	LS		2,500.00	1.00	2,500.00
	2.3	Traffic management	LS		5,000.00	1.00	5,000.00
	2.4	Site clearance for works	m2			636.80	-
		2.4.1 Above ground structures and trees	LS		3,000.00	1.00	3,000.00
		2.4.2 Cable location	LS		3,000.00	1.00	3,000.00
	2.5	Removing existing structures			-		-
		2.5.1 Pits	Item		200	-	-
		2.5.2 Culverts	m		50	13.50	675.00
	2.6	Diversion channel, if required	LS		1,000.00	1.00	1,000.00
3	**Excavation of trench**		**m3**			**476.54**	
	3.1	Soil	m3	37.5	48.15	211.20	10,169.44
	3.2	Road surface	m3		-	265.33	-
		3.2.1 Breakup and remove reinforced concrete ground slab 100mm thick	m2	50.2	64.46	-	-
		3.2.2 Breakup and remove bitumen paving with basecourse under	m2	2.95	3.79	530.67	2,010.07
	3.3	Shoring boxes					
		3.3.1 < 1m deep	m2	0	-	-	-
		3.3.2 1 - 3m deep	m2	29.7	38.13	691.71	26,378.25
		3.3.3 > 3m deep	m2	35.64	45.76	-	-

4	**Culvert/pipe supply and installation**						
	4.1	Pipes					
		4.1.1 d900	m	580	744.72	149.50	111,335.64
		4.1.2 d750	m	405	520.02	43.10	22,412.86
	4.6	Backfilling of trench by suitable materials (stabilised sand)	m3	144	184.90	198.76	36,750.43
5	**Stormwater Pit**						
	5.1	Kerb inlets with grates (900x600x600) - heavy duty	Item	385	494.34	7.00	3,460.38
	5.2	Pit with grate (600x600x600)	Item	980	1,258.32	-	-
	5.3	Manholes	Item		-	-	-
6	**Re-establishing the road surface**						
	6.1	Basecourse	m2	19.75	25.36	530.67	13,457.25
	6.2	Asphalt	m2	26.1	33.51	530.67	17,784.01
	6.3	Kerb and gutter (600x225)	m	125	160.50	-	-
7	**Disposal of excavation materials**						
	7.1	Soil	t	53	68.05	380.17	25,871.06
	7.2	Road materials	t	95	121.98	663.34	80,913.85
8	**Others**						
	8.1	Project Management (10%)					35,843.33
	8.2	Contingency (20%)					71,686.67
	Subtotal						**465,963.33**
	GST						**46,596.33**
	TOTAL						**512,559.66**

				Unit	Price from Rawlinson 2007	Rate	Quantity	Cost
Culvert/Pipe and Pit Laying								
1	**Preliminaries**							
	1.1	Survey, geotechnical and other investigations		Item		10,000.00	1.00	10,000.00
	1.2	Detailed design		Item		50,000.00	1.00	50,000.00
	1.3	Review of environmental factors		Item		5,000.00	1.00	5,000.00
	1.4	Permits		Item		15,000.00	1.00	15,000.00
	1.5	Dilapidation survey						
	1.6	Property acquisition		Item		770,000.00	3.00	2,310,000.00
2	**Establishment**							
	2.1	Mobilisation, OH&S and site camp		Item		2,000.00	1.00	2,000.00
	2.2	Erosion and sediment control measures		Item		2,500.00	1.00	2,500.00
	2.3	Traffic management		Item			1.00	-
	2.4	Site clearance for works		m2			133.09	-
		2.4.1	Above ground structures and trees	LS		10,000.00	1.00	10,000.00
		2.4.2	Cable location	LS		3,000.00	1.00	3,000.00
	2.5	Removing existing structures				-		-
		2.5.1	Pits	Item		200.00	-	-
		2.5.2	Culverts	m		50.00	-	-
	2.6	Diversion channel, if required		LS			-	-
3	**Excavation of trench**			**m3**			**263.61**	**-**
	3.1	Soil		m3	37.5	48.15	208.16	10,022.67
	3.2	Road surface		m3		-	55.45	-
		3.2.1	Breakup and remove reinforced concrete ground slab 100mm thick	m2	50.2	64.46		-
		3.2.2	Breakup and remove bitumen paving with basecourse under	m2	2.95	3.79	110.91	420.09
	3.3	Shoring boxes						
		3.3.1	< 1m deep	m2	0	-	-	-
		3.3.2	1 - 3m deep	m2	29.7	38.13	480.98	18,342.00
		3.3.3	> 3m deep	m2	35.64	45.76	-	-

4	**Culvert/pipe supply and installation**					-		-
	4.1	Pipes						
		4.1.1	d300	m	118	151.51	7.10	1,075.74
		4.1.2	d375	m	150	192.60	19.80	3,813.48
		4.1.3	d450	m	200	256.80	14.20	3,646.56
		4.1.4	d600	m	285	365.94	24.10	8,819.15
		4.1.5	d750	m	405	520.02	37.50	19,500.75
	4.6	Backfilling of trench by suitable materials (clean sand)		m3	44	56.50	238.54	13,476.69
5	**Stormwater Pit**					**-**		**-**
	5.1	Kerb inlets with grates (900x600x600) - heavy duty		Item	385	494.34	6.00	2,966.04
	5.2	Manholes		Item		-		-
6	**Re-establishing the road surface**			**m2**				
	6.1	Basecourse		m2	19.75	25.36	110.91	2,812.49
	6.2	Asphalt		m2	26.1	33.51	110.91	3,716.76
	6.3	Kerb and gutter (600x225)		m	125	160.50	-	-
	6.4	Footpath		m2		-	-	-
	6.5	Handrail		m		-		-
7	**Disposal of excavation materials**			**t**		**-**		**-**
	7.1	Soil		t	53	68.05	374.68	25,497.67
	7.2	Road materials		t	95	121.98	138.63	16,910.54
8	**Others**							
	8.1	Project Management (10%)						249,611.24
	8.2	Contingency (20%)						499,222.48
	Subtotal							**3,244,946.15**
	GST							**324,494.62**
	TOTAL							**3,569,440.77**

			Unit	Price from Rawlinson 2007	Rate	Quantity	Cost
		Culvert/Pipe and Pit Laying					
1	**Preliminaries**						
	1.1	Survey, geotechnical and other investigations	LS		20,000.00	1.00	20,000.00
	1.2	Detailed design	LS		50,000.00	1.00	50,000.00
	1.3	Review of environmental factors	LS		7,500.00	1.00	7,500.00
	1.4	Permits	LS		5,000.00	1.00	5,000.00
	1.5	Dilapidation survey	LS		20,000.00	1.00	20,000.00
2	**Establishment**						
	2.1	Mobilisation, OH&S and site camp	LS		5,000.00	1.00	5,000.00
	2.2	Erosion and sediment control measures	LS		3,000.00	1.00	3,000.00
	2.3	Traffic management	LS		5,000.00	1.00	5,000.00
	2.4	Site clearance for works	m2			761.24	-
		2.4.1 Above ground structures and trees	LS		5,000.00	1.00	5,000.00
		2.4.2 Cable location	LS		5,000.00	1.00	5,000.00
	2.5	Removing existing structures					-
		2.5.1 Pits	Item		200	-	-
		2.5.2 Culverts	m		50	-	-
	2.6	Diversion channel, if required	LS		-	-	-
3	**Excavation of trench**		m3			1,081.72	
	3.1	Soil	m3	37.50	48.15	764.53	36,812.17
	3.2	Road surface	m3		-	317.19	-
		3.2.1 Breakup and remove reinforced concrete ground slab 100mm thick	m2	50.20	64.46		-
		3.2.2 Breakup and remove bitumen paving with basecourse under	m2	2.95	3.79	634.37	2,402.87
	3.3	Shoring boxes					
		3.3.1 < 1m deep	m2	-	-	-	-
		3.3.2 1 - 3m deep	m2	29.70	38.13	2,181.82	83,203.38
		3.3.3 > 3m deep	m2	35.64	45.76	-	-
4	**Culvert/pipe supply and installation**						
	4.1	Pipes					

		4.1.1	d450	m	200.00	256.80	255.70	65,663.76
		4.1.2	d525	m	235.00	301.74	194.70	58,748.78
		4.1.3	d600	m	285.00	365.94	246.50	90,204.21
		4.1.4	914 x 609	m	642.00	824.33	23.40	19,289.28
	4.6	Backfilling of trench by suitable materials (stabilised sand)		m3	144.00	184.90	885.63	163,748.84
5	**Stormwater Pit**					**-**		**-**
	5.1	Kerb inlets with grates (900x600x600) - heavy duty		Item	385.00	494.34	14.00	6,920.76
	5.2	Manholes		Item		-		-
6	**Re-establishing the road surface**							
	6.1	Basecourse		m2	19.75	25.36	634.37	16,086.99
	6.2	Asphalt		m2	26.10	33.51	634.37	21,259.26
	6.3	Kerb and gutter (600x225)		m	125.00	160.50	600.20	96,332.10
7	**Disposal of excavation materials**							
	7.1	Soil		t	53.00	68.05	1,376.16	93,650.17
	7.2	Road materials		t	95.00	121.98	792.96	96,725.57
8	**Others**							
	8.1	Project Management (10%)						78,617.24
	8.2	Contingency (20%)						157,234.48
	Subtotal							**1,022,024.11**
	GST							**102,202.41**
	TOTAL							**1,124,226.52**

				Unit	Price from Rawlinson 2007	Rate	Quantity	Cost
Op R7 - Goodsell St (Partial)								
1	**Preliminaries**							
	1.1	Survey, geotechnical and other investigations		LS		12,500.00	1.00	12,500.00
	1.2	Detailed design		LS		40,000.00	1.00	40,000.00
	1.3	Review of environmental factors		LS		7,500.00	1.00	7,500.00
	1.4	Permits		LS		5,000.00	1.00	5,000.00
	1.5	Dilapidation survey		LS		15,000.00	1.00	15,000.00
2	**Establishment**							
	2.1	Mobilisation, OH&S and site camp		LS		5,000.00	1.00	5,000.00
	2.2	Erosion and sediment control measures		LS		3,000.00	1.00	3,000.00
	2.3	Traffic management		LS		5,000.00	1.00	5,000.00
	2.4	Site clearance for works		m2			793.00	-
		2.4.1	Above ground structures and trees	LS		2,500.00	1.00	2,500.00
		2.4.2	Cable location	LS		2,500.00	1.00	2,500.00
	2.5	Removing existing structures						-
		2.5.1	Pits	Item		200	-	-
		2.5.2	Culverts	m		50	-	-
	2.6	Diversion channel, if required		LS		-	-	-
3	**Excavation of trench**			m3			745.56	
	3.1	Soil		m3	37.50	48.15	415.15	19,989.40
	3.2	Road surface		m3		-	330.41	-
		3.2.1	Breakup and remove reinforced concrete ground slab 100mm thick	m2	50.20	64.46		-
		3.2.2	Breakup and remove bitumen paving with basecourse under	m2	2.95	3.79	660.83	2,503.09
	3.3	Shoring boxes						
		3.3.1	< 1m deep	m2	-	-	-	-
		3.3.2	1 - 3m deep	m2	29.70	38.13	1,495.05	57,013.34
		3.3.3	> 3m deep	m2	35.64	45.76	-	-
4	**Culvert/pipe supply and installation**							
	4.1	Pipes						
		4.1.1	d450	m	200.00	256.80	5.40	1,386.72
		4.1.2	d525	m	235.00	301.74	246.10	74,258.21
		4.1.3	d600	m	285.00	365.94	397.30	145,387.96
		4.1.4	914 x 609	m	642.00	824.33	23.40	19,289.28

	4.6	Backfilling of trench by suitable materials (stabilised sand)	m3	144.00	184.90	523.29	96,754.09
5	**Stormwater Pit**				**-**		**-**
	5.1	Kerb inlets with grates (900x600x600) - heavy duty	Item	385.00	494.34	5.00	2,471.70
	5.2	Manholes	Item		-		-
6	**Re-establishing the road surface**						
	6.1	Basecourse	m2	19.75	25.36	660.83	16,757.98
	6.2	Asphalt	m2	26.10	33.51	660.83	22,145.98
	6.3	Kerb and gutter (600x225)	m	125.00	160.50	608.30	97,632.15
7	**Disposal of excavation materials**						
	7.1	Soil	t	53.00	68.05	747.27	50,853.03
	7.2	Road materials	t	95.00	121.98	826.04	100,759.98
8	**Others**						
	8.1	Project Management (10%)					65,358.99
	8.2	Contingency (20%)					130,717.98
	Subtotal						**849,666.87**
	GST						**84,966.69**
	TOTAL						**934,633.56**

Culvert/Pipe and Pit Laying				Unit	Price from Rawlinson 2007	Rate	Quantity	Cost
1	**Preliminaries**							
	1.1	Survey, geotechnical and other investigations		LS		20,000.00	1.00	20,000.00
	1.2	Detailed design		LS		50,000.00	1.00	50,000.00
	1.3	Review of environmental factors		LS		7,500.00	1.00	7,500.00
	1.4	Permits		LS		5,000.00	1.00	5,000.00
	1.5	Dilapidation survey		LS		15,000.00	1.00	15,000.00
2	**Establishment**							
	2.1	Mobilisation, OH&S and site camp		LS		5,000.00	1.00	5,000.00
	2.2	Erosion and sediment control measures		LS		7,500.00	1.00	7,500.00
	2.3	Traffic management		LS		10,000.00	1.00	10,000.00
	2.4	Site clearance for works		m2			4,395.23	
		2.4.1	Above ground structures and trees	LS		-	-	
		2.4.2	Cable location	LS		5,000.00	1.00	5,000.00
	2.5	Removing existing structures						
		2.5.1	Pits	Item		200.00	-	-
		2.5.2	Culverts	m		100.00	570.30	57,030.00
	2.6	Diversion channel, if required		LS		5,000.00	1.00	5,000.00
3	**Excavation of trench**			**m3**			**8,734.05**	**-**
	3.1	Soil		m3	37.5	48.15	6,902.70	332,364.94
	3.2	Road surface		m3		-	1,831.35	-
		3.2.1	Breakup and remove reinforced concrete ground slab 100mm thick	m2	50.2	64.46	-	-
		3.2.2	Breakup and remove bitumen paving with basecourse under	m2	2.95	3.79	3,662.69	13,873.55
	3.3	Shoring boxes						
		3.3.1	< 1m deep	m2	0	-	-	-
		3.3.2	1 - 3m deep	m2	29.7	38.13	1,278.21	48,744.14
		3.3.3	> 3m deep	m2	35.64	45.76	1,663.48	76,123.73
4	**Culvert/pipe supply and installation**					-		-

	4.1	Pipes						
		4.1.1	3600 x 1372	m		-	157.70	-
		4.1.2	5030 x 1372	m		-	192.70	-
		4.1.3	2440 x 1295 x 3	m		-	219.90	-
	4.6	Backfilling of trench by suitable materials (stabilised sand)		m3	144	184.90	3,750.48	693,449.51
5	**Stormwater Pit**							
	5.1	Kerb inlets with grates (900x600x600) - heavy duty		Item	385	494.34	-	-
	5.2	Manholes		Item		-		-
6	**Re-establishing the road surface**							
	6.1	Basecourse		m2	19.75	25.36	3,662.69	92,882.23
	6.2	Asphalt		m2	26.1	33.51	3,662.69	122,745.63
	6.3	Kerb and gutter (600x225)		m	125	160.50	-	-
7	**Disposal of excavation materials**							
	7.1	Soil		t	53	68.05	12,424.86	845,536.40
	7.2	Road materials		t	95	121.98	4,578.37	558,469.12
8	**Others**							
	8.1	Project Management (10%)						156,721.37
	8.2	Contingency (20%)						313,442.75
	Subtotal							**2,037,377.84**
	GST							**203,737.78**
	TOTAL							**2,241,115.63**

				Unit	Price from Rawlinson 2007	Rate	Quantity	Cost
Op R9 - Optimation of Drainage to Camdenville Oval								
1	**Preliminaries**							
	1.1	Survey, geotechnical and other investigations		LS		5,000.00	1.00	5,000.00
	1.2	Detailed design		LS		5,000.00	1.00	5,000.00
	1.3	Review of environmental factors		LS		1,000.00	1.00	1,000.00
	1.4	Permits		LS		1,000.00	1.00	1,000.00
	1.5	Dilapidation survey		LS		500.00	2.00	1,000.00
2	**Establishment**							
	2.1	Mobilisation, OH&S and site camp		LS		500.00	1.00	500.00
	2.2	Erosion and sediment control measures		LS		1,000.00	1.00	1,000.00
	2.3	Traffic management		LS		1,000.00	1.00	1,000.00
	2.4	Site clearance for works		m2			69.17	-
		2.4.1	Above ground structures and trees	LS		1,000.00	1.00	1,000.00
		2.4.2	Cable location	LS		-	-	-
	2.5	Removing existing structures				-		-
		2.5.1	Pits	Item		200.00	-	-
		2.5.2	Culverts	m		50.00	-	-
	2.6	Diversion channel, if required		LS		10,000.00	-	-
3	**Excavation of trench**			m3			222.48	**-**
	3.1	Soil		m3	37.5	48.15	193.66	9,324.79
	3.2	Road surface		m3		-	28.82	-
		3.2.1	Breakup and remove reinforced concrete ground slab 100mm thick	m2	50.2	64.46	-	-
		3.2.2	Breakup and remove bitumen paving with basecourse under	m2	2.95	3.79	57.64	218.33
	3.3	Shoring boxes				-		
		3.3.1	< 1m deep	m2	0	-		-
		3.3.2	1 - 3m deep	m2	29.7	38.13	169.83	6,476.55
		3.3.3	> 3m deep	m2	35.64	45.76	-	-
4	**Culvert/pipe supply and installation**							
	4.1	Pipes						
		4.1.1	d900	m	580	744.72	124.20	92,494.22

	4.6	Backfilling of trench by suitable materials (stabilised sand)	m3	144	184.90	122.97	22,737.42
5	**Stormwater Pit**						
	5.1	Pit with grate (pit for max 1100mm dia, 2000mm deep)	Item	2115	2,715.66	8.00	21,725.28
6	**Re-establishing the road surface**						
	6.1	Basecourse	m2	19.75	25.36	57.64	1,461.69
	6.2	Asphalt	m2	26.1	33.51	57.64	1,931.65
	6.3	Kerb and gutter (600x225)	m	125	160.50	-	-
7	**Disposal of excavation materials**						
	7.1	Soil	t	53	68.05	348.59	23,722.26
	7.2	Road materials	t	95	121.98	72.05	8,788.66
8	**Others**						
	8.1	Project Management (10%)					17,286.99
	8.2	Contingency (20%)					34,573.99
	Subtotal						**224,730.91**
	GST						**22,473.09**
	TOTAL						**247,204.01**

Op R10 - Expansion of Camdenville Oval								
			Unit	Price from Rawlinson 2007	Rate	Quantity	Cost
1	**Preliminaries**						
	1.1	Survey, geotechnical and other investigations	LS		20,000.00	1.00	20,000.00
	1.2	Detailed design	LS		100,000.00	1.00	100,000.00
	1.3	Review of environmental factors	LS		7,500.00	1.00	7,500.00
	1.4	Permits	LS		5,000.00	1.00	5,000.00
	1.5	Dilapidation survey	LS		30,000.00	2.00	60,000.00
2	**Establishment**						
	2.1	Mobilisation, OH&S and site camp	LS		6,000.00	1.00	6,000.00
	2.2	Erosion and sediment control measures	LS		7,500.00	1.00	7,500.00
	2.3	Traffic management	LS		20,000.00	1.00	20,000.00
	2.4	Site clearance for works	m2			1,734.09	-
		2.4.1 Above ground structures and trees	LS		10,000.00	1.00	10,000.00
		2.4.2 Cable location	LS		5,000.00	1.00	5,000.00
	2.5	Removing existing structures			-		-
		2.5.1 Pits	Item		200.00	5.00	1,000.00
		2.5.2 Culverts	m		50.00	-	-
	2.6	Diversion channel, if required	LS		10,000.00	1.00	10,000.00
3	**Excavation of trench**		m3			1,989.64	**-**
	3.1	Soil	m3	37.5	48.15	1,267.10	61,010.98
	3.2	Road surface	m3		-	722.54	-
		3.2.1 Breakup and remove reinforced concrete ground slab 100mm thick	m2	50.2	64.46	-	-
		3.2.2 Breakup and remove bitumen paving with basecourse under	m2	2.95	3.79	1,445.08	5,473.66
	3.3	Shoring boxes			-		
		3.3.1 < 1m deep	m2	0	-	24.27	-
		3.3.2 1 - 3m deep	m2	29.7	38.13	2,948.65	112,446.01
		3.3.3 > 3m deep	m2	35.64	45.76	-	-
4	**Culvert/pipe supply and installation**						
	4.1	Pipes					
		4.1.1 d900	m	580.00	744.72	286.10	213,064.39
		4.1.2 d750	m	405	520.02	270.65	140,743.41

		4.1.3	d600	m	285	365.94	129.60	47,425.82
		4.1.4	d525	m	235	301.74	269.60	81,349.10
		4.1.5	d450	m	200	256.80	315.10	80,917.68
		4.1.6	d225	m	105.6	135.59	18.90	2,562.66
	4.6	Backfilling of trench by suitable materials (stabilised sand)		m3	144	184.90	1,386.42	256,343.16
5	**Stormwater Pit**							
	5.1	Kerb inlets with grates (900x600x600) - heavy duty		Item	820	1,052.88	49.00	51,591.12
	5.2	Kerb inlet with grate (pit for up to 1100mm dia pipe, 2000mm deep)		Item	2115	2,715.66	18.00	48,881.88
	5.3	Pit with grate (600x600x600)		Item	1444	1,854.10	5.00	9,270.48
	5.4	Pit with grate (pit for up to 1100mm dia, 2000mm deep)		Item	2115	2,715.66	3.00	8,146.98
	5.5	Manholes		Item		-		-
6	**Re-establishing the road surface**							
	6.1	Basecourse		m2	19.75	25.36	1,445.08	36,645.71
	6.2	Asphalt		m2	26.1	33.51	1,445.08	48,428.00
	6.3	Kerb and gutter (600x225)		m	125	160.50	-	-
7	**Disposal of excavation materials**							
	7.1	Soil		t	53	68.05	2,280.78	155,211.94
	7.2	Road materials		t	95	121.98	1,806.35	220,338.12
8	**Others**							
	8.1	Project Management (10%)						145,630.10
	8.2	Contingency (20%)						291,260.21
	Subtotal							**1,893,191.36**
	GST							**189,319.14**
	TOTAL							**2,082,510.50**

Op R10 - Expansion of Camdenville Oval								
			Unit	Price from Rawlinson 2007	Rate	Quantity	Cost
1	**Preliminaries**						
	1.1	Survey, geotechnical and other investigations	LS		5,000.00	1.00	5,000.00
	1.2	Detailed design	LS		5,000.00	1.00	5,000.00
	1.3	Review of environmental factors	LS		2,000.00	1.00	2,000.00
	1.4	Permits	LS		1,000.00	1.00	1,000.00
	1.5	Dilapidation survey	LS		500.00	2.00	1,000.00
2	**Establishment**						
	2.1	Mobilisation, OH&S and site camp	LS		1,000.00	1.00	1,000.00
	2.2	Erosion and sediment control measures	LS		2,000.00	1.00	2,000.00
	2.3	Traffic management	LS		-	-	-
	2.4	Site clearance for works	m2				-
		2.4.1 Above ground structures and trees	LS		2,000.00	1.00	2,000.00
		2.4.2 Cable location	LS		1,000.00	1.00	1,000.00
3	**Excavation of trench**						
	3.1	Soil (70% excavation volume)	m3	16.3	20.93	3,809.40	79,727.69
	3.2	Rock (30% excavation volume)	m3	29.8	38.26	1,632.60	62,468.50
4	**Disposal of excavation materials**						
	4.1	Soil	t	53	68.05	6,856.92	466,627.12
	4.2	Rock	t	53	68.05	4,081.50	277,754.24
5	**Others**						
	5.1	Project Management (10%)					16,219.62
	5.2	Contingency (20%)					32,439.24
	Subtotal						**955,236.41**
	GST						**95,523.64**
	TOTAL						**1,050,760.05**

APPENDIX E

Water Management Options – Pit/Pipe Details

ID	Type	Ignore	UCS	Len_or_ANA	n_or_n_F	US_Invert	DS_Invert	Form_Loss	pBlockage	Inlet_Type	Conn_2D
P-EE85	Q	F	N	0.495	0	8.73	7.98	0	0	3%SA1	SXZ
P-EE84	Q	F	N	0.495	0	8.69	7.94	0	0	3%SA1	SXZ
P-EE92	Q	F	N	0.54	0	8.59	7.69	0	0	1%RM7-S	SXZ
P-EE90	Q	F	N	0.25	0	8.52	7.77	0	0	1%RM7	SXZ
P-EE227	Q	F	N	0.585	0	8.8	8.1	0	0	1%SA1	SXZ
P-EE86	Q	F	N	0.495	0	8.81	7.91	0	0	3%SA1	SXZ
P-EE89	Q	F	N	1.17	0	8.86	7.61	0	0	3%SA1	SXZ
P-EE111	Q	F	N	0.585	0	11.66	10.16	0	0	3%SA1	SXZ
P-EE110	Q	F	N	0.585	0	11.5	10	0	0	3%SA1	SXZ
P-EE112	Q	F	N	0.675	0	11.85	11.35	0	0	3%SA2	SXZ
P-EE102	Q	F	N	0.495	0	5.74	5.14	0	0	3%SA1	SXZ
P-EE100	Q	F	N	0.585	0	5.55	4.35	0	0	3%SA1-S	SXZ
P-EE97	Q	F	N	0.54	0	5.55	5.15	0	0	1%SA1	SXZ
P-EE98	Q	F	N	0.54	0	5.47	4.3	0	0	1%SA1	SXZ
P-EE95	Q	F	N	0.405	0	6.44	5.99	0	0	3%SA1	SXZ
P-EE96	Q	F	N	0.45	0	6.19	4.85	0	0	1%SA1	SXZ
P-EE93	Q	F	N	0.45	0	7.22	6.52	0	0	1%SA1	SXZ
P-EE94	Q	F	N	0.45	0	7.06	5.9	0	0	1%SA1	SXZ
P-EE225	Q	F	N	0.09	0	5.39	4.89	0	0	1%RM7-S	SXZ
P-EE106	Q	F	N	0.63	0	7.527	6.077	0	0	3%SA1	SXZ
P-EE107	Q	F	N	0.585	0	7.56	5.96	0	0	3%SA1	SXZ
P-EE109	Q	F	N	0.585	0	7.57	6.27	0	0	3%SA1	SXZ
P-EE103	Q	F	N	0.63	0	9.88	8.48	0	0	1%SA1	SXZ
P-EE104	Q	F	N	0.63	0	13.15	11.75	0	0	1%SA1	SXZ
P-EE115	Q	F	N	0.585	0	9.53	8.23	0	0	5%SA1	SXZ
P-EE116	Q	F	N	0.585	0	9.53	8.23	0	0	5%SA1	SXZ
P-EE226	Q	F	N	0.9	0	5.21	3.9	0	0	1%SA3	SXZ
P-Lord3	Q	F	N	0.81	0	7	5.1776	0	0	1%RM7	SXZ
P-Lord4	Q	F	N	0.81	0	6.2	4.5213	0	0	1%RM7	SXZ
P-Lord2	Q	F	N	0.81	0	7.45	5.7117	0	0	1%RM7	SXZ
P-Lord1	Q	F	N	0.81	0	8.2	6.1409	0	0	1%RM7	SXZ
R1-P01	Q	F	N	0.5	0	5.38	4.88	0	0	1%SA3	SXZ
R1-P02	Q	F	N	0.5	0	5.4	4.9	0	0	1%SA3	SXZ
R1-P08	Q	F	N	0.5	0	7.83	6.45	0	0	1%SA1	SXZ
R1-P07	Q	F	N	0.5	0	7.96	7.06	0	0	1%SA1	SXZ
R1-P09	Q	F	N	0.5	0	8.472	7.05	0	0	1%SA1	SXZ
R1-P18	Q	F	N	0.5	0	13.4	12.4	0	0	1%SA2	SXZ
R1-P19	Q	F	N	0.5	0	13.3	12.3	0	0	1%SA2	SXZ
R1-P20	Q	F	N	0.5	0	12.65	11.65	0	0	1%SA2	SXZ
R1-P21	Q	F	N	0.5	0	12.55	11.35	0	0	1%SA2	SXZ
R1-P22	Q	F	N	0.5	0	9.06	8.01	0	0	1%SA2	SXZ
R1-P23	Q	F	N	0.5	0	8.99	8.04	0	0	1%SA2	SXZ
R1-P03	Q	F	N	0.5	0	5.98	4.98	0	0	1%SA1	SXZ
R1-P04	Q	F	N	0.5	0	5.878	4.45	0	0	1%SA1	SXZ
R1-P06	Q	F	Y	0.5	0	6.839	5.4	0	0	1%SA1	SXZ
R1-P05	Q	F	N	0.5	0	6.837	5.937	0	0	1%SA1	SXZ
R1-P10	Q	F	N	0.5	0	13.01	12.1	0	0	1%SA2	SXZ
R1-P11	Q	F	N	0.5	0	13.03	12.1	0	0	1%SA2	SXZ
R1-P12	Q	F	N	0.5	0	14.15	13.25	0	0	5%SA2	SXZ
R1-P13	Q	F	N	0.5	0	14.38	13.03	0	0	5%SA2	SXZ
R1-P14	Q	F	N	0.5	0	15.86	14.51	0	0	3%SA2	SXZ
R1-P15	Q	F	N	0.5	0	15.95	14.75	0	0	3%SA2	SXZ
R1-P16	Q	F	N	0.5	0	17.45	16.1	0	0	3%SA2	SXZ
R1-P17	Q	F	N	0.5	0	17.65	16.45	0	0	5%SA2	SXZ

ID	Type	Ignore	UCS	Len_or_ANA	n_or_n_F	US_Invert	DS_Invert	Form_Loss	pBlockage	Inlet_Type	Conn_2D
P-EE161	Q	F	N	0.72	0	7.91	7.31	0	0	1%SA2-S	SXZ
P-EE162	Q	F	N	0.77	0	7.91	7.34	0	0	1%SA2-S	SXZ
L-EE161B	Q	F	N	0.3	0	8.6	0	0	0	1%RM7	SXZ
R2-P01	Q	F	N	0.5	0	8.3	7.7	0	0	1%SA3	SXZ
R2-P02	Q	F	N	0.5	0	8.3	0	0	0	1%SA2	SXZ
R2-P03	Q	F	N	0.5	0	8.3	0	0	0	1%SA1	SXZ

ID	Type	Ignore	UCS	Len_or_ANA	n_or_n_F	US_Invert	DS_Invert	Form_Loss	pBlockage	Inlet_Type	Conn_2D
P-ES80	Q	F	N	0.72	0	6.55	6.15	0	0	1%SA2	SXZ
P-ES71	Q	F	N	0.54	0	6.49	5.39	0	0	5%SA2	SXZ
P-ES79	Q	F	N	0.45	0	6.64	5.89	0	0	4%RM7	SXZ
P-ES75	Q	F	N	0.2025	0	5.8	3.6	0	0	1%SA2-S	SXZ
P-ES72A	Q	F	N	0.63	0	5.86	5.26	0	0	1%SA1	SXZ
L-ES110	Q	F	N	0.5	0	5.9	5.35	0	0	1%SA3	SXZ
L-ES111	Q	F	N	0.5	0	5.9	4.96	0	0	1%RM7-S	SXZ
L-ES76A	Q	F	N	0.5	0	5.76	5.21	0	0	1%SA1-S	SXZ
L-ES110A	Q	F	N	0.5	0	5.9	5.35	0	0	1%SA2-S	SXZ
R3-P02	Q	F	N	0.5	0	11.75	10.7	0	0	3%SA2	SXZ
R3-P01	Q	F	N	0.5	0	12.01	10.96	0	0	3%SA2	SXZ
R3-P03	Q	F	N	0.5	0	11.64	10.5	0	0	3%SA2	SXZ
R3-P06	Q	F	N	0.5	0	8.9	7.78	0	0	3%SA2	SXZ
R3-P04	Q	F	N	0.5	0	9.12	8.07	0	0	3%SA2	SXZ
R3-P05	Q	F	N	0.5	0	8.95	7.9	0	0	3%SA2	SXZ
R3_P07	Q	F	N	0.5	0	8.1	6.9	0	0	2%RM7	SXZ
R3-P08	Q	F	N	0.5	0	9.71	8.66	0	0	3%SA2	SXZ
R3-P09	Q	F	N	0.5	0	8.68	7.63	0	0	3%SA2	SXZ
R3-P11	Q	F	N	0.5	0	7.07	5.5	0	0	2%RM7	SXZ
R3-P10	Q	F	N	0.5	0	7.74	6.69	0	0	3%SA2	SXZ
R3-P40	Q	F	N	0.5	0	4.8	3.75	0	0	4%RM7	SXZ
R3-P13	Q	F	N	0.5	0	12.23	10.9	0	0	3%SA2	SXZ
R3-P14	Q	F	N	0.5	0	11.7	10.58	0	0	3%SA2	SXZ
R3-P15	Q	F	N	0.5	0	9.56	8.51	0	0	3%SA2	SXZ
R3-P16	Q	F	N	0.5	0	9.4	8.28	0	0	3%SA2	SXZ
R3-P17	Q	F	N	0.5	0	8.5	7.3	0	0	6%RM7	SXZ
R3-P18	Q	F	N	0.5	0	16.1	15.05	0	0	5%SA2	SXZ
R3-P19	Q	F	N	0.5	0	15.78	14.73	0	0	5%SA2	SXZ
R3-P24	Q	F	N	0.5	0	8.32	7.27	0	0	5%SA2	SXZ
R3-P25	Q	F	N	0.5	0	8.17	6.82	0	0	5%SA2	SXZ
R3-P27	Q	F	N	0.5	0	6.28	4.93	0	0	1%SA2	SXZ
R3-P28	Q	F	N	0.5	0	6.08	4.73	0	0	1%SA2	SXZ
R3-P29	Q	F	N	0.5	0	4.72	3.37	0	0	4%RM7	SXZ
R3-P26	Q	F	N	0.5	0	7.66	6.31	0	0	5%SA2	SXZ
R3-P22	Q	F	N	0.5	0	10.76	9.71	0	0	5%SA2	SXZ
R3-P23	Q	F	N	0.5	0	10.6	9.4	0	0	5%SA2	SXZ
R3-P20	Q	F	N	0.5	0	13.32	12.27	0	0	5%SA2	SXZ
R3-P21	Q	F	N	0.5	0	13.3	12.18	0	0	5%SA2	SXZ
R3-P30	Q	F	N	0.5	0	6.24	5.72	0	0	1%RM7-S	SXZ
R3-P39	Q	F	N	0.5	0	5.838	5.41	0	0	1%RM7-S	SXZ
R3-P38	Q	F	N	0.5	0	5.855	5.46	0	0	1%RM7-S	SXZ
R3-P37	Q	F	N	0.5	0	5.855	5.51	0	0	1%RM7-S	SXZ
R3-P33	Q	F	N	0.5	0	10.28	9.23	0	0	5%SA2	SXZ
R3-P35	Q	F	N	0.5	0	7.44	6.39	0	0	3%SA2	SXZ
R3-P34	Q	F	N	0.5	0	8.5	7.45	0	0	5%SA2	SXZ
R3-P36	Q	F	N	0.5	0	6.51	5.46	0	0	3%SA2	SXZ
R3-P32	Q	F	N	0.5	0	6.5	5.75	0	0	1%SA2	SXZ
R3-P31	Q	F	Y	0.5	0	6.786	6.036	0	0	3%SA2	SXZ

ID	Type	Ignore	UCS	Len_or_ANA	n_or_n_F	US_Invert	DS_Invert	Form_Loss	pBlockage	Inlet_Type	Conn_2D
P-EE127	Q	F	N	0.63	0	13.16	12.56	0	0	1%SA2	SXZ
P-EE126	Q	F	N	0.63	0	13.15	11.85	0	0	1%SA1	SXZ
P-EE131	Q	F	N	0.63	0	16.83	16.43	0	0	1%SA2	SXZ
P-EE132	Q	F	N	0.56	0	16.61	16.31	0	0	1%SA2	SXZ
P-EE242	Q	F	N	0.54	0	17.32	16.72	0	0	5%SA3	SXZ
R4-P01	Q	F	N	0.5	0	17.4	17.1	0	0	6%RM7	SXZ
R4-P02	Q	F	N	0.5	0	17.35	17	0	0	6%RM7	SXZ
R4-P03	Q	F	N	0.5	0	17.3	16.9	0	0	6%RM7	SXZ
R4-P04	Q	F	N	0.5	0	17.25	16.8	0	0	6%RM7	SXZ
R4-P05	Q	F	N	0.5	0	16.814	16.51	0	0	5%SA2	SXZ
R4-P08	Q	F	N	0.5	0	15.6	13.8	0	0	1%RM7	SXZ
R4-P06	Q	F	N	0.5	0	16.8	16.45	0	0	1%RM7	SXZ
R4-P07	Q	F	N	0.5	16.73	16.38	0	0	0	1%RM7	SXZ

ID	Type	Ignore	UCS	Len_or_ANA	n_or_n_F	US_Invert	DS_Invert	Form_Loss	pBlockage	Inlet_Type	Conn_2D
P-EE213	Q	F	N	1.2	0	11.64	10.14	0	0	3%SA2	SXZ
P-EE214	Q	F	N	1.2	0	11.52	9.92	0	0	3%SA2	SXZ
P-EE215	Q	F	N	0.7	0	11.12	10.02	0	0	3%SA1	SXZ
P-EE243	Q	F	N	0.54	0	18.38	17.54	0	0	4%RM7	SXZ
P-EE244	Q	F	N	0.54	0	18.42	17.69	0	0	4%RM7	SXZ
L-EE224B	Q	F	N	0.5	0	16.52	0	0	0	1%RM7	SXZ
L-EE224A	Q	F	N	0.5	0	16.61	0	0	0	1%RM7	SXZ
R5-P02	Q	F	N	0.81	0	16.2	14.7	0	0	3%SA2	SXZ
R5-P01	Q	F	N	0.81	0	18.02	16.55	0	0	5%SA3	SXZ
L-EE245A	Q	F	N	0.5	0	16.9	15.25	0	0	3%SA2	SXZ
R5-P03	Q	F	N	0.81	0	15.2	13.5	0	0	3%SA2	SXZ
R5-P04	Q	F	N	0.81	0	13.9	12.2	0	0	3%SA2	SXZ
R5-P05	Q	F	N	0.81	0	12.68	11.1	0	0	3%SA2	SXZ
R5-P06	Q	F	N	0.81	0	11.5	10	0	0	3%SA2	SXZ

ID	Type	Ignore	UCS	Len_or_ANA	n_or_n_F	US_Invert	DS_Invert	Form_Loss	pBlockage	Inlet_Type	Conn_2D
P-EE149	Q	F	N	0.405	0	23.84	23.39	0	0	5%SA1	SXZ
P-EE148	Q	F	N	0.54	0	23.79	22.69	0	0	5%SA1	SXZ
P-EE150	Q	F	N	0.63	0	23.21	21.76	0	0	7%SA1	SXZ
P-EE151	Q	F	N	0.6	0	19.76	18.76	0	0	5%SA1	SXZ
P-EE152	Q	F	N	0.575	0.015	19.79	18.64	0	0	3%SA1	SXZ
P-EE154	Q	F	N	1.6	0	19.1	17.05	0	0	1%SA1	SXZ
P-EE155	Q	F	N	1.4	0	18.85	16.45	0	0	3%SA1-S	SXZ
P-EE157	Q	F	N	0.59	0	16.88	15.53	0	0	3%SA1	SXZ
P-EE158	Q	F	N	0.63	0	16.83	15.53	0	0	1%SA1	SXZ
P-EE159	Q	F	N	0.63	0	16.66	15.16	0	0	3%SA1-S	SXZ
P-EE160	Q	F	N	0.63	0	16.76	15.46	0	0	3%SA1-S	SXZ
P-EE28	Q	F	N	1.8	0	15.59	14.49	0	0	1%RM7	SXZ
P-EE27	Q	F	N	0.59	0	15.51	13.81	0	0	1%SA1	SXZ
P-EE26	Q	F	N	0.54	0	15.49	13.89	0	0	1%SA1	SXZ
P-EE25	Q	F	N	0.54	0	15.53	14.83	0	0	1%SA1	SXZ
P-EE38	Q	F	N	0.7	0.015	19.5	19	0	0	7%SA3	SXZ
P-EE36	Q	F	N	0.7	0	18.95	17.65	0	0	7%SA3	SXZ
P-EE34	Q	F	N	0.45	0.015	18.51	17.96	0	0	1%SA2	SXZ
P-EE30	Q	F	N	0.8	0	17.78	17.28	0	0	7%SA3	SXZ
P-EE143	Q	F	N	0.585	0	23.98	22.68	0	0	5%SA2	SXZ
P-EE144	Q	F	N	0.45	0	23.29	22.29	0	0	6%RM7	SXZ
P-EE145	Q	F	N	0.63	0	22.63	21.63	0	0	5%SA1	SXZ
P-EE147	Q	F	N	0.63	0	22.36	20.86	0	0	3%SA1-S	SXZ
R6-P01	Q	F	N	0.5	0	19.498	16.998	0	0	1%RM7	SXZ
R6-P05	Q	F	N	0.5	0	18.9	16.6	0	0	1%RM7	SXZ
R6-P02	Q	F	N	0.5	0	19	17.4	0	0	1%SA3	SXZ
P-EE35	Q	F	N	0.54	0	18.67	16.5	0	0	1%SA3	SXZ
R6-P03	Q	F	N	0.5	0	19.05	16.8	0	0	1%RM7	SXZ
R6-P04	Q	F	N	0.5	0	19	16.7	0	0	1%RM7	SXZ

ID	Type	Ignore	UCS	Len_or_ANA	n_or_n_F	US_Invert	DS_Invert	Form_Loss	pBlockage	Inlet_Type	Conn_2D
P-ES56	Q	F	N	1.26	0	8.58	7.33	0	0	1%SA2	SXZ
P-ES57	Q	F	N	0.5	0	8.64	7.14	0	0	3%SA2	SXZ
R7-P06	Q	F	N	0.5	0	9.35	7.7	0	0	3%SA2	SXZ
R7-P01	Q	F	N	0.5	0	14.7	13.65	0	0	3%SA2	SXZ
R7-P02	Q	F	N	0.5	0	13.5	12	0	0	3%SA1	SXZ
R7-P03	Q	F	N	0.5	0	12.42	10.92	0	0	3%SA1	SXZ
R7-P04	Q	F	N	0.5	0	11.33	9.83	0	0	3%SA1	SXZ
R7-P05	Q	F	N	0.5	0	10.44	8.94	0	0	3%SA1	SXZ
R7-P12	Q	F	N	0.5	0	11.25	9.75	0	0	3%SA1	SXZ
R7-P13	Q	F	N	0.5	0	13.1	11.6	0	0	3%SA1	SXZ
R7-P14	Q	F	N	0.5	0	13.4	11.9	0	0	3%SA2	SXZ
R7-P08	Q	F	N	0.5	0	15.1	13.6	0	0	3%SA1	SXZ
R7-P09	Q	F	N	0.5	0	14.04	12.54	0	0	3%SA1	SXZ
R7-P10	Q	F	N	0.5	0	13.22	11.72	0	0	3%SA1	SXZ
R7-P11	Q	F	N	0.5	0	12.55	11.05	0	0	3%SA1	SXZ
R7-P07	Q	F	N	0.5	0	9.1	7.5	0	0	3%SA1	SXZ

ID	Type	Ignore	UCS	Len_or_ANA	n_or_n_F	US_Invert	DS_Invert	Form_Loss	pBlockage	Inlet_Type	Conn_2D
P-ES75	Q	F	N	0.2025	0	5.8	3.6	0	0	1%SA2-S	SXZ
L-ES110	Q	F	N	0.5	0	5.9	5.35	0	0	1%SF1	SXZ
L-ES111	Q	F	N	0.5	0	5.9	5.36	0	0	1%SF1-S	SXZ
L-ES76A	Q	F	N	0.5	0	5.76	5.21	0	0	1%SA1-S	SXZ
L-ES110A	Q	F	N	0.5	0	5.9	5.35	0	0	1%SF1-S	SXZ
L-ES111_N	Q	F	N	0.5	0	5.9	5.36	0	0	1%SA1-S	SXZ
R9_P2	Q	F		0.5	0.015	-99999	-99999	0	0	1%RM7-S	sxZ
R9_P1	Q	F		0.5	0.015	-99999	-99999	0	0	1%RM7-S	sxZ

ID	Type	Ignore	UCS	Len_or_ANA	n_or_n_F	US_Invert	DS_Invert	Form_Loss	pBlockage	Inlet_Type	Conn_2D
P-ES80	Q	F	N	0.72	0	6.55	6.15	0	0	1%SA2	SXZ
P-ES71	Q	F	N	0.54	0	6.49	5.39	0	0	5%SA2	SXZ
P-ES79	Q	F	N	0.45	0	6.64	5.89	0	0	4%RM7	SXZ
P-ES75	Q	F	N	0.2025	0	5.8	3.6	0	0	1%SA2-S	SXZ
P-ES72A	Q	F	N	0.63	0	5.86	5.26	0	0	1%SA1	SXZ
L-ES110	Q	F	N	0.5	0	5.9	5.35	0	0	1%SA3	SXZ
L-ES111	Q	F	N	0.5	0	5.9	4.96	0	0	1%RM7-S	SXZ
L-ES76A	Q	F	N	0.5	0	5.76	5.21	0	0	1%SA1-S	SXZ
L-ES110A	Q	F	N	0.5	0	5.9	5.35	0	0	1%SA2-S	SXZ
R3-P02	Q	F	N	0.5	0	11.75	10.7	0	0	3%SA2	SXZ
R3-P01	Q	F	N	0.5	0	12.01	10.96	0	0	3%SA2	SXZ
R3-P03	Q	F	N	0.5	0	11.64	10.5	0	0	3%SA2	SXZ
R3-P06	Q	F	N	0.5	0	8.9	7.78	0	0	3%SA2	SXZ
R3-P04	Q	F	N	0.5	0	9.12	8.07	0	0	3%SA2	SXZ
R3-P05	Q	F	N	0.5	0	8.95	7.9	0	0	3%SA2	SXZ
R3_P07	Q	F	N	0.5	0	8.1	6.9	0	0	2%RM7	SXZ
R3-P08	Q	F	N	0.5	0	9.71	8.66	0	0	3%SA2	SXZ
R3-P09	Q	F	N	0.5	0	8.68	7.63	0	0	3%SA2	SXZ
R3-P11	Q	F	N	0.5	0	7.07	5.5	0	0	2%RM7	SXZ
R3-P10	Q	F	N	0.5	0	7.74	6.69	0	0	3%SA2	SXZ
R3-P13	Q	F	N	0.5	0	12.23	10.9	0	0	3%SA2	SXZ
R3-P14	Q	F	N	0.5	0	11.7	10.58	0	0	3%SA2	SXZ
R3-P15	Q	F	N	0.5	0	9.56	8.51	0	0	3%SA2	SXZ
R3-P16	Q	F	N	0.5	0	9.4	8.28	0	0	3%SA2	SXZ
R3-P17	Q	F	N	0.5	0	8.5	7.3	0	0	6%RM7	SXZ
R3-P18	Q	F	N	0.5	0	16.1	15.05	0	0	5%SA2	SXZ
R3-P19	Q	F	N	0.5	0	15.78	14.73	0	0	5%SA2	SXZ
R3-P24	Q	F	N	0.5	0	8.32	7.27	0	0	5%SA2	SXZ
R3-P25	Q	F	N	0.5	0	8.17	6.82	0	0	5%SA2	SXZ
R3-P27	Q	F	N	0.5	0	6.28	4.93	0	0	1%SA2	SXZ
R3-P28	Q	F	N	0.5	0	6.08	4.73	0	0	1%SA2	SXZ
R3-P29	Q	F	N	0.5	0	4.72	3.37	0	0	4%RM7	SXZ
R3-P26	Q	F	N	0.5	0	7.66	6.31	0	0	5%SA2	SXZ
R3-P22	Q	F	N	0.5	0	10.76	9.71	0	0	5%SA2	SXZ
R3-P23	Q	F	N	0.5	0	10.6	9.4	0	0	5%SA2	SXZ
R3-P20	Q	F	N	0.5	0	13.32	12.27	0	0	5%SA2	SXZ
R3-P21	Q	F	N	0.5	0	13.3	12.18	0	0	5%SA2	SXZ
R3-P30	Q	F	N	0.5	0	6.24	5.72	0	0	1%RM7-S	SXZ
R3-P39	Q	F	N	0.5	0	5.838	5.01	0	0	1%RM7-S	SXZ
R3-P38	Q	F	N	0.5	0	5.855	5.06	0	0	1%RM7-S	SXZ
R3-P37	Q	F	N	0.5	0	5.855	5.11	0	0	1%RM7-S	SXZ
R3-P33	Q	F	N	0.5	0	10.28	9.23	0	0	5%SA2	SXZ
R3-P35	Q	F	N	0.5	0	7.44	6.39	0	0	3%SA2	SXZ
R3-P34	Q	F	N	0.5	0	8.5	7.45	0	0	5%SA2	SXZ
R3-P36	Q	F	N	0.5	0	6.51	5.46	0	0	3%SA2	SXZ
R3-P32	Q	F	N	0.5	0	6.5	5.45	0	0	1%SA2	SXZ
R3-P31	Q	F	Y	0.5	0	6.786	5.74	0	0	3%SA2	SXZ

APPENDIX F

Water Management Options - CAD Sections

Please refer to document:

EC East Subcatchment Management Plan

Technical Report

Volume 1 – Management Study

Appendix F and G

APPENDIX G

Water Management Options – Layouts and Modelling Results

Please refer to document:

EC East Subcatchment Management Plan

Technical Report

Volume 1 – Management Study

Appendix F and G

APPENDIX H

Planning Control Matrix for Flood Liable Land

EC East Subcatchment - Proposed Planning Control Matrix for Flood Liable Land

Appendix H

Planning consideration for the development	Flood Risk															
	Low								High							
	Critical Uses & Facilities	Sensitive Uses & Facilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Parkland	Concessional development	Critical Uses & Facilities	Sensitive Uses & Facilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Parkland	Concessional development
Floor Level		3		2	2	2	1	4							2	2,4
Building Components		2		1	1	1	1	1							2	1
Structural Integrity		2		1	1	1	1	1							2	1
Flood Impacts		1	2,3	2,3	2,3	2,3	2,3	2,3							1,3	1,3
Car Parking and Driveway Access		1,4		1,2,3,4	1,2,3,4	1,2,3,4	1,4	1,4,5,6							1,4	1,4,5,6
Boundary Fencing		1		1,2	1,2	1,2	1,2	1,2							1,2	1,2
Evacuation		3,2 or 5	6	3,2 or 5	3,2 or 5	3,2 or 5	4,3	1							3,2 or 5	1
Management & Design		3,4,5	1	5	2,3,4,5	2,4,5	2,4,6	2,4,6							3,4,5	2,4,6

COLOUR LEGEND: Not Relevant (green) | Unsuitable Land Use (red)

General Notes

a Principles of development control presented in the NSW Governments Floodplain Development Manual are applicable

b One of the key principles of development control is to consider the density of development and assess its impact on the cumulative flood risk in the catchment. This principle should be applied where applicable e.g. multi unit development

c Freeboard equals an additional height of 500mm above a design flood level. For areas impacted by minor overland flows a freeboard of 300mm maybe considered

** Does not apply to single dwelling houses, secondary dwellings or dual occupancies in areas above the 1 in 100 year event plus freeboard

Floor Level

1	All floor levels to be as high as practical but not less than the 20 year flood level plus freeboard unless justified by site specific assessment.
2	All habitable floor levels to be no lower than the 100 year flood level plus freeboard, unless justified by site specific assessment (i.e. such as minor outdoor structures).
3	Habitable floor levels to be no lower than the PMF plus freeboard level. Non-habitable floor levels to be no lower than the PMF plus freeboard level unless justified by a site specific assessment.
4	Floor levels to be as high as practical but no lower than the existing floor level when undertaking alterations and additions

Building Components

1	All structures to have flood compatible building components below the 100 year flood level plus freeboard.
2	All structures to have flood compatible building components below the PMF plus freeboard level.

Structural Integrity

1	Applicant to demonstrate that the structure can withstand the forces of floodwater, debris and buoyancy up to and including a 100 year flood plus freeboard, or a PMF if required to satisfy evacuation criteria (see below). An engineer's report may be required
2	Applicant to demonstrate that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a PMF. An engineers report may be required.

Flood Impacts

1	Engineer's report required to certify that the development will not increase flood effects elsewhere, having regard to: (I) loss of flood storage; (ii) changes in flood levels and velocities caused by alterations to the flood conveyance ; and (iii) the cumulative impact of development for a standard suite of design flood events as specified by the Council
2	The flood impact of the development to be considered to ensure that the development will not increase flood effects elsewhere, having regard to: (I) loss of flood storage; (ii) changes in flood levels and velocities caused by alterations to the flood conveyance ; and (iii) the cumulative impact of developments within the floodplain. An engineers report may be required.
3	Any filling within the 100 year flood area will normally not be considered unless compensatory excavation is provided to ensure that there is no net loss of floodplain storage volume below the 1 in 100 year flood

Car Parking/Driveway Access

1	The minimum surface level of open car parking spaces, carports or garages, shall be as high as practical.
2	Lower ground garages located under the development below street level shall have an entry level at PMF or 100 year plus freeboard, whichever is higher.
3	The level of the driveway providing access between the road and parking space shall be no lower than 0.3m below the 100 year flood or such that the depth of inundation during a 100 year flood is not greater than either the depth at the road or the depth at the carparking space. A lesser standard may be accepted for single dwelling houses where it can be demonstrated that risk to human life would not be compromised.
4	Restraints or vehicle barriers to be provided to prevent floating vehicles leaving a site during a 100 year flood or a rarer event where proposed level of the carspaces is greater than 300mm elow the 1 in 100 year event **
5	Garage floor Levels to be no lower than 300mm above the finished adjacent ground level
6	Driveway and carparkig space levels shall be no lower than the minimum requirements normally applicable to this type of development. Where this is not practical, a lower level may be considered. In these circumstances , the level is to be as high as practical and, when undertaking alterations and additions no lower than the existing level

Note: A flood depth of 0.3m is sufficient to cause a typical vehicle to float.

Boundary Fencing

1	Any fencing that forms part of a proposed development should not create flood impacts and should have appropriate structural integrity
2	Fencing to be constructed in a manner that does not obstruct the flow of floodwaters. Fencing must be of permeable open type and in certain circumstances will be required to be designed to collapsed in a controlled manner.

Evacuation

1	Reliable access for pedestrians or vehicles required during a 100 year flood.
2	Reliable access for pedestrians or vehicles is required from the building, commencing at a minimum level equal to the lowest habitable floor level to an area of refuge above the PMF level
3	The development is to be consistent with any relevant flood evacuation strategy, Flood Plan adopted by Council or similar plan.
4	The evacuation requirements of the development are to be considered. An engineers report will be required if circumstances are possible where the evacuation of persons might not be achieved within the effective warning time .
5	A flood refuge above the PMF level is required on site. The flood refuge should be able to accommodate the usual occupants of the development
6	Applicant to demonstrate that evacuation in accordance with the requirements of this plan available for the potential development

Management and Design

1	Applicant to demonstrate that potential development as a consequence of a subdivision proposal can be undertaken in accordance with this plan
2	Applicant to demonstrate that area is available to store goods above the 100 year flood level plus freeboard
3	Applicant to demonstrate that area is available to store goods above the PMF level.
4	No storage of materials below the design floor level which may cause pollution or be potentially hazardous during any flood.
5	A site specific Flood Emergency Response Plan is required **
6	Consideration should be given to the preparation of a site specific Flood Emergency Response Plan.

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