ECOLOGICAL ENGINEERING

Bungarribee Precinct

Doonside Residential Development

WSUD Strategy

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Executive Summary

This report presents the Water Sensitive Urban Design (WSUD) Strategy for the Doonside residential development. The report integrates potable water conservation, pollution control and flow management measures with the unique Parklands setting. This strategy has been developed in collaboration with EDAW and Architectus, the Landscape Architects and Urban Designers for the project, ensuring that the WSUD elements proposed are complementary to the open space and built form.

The Doonside residential development is bounded by Doonside Road and Eastern Road on the east and north and by the Western Sydney Parklands to the west and south; specifically the waterway corridors of Eastern Creek and Bungarribee Creek. There are two ephemeral waterways (Southern and Northern Creeks) within the residential site. These waterways receive untreated stormwater from catchments external to the site and discharge to Eastern Creek.

The proposed residential development will significantly alter the hydrology of the existing site and generate stormwater pollution as a result of increased impervious surface area and urban activities. WSUD elements will be used to reduce pollutants carried in the stormwater from the Doonside residential development and from the upstream urban catchments that drain through the site. Discharge from the WSUD elements and from detention areas designed to reduce peak flows will be managed so that riparian areas and the creeks will receive flows more closely representative the predevelopment hydrology, with specific attention to limiting the critical peak flows.

The WSUD strategy has been guided by a series of water management principles for the site derived from the provisions within state and local government planning policies, as well as responding to the water management opportunities and constraints that the site presents. The WSUD Strategy is centred on achieving the following outcomes:

- Potable mains water reduction through demand management including water efficient fixtures and fittings, as well as using alternative sources of water based on matching water quality to uses on a "fit-for-purpose" basis.
- Stormwater runoff from the development, as well as from four of the five external catchments to the east of the development which flow through the site, to be treated to current best practice water quality standards.
- Post-development storm discharges to equal pre-development storm discharges for the one and a half year ARI event, so as to minimise the impact of frequent events on the natural waterways and to minimise bed and bank erosion.
- Post-development storm discharges up to the 100 year ARI event need to be controlled so as to avoid any increases in the peak discharges in Eastern Creek and Bungarribee Creek.

The elements of the proposed WSUD Strategy to meet these outcomes include water conservation, stormwater quality management and waterway protection as outlined below.

The strategy takes into consideration the commitment of the Department of Planning and Landcom as the land owners and developers of the site to delivering an innovative and unique development, striving for "world's best practice".

<u>Water conservation</u>

Potable water conservation will be achieved with water efficient fixtures and appliances, and the provision of alternative sources of (non-potable) water through a dual reticulation water supply network. Non-potable water will be supplied to meet toilet flushing, irrigation, and cold water laundry demands. Alternative water may be sourced from either harvested stormwater or treated wastewater (subject to feasibility of extending a recycled water pipeline from the Quakers Hill Sewage Treatment Plant). Rainwater tanks may also be configured to supply the hot water system for each house thereby further reducing non potable demand. The water conservation measures aim to reduce potable water use by as much as 65% compared with average usage (BASIX benchmark).

<u>Best practice stormwater pollutant reduction</u>

The Western Sydney Parklands adjacent to the site is a considerable ecological asset, and the receiving environment for urban stormwater runoff from this development. Pollution control measures will reduce the pollutants carried in stormwater from both the Doonside development areas and from four of the five existing upstream residential catchments which currently discharge stormwater to the site without treatment. WSUD elements such as wetlands and bioretention systems will be used to meet best practice targets, reducing the mean annual load of total suspended solids by at least 80% and total nitrogen and phosphorus by at least 45%. The elements proposed include linear bioretention systems planted with production based trees within the eco-medians (see section 5.1), linear bioretention systems at the park edge road (section 5.2) and wetlands within the Southern and Northern waterways (section 5.4.1 and 5.5.1).

<u>Waterway protection</u>

The WSUD Strategy for the Doonside development aims to address the legacy of inadequate controls on stormwater quality and peak flow management which have significantly impacted on the Eastern Creek and waterways within the vicinity of the Doonside development. Protection of aquatic habitat in waterways is associated with sustaining the geomorphic form of the beds and banks within the local waterways. Erosion protection requires management of the peak flows from frequent storm events for the 1.5year Average Recurrence Interval (ARI) event.

Peak discharges from both the development and from four of the five upstream residential catchments will be controlled through the use of shallow ephemeral detention areas within the natural floodplain of Eastern Creek and Bungarribee Creek. These detention areas will integrate seamlessly with the riparian zones, with planting of suitable floodplain vegetation. The detention storage required is achieved with low bunding and small inlet / outlet structures to control discharge to the local waterway. The duration of inundation of these systems is limited to periods of up to 24 hours. The discharge from both treatment and detention areas will be controlled so that the riparian areas and the waterway will receive flows that more closely represent the predevelopment hydrology, with specific attention to limiting the critical peak flows. Due to constraints on the availability of space in the northern portion of the site it is not possible to attenuate the stormwater from the external Kareela Avenue catchment. Options to attenuate and treat the Kareela Avenue catchment are considered to be important in the protection of the identified ecologically sensitive vegetation and the bed and banks of Eastern Creek, and should be investigated as this area is developed.

1 Introduction

The Western Sydney Parklands is a major new regional park for Western Sydney, and an outcome of the NSW Government's Metropolitan Strategy. The Parklands is initially being managed by the Department of Planning, prior to the establishment of a Parklands Trust. Landcom will develop the residential and employment areas adjoining the Parklands.

Ecological Engineering has been engaged by Landcom to develop a series of Water Sensitive Urban Design (WSUD) strategies for the key areas within the Bungarribee Precinct of the Western Sydney Parklands and the adjoining 'interface' lands. These areas include the Doonside and Rooty Hill residential sites, the Huntingwood West employment zone, and nominated activity areas within the Bungarribee Precinct.

The WSUD strategy developed for the 55 ha Doonside site is presented in this report. The strategy has been developed in collaboration with EDAW and Architectus, the Landscape Architects and Urban Designers for the development. The WSUD elements proposed for the site have been designed to be integrated into the open space and built form, adding aesthetically and functionally to the design.

This strategy has been further informed by discussions with the Department of Planning, Landcom, Blacktown City Council, and other stakeholders and consultants as required. The strategy is designed to integrate the site specific opportunities with the WSUD principles and objectives to deliver best practice water cycle management.

This Strategy for the Doonside residential development aims to optimise water cycle management for the site. The key sections of this report include:

- Opportunities and constraints identified for the site (Section 2).
- Water management principles and objectives based on relevant planning documents and developed in response to the unique nature of the site (Section 3).
- Assessment of the water quality treatment measures required to meet the objectives for the site (Section 4).
- Flood modelling and the integration of the required flood detention with the site layout (Section 4.4).
- Integration of the required measures with the masterplan for the site with details of the proposed constructed wetlands, bioretention systems and ephemeral detention areas (Section 5).
- Potable water conservation measures including demand management and use alternative water sources to meet non-potable demands - fit for purpose use of water (Section 6).
- Preliminary costing of proposed WSUD elements (Section 7).

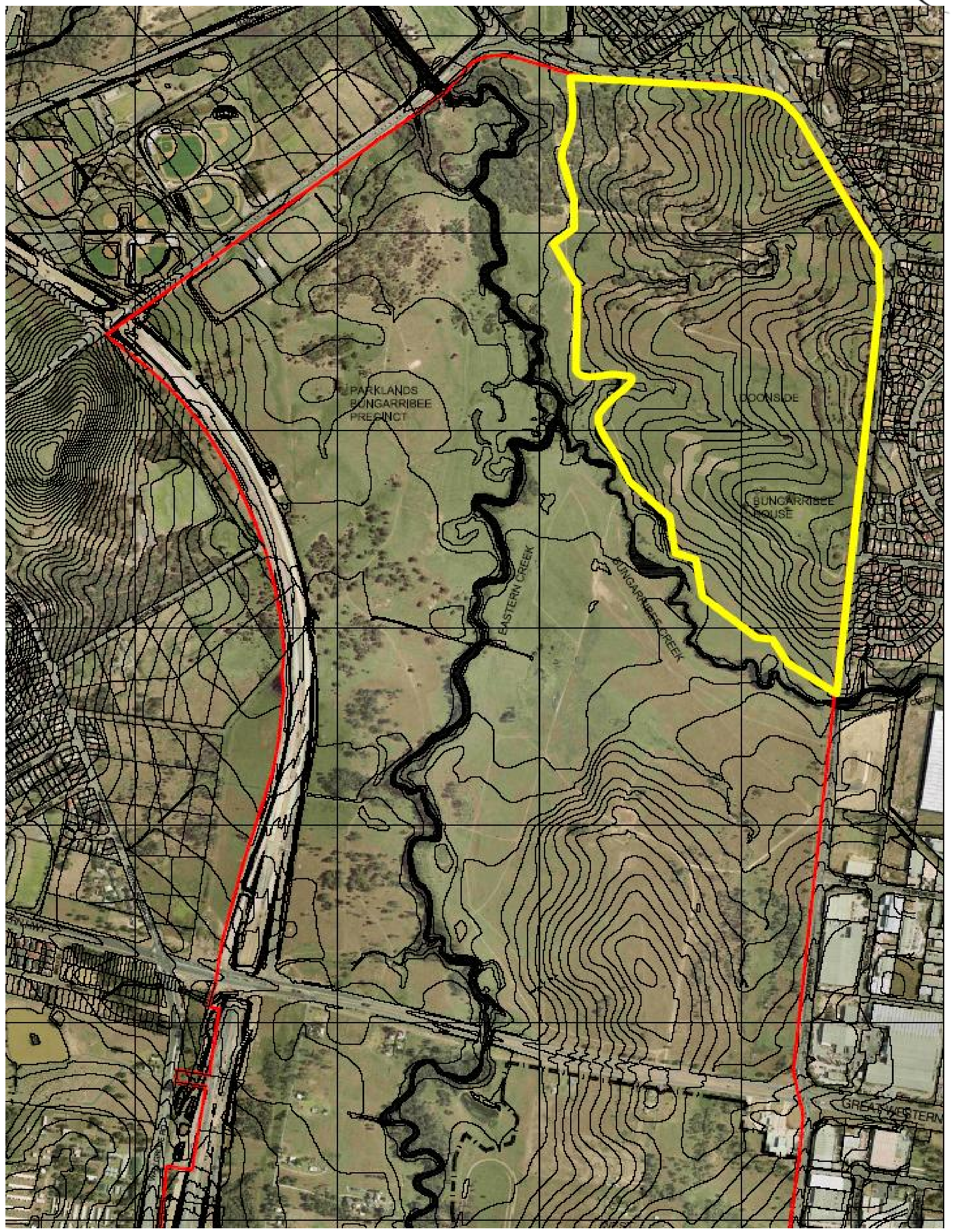


Figure 1.1: Aerial photo showing the Doonside site, at the northern end of the Bungarribee Precinct. (modified from Whelans)

2 Site Opportunities and Constraints

The Doonside residential development is bounded by Doonside Road to the east, the Western Sydney Parklands (floodplain areas of Eastern Creek and Bungarribee Creek) to the west and south and by and Eastern Road on the north. There are two ephemeral waterways that flow through the proposed development area (hereby referred to as the Southern and Northern Creeks (Figure 2-1)) and a small waterway which runs through the conservation area of the Parklands from near Kareela Ave (crossing Eastern Road from the cleared area at the northern boundary of the site). The characteristics of these waterways are detailed sections 2.2, 2.3 and 2.4.

Figure 2-1: Aerial photo showing the waterways and external catchments

Eastern Creek is the main waterway flowing through this part of the Western Sydney Parklands. Bungarribee Creek drains a significant catchment (700ha) to the east of Doonside Road. The corridors for these waterways form the critical ecological links and habitat corridors integral to the conservation vision of the Parklands.

2.1 External Catchments

There are five significant external catchments as illustrated in Figure 2-1, four of which pass through the residential development. The catchment areas have been determined using drainage data from Council and contour information. The discharge locations have been surveyed, with data collected detailing the pipe sizes and culvert elevation for these discharge points at the site boundary (Table 2-1). The external catchments discharge untreated stormwater to the site with significant impacts associated with deposition of sediment and nutrients, erosion, weed infestation and general disturbance (Figure 2-2).

Figure 2-2: Culverts from external catchments (S1, B, C (catchment K1))

Table 2-1: Culverts details for external catchment discharge points

	Discharge point	Culvert Details	Cat. Area	Catchment Description
S1	Culvert on Doonside Road, upstream section of the Southern Waterway	box culvert 1800 x 450mm	9.6 ha	Residential area (7.6ha), ridge park corridor (1ha) and recreation park (1ha)
S2	Culvert on Doonside Road, 215m north of the culvert for S1. The overland flow path is not a natural gully	825mm, inv 47.45 375mm, inv 47.38	8.4 ha	Residential area(7.8ha) and ridge park corridor (0.6ha)
N1	Culvert on Doonside Road, 90m south of Bungarribee Rd intersection. Overland flow path cuts through a minor natural gully	825mm, inv 45.99 675mm, inv 45.79	7.7 ha	Residential area (7.7ha)
N2	Silted culvert on Doonside Road, 110m north west of Bungarribee Rd intersection. Trench re-directs flow to a lower part of the Northern Waterway.	Silted culvert approx 2.6m depth, inv 42.4, unknown size.	16.2 ha	Residential area and Rainbow Shopping Centre complex, and small park areas totalling (1.6ha).
K1 'C'	Culvert on Eastern Road, small waterway running through conservation area to Eastern Creek (from nr Kareela Ave).	1350mm, inv 36.80 375mm, inv 36.88	14.5 ha	Residential area (6.5ha), school (1.5ha), cleared triangular area / waterway flow path (3ha), other roads(1ha), other park areas (2.5ha)
Additional stormwater discharge points along Eastern Road: D: 600mm, inv 44.11, catchment is part of the triangular cleared area B: 375mm, inv 35.06, catchment unclear (but small) A: 750mm, inv 32.51; 375mm, inv 32.30; 375mm, inv32.84; catchment areas unclear (but small)				

2.2 Northern Creek

The northern creek has been substantially modified by the creation of a series of online dams, which have been colonized by invasive weed species like *Thypa*. Two external catchments (with combined area of approximately 24 ha) discharge untreated stormwater to the site in the vicinity of the intersection of Doonside Road and Bungarribee Road. A constructed channel redirects stormwater from the larger upstream catchment to a section of the waterway down stream. The smaller of the two external catchments has eroded a flow path through the natural terrain and joins the northern creek via overland flow.

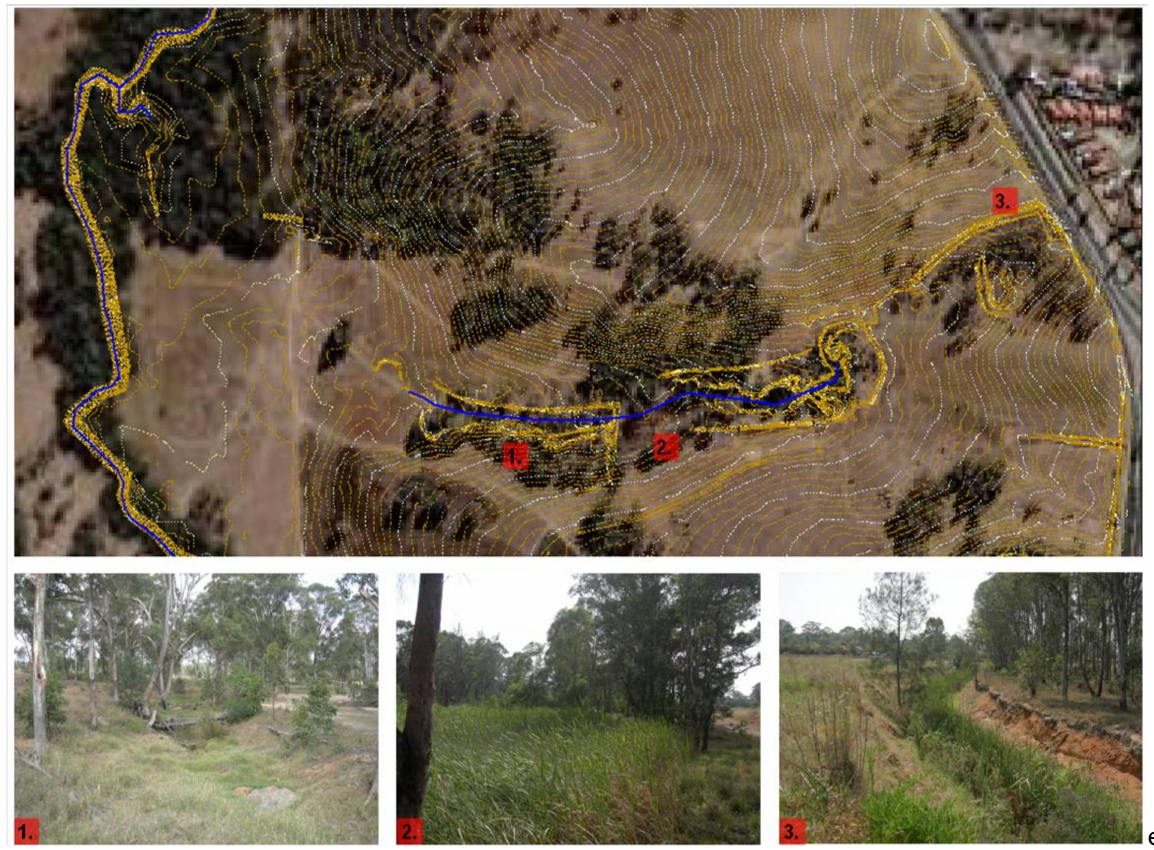
The terrestrial vegetation along the central part of the waterway (upstream of the constructed dam (2) in Figure 2-3) and in the conservation area to the north is identified as having high ecological value, namely Shale Plains Woodland, part of the *Cumberland Plains Woodland* Endangered Ecological Community (Ecological Australia, 2007). Along the other parts of the waterway the vegetation is classified as a moderate ecological constraint and includes Alluvial Woodland ((1) in Figure 2-3) and a scattered overstorey of Shale Plains Woodland (adjacent Doonside Road (near label 3) in Figure 2-3). The cleared areas along the waterway are exotic dominant grasslands.

Downstream of the dam structures the waterway form is more natural ((1) in Figure 2-3), with a wide shallow channel, (up to 40m width, 2m depth). The northern bank is constrained by the creation of a dirt road which has leveled this area.

The grade of the general terrain flattens as the waterway meets the floodplain and there is no channel evident and no connection between the northern creek and Eastern Creek. This is likely to be the result of a number of factors. The trunk sewer main draining to nearby Quakers Hill STP cuts the waterway at this point (approximately along the north-south alignment of the dirt track / path visible in the aerial photo). Substantial modification to the natural channel form and the surrounding terrain may have occurred in association with the construction of this sewer. The dam structures capture all but the largest flows from the upstream areas, cutting off flow to the waterway.

A small confluence with Eastern Creek is visible from survey information and suggests the original alignment through the riparian vegetation to the north-west. The banks of Eastern Creek in the vicinity of the Northern Waterway are particularly steep and the waterway is incised to a typical depth of 4 meters below the banks. There are no other signs of likely discharge pathways for the northern waterway.

The reconnection of this waterway to Eastern Creek to ensure a stable form for conveyance of flows from the developed catchment will require more detailed assessment, but two options exist. Rock drop structures could be used to stabilize a direct connection to Eastern Creek along an alignment that avoids the existing vegetation to the north. Alternatively it may be possible to reconnect the waterway along the assumed, original flow path without significantly impacting on valuable terrestrial vegetation given the extensive weedy understorey (dominated by wandering jew (*Tradescantia fluminensis*) and other weedy shrub species) in heavily shaded weedy areas. The channel formed to reconnect with Eastern Creek, and other rehabilitated sections of the Northern Waterway would be revegetated with suitable native species.



1. Wide, shallow channel of the downstream natural section of the Northern Waterway. Construction of a dirt road has leveled the bank on the northern side.

2. Extensive Typha stands throughout the constructed dams. Erosion related salinity issues evident where the soil B –horizon has been exposed.

3. Constructed channel, redirecting stormwater from the culvert at Doonside Road to downstream section of the Northern Waterway (length 200m).

Figure 2-3: Northern waterway

4. Extensive weedy understorey in the heavily shaded riparian areas (both ground covers and shrub species).

Figure 2-4: Reconnection of Northern Waterway with Eastern Creek

2.3 Southern Creek

The southern waterway is approximately 900m in length, and receives stormwater from two external catchments with a combined area of 18ha. There is evidence of significant sediment deposition and a large *Typha* stand extending from the southern culvert (culvert 1) on Doonside Road (Figure 2-5). The second catchment discharges stormwater at a culvert 215m further north along Doonside Road into another natural depression which drains towards the lower part of the Southern Waterway.

The upstream part of the Southern Waterway does not have a clearly defined flow path or channel, and stormwater would spread across the broad vegetated corridor (Figure 2-6).

Where the flow path of the waterway becomes identifiable, two online dam structures have been constructed, both colonized by invasive weedy species like *Thypa*. The riparian vegetation has been cleared along almost the entire waterway length, and areas of erosion and salinity impacts are evident.

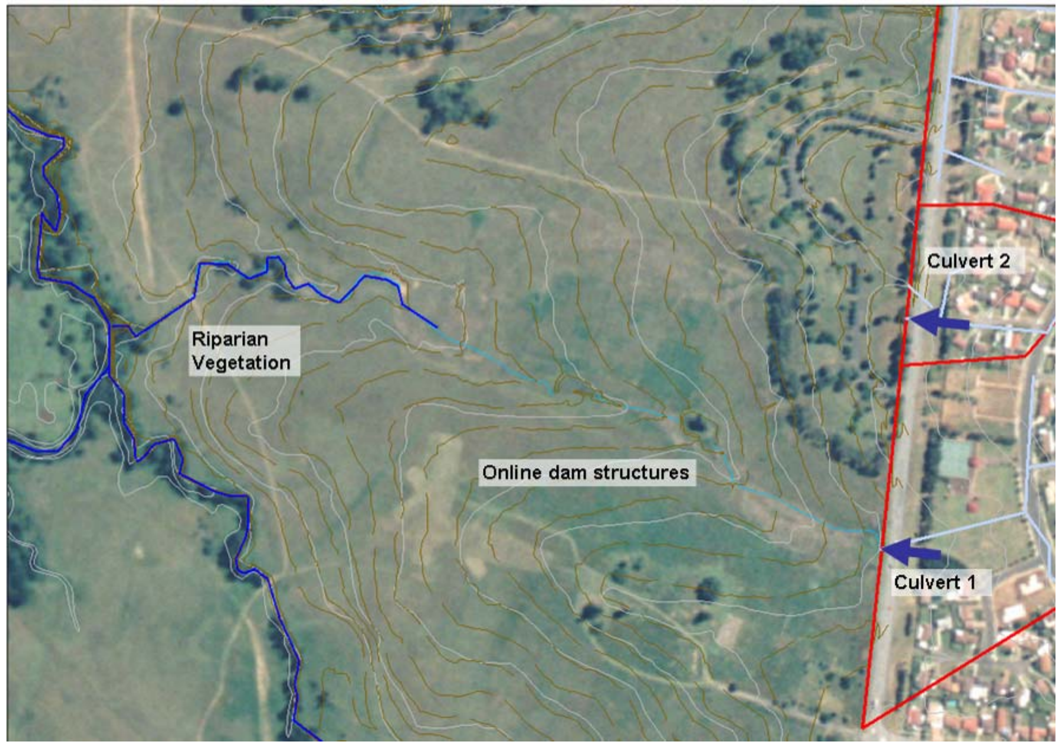


Figure 2-5: Southern Waterway

The only riparian canopy vegetation is found approximately 200m from the confluence of this waterway with Eastern Creek. In this section of the waterway the natural low flow channel has generally been protected from erosion and it represents a good geomorphic and ecological example of a natural creek in this location (Figure 2-9). There is a small stand of casuarinas with a carpet of native grass (Microlaena understorey) which provides a natural template for the rehabilitation of this waterway. The development layout has been configured to preserve this area and the existing alignment of the Southern Waterway. The WSUD strategy developed ensures the predevelopment flood hydrology is maintained (particularly for frequent events). The revegetation of the riparian zone for the lower section of the Southern Creek will extend the natural template presented to stabilise the modified sections in the lower half of the waterway.

Figure 2-6: Wide vegetated corridor, upstream section of the Southern Waterway

Figure 2-7: Online Dam and eroded channel Southern Waterway

Figure 2-8: Riparian vegetation along the Southern Waterway has been cleared except for a grove of Casuarina 200m confluence with Eastern Creek

Figure 2-9: Casuarina grove and microlaena grass carpet along the Southern Waterway

2.4 Kareela Ave waterway

A small tributary of Eastern Creek runs through the existing vegetation and conservation area from near Kareela Avenue (Figure 2-10), just north of the Doonside site. The main culvert on Eastern Road conveys the upstream catchment of approximately 14.5ha through 1350mm and 375mm pipes. There are additional stormwater discharge points along Eastern Road with smaller catchment areas. There is a significant residential area and school within the Kareela Avenue catchment in addition to the large cleared triangular area (the original flow path of the waterway upstream of the road crossing).

Figure 2-11 shows the impact of external stormwater discharges at the Eastern Road culverts conveying the Kareela Ave waterway. There are approximately seven stormwater discharge points (at four locations) along Eastern Road which either drain to this waterway, or have eroded pathways to Eastern Creek. These discharge points cause significant disturbance in terms of erosion and the creation of a point source of nutrient pollution which sustains increasing weed growth. Endangered ecological communities like the Cumberland Plain Bushland are threatened by invasive weeds which out compete native species.

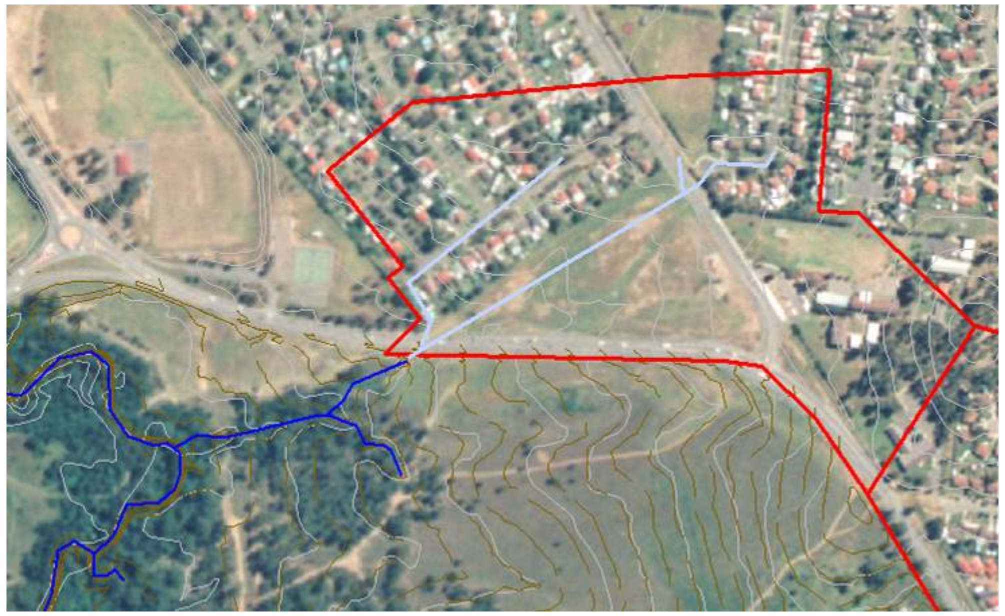


Figure 2-10 Kareela Ave Waterway downstream of the culvert on Eastern Road.

Figure 2-11 Weed growth and disturbance downstream of the culvert on Eastern Road.

2.5 Categorisation

The Department of Natural Resources has determined setbacks for waterways in and surrounding the Doonside residential development according to the Departments Riparian Corridor Management Study. These categorisations were determined through a desktop study, as noted in correspondence to URS in 2006 (WSP Interface Lands Drainage, Flood and Water Quality report), and include:

- Category 1 – Eastern Creek, Bungarribee Creek and Kareela Ave waterway
- Category 2 – northern waterway
- Category 3 – southern waterway

A site inspection was held to review these categorisations. There is general concurrence with the categorisation of Eastern Creek, however, as stated in the above sections the northern, southern and Kareela Ave waterways are all highly degraded. In particular the northern waterway has a series of online dams effectively stopping any flows to Eastern Creek, to which there is no connection. Prior to further discussion with the Department, the following suggestions are made as to possible categorisations, which should be reviewed in conjunction with the wider WSUD and flora and fauna strategies as well as the development layout.

The northern waterway, as discussed in section 2.2, has a highly modified channel and there is currently no waterway connection to Eastern Creek (Figure 2.3 and 2.4). It is potentially a category 3 waterway. Compensation should be made for a greater width of the riparian zone due to its flora and fauna values and terrestrial connectivity with Eastern Creek.

Due to the modified nature of the southern waterway, as detailed in section 2.3, only the downstream section of the creek is proposed as a category 3 waterway.

The Kareela Ave waterway, downstream of the Eastern Road culvert, is potentially a category 2 waterway, due to its terrestrial connectivity with Eastern Creek (Figure 2-10). The vegetation in the area is of high ecological value, with good connectivity to the riparian area of Eastern Creek (Ecological Australia, 2007). There are significant erosion points at the confluence and along this section of Eastern Creek that need to be stabilised in order to protect this waterway. The impacts of stormwater discharged from the upstream catchment need to be mitigated, possibly along the Eastern Road boundary where an existing erosion pathway has formed connecting some of the culverts directly to Eastern Creek at the Eastern Road crossing.

Bungarribee Creek is potentially a category 2 waterway. The length from Doonside Road to the confluence with Eastern Creek is in fairly good condition, at present. The waterway has a large developed catchment and a previous weir structure has been replaced (in 1999) with the construction of a large culvert bridge crossing at the Doonside Road. The waterway is significantly wider in the vicinity of this culvert, with *Typha* extending across the full width. It is likely that the impacts of untreated stormwater from the large developed urban and industrial catchment will progressively transferred along this section of Bungarribee Creek. There are opportunities being considered to protect Bungarribee Creek downstream of Doonside Road with stormwater management integrated with development proposed within the Parklands.

Eastern Creek is considered to be a category 1 waterway with the riparian area encompassed within the boarded biodiversity corridor proposed for the Parklands. Opportunities to protect this waterway though the mitigation of stormwater impacts is a key objective of the WSUD strategy presented in this report.

2.6 Development Layout

The layout proposed for the Doonside residential development is presented in Figure 2-12, with a total development footprint of 55ha within the 75ha site (yellow boundary). The development of the Doonside residential parcel, located adjacent to the Parklands Bungarribee precinct will raise funds to be returned to the Parklands Trust for the management of the Western Sydney Parklands. The residential area will be integrated into the Parklands setting and ensure a high quality residential neighbourhood incorporating best practice design and environmental protection.

The development has responded to a range of constraints to configure up to 730 residential lots and preserve the ecological and heritage assets of the site. The lot sizes range from 250m² - 550m². The majority of lots are greater than 500m². The layout proposed includes large landscape areas, 'eco-medians', with a combined area of 9,912m². The eco-median areas are described in section 5.1. The road area for the development totals approximately 19.27ha.

The Bungarribee Homestead Heritage Precinct is a large area to the south of the southern waterway. The site of the former homestead will be a feature of the development, with historical interpretation, extensive landscape areas and a future building / structure to service the community.

The development of the WSUD strategy for the site has involved significant collaboration with EDAW and Architectus, the Landscape Architects and Urban Designers for the project, ensuring that the WSUD elements proposed for the site have been designed to be integrated into the open space and built form.

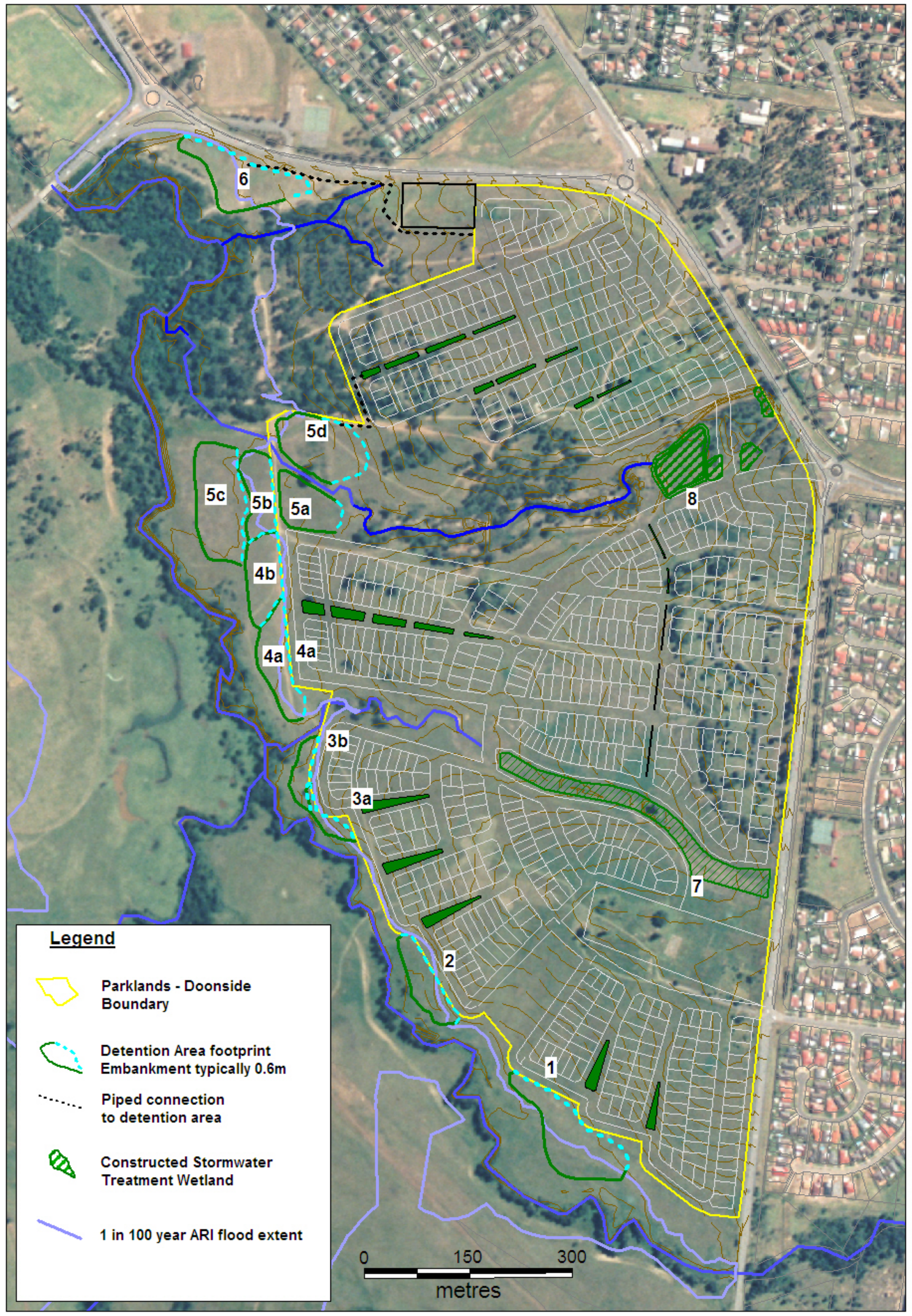


Figure 2-12 Indicative Doonside residential development layout

3 Water Management Principles and Objectives

Water management principles for the site have been derived from the provisions of state and local government planning policies, as well as responding to the site opportunities and constraints. The following section outlines the principles and objectives that have been established for the development. The Doonside WSUD Strategy is guided by the objectives outlined in this section.

3.1 Water Management Targets Western Sydney Parklands

The Western Sydney Parklands Management Vision establishes a range of ecologically sustainable development objectives for the Parklands (DIPNR 2004), including:

- Protect and restore biodiversity values across the Parklands including within core habitat and core habitat needs
- Manage and restore remnant vegetation within riparian zones and along drainage lines
- Ensure that landuse and development within the parklands maintains and enhances water quality runoff
- Implement WSUD principles in existing and future development of facilities within the parklands, such as recycling of water from adjacent treatment plants.

The *Sydney Regional Environmental Plan (SREP) 31 – Regional Parklands*, aims to "…promote recreation, biodiversity and heritage conservation and landscape protection for the Western Sydney Regional Parklands". It is supported by the *Development Control Plan No.1 – Interim Regional Parklands Management*. This DCP identifies key natural resource principles including:

- Protect and enhance the natural systems of the parkland, locating all development in areas that are already cleared.
- Conserve and enhance remnant bushland to ensure protection of biodiversity, threatened species, populations and ecological communities and areas of environmental importance.
- Conserve and enhance watercourses and riparian areas.
- Establish a biodiversity and pedestrian and cyclist movement corridors linking recreation areas and areas of environmental importance.
- Improve long-term Regional Parklands management and establish appropriate management systems (revegetate creek-lines to create good ecological status, control erosion, filter nutrient run-off and re-establish biodiversity links, protect habitat and remnant vegetation)

3.2 Landcom Water Management Targets

Landcom's WSUD Policy includes objectives for water conservation, pollution control and mitigation of the effect of increased flow as a result of catchment urbanisation. The implementation of the WSUD policy aims to achieve the protection of aquatic ecosystems and water resources. The policy has been developed to provide Landcom development staff, its consultants and private sector partners with an overview of WSUD guiding principles and practices together with selection guidelines of suitable and appropriate WSUD practices. The specific WSUD targets within the policy are listed in Table 2.1.

Table 2.1 – Landcom's WSUD Targets

Objective	Performance Measure and Target
1. WSUD Strategy	(a) 100% of projects to have project-specific WSUD strategies.
2. Water Conservation	(a) Combination of water efficiency and reuse options, 40% reduction on base case.
3. Pollution Control	(a) 45% reduction in the mean annual load of Total Nitrogen (TN).
	(b) 45% reduction in the mean annual load of Total Phosphorus (TP).
	(c) 80% reduction in the mean annual load of Total Suspended Solids (TSS).
4. Flow Management	(a) Post-development storm discharges = pre-development storm discharges for one and a half years ARI event. The purpose of this is to minimise the impact of frequent events on the natural waterways and to minimise bed and bank erosion.

To complement the WSUD targets, Landcom's mandatory WSUD requirements are:

- Priority must be given to the use of non-potable water sources for public domain irrigation within all Landcom projects (related to objective 2).
- Where reticulated recycled water is available from the local water utility, it must be used for appropriately matched uses such as toilet flushing, garden watering etc. (objective 2).

3.3 Blacktown Council DCP Water Management Targets

Blacktown City Councils (2000a and 2000b) Policies "Stormwater Quality Control" and "Stormwater Quality Control Policy Background Information and Guidelines for Application" are aimed at implementing the council's objectives for new development as listed in the Stormwater Management Plans for the area. The Policy applies to commercial areas, residential developments, and industrial developments greater than 1000m^2.

The policy sets both quantitative and qualitative objectives, and establishes a priority hierarchy for prioritising pollutants (hydrocarbons, litter, coarse sediments, fine sediments, and nutrients) based on the different types of development (industrial, commercial, residential etc). The policy establishes treatable flow volumes, requires modelling for larger catchments, and promotes a treatment train approach where critical pollutants are targeted for removal with a combination of appropriate treatment measures. For sites greater then 5 ha, other then residential developments, the policy requires the development of Stormwater Management Plan to be submitted as part of the development application.

Appropriate targets for the site include:

- Gross pollutants: 90% total annual load
- Coarse sediment: 80% total annual load
- Fine sediment: 50% total annual load
- Nutrients: 45% total annual load
- Hydrocarbons, oil & grease: 90% total annual load, total hydrocarbons < 10 mg/L

In addition to the pollution retention criteria listed above, there are qualitative operational objectives for new developments that have been adapted from the WSUD-Technical Guidelines for Western Sydney, 2004 and include:

- Limiting the direct connection between impervious areas and the stormwater drainage system and using vegetated flow paths where possible
- Maximising reuse of stormwater for non potable demands
- Infiltrating stormwater 'at source' where soil types allow
- Protecting natural wetlands, watercourses and riparian corridors and protecting drainage channels with base flow, defined bed or banks, or native riparian vegetation.
- Maintaining natural flow paths, discharge points and runoff volumes. The frequency of the bank-full flows should not increase as a result of development. Generally, no increase in the 2 year and 100 year ARI peak flows.
- Compatible multiple use of stormwater facilities
- No adverse impacts from stormwater discharging to urban bushland areas.

3.4 DCP Controls for Doonside

Based on the objectives identified in the above planning controls the following DCP provisions are recommended to be adopted for the Doonside development.

3.4.1 Water and Sewer Infrastructure

Objectives

a. Minimise the use of potable mains water.
b. Ensure that adequate provision is made for potable water supply.
c. Promote and encourage the re-use of stormwater both passively and actively.
d. Ensure that adequate provision is made for sewer facilities.
e. Minimise leakages from sewer.

Controls

a. All new residential dwellings are to demonstrate compliance with State Environmental Planning Policy – Building Sustainability Index (BASIX). Potable mains water can be reduced through demand management including the installation of water efficient fixtures and using alternative sources of water based on matching water quality to uses on a "fit-for-purpose" basis.
b. Potential of alternative water sources including wastewater and stormwater to meet non potable demand on the site should be investigated. Where reticulated recycled water is available from the local water utility, it must be used for appropriately matched uses such as toilet flushing, garden watering etc.
c. Priority must be given to the use of non-potable water sources for public open space irrigation.
d. Mains water supply is to be made available to every lot.
e. Mains water supply is to be provided within the road reserve wherever possible.
f. Low water demand species are to be used for landscaping.
g. Low infiltration or low pressure systems are to be utilised for sewer pipelines to reduce leakage.

3.4.2 Water cycle management

Objectives

a. Stormwater runoff from the development as well as the catchments to the east of the development which flows through the site, is to meet the following pollution reduction targets:
   - o total suspended solids – 80% reduction in the average annual load from that typically generated from an urban catchment
   - o total phosphorous (TP) and total nitrogen (TN) – 45% reduction in the average annual load from that typically generated from an urban catchment.
   - o litter and gross pollutants will be removed from stormwater leaving the site.
   - o Hydrocarbons, oil & grease: 90% total annual load, total hydrocarbon discharge < 10 mg/L
b. The configuration and sizing of appropriate WSUD measures to meet the stormwater quality objectives should be identified in accordance with a WSUD Strategy documented for development application. Compliance with these targets is to be determined through stormwater quality (MUSIC) modelling in accordance with the WSUD Strategy.
c. Post-development storm discharges to equal pre-development storm discharges for the one and a half year ARI event, so as to minimise the impact of frequent events on the natural waterways and to minimise bed and bank erosion.
d. Post-development storm discharges up to the 100 year ARI event need to be controlled so as to avoid any increases in the peak discharges in Eastern Creek and Bungarribee Creek..
e. Avoid stormwater management measures that may have adverse impacts on soil salinity.

Source controls

a. Stormwater quality controls to meet the development objectives can include a combination of gross pollutant traps, bioretention systems, rain gardens and wetlands. These systems can be located as discrete individual elements, as larger regional elements or a combination thereof.
b. Modelling at the detailed design stage for the WSUD Strategy should determine the appropriate size, configuration and location of these elements.
c. All WSUD elements are to minimise any potential impact on soil salinity.

Downstream controls

d. Retarding areas are to be provided within the development so that the one and a half year ARI event equals the pre-development one and a half year ARI event.

Minor and major drainage controls

The drainage system is to consist of the following components:

e. Minor drainage system – Pipe and street system able to convey runoff safely through the development up to the 5 year ARI storm.
f. Major drainage system – Overland flow paths must be designed to convey the 100 year ARI flows.
g. Combined retarding/wetlands to provide necessary quantity/quality controls while being able to cope with 100 year ARI flows.

4 Requirements to meet WSUD Objectives

The WSUD strategy is guided by a series of water management principles derived from the provisions of state and local government planning policies (Section 3), as well as responding to the site opportunities and constraints (Section 2). The WSUD Strategy is centred on achieving the following outcomes:

- Potable mains water reduction through demand management including water efficient fixtures and fittings, as well as using alternative sources of water based on matching water quality to uses on a “fit-for-purpose” basis.
- Stormwater runoff from the development, as well as from the external catchments to the east of the development which flow through the site, to be treated to current best practice water quality standards.
- Post-development storm discharges to equal pre-development storm discharges for the one and a half year ARI event, so as to minimise the impact of frequent events on the natural waterways and to minimise bed and bank erosion.
- Post-development storm discharges up to the 100 year ARI event need to be controlled so as to avoid any increases in the peak discharges in Eastern Creek and Bungarribee Creek.

A water balance has been developed which quantifies the urban water streams for the development – potable mains water, wastewater and stormwater (Section 4.2). Section 6 of this report addresses demand management, alternative water sources and fit for purpose use.

The following sections identify the elements of the proposed WSUD strategy aimed at improving stormwater quality prior to discharge to the Western Sydney Parklands. The water quality and detention requirements have informed the masterplanning of the site and are essential in meeting the stormwater related water management objectives.

4.1 Stormwater Management

Stormwater management for the Doonside residential development will address both water quality and hydrology. Stormwater runoff from residential areas contains elevated levels of pollutants including litter, suspended solids, nitrogen and phosphorus, heavy metals, hydrocarbons, oil and grease. WSUD elements can be used to reduce the pollutants typically carried in stormwater runoff. Modifications to the site hydrology result from the increase in impervious surface areas associated with development. Management of these increased flows is critical to protect of the ecological assets of the Parklands, specifically the bed and banks of downstream waterways.

Stormwater treatment elements include gross pollutant traps, bioretention systems, swales and wetlands. These systems can be located as discrete individual elements, or as larger regional elements, or a combination therein. These stormwater management features can be readily incorporated into the landscape and streetscape design of the residential area and the adjoining parkland. The optimal configuration of WSUD elements is typically a combination of the available treatment elements, with the detail of a strategy for a particular site determined in collaboration with the landscape and urban design teams.

Stormwater modelling was undertaken using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC), to determine the approximate size of the treatment elements. The model used eleven years (1967 – 1977) of 6 minute rainfall data from the Liverpool Bureau of Meteorology station which has a mean annual rainfall of 857 mm/yr and mean annual potential evapo-transpiration of 1496mm/yr. This station has rainfall comparable with the daily data available from the Prospect Dam Bureau of Meteorology station which has a mean annual rainfall of 866 mm/yr (120 year record from 1887).

4.2 Doonside Water Balance

The Doonside urban development covers an area of approximately 55ha, with a further 56ha of external catchments. The urban development is surrounded by additional areas of parkland adjacent to Eastern and Bungarribee Creeks, the heritage site of the former Bungarribee homestead, and vegetated buffer areas. A water balance was developed to quantify the water use, wastewater generation and stormwater runoff generated. The water balance provides an overview of water through the site including:

- Average annual rainfall, runoff and evapotranspiration/infiltration processes both prior to and following development (illustrating the impact of increasing impervious surface area)
- Estimated demand for mains water and assessment of non potable demands (toilet flushing, irrigation, laundry), and resulting sewage discharge.

4.2.1 Rainfall and Runoff

As a component of the water balance the predevelopment rainfall-runoff has been modelled and is presented for comparison with the average rainfall-runoff modelled for the developed site. The assumptions of the rainfall and runoff for development include:

- Rainfall: average rainfall of 857mm/yr = 471ML/yr falling on the 55ha site.
- Stormwater: prior to development, the majority of rainfall would infiltrate or be taken up through evapotranspiration. Modelling indicates that prior to development only 14% of rainfall (67ML/yr) is transported from the site as stormwater runoff. The development will introduce approximately 37.5ha of impervious surfaces associated with roads, footpaths, and houses (development area 75% impervious). This will result in a significant increase in stormwater runoff, and it is estimated that 286 ML/year will run off the site (67% of rain falling on the site).
- External Stormwater: External catchments with a total area of approximately 56ha drain to the site. Prior to the development of these catchments, the modelled stormwater runoff is 69ML/yr. This increases to an average annual runoff of 257ML/yr due to the impervious surfaces of the residential areas, school, shopping village and roads which are estimated to total 34ha, assumed 60% impervious catchment. Note that the impervious proportion is low as the catchment includes park/ridge/vegetated areas.

4.2.2 Water Demands and Discharge

The estimated number of dwellings for the proposed for the development is 716, with 553 detached dwellings (450 sqm+) and 163 small lot/attached dwellings (<350 sqm). The projected number of residents is 2210, based on occupancy rates for Blacktown LGA from 2001, 3.2 persons per detached dwelling, 2.7 persons per attached dwelling. (Elton Consulting, 2007). The potable and non-potable water demands have been based on this population estimate and water consumption inline with BASIX estimates of water use in Sydney.

- **Potable water import**: The total water demand is 144ML/yr. More than half of this demand is for uses that do not require drinking quality water. The indoor demand is 116ML/yr. Potable water demands include shower, bathroom, kitchen, hot water laundry and distribution losses. Note that hot water demands are 65% of the indoor potable water demand and that a proportion of this can be supplied by harvesting rainwater, and connecting the tank to the hot water service (preferably solar).
- **Non-potable demands**: The non-potable demands include cold water laundry (33ML/yr), toilet flushing (15ML/yr), irrigation (20ML/yr) and other minor outdoor uses/losses (4ML/yr).
- **Irrigation**: The estimated annual irrigation requirement for private allotments is 20ML/yr, assuming an irrigation application of 0.5m/yr (0.5kL/m²/yr), with the area to be irrigated estimated at 30% of the pervious area (3.75ha). Note that it is assumed that most of the pervious areas (70%) will not be irrigated, and use indigenous, low water use plant species. The irrigation demand will vary with evaporation and rainfall. Irrigation demands can be met with non-potable water. Particular areas with high irrigation demands may be proposed for community fruit/nut production based trees and vegetable / intensive garden areas. Opportunities to meet such demand with either harvested rainwater / stormwater or treated wastewater is recommended.
- **Wastewater**: Water used indoors will be discharged to sewer, with the exception of some of the water consumed or lost to leaks. Approximately 108ML/yr will be discharged to the sewer, treated at Quakers Hill STP and then discharged to Eastern Creek, or provided for reuse for industry and other non potable uses.

The water balance for the site prior to development is shown in Figure 4-1. This contrasts strongly with the water balance for the developed site as shown in Figure 4-2 with stormwater runoff from the site increasing from 61ML/yr to 286ML/yr as a result of the increase in impervious surface area. This response in the hydrology to urban development highlights the critical need for protection of the ecological assets of the Parklands.

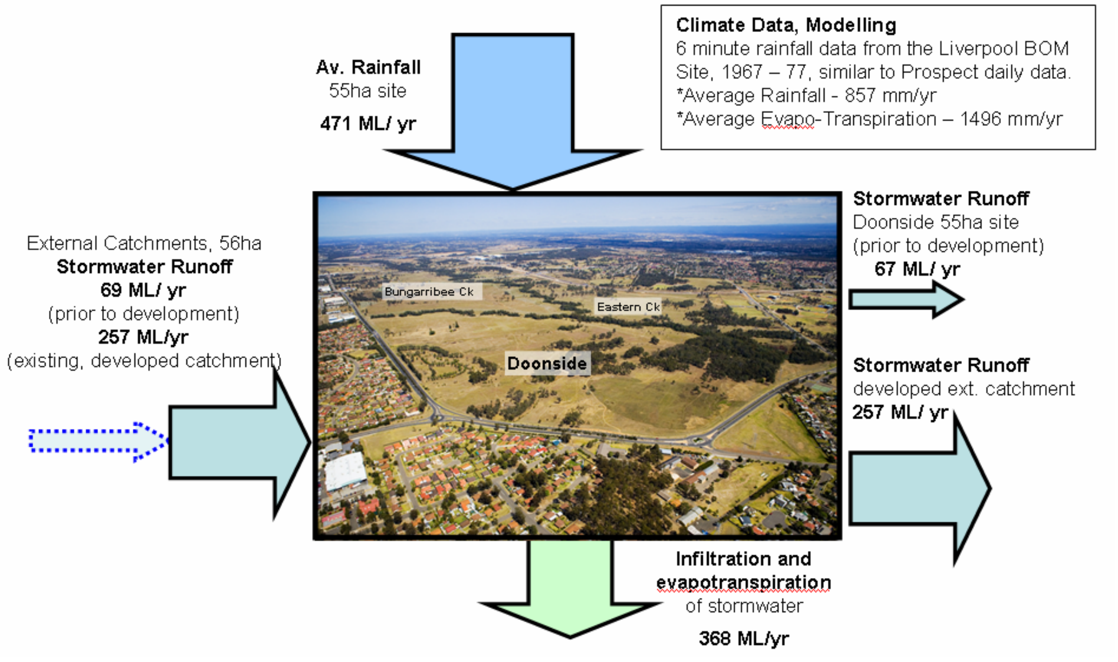


Figure 4-1 Water Balance for the Doonside site prior to development

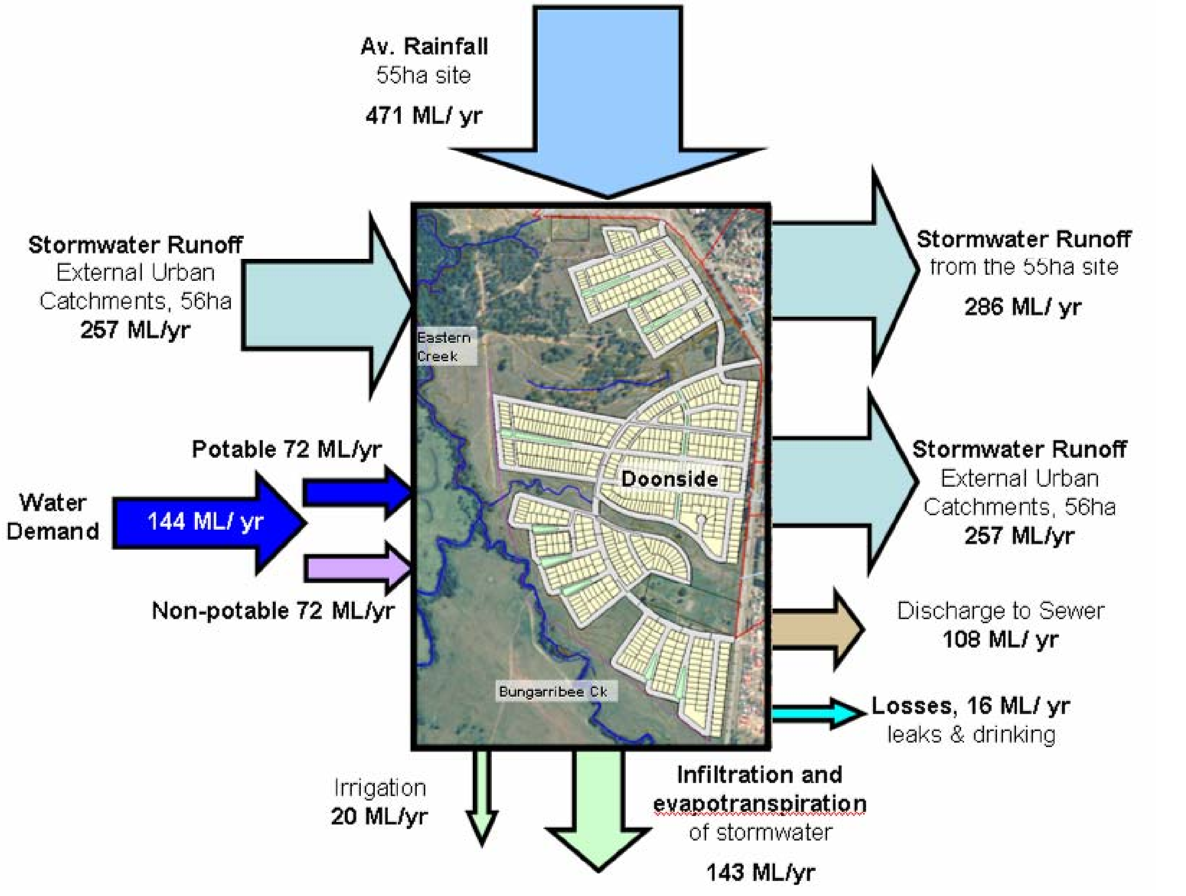


Figure 4-2 Water Balance for the 55 ha Doonside Residential Development Area.

4.3 Water Quality Requirements

The water quality objectives for the Doonside urban development require that stormwater runoff from the site and from the external catchments to the east of the development, be treated to current best practice water quality standards. The required treatment areas are detailed in this section. The integration of these areas within the masterplan are discussed in section 5.

4.3.1 Treating stormwater from the development

Bioretention systems are proposed to treat stormwater runoff from the development. MUSIC modelling was undertaken to determine the approximate size of the treatment elements, and it was found that the required treatment area is 8,100m², or approximately 2% of the impervious area. The urban development was assumed to be approximately 75% impervious, including road and lot area; but excluding the 'eco-medians', the Bungarribee heritage site, waterway corridors, vegetated noise buffers and parkland surrounding the development. Linear bioretention systems are proposed within the eco-medians, along the parkland interface and within parking bay pocket raingardens. The configuration of these systems is detailed in sections 5.1 to 5.3. Suitable species for planting within bioretention systems and wetland areas are provided in Appendix 1.

Figure 4-3 illustrates the treatment performance of the combined bioretention area needed to meet best practice water quality standards, namely at least an 80% reduction in total suspended solids, and 45% reduction in both total phosphorus and total nitrogen.

The bioretention system has been modelled with the following parameters:

- extended detention 0.15m (temporary ponding at the surface following rain events)
- filter depth 0.6m (note total depth is 0.9m due to additional 0.3m layer below filter media for transition media and drainage layer containing a perforated drainage pipe)
- median particle size 0.5mm diameter
- saturated hydraulic conductivity 180mm/hr
- surface area twice the filter area. The surface area is the planted area, and includes the embankment edges to allow ponding. The filter area refers to the flat surface with trench of sandy loam soil beneath. The linear systems proposed have a significant surface area to filter area ratio (approximately 2:1).

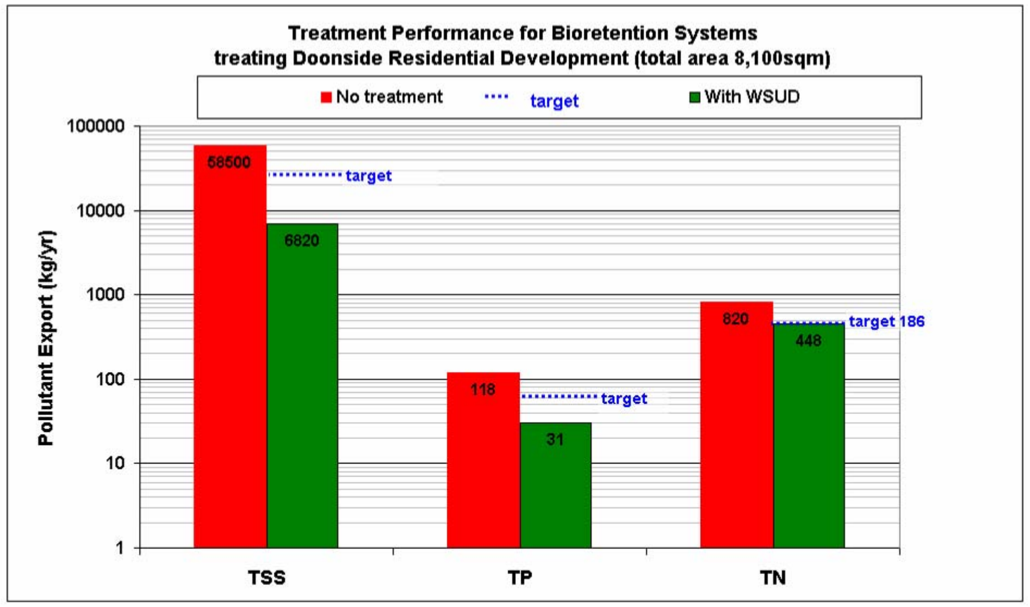


Figure 4-3 Treatment Performance for bioretention systems treating stormwater from the development.

4.3.2 Treating external catchment runoff discharging to the Southern Waterway

Wetlands areas within the southern waterway corridor are proposed to treat stormwater runoff from the two external catchments that drain to the southern waterway. MUSIC was used to determine the approximate size of the treatment elements required to meet current best practice water quality standards. The external catchment area totals 18ha, and discharges to the site from two culvert discharge locations adjacent to Doonside Road. The impervious area of these catchments is estimated at 9.24ha. The treatment train recommended includes a gross pollutant trap, additional sedimentation and a wetland. The GPT will remove coarse sediment and litter which will assist in maintenance of the system. The required wetland treatment area is 3,750m², or approximately 4% of the impervious area of the external catchment. The urban areas of the external catchment are assumed to be approximately 60% impervious with park areas of 2.6ha excluded from this figure. The configuration of the wetland areas along the upper part of the southern waterway is detailed in section 5.4.1. Figure 4-4 illustrates the treatment performance of the wetland area needed to meet best practice water quality standards.

The treatment train (GPT, sedimentation area and wetland) has been modelled with the following parameters:

- GPT: TSS reduction increasing from 0 to 68% for the concentration range 75 – 700mg/L, TP reduction increasing from 0 to 33% for concentration range 0.5 – 5mg/L, no reduction in TN.
- A sedimentation basin (typical depth 2m) may be used or the inlet zone of the wetland may be configured to provide sufficient reduction in fine particulate matter. The footprint required for the sedimentation area is between 200 and 500m² subject to detailed design.
- The wetland surface area required is approximately 3,500m², with a permanent pool depth of 0.5m and provision for 0.3m extended detention.

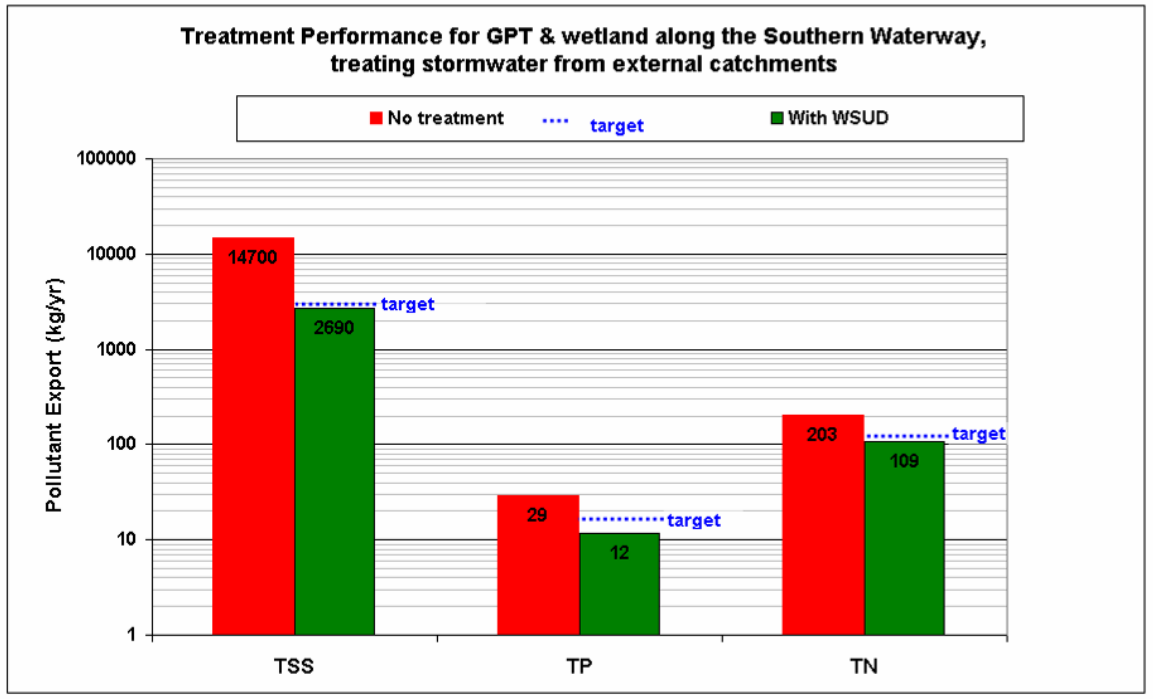


Figure 4-4 Treatment Performance for GPT & wetland along the southern waterway, treating stormwater from external catchments

4.3.3 Treating external catchment runoff discharging to the Northern Waterway

Wetlands areas within the northern waterway corridor are proposed to treat stormwater runoff from the two external catchments. The external catchment area is 24ha, with an impervious area of 13.4ha. Similar to the southern waterway, the treatment train includes a GPT, additional sedimentation and a wetland. MUSIC modelling determined that the size of the treatment area required is 5,400m², or approximately 4% of the impervious area of the external catchment. The urban areas of the external catchment are assumed to be approximately 60% impervious and park areas totalling 1.6ha are excluded from the contributing catchment. The configuration of the wetland areas along the upper part of the northern waterway is detailed in section 5.5.1. Figure 4-3 illustrates the treatment performance of the wetland area needed to meet best practice water quality standards. The treatment train (GPT, sedimentation area and wetland) has been modelled with the same parameters: as detailed for the southern waterway wetland areas. The sedimentation area required is between 300 and 700m², and wetland area of approximately 5,000m².

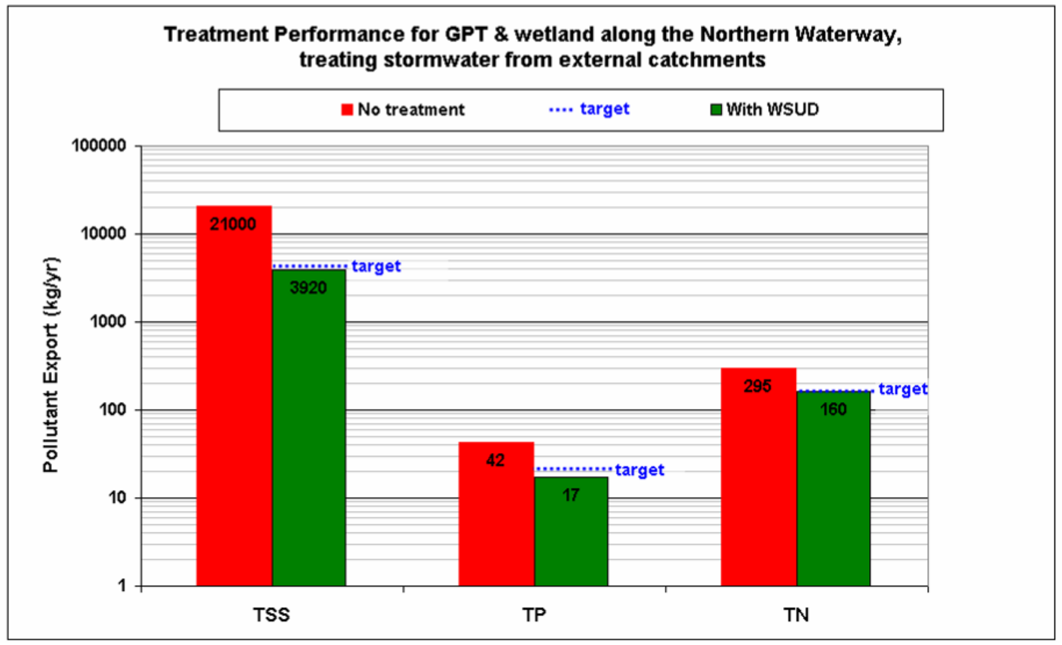


Figure 4-5 Treatment Performance for GPT & wetland along the northern waterway.

4.4 Detention requirements for waterway protection and flood control

Protection of aquatic habitat in waterways is associated with sustaining the geomorphic form of the beds and banks. Erosion protection requires attenuation of peak flows from frequent storm events up to an equivalent of the 1.5year ARI event. Peak discharges from these storm events will be controlled for both the development and for the upstream residential catchments, with peak flow discharge returned to predevelopment levels.

Detention is proposed in the upstream sections of the two waterways that run through the site (northern and southern waterways), in conjunction with water quality improvement for the stormwater runoff from external catchments discharging to these waterways. Additional detention areas are configured within the natural floodplain, adjacent to Eastern Creek and Bungarribee Creek, through the use of shallow, ephemeral detention areas. The objective is to create less engineered structures that integrate as seamless extensions of the riparian zones, with the area planted with suitable floodplain vegetation. The detention storage required is achieved with bunding to a maximum elevation of 0.7m. Embankments at the downstream edge of the detention areas will be raised and tie back into the natural ground surface level at the upstream edge. The embankments extend into the Eastern Creek floodplain but will have flood free crests to operate normally in the 100-year event. The estimated width of the compacted soil embankment is 6-9m. The footprint of the inundated area for significant storm events will be large, with stormwater ponding to a shallow depth across the floodplain behind the line of constructed embankments. Small inlet / outlet structures will be used to control the discharges to the watercourses in frequent events. The duration of inundation of these systems is limited to short periods in the order of 20 hours following the end of a major rain event. The discharge from the treatment measures and detention areas will be controlled so that the riparian areas and the waterway will receive peak flows that more closely represent the predevelopment hydrology, with specific attention to limiting the critical peak flows. The detention storages will also attenuate peak 100-year flows to maintain existing flow rates from the site and manage the interaction between the peak 100-year hydrograph in Eastern Creek.

Hydrologic modelling of the site and external catchments was undertaken using RORB hydrologic software. The model was used to produce design flood hydrographs for the site and external catchments under predevelopment, existing and the proposed development scenarios. The proposed development model was used to conceptually design and assess detention storage requirements to meet discharges targets from the site. RORB models and simulation details have been provided to Blacktown Council.

The development will span approximately 2 km along Bungarribee and Eastern Creeks, and there is no suitable location for a single centralised detention storage to address all the flows from the site. Two main depressions cross the site, with waterways to be rehabilitated and flanked by detention areas. A series of detention areas are proposed to attenuate flows discharging to local creeks. Three detention areas are required to attenuate flows from external catchments, with the remaining areas primarily attenuating flows from the proposed development to restore the predevelopment 1.5-year peak discharges to Eastern Creek. The location and required footprint of the detention areas and their receiving catchments are shown in Figure 4-6. The following sections describe the form and conceptual design of the detention areas.

4.4.1 Detention Requirements for the Doonside residential development

The proposed residential development will replace approximately 55 ha of rural lands with medium and high density residential development. The location and form of the proposed detention areas will minimise the earthworks needed to provide the required detention volumes. Conceptual details are presented in Figure 4-6. Appendix 3 shows peak storage volumes for design storm events and flood attenuation performance at Eastern Creek.

Table 4-1 - Conceptual detention area details, catchments and hydrologic performance

Detention Area Name	1	2	3	4	5	6
Catchment area (ha)	7.54	5.05	5.05*	13.87*	22.72*	6.53
Design pipe outlet discharge (m^3/s)	0.1	0.1	0.07	0.12	0.36	0.05
1yr ARI storage volume (m^3)	150	800	550	2850	5780	2000
2yr ARI storage volume (m^3)	1800	1200	990	4650	9060	3100
100yr ARI storage volume (m^3)	3250	2100	1880	7500	19000	7110
Storage footprint (m^2)	10800	4960	3790	11920	29750	8940
Average 100yr ARI depth (mm)	300	420	500	630	640	890
1-yr Predevelopment target flow (m^3/s)	0.08	0.04	0.35		0.35	0.03
1-yr flow from developed site with detention (m^3/s)	0.08	0.05	0.35		0.4	0.03
2-yr Predevelopment target flow (m^3/s)	0.11	0.06	0.40		0.45	0.04
2-yr flow from developed site with detention (m^3/s)	0.10	0.06	0.4		0.45	0.04
Existing peak 100-yr to Eastern Creek	0.9	0.6	3.9		5.0	0.3
Peak 100-year flow from developed catchment with detention (m^3/s)	0.8	0.5	2.1		2.8	0.3
Existing 100-yr 36-hr flow to Eastern Ck	0.4	0.2	2.1		2.8	0.25
100 year flow from developed catchment with detention (m^3/s)	0.5	0.3	2.1		2.8	0.25

* External catchments not included

In the above table area 3 and Area 4 form part of flow control measures for the Southern Waterway catchment. Area 5 forms part of flow control measures for the Northern Waterway external catchments. Area 4 and Area 5 can perform as a singe consolidated storage but have been represented as a number of separate tiered entities.

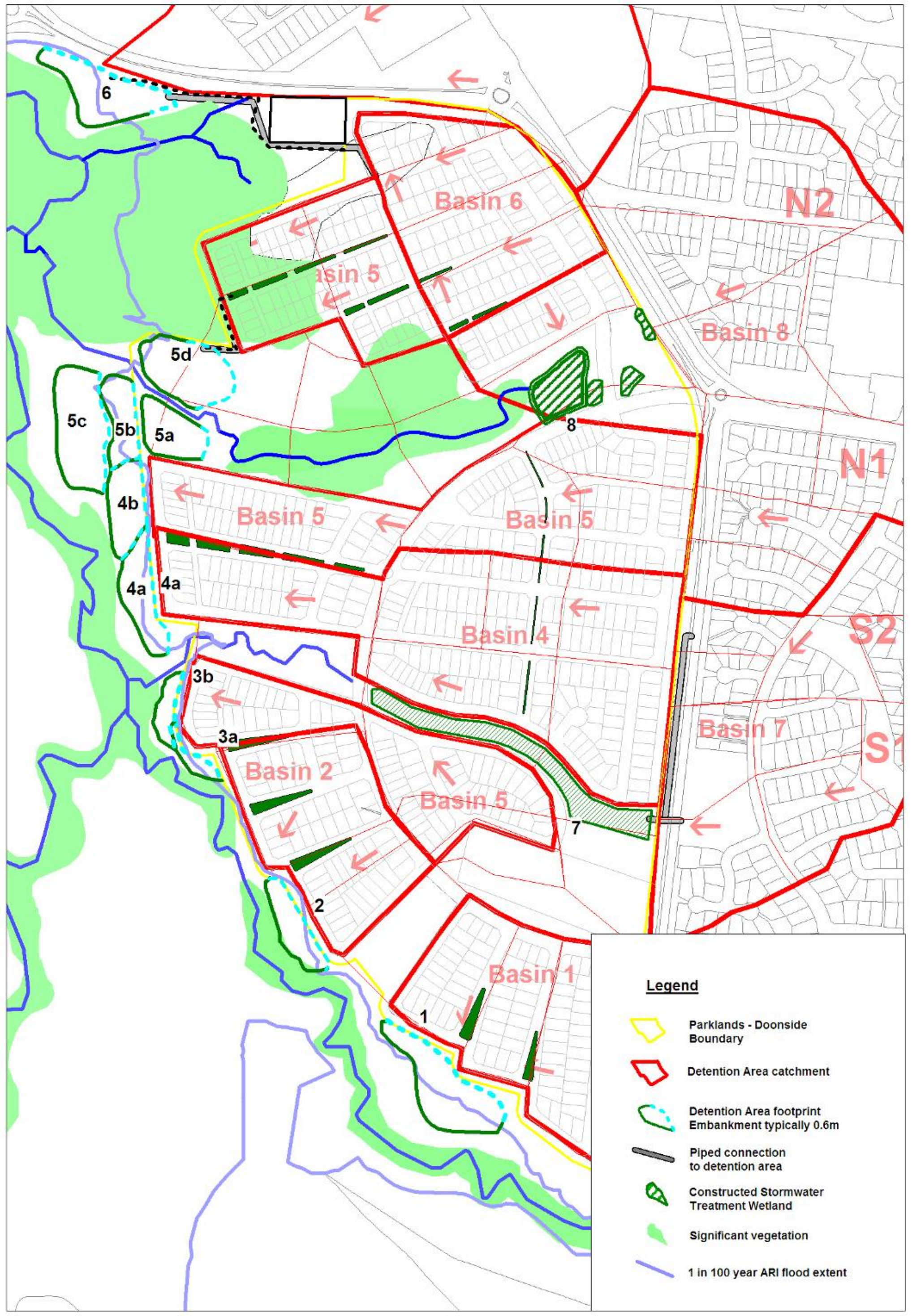


Figure 4-6 Detention area locations and catchments. (Further details in Appendix 2)

The required embankments are typically 0.5m high (maximum 0.7m) with a designated weir to control overflow. Low flow outlets have been conceptually modeled as small diameter pipes to meet 1.5-year flow objectives. Outlets such as pipes and orifice plates, will be sized to meet design discharges at the detailed design stage.

Typically, the provision of 1.5-year detention volumes can be achieved with the first 400mm of storage, however additional storage is required to ensure that peak 100-year flows in Eastern Creek are not exacerbated. The optimisation of storage area wall height and weir length will be undertaken at detailed design. The configuration of the detention area footprint has aimed to achieve the storage area volumes from existing ground topography. Where necessary, additional reshaping can provide more storage volume and reduce the inundation extent. The footprints indicated provide the 100-year storage volumes.

Where possible the detention storages have been located within rural grass land areas to avoid protected vegetation communities. The northern portion of the site contains stands of Cumberland Plains Woodland that are to be retained for their ecological value. The configuration of smaller detention areas has been optimized to minimize the impact on the themeda grasslands and Shale Plains Woodlands. Piped connections to the detention areas will be laid along an existing dirt roads where possible, and in narrow trenches. The operation of these detention areas can be controlled to limit the area inundated by events up to the 2 year ARI. Full inundation will occur in the 1 in 100 year ARI event. Vegetation within the detention areas will experience periods of inundation during flood events beyond the 3-month event. More frequent inundation is limited to the stormwater quality treatment areas within the development boundary.

The hydrologic performance of the detention areas is summarised in Table 4-1, which shows the detention required to be provided across the development to restore pre development flows to Eastern Creek for the 1.5 year ARI event. Further, modelling of the full range of 100-year storm event durations show that the proposed detention storages ensure the development will not increase the peak 100 year discharge from the site. A comparison of existing and developed site 100-year 36-hour hydrology was undertaken to assess the likely impact of the development on the 36-hour flood hydrograph in Eastern Creek. This event is known to be critical to flooding in Eastern Creek, and without proper attenuation runoff from the site could result in exacerbated flooding. Flood hydrographs provided by Bewsher Consulting show the peak 100 year flood discharge in Eastern Creek is approximately 230m^3/s at the site, and occurs approximately 20 hours after the onset of the 36 hour storm. RORB modelling shows the proposed detention areas maintain the 36-hour peak flows to within 0.15m^3/s at a given discharge point, and a cumulative increase in the 36-hour peak of less than 1m^3/s can be expected across the development. RORB modelling undertaken as part of this project show that peak 36 hour discharge from the development will occur at approximately 20 hours after the onset of the storm, however the resolution of modelling is insufficient to assess whether there is a real risk of hydrographs interacting with the peak in Eastern Creek. Given the relatively low increase in flood discharge from the development to Eastern Creek, the impact on downstream flooding is considered to be negligible.

4.4.2 Detention Requirements for External Catchments

Due to the unique nature of the development in relation to the Western Sydney Parklands, it is proposed that this development attenuate flows through the site to protect downstream waterways, and hence the Parklands themselves. This objective is consistent with "worlds best practice" espoused by the client. Detention areas 7, 8 and 9 in Figure 4-6 are proposed to attenuate flows from the external catchments to meet flow management targets. These detention areas also act to attenuate larger flows from less frequent events adding benefit to the flow management strategy. The conceptual design of the proposed detention areas is presented in the following sections.

4.4.2.1 Southern Waterway

The external catchment of the southern waterway comprises 16.6 ha of medium density residential development. The upper catchment of these waterways is steep, with grades up of to 10%. The catchment drains beneath Doonside Road via two culverts; one discharges directly to the waterway (Catchment S1), the other discharges approximately 230m to the north (Catchment S2) as shown in Figure 2-1.

It is proposed to divert Catchment S2 immediately south to the Southern Waterway on the western side of Doonside Road and provide online storage within an engineered and landscaped waterway. Detention will be provided within a reshaped waterway that incorporates a chain of cascading storages and water quality treatment wetlands. A series of 1m high weirs crossing the waterway with reshaped 1 in 6 side slopes will provide a minimum of 5850 m^3 of detention storage. Additional storage may be detailed through the design process. This volume will return the predevelopment peak 1.5-year flow from the upper catchments with additional ponding capacity once weirs are engaged during the 2-year event. Flow delivery and outlet structures will be configured to ensure that the terraced storage areas are engaged as active storage, cascading to the next, only when the all design discharges are achieved. Low flow discharge will be provided to ensure pre-development flows are not attenuated and that the storage drains and remains active storage. Freeboard of 300mm will be provided to pass the 100-year peak discharge of 5.9m^3/s at the upstream end of the storage. A conceptual section and diagram of Detention Area 7 is presented in Figure 4-7.

Figure 4-7 Conceptual illustration of Detention Area 7

4.4.2.2 Northern Waterway

Detention Area 8 in Figure 4-6 is proposed to attenuate flows from external catchments for the northern waterway. The external catchment that forms the northern waterway comprises 23.9ha of medium density residential development. Catchments N2 and N1 drain beneath Doonside Road via two culverts as shown in Figure 2.1; Catchment N2 discharges to a cut drainage line and thence to the Northern Waterway. Catchment N1 discharges from approximately 90m south of the Bungarribee Road intersection with Doonside Road.

The opportunity exists to provide a combined detention and stormwater treatment at the entry road on a reach of creek that is highly modified by an online dam and constructed drainage ditch. Directing stormwater from external catchments to suitable locations at the entry roads is made difficult by constraining topography, the culvert invert elevations and the proximity of a stand of vegetation to be conserved.

It is proposed to provide detention for external catchment N2 and a small catchment from the Doonside development just to the north of the proposed area for detention and the constructed wetland. Detention Area 8 will discharge up to 0.3m^3/s to the Northern Waterway, returning peak 1.5-year predevelopment peak flows to the creek for frequent events. Once the capacity of this storage area is exceeded, flows (in excess of 0.3m^3/s and up to the 100 year) will be conveyed via the northern waterway to floodplain detention area 5 to provide the required attenuation.

Frequent low flows entering the site from Catchment N1 will drain to stormwater quality treatment facilities adjacent to the site entry road. Larger storm events up to the 100-year flow will be conveyed via the northern waterway to floodplain detention area 5 for attenuation prior to discharge to Eastern Creek.

Detention area 5 provides approximately 11,500m^3 of storage. The required storage for the 100 year ARI may be configured in tiered areas adjacent to the northern waterway to reduce the embankment elevation in a single location. Detention areas 4 and 5 can be consolidated into a single detention area should construction and landscaping factors require it.

4.4.2.3 Kareela Avenue Waterway

The Kareela Ave Waterway at the northern edge of the site drains through a conservation area and requires stormwater attenuation to protect vegetation within this conservation area as well as minimise ongoing erosion within Eastern Creek. The detention volume required is 6,800m^3 so as to restore the peak 1.5-year hydrology of the external catchment, and provide this stormwater attenuation. Opportunities should be considered for detention and water quality improvement for this catchment so that the geomorphic and waterway rehabilitation outcomes provided within the rest of the adjacent Doonside Residential development, as proposed within this WSUD Strategy, are not compromised.

4.5 Floodplain storage offsetting

Detention areas to attenuate increased stormwater flows from the Doonside development are proposed within the 100-year Eastern Creek flood extent to maximise the developable area within the site. Basins will occupy areas of floodplain less than 1 m deep and spillway design will ensure that the storage area crests remain functional during the critical 100-year 36 hour event. Any potential impacts of encroachment into the floodplain can be mitigated by providing additional floodplain storage opposite the site within the Parklands Bungarribee Precinct on the western bank of Eastern Creek.

Flood modelling undertaken by Bewsher (2007) for the project has identified 100-year flood levels and flood extent within the floodplain at the Doonside site. The flood surface profile shows a flat hydraulic grade line along Eastern and Bungarribee Creeks with hydraulic grades reducing from 0.4% at the Doonside upstream boundary to 0.02% at Eastern Road. This indicates that flooding is driven by more so by floodplain storage than channel conveyance in a 100-year event. A loss of floodplain storage in this vicinity will produce a small increase in flood levels, which can be mitigated by providing equivalent floodplain storage in the vicinity. The offset storage volume will be created by lowering the floodplain within the proposed Parklands sports zone, which will replace the floodplain volume lost to the Doonside detention areas at the same elevation as the detention areas. The net impact on flood levels will be negligible and can be verified with hydraulic modelling at the detailed design stage.

There are many opportunities to provide the flood storage within the sports zone. Figure 4.8 shows the equivalent area to be lowered by up to 700mm to replace all potential volume of floodplain storage lost to the Doonside detention areas.

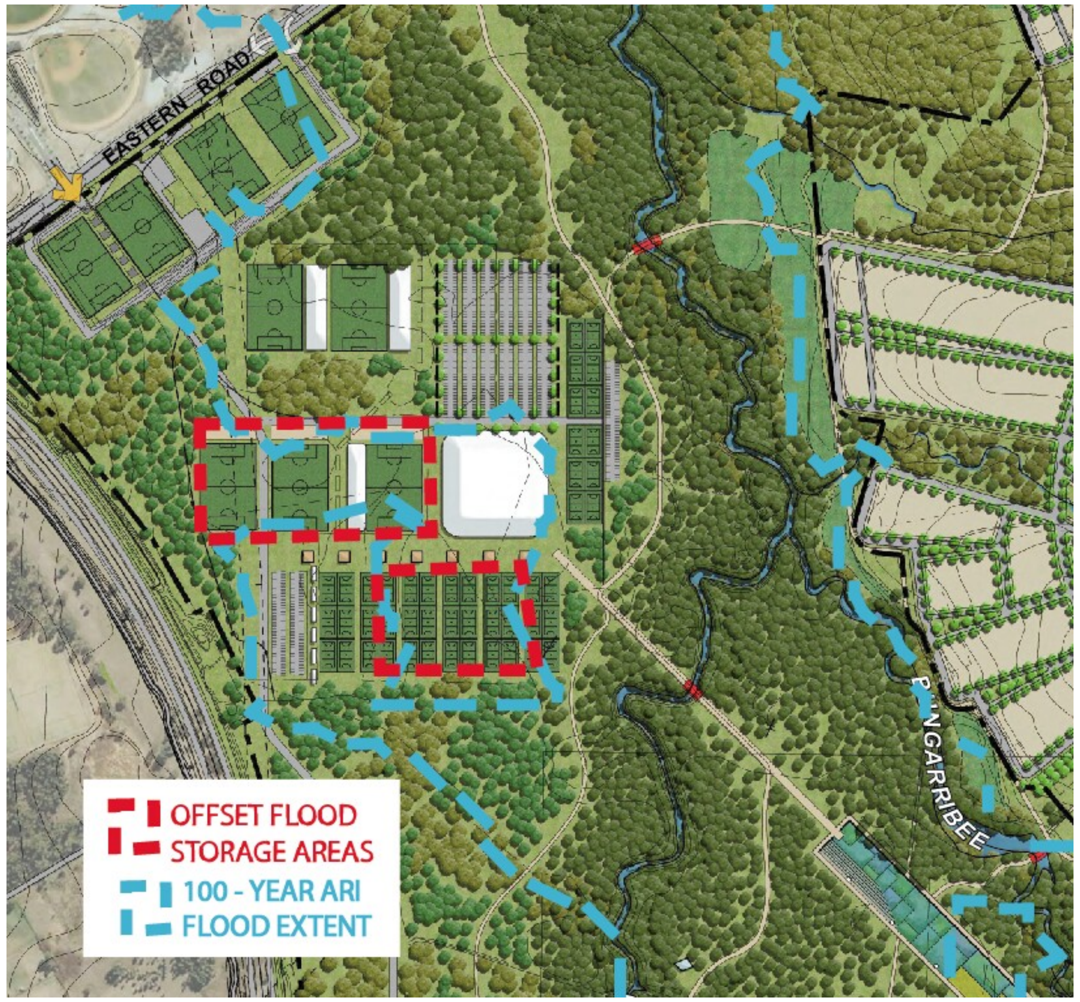


Figure 4-8 Floodplain storage offset opportunities

5 Incorporating WSUD into the Masterplan

The WSUD Strategy for the Doonside Residential Development integrates potable water conservation, pollution control and flow management measures with the unique masterplan layout. The natural form of the waterways, ecological objectives, urban form and the landscape design have been integrated to deliver an urban design outcome that is ‘sensitive to water’, particularly the objectives of protecting and/or enhancing the ecological values of the water environment and the management of water as a scarce resource. The integration of the landscape design with the ecological objectives has resulted in the creation of unique elements which respond to the natural attributes of the Doonside site. The details of critical elements of the WSUD strategy are described in more detail in this section.

5.1 Eco-medians

The vegetated eco-medians acknowledge the setting of this residential area within the wider context of the Western Sydney Parklands. The eco-medians are fingers of parkland that integrate with the urban setting, maintaining view corridors and a connection to the assets of the adjacent Parklands (Figure 5-1). The eco-medians consist of three zones which transition from an Eucalyptus grove, to production based trees and through to a Melaleuca grove with seating, as well as a stormwater detention function (Figure 5-2).

Stormwater runoff from approximately one-third of the Doonside residential development can be directed to the eco-medians. The remaining areas are to be directed to bioretention systems on the interface with the Parklands or to pocket raingardens along the road corridors of the development. Within the eco-medians water quality will be improved by passing the stormwater through soil filtration beds. These linear bioretention systems will be planted with production based trees. The selection of tree species will take into consideration the benefits of trees that do not block desirable sunlight in winter, do not raise long term maintenance issues, do not have a significant potential to bring adverse impacts to the native vegetation within the Parklands, reflect on the heritage of the site where orchards were once planted and link with aspirations from the community for local produce gardens. The treatment area provided ensures that the resulting water quality meets best practice targets, reducing the mean annual load of total suspended solids by 80% and total nitrogen and phosphorus loads by 45%.

The width of the bioretention strips are typically 2 – 2.5m, with the length dependent on the catchment area, varying from 25 – 90m. The systems will be tiered as required, due to the need for a flat area for the stormwater to pond and pass through the bioretention system. If the surface is not level the water will only pond in the deeper areas, reducing the effectiveness of the system. Single cross fall roads enable water to be easily directed to the surface of the bioretention system. Stormwater from other parts of the development, carried in pipes, may be configured with adequate cover beneath the roads and then be ‘day-lighted’ to discharge to the bioretention surface. The areas that are nominated to drain to the eco-medians are illustrated in Appendix 2, but will be confirmed through the detailed design phase. The configuration of drainage to the eco-medians will be effective to ensure that drainage performance standards are not compromised.

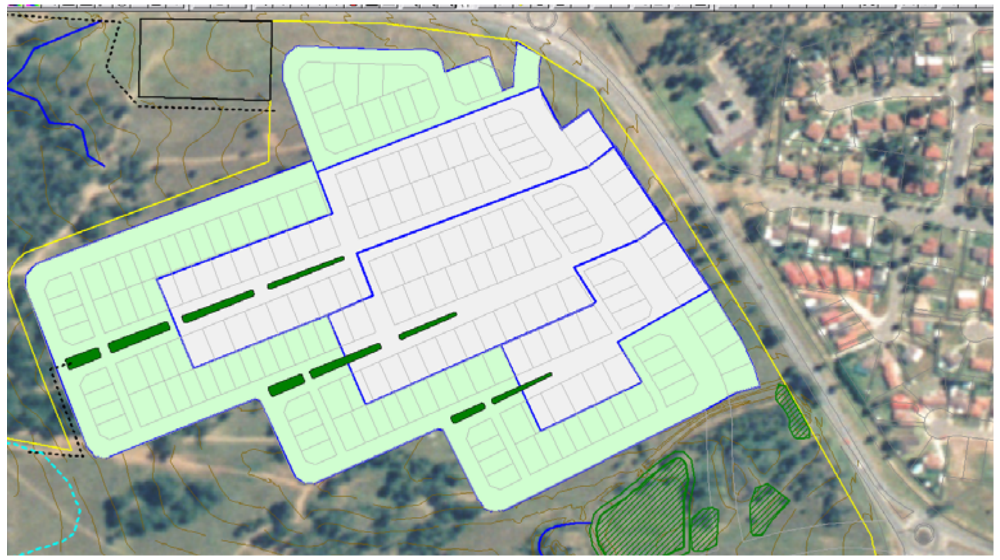


Figure 5-1 Eco-medians; functional elements linking the development with the Parklands. White areas drain to the eco-medians, green shading indicates drainage to linear systems on the parkland interface.

Figure 5-2 Eco-median zones; incorporate water quality and detention functional elements (EDAW)

5.1.1 Detention within Eco-median Melaleuca Grove

Detention of stormwater following rainfall is provided in the Melaleuca grove. This is illustrated in Figure 5-3 and Figure 5-4. Visual depth markers highlight the inundation in response to rainfall and aim to engage the community with the water cycle in their urban environment. The inundation of these areas will facilitate additional water quality improvement and harvesting of stormwater for reuse to meet the irrigation needs of the production based trees. Detention of stormwater within these areas will reduce the frequency and depth of inundation that occurs in the shallow ephemeral detention areas provided in the flood plain (see details of these areas in section 4.4).

Figure 5-3 Eco-median Melaleuca Grove – dry period; gravel base, seating, vegetation (EDAW)

Figure 5-4 Eco-median Melaleuca Grove following rainfall. Detention of stormwater, harvesting for reuse and water quality improvement (EDAW)

Treated stormwater can be stored in above ground or underground tanks within the eco-median and used to meet irrigation demands for the production based trees. As these trees are planted on soil filtration media with underdrains, any excess irrigation water will be collected by the underdrains and returned to the storage. Similarly overland flow from the production tree bioretention area will be directed to the vegetated parts of the Melaleuca Grove and thence to the storage. This 'closed loop' will control the transport of nutrients and any chemicals that may be applied to the trees within the urban areas thereby minimising the risk to the Parklands biodiversity corridor. The configuration of the production based trees 'upstream' of the Melaleuca Grove will act as a barrier to the transportation of seeds to the Parklands.

5.2 Parkland Interface bioretention systems

Significant areas of the development cannot drain to the eco-medians. Linear bioretention systems on the parkland interface are proposed to treat stormwater that is not directed to the bioretention eco-medians. These systems will provide a vegetated transition from the urban development to the parkland areas, and will be set at a lower elevation than the adjacent road / paths (Figure 5-5) to ensure that stormwater pipes can discharge to the surface of these systems. The bioretention systems will act as buffers to the parklands, mitigating stormwater pollution impacts associated with the adjacent urban development (controlling pollutant runoff, providing a visual separation / demarcation to the parklands and aesthetically enhancing the interface with a concentration of attractive native vegetation species).

These systems have been sized to achieve best practice stormwater quality objectives for stormwater runoff from the contributing development areas. The width of the bioretention strips is typically 2 – 2.5m and length varies from 50 – 220m depending on the catchment area. The systems require a flat area to enable the stormwater to pond and pass effectively through the bioretention system. Tiered systems can be used where the surface grade varies. Delivery of stormwater to the systems will ensure even distribution and energy dissipation to limit disturbance to the bioretention surface. Treated stormwater collects through perforated pipes at the base of the bioretention system. This water can be harvested for reuse or directed via a suitable flow path to the receiving waters. The flow path can be configured as a swale or a piped connection to downstream detention areas/waterways. Provision for overflow from the system is also important and will direct stormwater to the ephemeral floodplain detention areas. These systems can be configured to more closely replicate the predevelopment hydrology received by terrestrial vegetation.

Figure 5-5 Linear bioretention systems on the interface with the parklands.

5.3 Parking Bay raingardens

In addition to the bioretention systems proposed within the eco-medians and at the development-parkland interface, for catchments where treatment area is limited, a number of small bioretention raingardens can be configured within the road corridor to ensure that all of the development area is treated. As illustrated in Figure 5-6 these systems create an interesting streetscape, can have a roll in traffic calming and as functional water quality systems in close proximity to residential lots they provide an opportunity to engage with the community. Communicating an understanding of the operation of these systems and the other WSUD elements within the development is an important educational outcome with strong environmental benefits. The maintenance of these systems may also be enhanced where residents take an interest in their function and appearance.

Raingardens would be used in areas within the development with limited space available for treatment. Up to 40 parking bay bioretention systems, with a combined area of 560 m^2 are proposed to address runoff from these areas. Each raingarden is assumed to have a footprint of 15m^2 (3m x 5m). A larger number of smaller systems such as bioretention street trees (typically 2m x 3m) would also be suitable. As an example, a possible configuration for the areas south of the heritage site is given in Figure 5-7 and Table 5-1. Note that as the lot layout and stormwater drainage is finalised the treatment configuration can be confirmed, providing raingardens equivalent to 2% of the impervious catchment area directed to them..

Figure 5-6 Examples of bioretention raingardens with streetscapes (parking bay type systems).

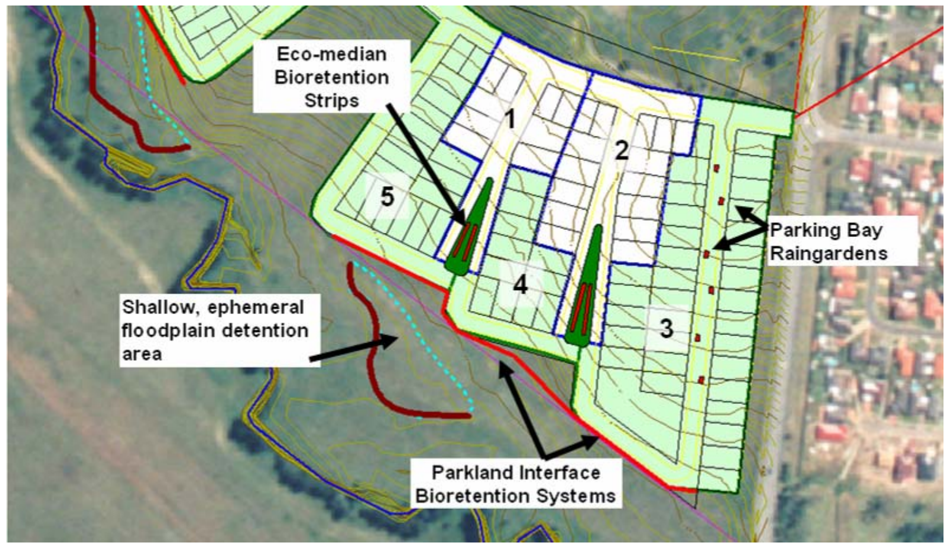


Figure 5-7 Possible configuration of bioretention systems treating the southern catchment.

Table 5-1 Details of the configuration of bioretention systems proposed in Figure 5-7

Cat	Area (m2)	Eco Median	Imp Area (75%)	Bioretention Area (2%)	Configuration	Dimensions
1	9,204	870	6,251	125	2 strips within ecomedian	each strip approx 30m x 2m
2	13,150	1,089	9,046	181	2 strips within ecomedian	each strip approx 45m x 2m
3	27,040		20,280	406	Linear strip, parkland interface and parking bay rain gardens	approx 170m x 2m 6 raingardens; 3m x 5m
4	7,739		5,804	116	Linear strip, parkland interface	approx 60m x 2m
5	14,710		11,033	221	Linear strip, parkland interface	approx 110m x 2m
all	71,843m^2	1,959m^2	52,413m^2	1,048m^2		1,070m^2

5.4 Southern Waterway

The upstream section of the southern waterway receives stormwater discharges from external residential catchments. At present, this part of the waterway does not have a clearly defined channel, and flows appear to spread across a broad vegetated corridor. Wetland and stormwater detention elements are proposed along the uppermost section of the waterway in order to improve the quality of stormwater discharged from the external urban catchments and to manage the erosive peak flows associated with the modified hydrology of the impervious catchment areas to the east of Doonside Road.

The downstream section of the southern creek (to the west of the proposed road crossing within the Doonside residential development) will be retained and rehabilitated to enhance its existing natural waterway form. Along this section of the waterway the natural low flow channel has generally been protected from erosion. A small stand of casuarinas with a carpet of native grass (Microlaena) provides the natural template for the rehabilitation of the waterway. The development layout has been configured to preserve this section of the southern waterway and the existing alignment. The WSUD strategy developed ensures the predevelopment flood hydrology is maintained (particularly for frequent events). The revegetation of the riparian zone for the lower section of the Southern Creek will extend the natural template presented to stabilise the modified sections in the lower half of the waterway.

5.4.1 Detention and Water Quality along the Southern Waterway

Water quality improvement and detention areas proposed along the upper section of the Southern Waterway will manage stormwater runoff from external catchments, thereby protecting the natural form of the downstream section of this waterway.

The urban design objectives and water quality and detention requirements have been integrated to create a cascade of detention areas separated by pedestrian crossing points. These are illustrated in Figure 5-8 and Figure 5-9. Each detention area contains ephemeral markers and play elements that draw the community to these areas and help to mark the change that rainfall/runoff brings to the waterway.

The vegetation will include wetland species to improve stormwater quality. As detailed in Section 4.3.2 the required wetland treatment area is 3,750m^2, or approximately 4% of the impervious area of the external catchment. A GPT is recommended to concentrate the coarse sediment and litter removal which will assist in maintenance of the system. Additional sedimentation occurs in a deeper zone prior to the main macrophyte area of wetland.

Figure 5-8 Southern Waterway during dry periods.

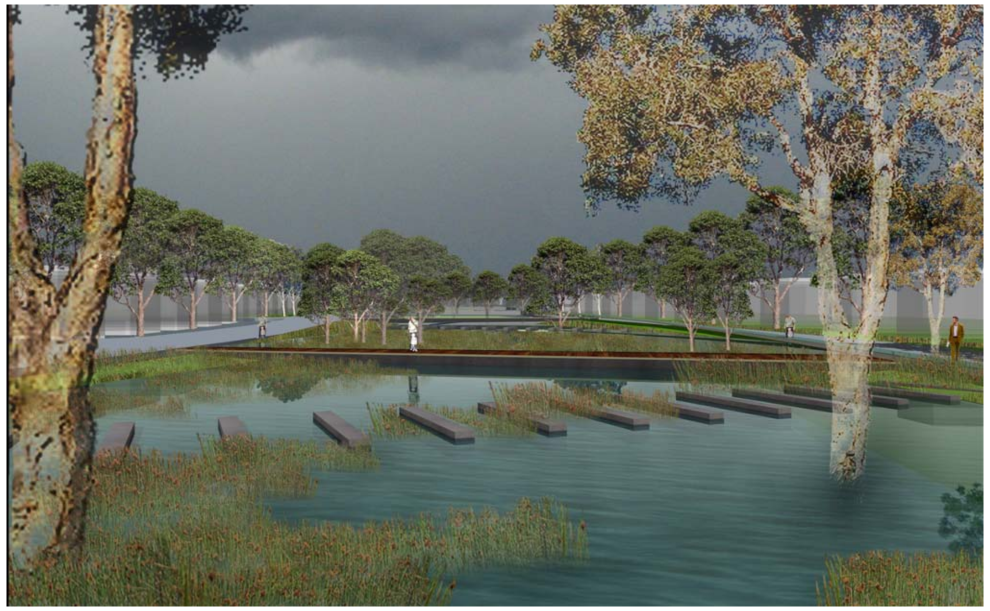


Figure 5-9 Southern Waterway following rain event.

Figure 4-7 illustrates the configuration of the detention areas along the Southern Waterway. The waterway will convey flows, with weirs providing the detention required to restore the predevelopment peak 1.5yr ARI flow to the downstream waterways. Through detailed design the control structures and distribution to wetland areas can be refined. The wetland areas will be inundated by low flows such that they are protected from high velocity flows.

Figure 5-10 illustrates the possible configuration of the vegetation through the cascading detention area proposed. The urban form alters the layout, however as with natural systems the species that occur within the base of a waterway channel and require frequent wetting will be located in the lower parts of the basin (areas a darker shade of green in Figure 5-12). Those species that exist further from the channel will dominate the more elevated areas within each tier of the cascading basin.

The progression along the watercourse will mark a transition from ephemeral wetland species through to the ephemeral Melaleuca (Paperbark) and Casuarina glauca (Swamp Oak) complex – the form of the natural downstream section of the waterway. Each vegetation combination (complex) will include species within the grouping that are appropriate for the hydrology experienced within that section of the basin. Figure 5-11 provides examples of the three groupings of vegetation proposed along the Southern Waterway. A list of suitable species for planting within bioretention systems and wetland areas is provided in Appendix 1.

The groves of Eucalyptus or Melaleuca canopy vegetation would provide shade along the waterway.

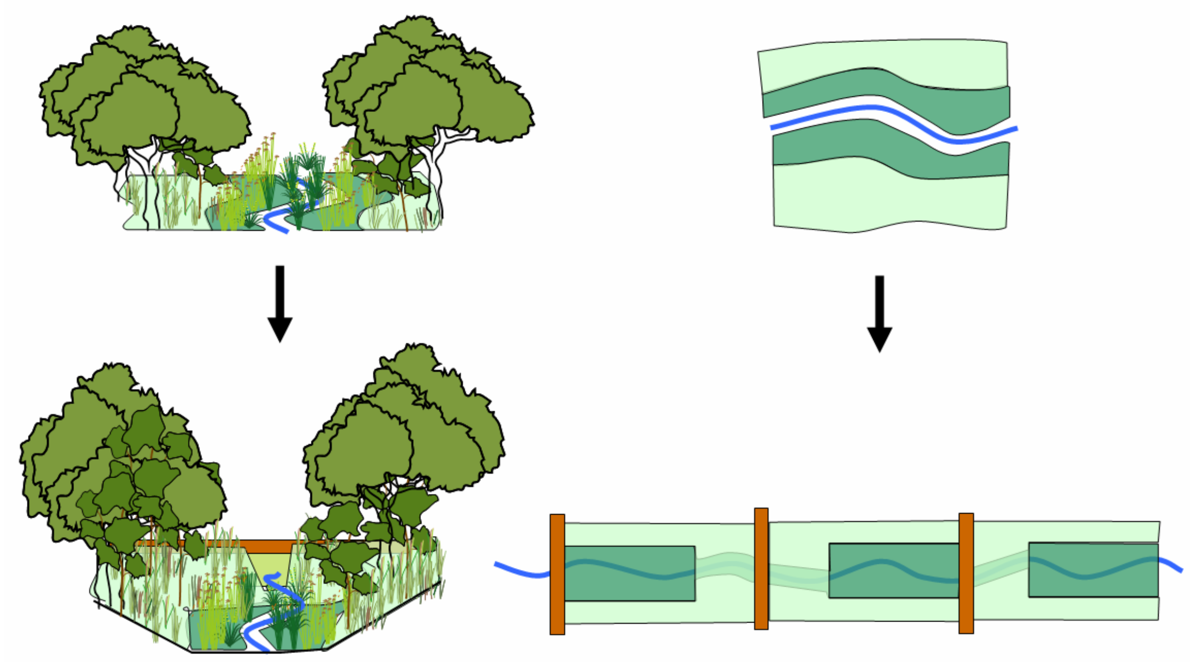


Figure 5-10 Configuration of vegetation proposed along the Southern Waterway.

Ephemeral wetland

Baumea articulata

Carex apressa

Schoenoplectus mucronatus

Schoenoplectus validus

Wetland species range in height from 0.5 – 1.5m. The final selection of species will be tailored to meet the desired landscape theme.

Ephemeral *Melaleuca* (paperbark) complex

***Melaleuca* woodland with grasses and sedges in understorey. Suitable Paperbark species range in height from 2 to 20m.**

***Melaleuca decora* flowers**

***Centella asiatica* – Swamp Pennywort**

***Juncus usitatus* – Common Rush**

***Schoenus apogon* – Common bog-rush**

Casuarina glauca (Swamp oak) complex

***Casuarina glauca* – Swamp Oak**

***Microlaena stipoides* – Weeping Rice Grass**

The Casuarina glauca (Swamp oak) complex is the natural form of the remaining, intact riparian vegetation along a small part of the Southern Creek, and is the dominant form of riparian vegetation along Bungarribee and Eastern Creeks.

Figure 5-11 Examples of the vegetation types proposed along the Southern Waterway.

5.5 Northern Waterway

The northern creek form has been substantially modified by the creation of online dam structures, which have been colonised by *Thypa*. A constructed wetland is proposed in the upstream sections of the northern waterway to remove pollutants and improve water quality from the upstream urban catchments to the east of Doonside Road. Detention of flows from the external residential catchments will reduce the peak flows characteristic of developed urban catchments and protect the geomorphic form of the receiving waterways.

Opportunities exist to integrate the stormwater management elements described below with urban landscaping objectives, such as the creation of an entrance feature and areas that enhance the habitat value for fauna (standing water suitable for the fishing bat).

5.5.1 Detention and Water Quality for the Northern Waterway

There are opportunities to configure detention area upstream of the proposed road crossing in addition to the areas associated with the treatment wetlands. As detailed in Section 4.3 the required stormwater quality treatment area is approximately 5,300m^2. The larger external catchment discharges stormwater to the site via a culvert at RL 42.4 (2.6m deep). The culvert contained significant sediment at the time of survey, thus the size and details were not able to be specifically determined. The smaller catchment discharges via two pipes (675mm, 825mm) at approximately RL 46.0 and 45.8.

A perched wetland could be configured at the intersection of the main entrance road, treating stormwater from the smaller of the two catchments. This location would be highly visible from the entrance and spine roads of the development, and would be a desirable landscape feature in addition to providing its water quality function. The treatment area for the larger catchment could be integrated at the base of the detention area proposed. The GPT and initial sedimentation area for the wetland may be located adjacent to the existing culvert and boundary with the road, screened by vegetation. This preliminary configuration option is presented in Figure 5-12.

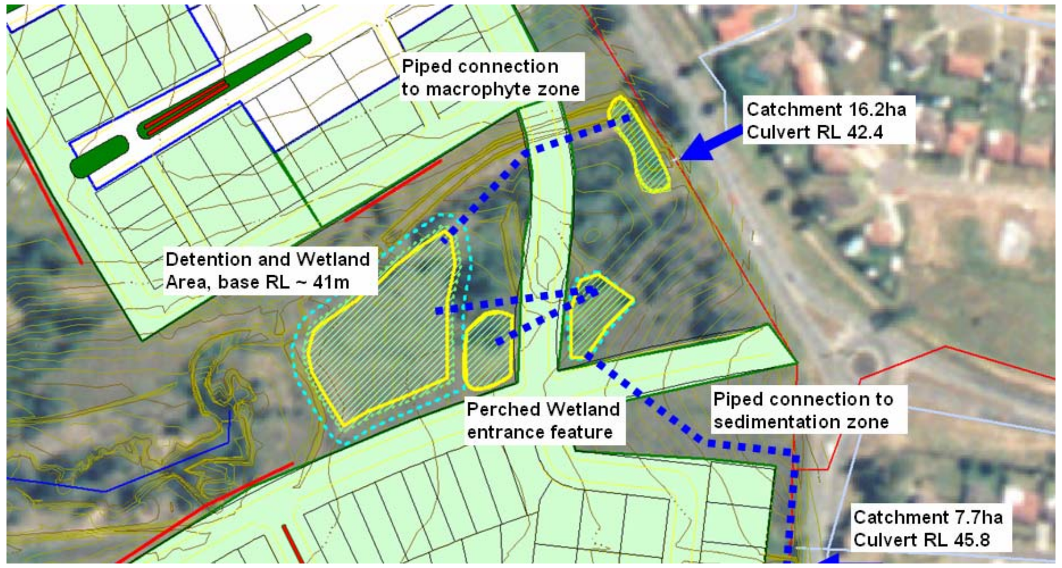


Figure 5-12 Northern Waterway; configuration of water quality wetland and detention areas

5.5.2 Rehabilitation of the Northern Waterway

The WSUD elements proposed in Section 5.5.1 will return the critical 1.5 year ARI peak flow hydrology of the waterway to that experienced prior to development of urban areas within the catchment. The water quality treatment wetlands will reduce the nutrient load and sediment transport, protecting the downstream waterways from pollutants. To complement these stormwater control measures it is proposed that the downstream section of the northern creek be rehabilitated to a natural form with the existing farm dams removed and a flow path re-established to connect the waterway with Eastern Creek.

Figure 5-13 illustrates the natural form of a small section of the Northern Waterway downstream of the existing, online dam structures. A rehabilitated channel would have a geomorphology comparable with this area. Stabilisation of the bed in certain locations would be required, with occasional rock drop structures to accommodate grade changes and susceptible erosion points. Modelling undertaken as part of the detailed design, will identify the works required. Substantial revegetation of the waterway channel with adequate planting densities will help to maintain the stability of the rehabilitated areas and assist in managing the transition from pasture grasses to native dominant species.

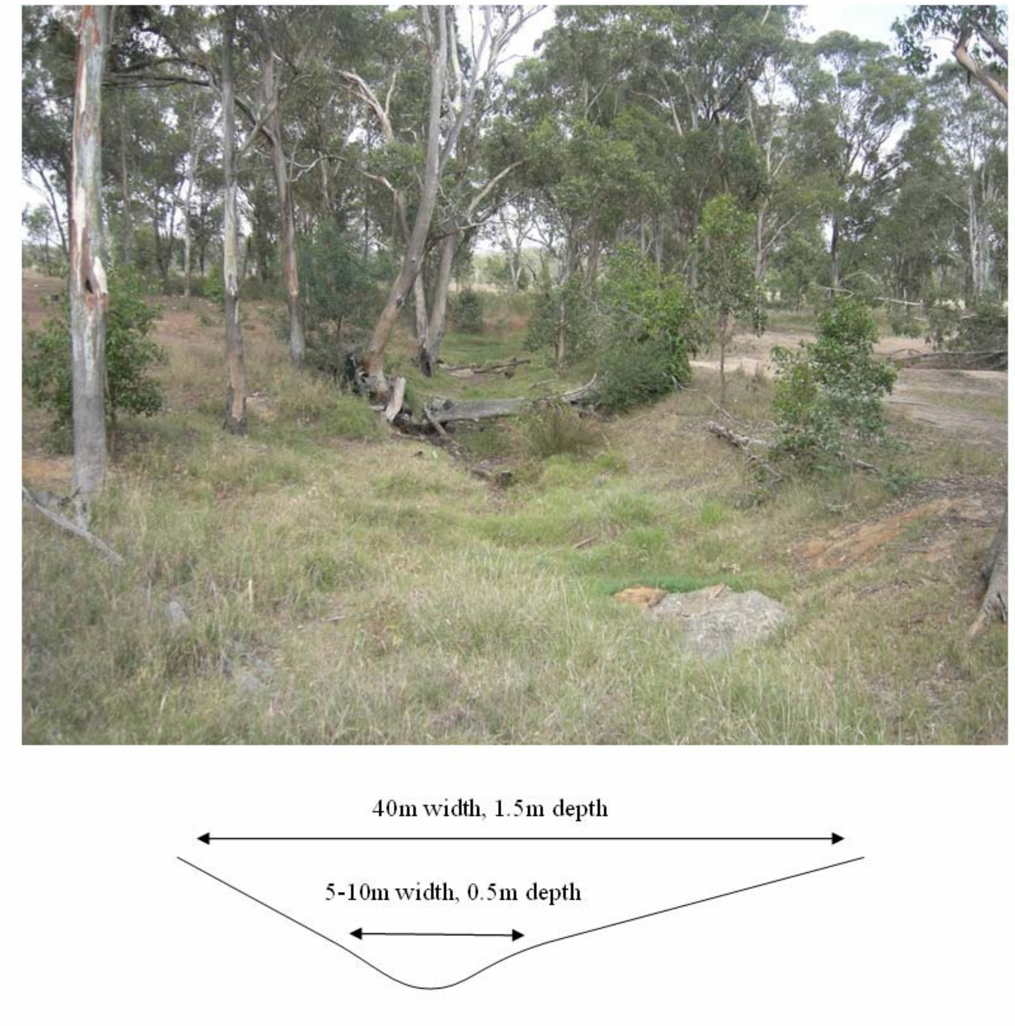


Figure 5-13 Northern Waterway natural form, downstream of existing online dam structures.

5.5.3 Reconnecting the Northern Waterway and Eastern Creek

As presented in Section 2.2, there is no channel connecting the northern waterway to Eastern Creek. This is the result of a series of factors including construction of the trunk sewer to Quakers Hill STP which cuts across the waterway at this point, and the dams along the creek limiting flows to the downstream section of the waterway. .

Reconnection of this waterway to Eastern Creek is proposed to ensure a stable form for conveyance of flows. While assessment of the works required would be undertaken through detailed design, a direct connection to Eastern Creek could be created, avoiding the existing vegetation to the north. Alternatively reconnection of the waterway could occur along the assumed original flow path, however, this may have impacts on terrestrial vegetation. Further assessment of these options would determine the optimum configuration, alignment, extent of rehabilitation works required and the recommended revegetation strategy.

5.6 Bungarribee Creek and Eastern Creek

The riparian zone and floodplain adjacent to the creeklines within the Parklands will be revegetated with species indigenous to the Cumberland Plain Woodlands to form the biodiversity corridor. Sections of the waterway will require bed and bank stabilization to address existing erosion points. Weed growth within the corridor will need to be managed.

There are numerous small stormwater pipes that discharge untreated stormwater from external catchments to areas adjacent to the biodiversity corridor, and the receiving waters of the Parklands. These stormwater pipe discharge points concentrate nutrients and create disturbance resulting in weed growth and erosion. Treatment and detention of this water is important to protect the Parklands vegetation and downstream waterways. Opportunities can be assessed over time to address particular locations as works occur in these areas. In some cases works may be able to be undertaken within the external catchments to better manage the stormwater discharge. The water quality and flow management measures adopted to treat the large external catchments that pass through the Doonside residential development illustrate the recommended strategy for protection of receiving waterways and ecosystems.

5.6.1 Crossing Points

Pedestrian linkages crossing over Eastern Creek and Bungarribee Creek will connect the Doonside development to the sports precinct, and other areas of the western side of the parklands, and to the Airstrip and adjacent precincts. Two crossing points have been selected to match the requirements of pedestrian linkage with sections of the riparian zone where there is already evidence of disturbance to the riparian zone or waterway. The crossing points will be designed to limit impacts on the waterway and on the riparian vegetation. Structural supports for the bridge would be constructed beyond the banks to limit interference to the stream. The design of these crossing will be to

a. ensure light penetration to vegetation beneath and

b. reduce the impact on flow hydrology by reducing rain shadowing and the concentration of drainage points from the bridge surface.

In addition, as illustrated in the development layout, there are crossing points over the northern and southern waterways, with road crossings within the development and pedestrian/cycleways within the parklands. Culverts will be used for the two road crossings within the development. The crossing points within the parklands will be configured to minimise impacts as described for the Bungarribee and Eastern Creek pedestrian crossing points.

5.7 Shallow Detention Areas within the floodplain

Shallow, ephemeral detention areas have been configured within the floodplain to manage discharge for the one and a half year ARI event, so as to minimise the impact of frequent events on the natural waterways and to minimise bed and bank erosion.

Protection of aquatic habitat in waterways is associated with sustaining the geomorphic form of the beds and banks. The shallow, ephemeral, floodplain detention areas will integrate seamlessly with the riparian zones, with planting of suitable vegetation and limited impact on the existing landform. The detention storage required is achieved with low bunding and small inlet / outlet structures which control the discharges to the watercourses (Figure 5-14). The duration of inundation of these systems is limited to short periods (up to 24hrs). The discharge from the treatment measures and detention areas will be controlled so that the riparian areas and the waterway will receive flows that more closely represent the predevelopment hydrology, with specific attention to limiting the critical peak flows.

Figure 5-14 Shallow inundation of floodplain areas to manage peak flows from urban development areas.

6 Potable Water Conservation and Dual Reticulation

Potable water conservation will be achieved with water efficient fixtures and appliances, and the provision of alternative sources of (non-potable) water through a dual reticulation water supply network. Non-potable water will be supplied to meet toilet flushing, irrigation, and cold water laundry demands. The potable mains water strategy for the development is outlined in the following sections.

6.1 Demand Management

Demand management through the use of water efficient fixtures and appliances is a critical and cost-effective way to reduce potable water consumption. These measures include water efficient toilets, fixtures and fittings as well as smart irrigation of landscaped areas. Building guidelines can address appropriate metering, monitoring and management practices to ensure the conservation of potable mains water.

Table 6-1 shows the indoor water demand for the Doonside development based on the projected residential population of 2210. The table illustrates that approximately 20% of potable mains water consumption can be reduced through efficient fittings in comparison with the BASIX benchmark daily usage. The total water usage (annual) is based on the population estimate for the site (2210 people, 716 lots) as detailed in Section 4.2.2.

Table 6-1 –Estimated Indoor Water Demand for the Doonside Residential Development

	BASIX Benchmark[1] L/p/d	Efficient Fittings L/p/d	**Total Water Usage (ML/yr)**	Hot Water Usage (ML/yr)	Potable Demands (ML/yr)	Non Potable Demands (ML/yr)
Shower	57	37	**32**	22	9	
Laundry	55	55	**47**	9		38
Toilet	35	20	**17**			17
Kitchen	16	16	**14**	10	4	
Bathroom	15	15	**13**	9	3	
Leaks	12	12	**10**		10	
TOTAL Indoor Demand	190	155	**132**	51	27	55

[1] Daily water usage data - BASIX Benchmark water consumption - Litres / person / day

[2] Annual water usage data - Megalitres / year, using population estimate of 2210 people

The hot water usage represents a significant proportion of the annual demand and can be substantially met with rainwater harvesting as detailed in section 6.2.3. The modelling assumes that hot water usage represents 70% of shower demand, 20% of laundry demand and 73% of kitchen and bathroom demands. The non-potable demand will also include outdoor use. This is estimated at 20ML/yr for the development, but is highly dependent of the practices of individuals and the irrigation infrastructure provided. Most of the urban pervious areas (70%) have been assumed to be planted with indigenous, low water use vegetation that does not require irrigation.

6.2 Alternative Water Sources

Alternative water sources include wastewater, stormwater or roof runoff and groundwater which can be used to meet non potable demands. "Fit for purpose" use is where alternative water sources are used for demands which do not require potable water, including toilet flushing and air conditioning systems reliant on evaporative cooling. Building design guidelines can be used to ensure that non-potable water is appropriately connected to meet appropriate demands.

For the Doonside site it is possible that recycled water from the Quakers Hill STP may become available. This would be preferable for the site as it will result in the greatest proportion of non potable demands being met with the smallest footprint requirements. Alternatively, stormwater harvesting is an option to meet a proportion of the non-potable demands (Section 6.2.2).

6.2.1 Treated Wastewater

The Quakers Hill Sewage Treatment Plant (STP) is located 7km from the site. Planning, costing and negotiation of using recycled water from the STP to supply One Steel and Blacktown Councils sports/recreation areas at Nurragingy Reserve, make this a possibility in 2008.

A recycled water pipeline is also being considered to service the Doonside residential development and the Huntingwood West Employment Zone. Areas to the north of the Quakers Hill Sewage Treatment Plant may at a later stage be supplied with recycled water. The scheme is driven by the Metropolitan Water Plan, but requires full cost recovery and suitable water quality. The quality of recycled water to be supplied to possible users may require an upgrade of elements within the Quakers Hill Sewage Treatment Plant.

The scheme would be voluntary for potential commercial users with detailed negotiation required. Residential use would be mandated with the dual reticulation supplied, pricing determined by IPART and cost recovery through DSP charges. To service Doonside a reservoir would be constructed on Sydney Water land near the development.

The Quakers Hill STP is one of the three plants which may be linked so as to consolidate these plants for a major reuse scheme proposed for Western Sydney. The timeframe for these works is uncertain.

6.2.2 Stormwater Harvesting

Stormwater runoff should be managed as a resource with consideration given to harvesting from roof surfaces for reuse within buildings and at a precinct scale. Maintaining predevelopment flows to the downstream waterways is important and the configuration of a stormwater harvesting scheme would address this issue. The impervious surface area associated with developed urban catchments results in a significant increase in stormwater runoff. The external catchments and the development site present an opportunity for stormwater harvesting.

The WSUD Strategy for the Doonside development has detailed the stormwater treatment requirements for the protection of the waterways downstream. The water treated through the wetlands and bioretention systems proposed for the site can be pumped to storage areas and plumbed to meet significant non potable demands through the development. The configuration of storage, pumps, filters and connections to the dual reticulation supply network would be determined if treated wastewater is not available.

6.2.3 Rainwater Tanks for Hot Water

Harvesting roof runoff to meet hot water demands will further reduce potable water import where centrally reticulated reuse water is supplied for other non potable demands. Centralised provision of non-potable water is typically configured to meet demands for toilet flushing, garden irrigation, cold water washing machine tap demands and public space irrigation. There is an opportunity to further reduce potable water use even with the rainwater harvesting from roofs to supplement hot water demands. Figure 6-1 illustrates the proportion of hot water demands that can be met with various tank sizes, based on a modelled roof area of 200m² and daily demand of 188L/d. Tank sizes of between 3 and 5kL will meet between 66 and 77% of the hot water demand, thereby further reducing the potable water use in the development. As the need for hot water is a constant and significant demand a high proportion of harvested water is used. With an adequate proportion of the roof area connected to the tank with each storm event the tank is refilled. Mains water top up will be required for the proposed system.

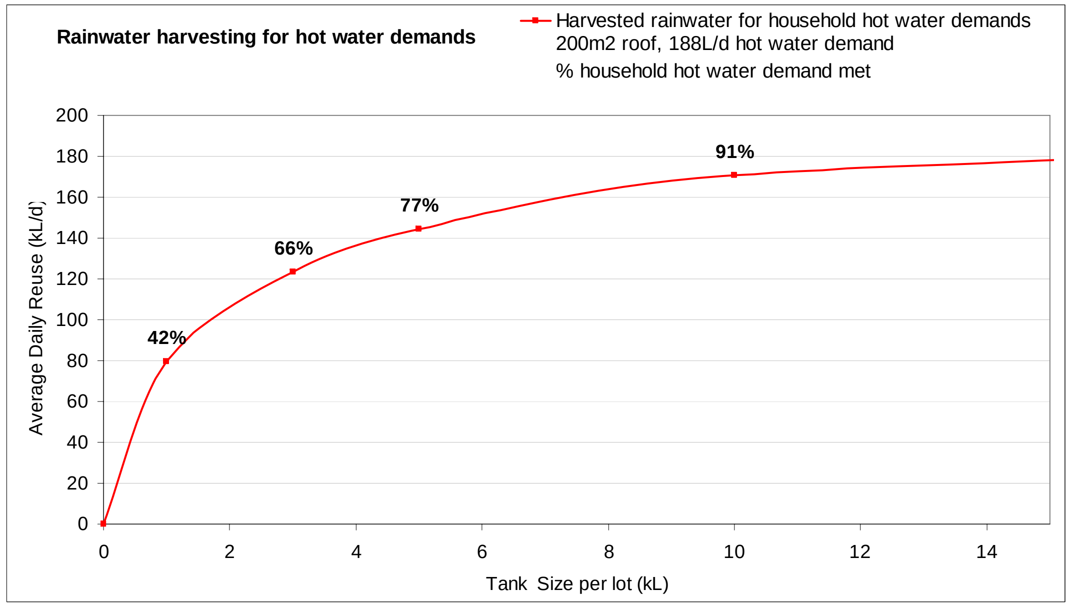


Figure 6-1-Rainwater tank sizing to meet hot water demands

In South Australia rainwater tanks will be used to meet residential hot water demands within the Lochiel Park development (Land Management Corporation). The use of rainwater tanks plumbed to the hot water supply, in addition to ensuring a non potable water supply is available for toilet flushing/irrigation, would result in significantly greater potable water savings than the minimum BASIX requirements.

The use of rainwater to meet hot water demands demonstrates the WSUD objective of matching available water sources with the most appropriate uses where the quality is fit-for-purpose, to reduce the demand for potable mains water. The hierarchy of source to use matching for typical household uses is an attempt to match the quality of available water sources to appropriate uses. Potable drinking water is only required for direct human consumption, or where there is a high degree of contact with water. This includes uses in the kitchen, shower and bathroom taps. For other purposes, non-potable water can be substituted. Rainwater is suitable for a range of purposes, and is the only alternative water source appropriate for the hot water system. Treated greywater can be used for clothes washing, garden irrigation and toilet flushing, and treated wastewater can be used for garden irrigation and toilet flushing. For precinct-scale reuse of harvested stormwater or treated wastewater the available quantity is greater than at a household scale and thus is able to meet all non-potable demands (clothes washing, irrigation and toilet flushing).

6.2.4 Groundwater

No information is available that suggests that known groundwater reserves are easily accessible to meet non potable demands for the Doonside Development.

6.3 Dual Reticulation

The reticulation for the development should be designed to integrate with a possible reuse pipeline even if the scheme to provide treated wastewater from the Quakers Hill STP has not been finalised. Where dual reticulation infrastructure is provided, initially harvested stormwater (supplemented with mains water) can be used as the alternative water source. Plumbing design should be configured to adapt to future opportunities, specifically centralised provision of non potable water. Non potable water may also be used to meet irrigation demands of the adjacent parklands - active recreation areas.

The substitution of potable water with alternative water sources where available would result in a significant reduction in potable water consumption. Provision of a dual reticulation network for the development is advised, even if a non potable water source may not be immediately available so as to be resilient to future opportunities, with connection points suitably located to integrate with a centrally reticulated non potable water source.

In assessing the water conservation strategy for this project, it is apparent that there are significant benefits in providing a dual reticulation network. The construction of a dual reticulation network in a greenfield development is cost effective and allows the development to benefit from future advancements in water recycling technologies. Such a system can ultimately maximise water conservation, minimise the transport of water and wastewater from the site, and minimise treatment costs of water and sewerage. Through provision of a dual reticulation network and infrastructure for supplying an alternative source of water, the entire non potable demand for each house could be met, corresponding to significant potable water savings each year. This would be a significant reduction in potable water use and the site could achieve a BASIX score of 65(+). The dual reticulation network would be plumbed to supply reuse water for toilet flushing, garden watering and laundry.

There has been some significant advancement in technology for water recycling over the past five years, leading to many innovative application of small-scale water reuse schemes. There are already technologies for stormwater harvesting and reuse, greywater reuse, sewer mining and local wastewater treatment plant and it is anticipated that they will become more and more cost effective for a range of development scale over the next ten years. Regulation requirements and water quality standards for water recycling will continue to be streamlined over the next decade. The benefits of such technological advancement can only be realised if the necessary reticulation infrastructure are in place in developments being planned today.

6.3.1 Plumbing Configuration

The configuration of plumbing connections within individual houses is critical in facilitating future connection to a centralised recycled water pipeline to supply toilets, laundry and garden irrigation. It is cost effective when the pipe work infrastructure is initially configured to design for future opportunities. Even if a non-potable water supply is not available initially to supply reuse water to individual lots, a future connection should be easily accommodated to facilitate reuse of non-potable water.

6.4 Microclimate Control

Where a non potable water supply is available, strategic location of areas of vegetation with a high demand for non potable water may assist in bringing microclimate benefits to the Doonside site. This opportunity contrasts with demand management measures applicable also to alternative water sources, but warrants further consideration as the detail design for the site progresses.

6.5 Water Supply and Sewerage

As identified in the Civil Infrastructure Masterplan Report (YSCO Geomatics), potable water supply will be configured to distribute water to all lots within the development. The mains will be located within the road reserve where possible, with connection to the existing water main supply adjacent to the site. Sewage from the site would be transported to the Quaker's Hill Sewage Treatment Plant.

6.6 Wastewater minimisation

Wastewater minimisation will be achieved though the potable water conservation measures outlined above; demand management, use of alternative water sources and dual reticulation. No alternative wastewater treatment options are advised for the Doonside residential development due to the proximity to the Quakers Hill Sewage Treatment Plant. This centralised wastewater system provides tertiary treatment and is likely to facilitate centralised provision of non potable water. The issues of ageing reticulation networks and those reaching capacity limitations are not considered critical for this area. Efficient use of the community's current investment in centralised treatment is favoured over onsite treatment options.

6.7 Building Design Guidelines for Doonside

The Department of Planning and Landcom as the land owners and developers of the Doonside site have shown commitment to delivering an innovative and unique development, striving for "world's best practice" for the Doonside residential development.

The WSUD measures proposed for the Doonside development aim to address the water quality and flow management for external catchments in addition to best practice management of stormwater runoff from the site. In addition to the DCP controls and the WSUD objectives adopted for the site, consideration may be given to additional measures that deliver further benefits in terms of potable water conservation, pollution control and flow management. Some of these measures are non structural or related to the delivery of infrastructure within the lots.

Issues include the configuration of plumbing connections within individual houses to facilitating future connection to a centralised recycled water pipeline (Section 6.3.1), education and other non structural measures.

6.7.1 Education and other non structural measures

The elements of the WSUD strategy should be explained for the residents of the Doonside development as their support is important for the ultimate success of the strategy. The practices of individuals can have significant implications in terms of water quality and water conservation. Many residents may be interested in actively engaging with the eco-medians and may assist in maintaining these public space areas particularly in terms of surveillance and identifying problems that may arise. The designed operation for ponding of water in wetlands and bioretention systems for water quality and in the detention areas for flow management should be understood, and the benefits of these systems communicated.

7 Costing

The Doonside development WSUD Strategy will optimise the water cycle management opportunities for the site, delivering best practice water cycle management. Costing estimates for the various components of the strategy are provided below. These are provided as preliminary estimates only, outlining capital and maintenance costs. These estimates serve as a guide to the overall financial planning of the development prior to the detailed design stage where costs are able to be more clearly defined.

Table 7-1 – Summary table of estimated costs for stormwater detention and water quality

STORMWATER DETENTION AND WATER QUALITY	Capital Cost
1. GPT – external catchments	$360,000
2 a. SOUTHERN WATERWAY WETLAND	$400,000
2 b. SOUTHERN WATERWAY DETENTION	$1,150,000 +
3 a. NORTHERN WATERWAY WETLAND	$500,000
3 b. NORTHERN WATERWAY DETENTION	$250,000
4 a. FLOODPLAIN DETENTION	$650,000
4 b. FLOODPLAIN DETENTION OFFSET EXCAVATION	$225,000
5 a. Eco-median Bioretention strips	$350,000
5 b. Linear Parkland Interface Systems	$510,000
5 c. Parking Bay Raingardens	$120,000
5 d. Eco-median Melaleuca Grove Stormwater/Irrigation Harvesting	$135,000
TOTAL	$4,680,000 +

EXTERNAL CATCHMENTS CONVEYANCE

A piped connection is required for the smaller of the two external catchments draining to the southern waterway to the detention areas for flows up to 100 year ARI. This is approximately 250m long and costs $250,000. Similarly for the smaller external catchment (N1) draining to the northern waterway, a piped connection is needed to convey flows from the existing culvert to the northern waterway. Detention is provided in the floodplain areas. Piped connections through the entrance road embankments will also be required.

Table 7-2 – Summary table of estimated costs for waterway rehabilitation

NORTHERN WATERWAY	Capital Cost
6. Reconnection of the Northern Creek to Eastern Creek	$100,000
7. Recreation of channel through floodplain	$120,000
8. Rehabilitation of existing waterway to floodplain from detention areas	$140,000
8. Revegetation of riparian area (beyond channel)	Revegetation strategy
SUB-TOTAL	$360,000 +
SOUTHERN WATERWAY	
9. Stabilisation and channel formation works	$100,000
10. Revegetation of the southern waterway (downstream of road crossing)	$90,000+
SUB-TOTAL	$190,000+
KARELLA AVENUE WATERWAY	
11. Stabilisation of small sections of the waterway (onsite)	$50,000
12. Revegetation of the waterway (onsite)	$50,000
13. Bioretention System to improve water quality (within ext cat or onsite)	$70,000 *
SUB-TOTAL	$170,000
TOTAL	$720,000+

* configuration in external catchment with attenuation of flows is desirable for geomorphic protection. The water quality treatment area could be located on site, however the footprint is not available for attenuation of 1:2 year ARI.

Table 7-3 – Details of estimated costs for stormwater detention and water quality requirements

STORMWATER DETENTION AND WATER QUALITY	Capital Cost	Annual Maintenance Cost	Details & Assumptions
1. Gross Pollutant Traps – course sediment removal for external catchments	$360,000	$30,000	3 GPT units: sizing based on catchment area and modelled 3 month flow. Cost includes installation $100k (small), $120k (med) and $140k (large). Total $360k. Northern catchments $220, combined southern catchments $140k. Maintenance cost depends on clean outs regime (assumed 6 clean outs per year)
2. SOUTHERN WATERWAY			
2 a. WETLAND	$400,000	$10,000	The costing of the wetland determined with MUSIC (v 3.0.1), which uses 'cost/size' relationships based on data collected from around Australia in 2002-04, adjusted to $2007. Includes vegetation (this component is estimated to be $100 – 150k)
2 b. DETENTION (southern waterway)	$1,150,000 – $1,450,000 depending on design	Minimal additional cost above desired landscaping management regime	The provision of the detention footprint in addition to the wetland area as detailed above involves excavation (approximate $400k), up to 12 formed weir structures across waterway ($300k), distribution channel / structures ($200k-500k depending on design) and planting ($250k). Excludes surface finish for weir structures and landscape features desired.
3. NORTHERN WATERWAY			
3 a. WETLAND	$500,000	$12,500	The costing of the wetland determined with MUSIC; vegetation component estimated at $150-200k.
3 b. DETENTION	$250,000	Minimal additional cost above desired landscaping management regime	The provision of the detention footprint in addition to the wetland area as detailed above involves excavation or bunding (approximate $200k) and planting ($50k). Inlet/Outlet structures costs included with those for distribution to the wetland areas.
4. FLOODPLAIN DETENTION	$650,000	Minimal additional cost above desired landscaping management regime. Maintenance includes checking bund, inlet/outlet structures, landscape management.	Provision of detention in the floodplain involves bunding ($60-180k), excavation of some areas ($120-260k), pipe connections (up to 200k). Outlet structures and swales from detention areas (up to $220k). Planting to be defined by the revegetation strategy (estimate at \$2.60 – \$10/m² on bund ($50-200k), regraded areas ($40-$150k)). The length of embankments totals approx 3000m, assumed width 7m, height 0.6m. Footprint 7ha, up to half of this area may require some regrading.
5. BIORETENTION SYSTEMS			
5 a. Eco-median Bioretention strips (35% site treatment)	$350,000	$15,000+ The maintenance cost for the bioretention systems is highly variable with the range of planting selected from native species to 'production based trees'.	Footprint 3000m², Combined length 1400m. Costs include earthworks (80k), soil media etc (70k), tiering for level surface, drainage and connections (200k). Note cost excludes planting of production based trees – included in EDAW landscape estimates; ~ $130k and Melaleuca area (see 5d below)
5 b. Linear Parkland Interface Systems (58% site treatment)	$460,000		Footprint 4850m², Combined length 2300m. Costs include earthworks (140k), soil media etc (110k), planting (100k), tiering for level surface, drainage and connections (160k)
5 c. Parking Bay Raingardens (7% site treatment)	$120,000		Footprint 560m², 37 raingardens each 5m x 3m Costs include earthworks (20k), soil media etc (15k), planting (10k), drainage and connections (75k)
5 d. Eco-median Melaleuca Grove Harvesting	$135,000	$9,000	Ephemeral wetland vegetation in 70% of melaleuca grove area (35k), tanks, pumps & connections (100k) for harvesting treated stormwater / excess irrigation.

The cost estimates provided for rehabilitation of the waterway areas are highly variable as they are dependent on the rehabilitation strategy. These costs are particularly difficult to detail without a detailed assessment to determine the extent of work. The area to be planted has a significant impact on costing. The waterway channel (for conveyance of up to the 1 in 2 year ARI) will need to be planted in sufficient density for stabilisation and weed suppression. The species suitable for the frequently inundated parts of the waterway channel are typically more expensive than terrestrial vegetation (~\$20/m^2 for supply and planting of sufficiently established wetland species at 6-8 plants/m^2 in Sydney). Planting within the riparian zones will also require adequate density, particularly of ground covers. Mechanical seeding may be appropriate in some areas to reduce the cost to ~\$2-3/m^2.

Table 7-4 – Details of estimated costs for waterway rehabilitation works

WATERWAY REHABILITATION	Capital Cost	Details & Assumptions
NORTHERN WATERWAY REHABILITATION		
6. Reconnection of the Northern Creek to Eastern Creek	\$100,000	This cost is highly dependent on the extent of works required, particularly the need for rock stabilisation, in addition to the desired rehabilitation planting. Two alignment options exist with detailed assessment required to determine potential impacts on vegetation and the optimal alignment. Incised, steep banks of Eastern Creek, 4m drop. The channel size is small as flows are attenuated in upstream detention areas (100year flow 3m^3/s).
7. Recreation of channel through floodplain	\$120,000+	The length of the waterway through floodplain is approx 350m. Costs include earthworks (70k), planting (50k). Additional waterway features for enhanced habitat and aesthetic value would increase the width and cost when com.
8. Rehabilitation of the existing waterway upstream of the floodplain	\$140,000+	The length of the existing waterway from the proposed wetland/detention area to the floodplain is approx 450m. The online dams would be removed. Some sections of the waterway may need to be realigned where they are close to the development. Costs include earthworks (90k), planting (50k). Providing interesting channel form with benched areas for enhanced habitat and aesthetic value would increase the estimated cost.
8. Revegetation of riparian area (beyond channel) is included in conservation plan for revegetion of the site (Note: estimate \$185k for northern waterway riparian area)		The length of the existing waterway from the proposed wetland/detention area to Eastern Creek is approx 850m. The riparian width from the channel banks is a minimum of 10m on either side for a category 3 waterway. Estimated planting cost at \$10/m^2 is (170k). Minor earthworks may be required in some sections to modify existing dirt roads etc (15k+).
SOUTHERN WATERWAY REHABILITATION (between road crossing and Eastern Creek)		
9. Stabilisation of small sections of the waterway and channel formation works along half of the waterway	\$100,000	This cost is highly dependent on the extent of works required, particularly the need for rock stabilisation, in addition to the desired rehabilitation planting. There are small sections along the waterway where stabilisation works will be required to protect against erosion. The channel size is small as flows are attenuated in the upstream detention areas. Further assessment is required to refine this cost estimate.
10. Revegetation of the southern waterway (downstream of road crossing)	\$90,000-\$260,000	The length of the existing waterway from the road crossing (end of proposed wetland/detention area) to Eastern Creek is approx 430m. The waterway corridor (area between the fingers of the development) including the required riparian width totals approximately 1.3ha. Estimated planting cost at \$20/m^2 is (260k). Component within the waterway channel is approximately 90k.

KAREELA AVENUE WATERWAY REHABILITATION (downstream of Eastern Rd) AND BIORETENTION FOR WATER QUALITY		
11. Stabilisation of small sections of the waterway	\$50,000	This cost is highly dependent on the extent of works required, particularly the need for stabilisation structures. The waterway channel size is small as flows are attenuated in the adjacent detention area (#9). The length of the existing waterway from Eastern Road to Eastern Creek is approx 250m. There is an additional tributary of approx 100m length through the conservation area which will receive attenuated flows from the development (detention areas 6a-e). Channel forming works would be minor as the vegetation in the area is of high ecological value (Shale Plains Woodland Endangered Ecological Community). Further assessment is required to refine this cost estimate.
12. Revegetation of the waterway channel	\$50,000	Revegetation of the channel through the conservation area would require careful planning, Where understorey vegetation is desired along these flow paths, in accordance with the restoration plans, species adapted to the hydrology of the waterway channel would be planted. Estimated planting cost at \$20/m^2 is (50k); assumed width 7.5m, length 350m.
13. Bioretention System to improve water quality	\$70,000	A bioretention system with surface area of approximately 800m^2 would be able to treat the external urban catchment for the waterway to meet best practice load reduction targets. The estimated cost based MUSIC (v 3.0.1), 'cost/size' relationships is \$70k, with a maintenance estimate of \$7,000/yr. The bioretention system could be located within the adjacent detention area or immediately downstream of the culvert or possibly within the urban catchment (on the northern side of Eastern Road).

Kareela Avenue Waterway

The rehabilitation plan for the Kareela Ave waterway which passes the Parklands on the northern boundary of the Doonside residential development area requires careful collaboration with the proposed conservation measures planned for the terrestrial vegetation in this area.

Maintenance of Established Waterways

Significant maintenance costs will be determined primarily by any landscaping requirements for the rehabilitated sections of the waterways. It is anticipated that will adequate planting densities and careful establishment, there will not be a significant on going maintenance cost. The maintenance costs are itemised for the gross pollutant traps and the wetland areas (Table 7-3) at the upstream sections of these waterways. These elements will concentrate the required maintenance in terms of litter collection and interception of sediment. A large storm event may destabilise sections of a waterway and remediation works would be advisable following significant storms.

Table 7-5 – Details of estimated costs for potable water conservation opportunities

POTABLE WATER CONSERVATION	Capital Cost	Details & Assumptions
11. Stormwater Harvesting • Eco-Median Melaleuca Groves or at a • Precinct Scale for non potable demands	\$50,000 to \$500,000	Harvesting options depend on reuse demand: irrigation of production based trees, additional irrigation, or to meet a significant proportion of the non-potable demand if treated waste water is not available. External catchments stormwater treated in wetlands can be harvested. External catchment 42ha, 22.6ha imp area. Eco-median catchment 15.5ha, 11.6ha imp. Tanks could be configured above or below ground. A lined, gravel trench within the eco-median area could be used to store water. Pumping to a central storage from the distributed treatment locations is also a possibility.
12. Dual Reticulation	\$1,360,000	Reticulation of non potable water, \$2,000 per lot, 680 lots
13. Rainwater tanks for Hot Water Supply	\$2,040,000	Small rainwater tanks - plumbed to the hot water system, \$3,000 per lot, 680 lots. Potable water top up options may vary the cost. Similarly option for larger, underground tank where above ground tank is not desired.
14. Water Efficient Fixtures	-	Negligible incremental cost in comparison with less efficient fixtures.

The preliminary costing estimates provided are intended to serve as a guide to the overall financial planning of the development prior to the detailed design stage where costs are able to be more clearly defined.

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Appendix 1 – Wetland and bioretention vegetation

The Doonside site lies within the Blacktown LGA of the Cumberland Plains. Ecological communities present within the immediate vicinity of the site include Shale-Plains Woodland and Alluvial Woodland, and are listed as endangered ecological communities under the Threatened Species Conservation Act 1995.

A list of the plant species that are suitable for planting in the bioretention system is provided in Table 1. Several of the shrub species recommended for planting along the wetland batters would also be suitable for the bioretention system (Table 2). The details of the plant species to be planted in the various wetland zones are provided in Table 2. The selection of plant species has been guided by the Shale-Plains Woodland and Alluvial Woodland ecological communities present within the Blacktown LGA of the Cumberland Plains.

The species have been purpose selected for the stormwater treatment wetlands and bioretention systems, with consideration given to the hydrologic conditions expected within the systems. The planting location and species mixes are designed to ensure that optimal stormwater treatment performance is achieved. In particular, macrophyte species have been chosen that suit the frequency of inundation, depth of permanent pools and the depth of extended detention.

Species marked with an asterix in the table below are indigenous to the Shale Plains Woodland or Alluvial Woodland classification (of Tozer 2003 and NSW NPWS 2002), common to the Doonside area. All other species are native to wetland areas of the Cumberland Plain.

Table 1 Recommended plant species for Doonside bioretention systems.

Grasses and sedges	
Carex appressa*	Tall sedge
Carex inversa*	Knob sedge
Dianella longifolia*	
Dianella revoluta*	Blue flax-lily
Lomandra longifolia*	Spiny-headed matt rush
Lomandra multiflora*	Many-flowered matt-rush
Poa labillardierei*	Tussock grass
Themeda australis*	Kangaroo grass
Shrubs	
Bossiaea prostrata*	Shrub
Bursaria spinosa*	Blackthorn
Casuarina glauca*	Swamp Oak
Davesia ulcifolia*	Gorse Bitter-pea
Dillwynia sieberi*	Prickly Parrot-pea
Dodonea viscosa*	Native Hop Bush
Pultanaea microphylla*	Spreading Bush-pea

Table 2 - Recommended plant species for the Doonside stormwater treatment wetlands

Wetland zone Littoral/ephemeral marsh (NWL to +0.2m)	Alisma plantago-aquatica Carex appressa Carex gaudichadiana Carex polyantha Cyperus lucidus Cyperus sphaeroideus Eleocharis acuta Juncus subsecundus Juncus usitatus Lythrum salicaria Microlaena stipoides Persicaria decipiens Persicaria prostrata	Water plantain Tall sedge Tufted sedge Leafy flat sedge Common spike-rush Finger rush Purple loosestrife Weeping grass Slender knotweed
Shallow marsh (NWL to - 0.2m)	Baumea rubiginosa Isolepis inundata Eleocharis acuta	Soft twig-rush Swamp club-rush Common spike-rush
Marsh (-0.2m to -0.35m)	Baumea rubiginosa Bolboshoenus caldwellii Schoenoplectus mucronatus Schoenoplectus pungens	Soft twig-rush Sea club rush Sharp club-rush
Deep marsh (-0.35m to -0.5m)	Baumea articulata Eleocharis sphacelata Schoenoplectus validus	Jointed twig-rush River club rush
Submerged marsh (-0.5m to 1m)	Myriophyllum variifolium Potamogeton ochreatis Potamotgeton tricarinatus Triglochin procera	 Blunt pondweed Floating pondweed
Ephemeral Zone	Austrodanthonia racemosa* Casuarina glauca* Cotula coronipifolia Imperata cylindrical Melaleuca linariifolia* Microlaena stipoides* Poa labillardierei	Wallaby grass Swamp oak Water buttons Blady grass Flax leaved paperbark Weeping grass Tussock grass
	Bursaria spinosa* Daviesia ulicifolia* Dianella longifolia Dillwynia sieberi* Echinopogon ovatus* Entolasia marginata* Lomandra filiformis* Lomandra longifolia* Microlaena stipoides* Poa labillardierei Themeda australis*	Sweet bursaria Gorse bitter pea Forest Hedgehog-grass Bordered Panic-grass Wattle matt-rush Spiny-headed matt rush Weeping grass Tussock grass Kangaroo grass

* Species with an asterix are indigenous to the Shale Plains Woodland or Alluvial Woodland classification (of Tozer 2003 and NSW NPWS 2002), common to the Doonside area.
All other species are native to wetland areas of the Cumberland Plain.

Appendix 2 – Detention area locations and catchments and hydrologic performance