REDLAND CITY COUNCIL

Stormwater Quality Infrastructure Plan for Upper Eprapah Ck Catchment

Water Quality Analysis






May 2013

M8000_020

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M8000_020 Stormwater Quality Infrastructure Plan for Upper Eprapah Creek Catchment					
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1. INTRODUCTION

Engeny was commissioned by Redland City Council (RCC) to prepare a Stormwater Quality Infrastructure Plan for the Upper Eprapah Creek catchment (west of Cleveland-Redland Bay Road). The purpose of this study was to determine the stormwater quality infrastructure requirements and associated costs for the catchment area. The study is an update and further development of the stormwater quality assessment previously undertaken in the Upper Eprapah Creek Catchment Study (Engeny, 2012) and includes infrastructure cost estimation and water quality modelling using MUSIC Version 5. This study has also focused on identifying stormwater quality infrastructure requirements for future development areas including Bunker Road and Estuary Avenue in Victoria Point.

The stormwater infrastructure plan will assist Council in applying appropriate planning and acquisition principles for servicing forecasted demands as well as improving the existing water quality within the Upper Eprapah Creek catchment.

The stormwater quality catchments (study area) are shown in Figure 1.1. A summary of the previous Upper Eprapah Creek Catchment Study is provided below.

1.1 Summary of Previous Study

Engeny was previously commissioned by RCC to undertake a regional scale study of water quantity and quality within the Upper Eprapah Creek (UEC) catchment area. A summary of the previous study is provided in this section of the report however reference should be made to the study report titled: *Upper Eprapah Creek Catchment Study (Engeny, 2012)* for specific information on the study including methodology, findings and recommendations.

This study allowed for quantification of flooding behaviour within the catchment, as well as a water quality analysis including the conceptual selection, location and assessment of water quality treatment devices.

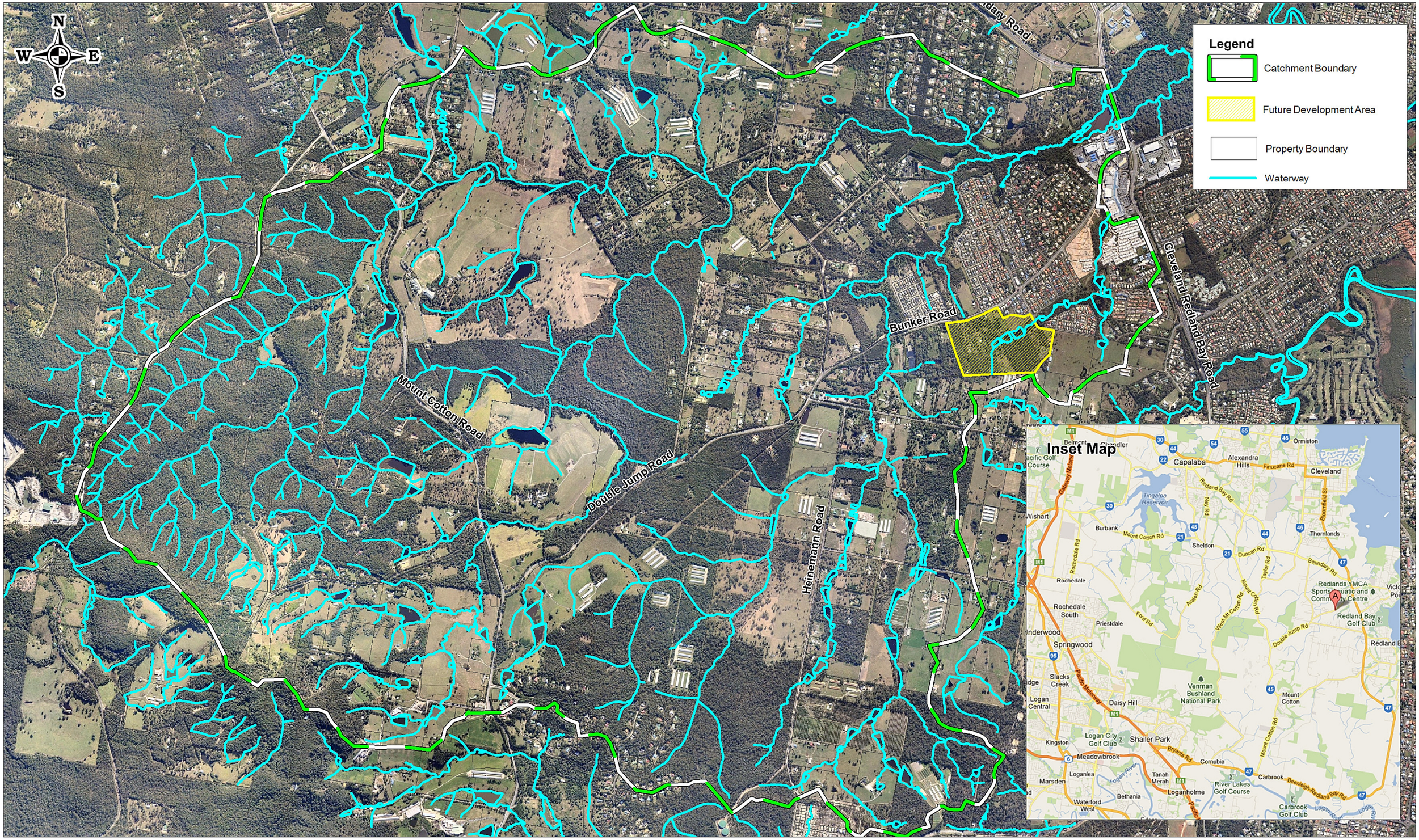
Flood modelling results suggested that cross-drainage culvert structures servicing the major road corridors through the UEC catchment area may be under sized to provide adequate drainage immunity. Roads of particular concern due to traffic conveyance included:

- Mount Cotton Road (State Controlled Road);
- Springacre Road; and
- Bunker Road.

Flood modelling results suggested that for design flood events simulated for the UEC catchment, major flow path inundation was typically limited to rural non-urban properties, open space areas and/or existing defined watercourses. Possible inundation of a number of private properties in a select number of areas located immediately south of the commercial eastern shopping centre was predicted to occur during the all ARI events.

The quantitative analysis of water quality within the UEC catchment identified an opportunity for a limited number of water quality treatment locations. Five locations were deemed conceptually feasible as suitable locations (bioretention and constructed wetlands) however this would only service a limited urbanised and future urbanised area.

As a result, the study determined that the treatment of water quality within the total UEC developed catchment may not achieve the South East Queensland Regional Plan load based reduction targets. However, it was advised that appropriate design and location of proposed water quality treatment measures would assist with the overall improvement of net contaminant releases to Eprapah Creek.



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Stormwater Quality Infrastructure Plan for Upper Eprapah Creek Catchment

Figure 1.1

Study Area

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2. STUDY DATA

2.1 Topographical Data

RCC provided a 1 m Digital Elevation Model (DEM) of the entire study area. This DEM was used for the development of the MUSIC (Version 5.0) water quality model.

2.2 Land Use Information and Aerial Photography

Land use data for the study area has been based on RCC's latest Strategic Land Use Plan in the Planning Scheme, (RPS), which was provided in ESRI shape file format at the start of the study (Zoning Version 4.shp). This provided the ultimate development land zoning information for the study area. The ultimate RCC land use mapping for the catchment is presented in Figure 3.2.

Aerial imagery was also provided by RCC in the form of ECW files (2009) and was used for the study.

2.3 Geographic Information System (GIS) Data

GIS information for the study area was provided by RCC to assist with the completion of the water quality analysis. This data included the following:

- 0.25 m interval ground contours (2009);
- Environmental Data;
  - Koala management areas
  - Non remnant vegetation areas
  - Remnant vegetation areas
  - SEQ biodiversity assessment
  - Tree protection areas
  - Wetlands of significance
- Miscellaneous Data;
  - Catchment planning boundary
  - Cadastre
  - Road centrelines
  - Council land
  - Council catchments
- RPS Overlays;
  - Catchment water bodies
  - Catchment waterways
  - Drainage buffers

- Flood prone storm tide, DPL and overlays
- Habitat protection – State Koala Policy
- Tidal influence
- Water bodies
- Waterways

- Drainage Infrastructure;
  - Headwalls
  - Surface drains
  - Manholes / catchpits
  - Pipes / culverts

3. WATER QUALITY ANALYSIS

In order to develop a stormwater quality infrastructure plan for the Upper Eprapah Creek catchment, a quantitative assessment of stormwater runoff quality has been undertaken for the ultimate land use scenario (Zoning Version 4.shp). This assessment was undertaken to assess opportunities to locate treatment measures, assess the effectiveness of proposed treatment measures and to conceptually determine their required footprint within available existing land and future development areas (i.e. Bunker Road).

As advised by RCC, the load based objectives identified within the South East Queensland Regional Plan and those adopted by the Healthy Waterways Partnership have been used. Load based objectives compare loads produced by an unmitigated developed catchment to the loads generated from the developed catchment where Water Sensitive Urban Design (WSUD) measures have been incorporated into the water quality model. Load based targets stipulated in the South East Queensland Regional Plan 2005-2026 Implementation Guideline No. 7 were adopted for discharge targets from urban areas, in addition to RCC objectives as outlined in Table 3.1.

Table 3.1 RCC Water Quality Objectives

Pollutant Type	Objective	South East Queensland Regional Plan Load Based Reduction Targets
Total Suspended Solid	Reduction in average annual load of pollutants leaving the developed unmitigated scenario compared to the developed mitigated scenario	80 %
Total Phosphorous	Reduction in average annual load of pollutants leaving the developed unmitigated scenario compared to the developed mitigated scenario	60 %
Total Nitrogen	Reduction in average annual load of pollutants leaving the developed unmitigated scenario compared to the developed mitigated scenario	45 %
Gross Pollutants	Reduction in average annual load of pollutants leaving the developed unmitigated scenario compared to the developed mitigated scenario	90 %

3.1 Water Quality Model Development

A quantitative assessment of stormwater runoff quality has been undertaken for the ultimate land use scenario of the catchment. The pollutant export loads from the catchment were assessed using the Cooperative Research Centre for Catchment Hydrology's (CRCCH) Model for Urban Stormwater Improvement Conceptualisation (MUSIC Version 5.0). MUSIC is a decision support tool, used to plan and design appropriate urban stormwater management systems at the conceptual level. MUSIC Version 5.0, released in 2011, was used for this assessment.

3.2 MUSIC Model Parameter Guidelines

As Redland City Council does not have specific guidelines on MUSIC modelling, the Water by Design MUSIC Modelling Guidelines Version 1 was used, in conjunction with the Healthy Waterways "Water Sensitive Urban Design Technical Design Guidelines for South East Queensland". The stormwater quality treatment devices incorporated into the catchment model have been setup based on the design parameters recommended by the Water by Design MUSIC Modelling Guidelines and Healthy Waterways Guidelines (2010).

3.3 Model Establishment

The MUSIC model was established for the unmitigated ultimate catchment development and mitigated ultimate catchment development scenarios and details are as follows:

1. Climate data for the catchment was sourced from the Bureau of Meteorology (BOM). Rainfall data was used from the Redlands BOM station (40265) for 1997-2006 rainfall events with six (6) minute rainfall intervals.
2. Land uses for the ultimate catchment were derived from GIS land use mapping information supplied by RCC. The representation of each land use zoning within MUSIC has been defined in and is illustrated in Figure 3.1.
3. The natural assimilative capacity of any waterway was not able to be represented within the MUSIC model as Version 5 does not have the capability to perform in-stream treatment effectiveness assessment.

Table 3.2 Land Uses adopted in MUSIC

Sub-catchment ID	Area (ha)	MUSIC Land Use	Impervious Fraction (%)
UR1	11.55	Urban Residential	55
UR2	31.19	Urban Residential	45
EUR1	5.92	Urban Residential	40
EUR2	21.07	Urban Residential	40
LDR1	10.82	Urban Residential	30

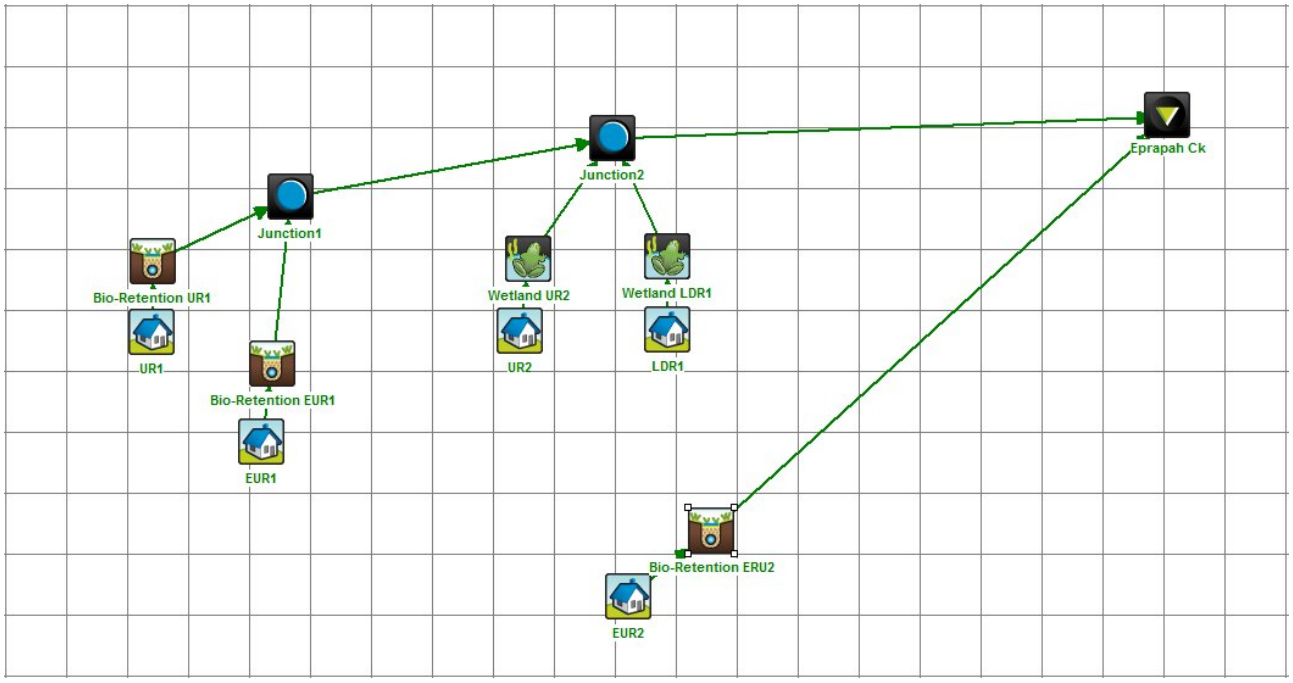


Figure 3.1 MUSIC Model Schematic

3.4 Typical Treatment Train

Best management practices in WSUD techniques were proposed to be implemented where possible within the Upper Eprapah Creek catchment. WSUD can include any number of water quality treatment measures including wetlands, bioretention basins, bio-swales, swales, gross pollutant traps (GPT's) and other forms of treatment measures.

3.4.1 Consideration of Treatment Options and Locations

The selection of treatment devices and locations was undertaken based on experience, landform, available land, surrounding waterways, future development areas and a review of the Upper Eprapah Creek Catchment Study (Engeny, 2012). It is noted that GPT's have not been included in the MUSIC modelling for the catchment as it is envisaged that pre-treatment will occur via the use of trash racks or sediment forebays located immediately upstream of the treatment systems where deemed appropriate. It may be feasible to install such devices in specific areas of high litter generation (i.e. shopping centres) where alternative treatment measures are unsuitable however these areas are often isolated pockets that require specific investigation and are therefore outside the scope of this infrastructure plan.

For the purpose of this study, constructed wetland and bioretention systems are proposed due to treatment effectiveness and suitability within the landform. A summary of each treatment measure is as follows:

Bioretention Basins

Bioretention basins use ponding above a bioretention surface to maximise the volume of runoff through the filtration media. Their operation for treatment is in a similar manner as for a bioretention swale, but typically they convey flows above the design event through overflow pits.

The treatment system operates by firstly filtering surface flows through surface vegetation and then percolating runoff through prescribed filtration media that provides treatment through fine filtration, extended detention and some biological uptake. They also provide flow retardation for smaller events and are particularly efficient in removing nutrients. An example of a street scale system is provided in Plate 3.1.



Plate 3.1 Example of Street Scale Bioretention

Constructed Wetlands

Constructed wetland systems are shallow, extensively vegetated water bodies that use enhanced sedimentation, fine filtration and biological uptake processes to remove

pollutants from stormwater. Water levels rise during rainfall events and outlets are configured to slowly release flows, typically over two to three days, back to dry weather water levels. In addition to treating stormwater, constructed wetlands can also provide habitat, passive recreation, improved landscape amenity and temporary storage of treated water for reuse schemes.

Wetlands generally consist of an inlet zone (sedimentation basin to remove coarse sediments a macrophyte zone (a shallow heavily vegetated area to remove fine particulates and uptake soluble pollutants) and a high flow bypass channel (to protect the macrophyte zone from scour and vegetation damage). A typical layout and cross section for a constructed wetland is included in Plate 3.2.

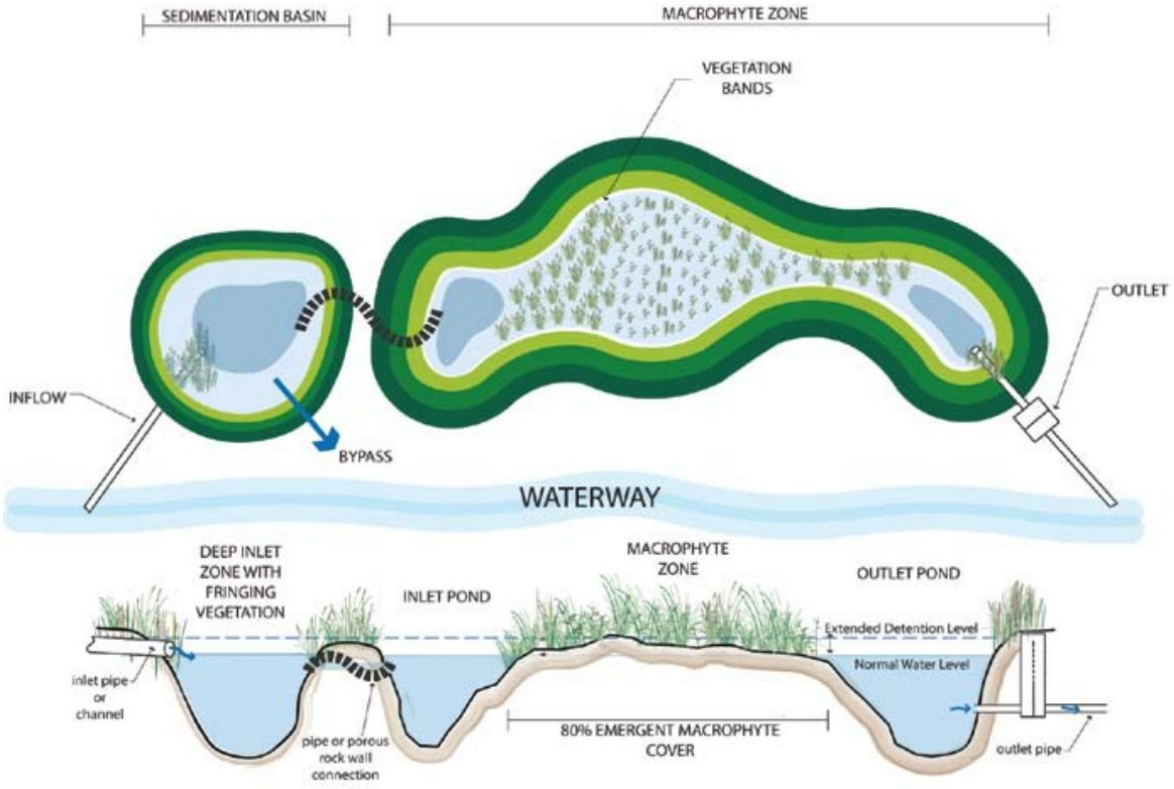


Plate 3.2 Example of a Constructed Wetland

Review of the Upper Eprapah Creek catchment land use revealed that a vast majority of the western and southern study area is zoned rural non-urban and conservation. The focus area for water quality treatment has been the north eastern developed area.

Retro-fitting water treatment devices to currently developed areas are often difficult and unachievable due to the lack of available land and the already constructed drainage system. As such, the ability to meet current water quality targets for already developed areas is limited; however attempts should still be made to improve water quality where treatment devices are able to be incorporated into developed areas. The review of

available locations within the Upper Eprapah Creek catchment has focused on open space public areas that would suit the formalisation of practical water quality treatment measures without being frequently impacted by regional flooding from waterways.

Remnant farm dams are evident throughout the catchment and a majority of these have been retained by RCC and act as pond systems. A number of offline stormwater discharge locations are also evident.

Two currently urbanised areas referred to as UR2 and LDR1 in Figure 3.2, discharge into vegetated offline gullies which form part of Eprapah Creek. An opportunity may exist to retro-fit constructed wetlands into these areas to assist in mitigating urbanised pollutant runoff prior to discharge into the creek.

The sub-catchment referred to as UR1 is currently under development by Ausbuild (Eprapah Estate) and it is unknown what stormwater quality infrastructure is being implemented for the development, however this study has estimated the required bioretention system size for the water quality objectives to be achieved for the development based on the land use adopted for this study.

There are two areas in the eastern, urbanised portion of the catchment that are zoned as future development areas (EUR1 and EUR2). Opportunities may exist within these currently undeveloped areas to incorporate bioretention basins to assist in the mitigation of pollutant loads that will be generated from the development. The final location of the systems will be largely based on the drainage system and development plan however for the purpose of this study, one system has been located on either side of the drainage channel in EUR2 and one system is shown for EUR1. It is noted that the total bioretention basin area which has been modelled as one treatment device in the MUSIC model can be divided to number of bioretention basins based on development plan.

The proposed treatment measures have been conceptually modelled in MUSIC to determine the required infrastructure sizes however further design will be required to determine the configuration and layout of the systems with consideration of the existing drainage system and the development plan for greenfield areas.



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Stormwater Quality Infrastructure Plan for Upper Eprapah Creek Catchment

Figure 3.2

Water Quality Catchment Layout with Ultimate Landuse

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3.5 Proposed Stormwater Quality Infrastructure

Figure 3.3 shows the proposed stormwater quality infrastructure plan and Table 3.3 and Table 3.4 outlines the details of the proposed systems that have been modelled in MUSIC.

Table 3.3 Proposed Bioretention Basin Conceptual Parameters

Parameter	UR1	EUR1	EUR2
Extended Detention Depth (mm)	300	300	300
Surface Area (m^2)	1400	700	2350
Filter Area (m^2)	1200	600	1900
Filter Depth (mm)	400	400	400
TN Content of Filter Media (mg/kg)	800	800	800
Saturated Hydraulic Conductivity (mm/hr)	200	200	200

Table 3.4 Proposed Constructed Wetland Conceptual Parameters

Parameter	UR2	LDR1
Inlet Pond Volume (m^3)	600	360
Extended Detention Depth (mm)	500	500
Surface Area (m^2)	12000	6000
Permanent Pool Volume (m^3)	3600	1800
Equivalent Pipe Diameter (mm)	150	150
Notional Detention Time (hrs)	45	22.5

The proposed parameters listed in the tables above are conceptual only and further detailed investigations would be required to facilitate design and implementation. The parameters are offered to allow RCC to conceptually assess the proposed water quality treatment measures applicability to each individual location and situation.



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Stormwater Quality Infrastructure Plan for Upper Eprapah Creek Catchment

Figure 3.3

Storm Water Quality Infrastructure Plan

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3.6 Stormwater Quality Results

A summary of the MUSIC model results for the ultimate development scenario water quality assessment is summarised in Table 3.5 below.

Table 3.5 MUSIC Modelling Results

Location	Pollutants	Unmitigated	Mitigated	Reduction (%)	Target	Target Achieved
Receiving Node	TSS (kg/yr)	89900.0	15800.0	82.4	80	✓
	TP (kg/yr)	184.0	64.40	65.0	60	✓
	TN (kg/yr)	899.0	475.0	47.1	45	✓
	GP (kg/yr)	12400.0	0.0	100.0	90	✓
UR1	TSS (kg/yr)	15400.0	2060.0	86.6	80	✓
	TP (kg/yr)	31.5	12.3	61.0	60	✓
	TN (kg/yr)	152.0	72.2	52.5	45	✓
	GP (kg/yr)	2050.0	0.00	100.0	90	✓
UR2	TSS (kg/yr)	36800.0	8400.0	77.2	80	X
	TP (kg/yr)	75.1	24.4	67.5	60	✓
	TN (kg/yr)	359.0	216.0	40.0	45	X
	GP (kg/yr)	4960.0	0.0	100.0	90	✓
EUR1	TSS (kg/yr)	6450.0	954.0	85.2	80	✓
	TP (kg/yr)	13.0	5.1	60.8	60	✓
	TN (kg/yr)	64.6	30.7	52.5	45	✓
	GP (kg/yr)	879.0	0.0	100.0	90	✓
EUR2	TSS (kg/yr)	21900.0	2950.0	86.5	80	✓
	TP (kg/yr)	44.7	17.9	60.1	60	✓
	TN (kg/yr)	226.0	105.0	53.3	45	✓
	GP (kg/yr)	3130.0	0.0	100.0	90	✓
LDR1	TSS (kg/yr)	9320.0	1460.0	84.3	80	✓
	TP (kg/yr)	19.5	4.7	75.6	60	✓
	TN (kg/yr)	97.7	51.4	47.4	45	✓
	GP (kg/yr)	1340.0	0.0	100.0	90	✓

Results show that the load-based objectives are achieved for all sub-catchments except sub-catchment UR2 due to the limited availability of land available thus restricting the size of the treatment system. However, appropriate design and location (with consideration of flooding extents) of these measures will assist with the overall improvement of net contaminant releases to Eprapah Creek, and as such should be investigated further.

3.7 Construction Cost Estimation

Construction cost estimation for the bioretention basins and wetlands was obtained from the costing module of the MUSIC model. It should be noted that the connection from the outlet of each catchment to the bioretention basins has not been included in the cost estimation as this should be undertaken at the detailed design stage. It should also be noted that cost estimation is based on upper acquisition cost as calculated in MUSIC Version 5. The total acquisition cost does not include land acquisition, annual maintenance, annual renewal, annual establishment or decommissioning costs.

Stormwater quality infrastructure cost estimation results are provided in Table 3.6 below.

Table 3.6 Water quality infrastructure cost estimation

Treatment Device	Total Acquisition Cost($)
Bioretention UR1	$249,253
Bioretention EUR1	$147,433
Bioretention EUR2	$365,434
Wetland UR2	$1,489,591
Wetland LDR1	$957,776
Total Acquisition Cost($)	$3,209,487

4. CONCLUSIONS/RECOMMENDATIONS

Engeny was commissioned by Redland City Council (RCC) to develop a stormwater quality infrastructure plan for the Upper Eprapah Creek catchment. The majority of the catchment has reached full development potential however this study has focused on identifying potential water quality treatment locations within both existing and future development areas.

This analysis has been based on latest industry practices and water quality analysis using MUSIC Version 5 software. This study includes the review and utilisation of the water quality analysis undertaken for the Upper Eprapah Creek Catchment Study by Engeny in 2012.

The stormwater quality infrastructure plan includes five (5) sub-catchments where proposed water quality treatment measures have been identified and sized. The proposed measures do not result in the prescribed water quality objectives being achieved for the overall study area however except for sub-catchment UR2, the objectives are achieved for the other four sub-catchment areas. Table 4.1 provides a summary of the proposed treatment measures for each sub-catchment.

Table 4.1 Summary of Proposed Water Quality Infrastructure

Sub-catchment ID	Proposed Treatment	Surface Area (m^2)	Cost Estimation
UR1	Bioretention Basin System	1400	$249,253
UR2	Wetland System	12000	$1,489,591
EUR1	Bioretention Basin System	700	$147,433
EUR2	Bioretention Basin System	2350	$365,434
LDR1	Wetland System	6000	$957,776

The results and outputs from this study allow Council to assess the feasibility of the proposed water quality treatment measures (including locations) in order to assist with the overall improvement of net contaminant releases to Eprapah Creek. It is recommended that the locations and types of stormwater quality treatment devices are reviewed when additional planning is undertaken for proposed developments. The stormwater infrastructure construction cost estimates are preliminary estimates and should also be reviewed once additional planning and design has been undertaken.

5. REFERENCES

Healthy Waterways/Water by Design, *MUSIC Modelling Guidelines for South East Queensland*, 2010.

Engeny Water Management, *Upper Eprapah Creek Catchment Study*, 2012.

6. QUALIFICATIONS

a. In preparing this document, including all relevant calculation and modelling, Engeny Management Pty Ltd (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b. Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

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APPENDIX A

MUSIC Model Cost Estimation Screenshots

Bio-Retention EUR1 - Life Cycle Cost Results

Summary | Relative Distribution | Temporal Distribution | Sensitivity to Real Discount Rate

Costing Inputs

Life Cycle (yrs)	50	Renewal/Adaptation Cost	$65,711	Real Discount Rate (%)	5.50
Acquisition Cost	$147,433	Renewal Period (yrs)	15	Annual Inflation Rate (%)	2.00
Annual Maintenance Cost	$13,277	Decommissioning Cost	$67,421	Base Year for Costing	2012
Annual Establishment Cost	$0	Establishment Period (yrs)	0		

Costing Results



Life Cycle Cost of Bio-Retention EUR1 ($2012)	$424,733
Equivalent Annual Payment Cost of the Asset ($2012/annum)	$8,495
Equivalent Annual Payment per m3/s maximum flow reduction	$420,190.2E
Equivalent Annual Payment/ML flow reduction/annum	$6,375.44
Equivalent Annual Payment/kg Total Suspended Solids/annum	$1.61
Equivalent Annual Payment/kg Total Phosphorus/annum	$1,092.37
Equivalent Annual Payment/kg Total Nitrogen/annum	$255.95
Equivalent Annual Payment/kg Gross Pollutant/annum	$9.67

Close

Wetland LDR1 - Life Cycle Cost Results

Summary | Relative Distribution | Temporal Distribution | Sensitivity to Real Discount Rate

Costing Inputs

Life Cycle (yrs)	80	Renewal/Adaptation Cost	$504,984	Real Discount Rate (%)	5.50
Acquisition Cost	$957,776	Renewal Period (yrs)	20	Annual Inflation Rate (%)	2.00
Annual Maintenance Cost	$26,787	Decommissioning Cost	$726,392	Base Year for Costing	2012
Annual Establishment Cost	$0	Establishment Period (yrs)	0		

Costing Results



Life Cycle Cost of Wetland LDR1 ($2012)	$1,701,014
Equivalent Annual Payment Cost of the Asset ($2012/annum)	$21,263
Equivalent Annual Payment per m3/s maximum flow reduction	$9,433.65
Equivalent Annual Payment/ML flow reduction/annum	$2,416.31
Equivalent Annual Payment/kg Total Suspended Solids/annum	$2.57
Equivalent Annual Payment/kg Total Phosphorus/annum	$1,399.60
Equivalent Annual Payment/kg Total Nitrogen/annum	$462.25
Equivalent Annual Payment/kg Gross Pollutant/annum	$15.82

Close

Wetland UR2 - Life Cycle Cost Results

Summary | Relative Distribution | Temporal Distribution | Sensitivity to Real Discount Rate

Costing Inputs

Life Cycle (yrs)	80	Renewal/Adaptation Cost	$785,382	Real Discount Rate (%)	5.50
Acquisition Cost	$1,489,591	Renewal Period (yrs)	20	Annual Inflation Rate (%)	2.00
Annual Maintenance Cost	$49,752	Decommissioning Cost	$1,129,728	Base Year for Costing	2012
Annual Establishment Cost	$0	Establishment Period (yrs)	0		

Costing Results



Life Cycle Cost of Wetland UR2 ($2012)	$2,790,496
Equivalent Annual Payment Cost of the Asset ($2012/annum)	$34,881
Equivalent Annual Payment per m3/s maximum flow reduction	$5,703.87
Equivalent Annual Payment/ML flow reduction/annum	$1,971.24
Equivalent Annual Payment/kg Total Suspended Solids/annum	$1.23
Equivalent Annual Payment/kg Total Phosphorus/annum	$679.88
Equivalent Annual Payment/kg Total Nitrogen/annum	$247.00
Equivalent Annual Payment/kg Gross Pollutant/annum	$7.03

Close

Bio-Retention ERU2 - Life Cycle Cost Results

Summary | Relative Distribution | Temporal Distribution | Sensitivity to Real Discount Rate

Costing Inputs

Life Cycle (yrs)	50	Renewal/Adaptation Cost	$162,873	Real Discount Rate (%)	5.50
Acquisition Cost	$365,434	Renewal Period (yrs)	15	Annual Inflation Rate (%)	2.00
Annual Maintenance Cost	$21,743	Decommissioning Cost	$167,112	Base Year for Costing	2012
Annual Establishment Cost	$0	Establishment Period (yrs)	0		

Costing Results



Life Cycle Cost of Bio-Retention ERU2 ($2012)	$864,480
Equivalent Annual Payment Cost of the Asset ($2012/annum)	$17,290
Equivalent Annual Payment per m3/s maximum flow reduction	$14,338.00
Equivalent Annual Payment/ML flow reduction/annum	$4,078.52
Equivalent Annual Payment/kg Total Suspended Solids/annum	$0.89
Equivalent Annual Payment/kg Total Phosphorus/annum	$621.68
Equivalent Annual Payment/kg Total Nitrogen/annum	$144.43
Equivalent Annual Payment/kg Gross Pollutant/annum	$5.52

Close

Bio-Retention UR1 - Life Cycle Cost Results

Summary | Relative Distribution | Temporal Distribution | Sensitivity to Real Discount Rate

Costing Inputs

Life Cycle (yrs)	50	Renewal/Adaptation Cost	$111,092	Real Discount Rate (%)	5.50
Acquisition Cost	$249,253	Renewal Period (yrs)	15	Annual Inflation Rate (%)	2.00
Annual Maintenance Cost	$17,591	Decommissioning Cost	$113,983	Base Year for Costing	2012
Annual Establishment Cost	$0	Establishment Period (yrs)	0		

Costing Results



Life Cycle Cost of Bio-Retention UR1 ($2012)	$636,183
Equivalent Annual Payment Cost of the Asset ($2012/annum)	$12,724
Equivalent Annual Payment per m3/s maximum flow reduction	$44,547.60
Equivalent Annual Payment/ML flow reduction/annum	$4,743.98
Equivalent Annual Payment/kg Total Suspended Solids/annum	$0.94
Equivalent Annual Payment/kg Total Phosphorus/annum	$666.96
Equivalent Annual Payment/kg Total Nitrogen/annum	$159.01
Equivalent Annual Payment/kg Gross Pollutant/annum	$6.20

Close