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Gateway Enterprise Park, Bathurst

Stormwater, Flooding and Riparian Corridor Assessment

7458

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Infrastructure & Environment
8-14 Telford Street
Newcastle East NSA 2300 Australia
Tel: +61 2 4928 7777
Fax: +61 2 49262111
www.worleyparsons.com
WorleyParsons Services Pty Ltd
ABN 61 001 279 812

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GATEWAY ENTERPRISE PARK BATHURST

STORMWATER FLOODING AND RIPARIAN CORRIDOR ASSESSMENT

PROJECT 7458 - GATEWAY ENTERPRISE PARK BATHURST

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
A	Draft for Client Review	Chris Kuczera & Josh Ford		NA		N/A	
B	Final for submission	Chris Kuczera & Josh Ford	Ben Patterson				
C	Revised Final for submission	Chris Kuczera & Josh Ford	Ben Patterson	BGP. 10.12.08.			

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1. PROJECT BACKGROUND

1.1 Background

WorleyParsons were engaged by *Calare Civil Pty Ltd* to undertake a stormwater, flooding and riparian corridor assessment in support of the Project Application (*PA*) for the proposed Gateway Enterprise Park Development, which is located approximately 4km to the East of Bathurst. The development proposal includes a road and rail freight terminal as well as commercial lots.

1.2 Study Objectives

The following objectives have been adopted for this assessment:

- Assessment of the catchment hydrology to determine peak flows at the development site and determine the likely impact of the development proposal on the local hydrology.
- Assessment of the flood behaviour over the site and establish flood management recommendations.
- Development of a stormwater management strategy which mitigates potential water quality impacts and increased peak flows and runoff volumes on downstream watercourses and receiving waters.
- Assessment of the existing state of the two water courses located within the site.
- Development of a conceptual riparian corridor management strategy with regard to the principles of the *Water Management Act* (*2000*).

1.3 Site Description

The site is located to the south of the Great Western Highway, approximately 4km to the east of the Bathurst Town Centre. The site has northern frontage to the Great Western Highway and southern frontage to the Great Western Railway. Refer to **Figure 1** for the site locality.

The site has a total area of approximately 29.74ha. The south eastern portion of the site contains the former Kelso Gravel Quarry. Currently the site is used for cattle grazing.

Two water courses traverse the site. Both water courses are significantly incised and are densely vegetated with non-indigenous flora, particularly Willows and Blackberries. Raglan Creek is the larger water course, which bisects the site, running from the east to the northern site boundary where it discharges under the Great Western Highway through box culverts. The second water course is a tributary to Raglan Creek and is aligned adjacent to the Great Western Highway, traversing the northern boundary of the site. This tributary joins Raglan Creek approximately 150m upstream from the Great Western Highway culverts. This tributary of Raglan Creek is referred to as the "Minor Watercourse" in this report.

Figure 2 contains a recent survey of the site, which identifies the alignment of both water courses.

1.4 Proposed Development

The proposed development master plan for the Gateway Enterprise Park Development is presented in **Figure 3.** The key components of the development proposal are:

- A road and rail intermodal freight handling facility.
- Commercial and industrial developments.
- Rehabilitation of Raglan Creek and its tributary.

1.5 Previous Studies

In August 2006, a Concept Plan Application was submitted for the development proposal. Subsequently, the Concept Plan was approved by the NSW Minister of Planning subject to conditions, which are defined in Schedule 2 of the Concept Plan Approval (*ref Application no 05-0047*). A *Hydraulics Services Masterplan Report* was prepared by *Whipps-Wood Consulting* as part of the Concept Plan Application (*ref: Whipps-Wood July, 2005*). This report included a qualitative assessment of the flood, stormwater and riparian corridor management requirements for the site.

1.6 Relevant Legislation and Guidelines

Australian Rainfall and Runoff

Australian Rainfall and Runoff (*AR&R*) is a document published in 1987 by the Institution of Engineers, Australia (IEAust). This document has been prepared to provide designers with the best available information on design flood estimation and is widely accepted as a design guideline for all flood and stormwater related design in Australia.

Australian Runoff Quality

Australian Runoff Quality (ARQ) is a document published in 2005 by IEAust which provides design guidelines for all aspect of water sensitive urban design (*WSUD*), including preventative measures, source controls, conveyance controls and end of line controls. Additionally, it provides guidance for water quality modelling as well as stormwater harvesting and re-use.

Floodplain Development Manual

The Floodplain Development Manual is a document published by the New South Wales State Government in 2005. The document details Flood Prone Land Policy which has the primary objective of reducing the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods. At the same time, the policy recognises the benefits from occupation and development of flood prone land.

Water Management Act 2000

Under Part 3 of Chapter 3 of the *Water Management Act 2000* (*WMA*), approval is required to undertake controlled activities within water-front land. The *WMA* defines water-front land as any land within 40m from the top of bank on either side of a stream or watercourse. Under the WMA, any works within water-front land require approval through the *Department of Water and Energy* (*DWE*). Additionally, DWE require that adequate riparian buffers be provided to protect the geomorphologic and environmental characteristics of the stream. Further information on riparian setbacks is provided in **Section 5** of this report.

1.7 Available Data

Both map and survey data was used to define catchments within the study area. The following information was used as part of this investigation:

- 1 to 25,000 topographic map (*provided by Department of Lands under license*).
- A survey of the site provided by *Tablelands & Buttsworth Surveyor's*.
- Aerial photographs provided by Google Earth™.

Additionally, a site inspection was undertaken on the 21st July, 2008.

2. HYDROLOGIC ASSESSMENT

A hydrologic assessment of the catchment was undertaken to examine the existing state and developed state hydrology. This section outlines the methodologies implemented in the development of the hydrologic model and presents model results for the existing and developed state scenarios.

2.1 RAFTS Hydrologic Model

The Runoff Analysis and Flow Training Simulation (*RAFTS*) software package was employed to quantify flood discharges from the proposed development site. *RAFTS* is a deterministic runoff routing model that simulates catchment runoff processes. It is recognised in *'Australian Rainfall and Runoff* (*AR&R 1987*), as one of the available tools for use in flood routing within Australian catchments.

RAFTS was chosen for this investigation because it has the following attributes:

- it can accommodate variations in catchment characteristics.
- it can accommodate stormwater controls such as detention basins.
- it can be used to estimate discharge hydrographs at any location within a catchment.

The parameters adopted in the RAFTS model are shown in **Appendix A**.

2.2 Development of Model

A *RAFTS* hydrologic model was developed for the contributing catchments upstream of the site. The hydrologic results from the *RAFTS* model were used for the following aspects of this study:

- To estimate runoff hydrographs for a range of storm durations and average recurrence intervals (*ARI's*) at locations within the study area. Subsequently, these results were used for hydraulic modelling to assess flood behaviour over the site.
- To assess the impact of the proposed development on the Raglan Creek catchment hydrologic regime at locations both within and external to the study area.
- To develop an appropriate strategy to manage surface water runoff from the site.

2.2.1 Catchment Features

The natural drainage within the site is characterised by Raglan Creek running through the centre of the site from the east to the northern site boundary. Raglan Creek discharges under the Great Western Highway through 4 Reinforced Concrete Box Culverts (*RCBC*) (*Refer to **Photo 1***). The contributing catchment of Raglan Creek is approximately 330ha and consists of a variety of land-uses including, cleared rural land, industrial facilities and medium density residential areas. There are numerous dams within the catchment. However, a site inspection identified that these dams are offline to Raglan Creek.

The Minor Watercourse (*a tributary of Raglan Creek*) runs parallel to the Great Western Highway, traversing the northern boundary of the site. The contributing catchment for this watercourse is approximately 222ha and predominantly consists of cleared agricultural land.

Figure 4 defines the sub-catchment extents adopted for the *RAFTS* model. Details of adopted model parameters and key model results are present in the following sections.

2.2.2 Model Parameters

The following methodologies were adopted in determining rainfall runoff parameters:

- **Impervious Percentages -** were determined using a recent aerial photograph of the contributing catchment area.

- **Catchment Roughness -** values were determined based on existing land-use and vegetation cover (*determined by site visit and the aerial photograph*).

- **Catchment Slopes -** were digitised from a 1 to 25,000 topographic map.

- **Rainfall Runoff Parameters -** There is no known definitive information regarding initial and continuing loss rates in the Bathurst area. Hence, adopted rainfall loss rates were based on the recommended ranges outlined in the *RAFTS User Manual* and documented in *AR&R 1987*.

Table 2-1 presents the hydrologic parameters adopted for the existing and developed state hydrologic models. A detailed list of all sub catchment parameters adopted is attached in **Appendix A.**

Table 2-1 – Adopted RAFTS parameters

Existing Catchments		
	Impervious Surfaces	**Pervious Surfaces**
Initial Loss (mm)	1.5	25
Continuing Loss rate (mm/hr)	0	2.5
Catchment Roughness	0.025	0.04
Proposed Development Catchments		
	Impervious Surfaces	**Pervious Surfaces - Urban Catchment**
Initial Loss (mm)	1.5	15
Continuing Loss rate (mm/hr)	0	2.5
Catchment Roughness	0.015	0.035

Sub-catchment lag times were estimated based on average channel gradient and longitudinal channel distance. All sub-catchment lag times are attached in **Appendix A.**

2.3 Stormwater Management Strategy

The increased hydraulic efficiencies typical of urban catchments can result in "*peak discharges corresponding to a 5 year ARI event in a rural catchment occurring on average twice a year following urban development of a catchment*" (*ARQ, IEAust, 2006*). The increased frequency of moderate flooding disturbs the natural flow cycle which is crucial to maintaining aquatic biodiversity. Furthermore, increasing the flood frequency would result in an increase in the occurrence of stream forming flows (*typically defined as a 2 year ARI event*) resulting in increased erosion rates of downstream waterways. Hence, it is proposed to provide 20 mm of retention storage per unit area of impervious surfaces in the proposed development. This would be integrated into water quality controls, which are to be located offline to creek lines and located outside of the Core Riparian Zone (*CRZ*). The proposed 20mm retention storage would provide the equivalent of 2 year ARI detention and would be designed to empty within 24 hours of the cessation of rainfall.

2.4 Results

The *RAFTS* modelling was undertaken in order to estimate existing and developed state runoff hydrographs at all *RAFTS* nodes in the modelled catchment. The model results were determined at the following locations:

- Raglan creek, immediately upstream of the site.
- Minor Watercourse immediately upstream of the site.
- Discharge from the proposed development area only (*not including discharge form the greater catchment*).
- The discharge through the Great Western Highway culverts (*the combined flow from the site and the upper extents of both Raglan Creek and the Minor Watercourse*).

A full set of model results from all rainfall events assessed at the above locations is tabulated in **Appendix B**. Peak flows from the proposed development area and at the Great Western Highway Culverts are presented in **Table 2-2**.

Table 2-2 – Key Model results

	At Great Western Highway Culverts			**Proposed Development Area Only**		
ARI	Existing State	Developed State (No Controls)	Developed State (Controls)	Existing State	Developed State (No Controls)	Developed State (Controls)
	Peak flow (m^3/s) / *Critical Storm Duration*					
2 year	9.4	9.7	9.7	0.6	4.0	0.6
	540min	*540min*	*540min*	*540min*	*30min*	*540min*
5 year	15.7	16.0	16.1	1.0	5.1	1.1
	540min	*540min*	*540min*	*540min*	*90min*	*540min*
20 year	23.5	23.8	24.0	1.5	7.1	1.6
	540min	*540min*	*540min*	*540min*	*30min*	*540min*
100 year	31.0	31.1	31.4	2.0	8.8	3.5
	540min	*540min*	*540min*	*60min*	*30min*	*60min*

With reference to **Table 2-2** (*proposed development area only results*), modelling indicates that the introduction of impervious surfaces could potentially increase peak flows from the proposed development area from approximately 0.6m^3/s to 4.0m^3/s in more frequently occurring events (*i.e* 2 *year ARI*) and from 2.0m^3/s to 8.0m^3/s for less frequent events (*i.e 100 year ARI*). This significant increase in peak flow is the result of increasing the efficiency of the catchment drainage (*catchment roughness*) and elimination of the rainfall losses which naturally occur on pervious surfaces. As discussed in **Section 2.3**, it is proposed to capture the initial 20mm of runoff from the development area. Modelling indicates that this would significantly reduce the peak flows. During frequently occurring events, such as a 2 year ARI storm, flows would be maintained at existing levels (*0.6m^3/s*). This would contribute to maintaining the naturalised flow regime in Raglan Creek, reducing the potential for erosion of the water course. During less frequent events (*i.e 100 year ARI flood*), where rainfall intensities are greater, the 20mm of storage would not provide sufficient detention to maintain existing peak flows at existing levels. However, modelling indicates that the peak flows would be reduced by over 60% from the unmitigated case.

Predicted peak flows at the Great Western Highway Culverts (*immediately downstream of the proposed development area*), are also presented in **Table 2-2**. These results include runoff from both the development area and the greater contributing catchment. Modelling indicates that the proposed development would result in a marginal increase in peak flows by approximately 1 to 2% for a range of return period storm events. It is noted that the mitigated flows are slightly higher than the non-mitigated flows. This is because the development area is at the downstream end of the catchment and the proposed mitigation measures would hold water, releasing a small portion of it when the peak flow from the upstream catchment reaches the site. If no mitigation measures are adopted, the runoff would discharge into Raglan Creek prior to the upstream peak flow arriving at the site. This situation is unavoidable given the proximity of the development site in the greater Raglan Creek Catchment. Notwithstanding, the benefits of the mitigation measures in managing runoff during frequently occurring events (*which would reduce the erosion potential in the downstream watercourse*) are considered paramount to a 1 to 2% increase in peak flows during a major storm event.

As part of the stormwater management plan, it is proposed to pipe discharges up to and including a 100 year storm event through the Minor Watercourse. Hydrologic modelling of this channel indicated that the 100 year discharge for the developed system would be approximately 12m^3/s. In order to effectively convey this flow, a 1500mm diameter circular concrete pipe would be required, assuming a hydraulic gradient of 3% along the length of the proposed pipe. In addition, adequate inlet and outlet structures would be required to ensure all flows are captured into the piped system and discharged downstream without causing stream bank erosion.

3. FLOOD ASSESSMENT

A flood assessment was undertaken to assess the flood behaviour over the site and identify potential flood related development constraints. The predicted peak flows determined in the hydrologic assessment (*refer to **Section 2***) were applied to the hydraulic model. Hydraulic models were developed for both the existing and developed states, with the latter including two proposed box culvert sections. Additionally, both models included the existing box culverts under the Great Western Highway, at the downstream end of the proposed development site.

3.1 Channel Features

Both Raglan Creek and its tributary are significantly incised and are densely vegetated with non-indigenous flora, particularly Willows and Blackberries (*Refer to **Photos 2, 3, 4 and 5***).

3.2 HEC-RAS Hydraulic Model

The *HEC-RAS* software package was used to develop a hydraulic model of the two channels aligned through the proposed development site. *HEC-RAS* is an integrated software package designed to enable one-dimensional river modelling using steady-flow, based on a single geometric representation of the stream network. It is the successor to the steady flow *HEC-2 Water Surface Profiles* software, which has been used widely to simulate flood behaviour in river and channel systems, particularly where structures constrain free surface flow. In its simplest application (*steady-flow simulations*), it automates the well known and respected *Standard Step Method* for backwater analysis.

The *HEC-RAS* software was developed by the US Army Corp of Engineers. The program enables bridges and culverts to be modelled using the physical dimensions of the structures. This makes it particularly useful for the Gateway Enterprise Park system which requires the modelling of a number of existing and proposed culverts.

3.3 Development of Model

A hydraulic model simulates the movement of a flood through a river and its floodplain. The hydraulic model incorporates channel slope, roughness, and structures such as culverts and embankments.

A hydraulic model is based on the topographic representation of a water course channel and floodplain. As discussed in **Section 1.7,** survey data of the site area was provided by the client. This data was assessed in conjunction with a site inspection to determine the most suitable locations for cross-sections extracted for the hydraulic model.

The HEC-RAS model was developed using 12D CAD based software. 12D was used to generate model cross-sections from the 3D digital terrain model which is informed by the survey data. 12D accurately determines the geometry of each cross-section as well as cross-section chainage. The selected cross-section locations are presented in **Figure 5**.

3.3.1 Channel and Floodplain Parameters

Manning's 'n' values are used to represent friction between water and a channel or floodplain. Generally, higher Manning's 'n' values imply increased friction and higher flood levels. With reference to **Photos 2, 3, 4 and 5**, the existing channel is heavily infested with non-indigenous flora. Accordingly, a Manning's 'n' roughness of 0.1 was adopted for the inner channel areas. A Manning's 'n' roughness of 0.04 was adopted for over-bank regions, which are predominantly vegetated with pasture grasses only. These roughnesses were adopted in both the existing and developed state models.

Contraction and expansion coefficients (*for evaluating creek transition losses*) of 0.1 and 0.3 were adopted for gradual contraction and expansion, respectively. Higher coefficients of 0.3 and 0.5 were adopted for cross-sections immediately upstream and downstream of culverts. Ineffective flow areas were included in the model for ponded water in side channels or inactive flow areas.

3.3.2 Model Boundary Conditions

Upstream and downstream boundary conditions were estimated by applying normal depth conditions to an average channel grade in the lower and upper reaches of each tributary, respectively.

3.3.3 Modelling Structures

As the objective of this flood assessment is to define the post development flood behaviour, it is imperative that the modelling accounts for the influence of structures on the flood hydraulics.

The existing four 2.45m by 2.45m concrete box culverts under the Great Western Highway at the downstream end of the development site were included in the hydraulic model to assess the culvert capacity and its impact on the local flood behaviour. Survey of the culverts indicated that the culvert depths varied significantly between the upstream and downstream end of the culvert. The measured upstream invert level was 676.38m AHD and the downstream invert was 677.78m AHD. The obvert of both culverts was similar suggesting different sized RBC units were used for the upstream and downstream sections of the culverts. One possible explanation for this is that the culvert was extended as part of a road upgrade. It is possible that when the culverts were extended, deeper culverts were used. The upstream culvert has accumulated nearly 1.5m of silt, which is not surprising considering the negative culvert grade levels. Accordingly, the culverts were modelled with a 1.5m blockage which is equivalent to the measured siltation level. An additional blockage factor was also applied to account for the guardrail above the box culverts.

In the developed state model, an additional two box culvert crossings within the subject site were incorporated into the model. This was undertaken to determine the impact of the culverts on the local flood behaviour and provide a preliminary design specification for the box culverts. Refer to **Figure 7** for proposed culvert locations and preliminary specifications.

3.4 Design Flood Estimation

Hydraulic modelling indicates that the peak 100 year ARI flood level within the subject site is generally 1 to 2m below the top of bank. Hence, no out of channel flooding would be expected. This is typical of water courses which are significantly incised. Average cross-sectional velocities ranged between 1 to 2 m/s, depending on the channel grade and cross section geometry.

Modelling indicates that the existing culverts under the Great Western Highway have an estimated 20 year ARI capacity and would likely overtop during a 100 year ARI event.

Longitudinal sections of both the existing state and developed state models are presented in **Figure 6**. Tabulated HEC-RAS output at each cross-section for both existing and developed models is attached in **Appendix C**.

It is recommended that a minimum freeboard of 1m be applied above the predicted flood level. This freeboard is greater than the minimum free board of 500mm specified in the floodplain development manual. The additional freeboard is recommended as the predicted flood levels would be particularly sensitive to blockages, such as log jams, in the channel. Recommended flood planning levels at each cross-section are specified in **Figure 6** and **Appendix C**.

Additionally, it is recommended that overland flow paths be provided above the culverts. This would allow flood water to spill over the culverts in a controlled manner in the unlikely event of a significant culvert blockage or a flood event in excess of a 100 year ARI flood event.

As discussed in **Section 3**, it is proposed to install a piped stormwater system to replace the existing Minor Watercourse (*within the subject site extents*), which is significantly degraded. The justification for installing the piped system is discussed in **Section 5.2**. The piped system would be designed to capture and convey a 100 year ARI flow. Preliminary estimates indicate that a 1500mm stormwater pipe would be required. Additionally, appropriate inlet and outlet headwalls, wingwalls and scour protection would be provided.

Figure 7 presents the proposed preliminary trunk drainage design for the development.

4. STORMWATER MANAGEMENT PLAN

A stormwater management plan (*SWMP*) was established with the objective of reducing the water quality and water quantity impacts of the proposed development on the downstream watercourse and receiving waters. This section details the proposed stormwater management plan.

4.1 Discussion

Water quality control is an important aspect of the SWMP. The preservation of acceptable water quality is essential in order to maintain the environmental, recreational and aesthetic qualities of the on-site creeks and other downstream water bodies. The following extract from Table 13.2 in the *Australian Runoff Quality (ARQ)* summarises the key adverse impacts of urbanisation on waterways:

1) Increased rate and volume of runoff.
2) Increased frequency of high velocity flows.
3) Increased rates of erosion, sedimentation and channelisation.
4) Reduction in the loss of riparian zones.
5) Reduction in the loss of in-stream habitat.
6) Decreased water quality.
7) Containment of sediments.
8) Introduction of barriers to the dispersal of biota and the loss of continuity between up-stream and downstream communities
9) Reduced diversity of indigenous flora and fauna and the introduction of pests and weeds.

The objective of this SWMP is to develop a water quality mitigation strategy for the proposed development. Accordingly, the SWMP would address the nine potential impacts of the development listed above. The development of the SWMP includes:

- Establishment of water quality control strategies.
- Establishment of water quality treatment targets.

- Indicative sizing of water quality and quantity control devices.
- Establishment of riparian corridors and stream rehabilitation where required.

This section discusses the water quality and quantity control strategies, while **Section 5** discusses riparian corridors and creek line rehabilitation strategies.

4.2 Stormwater Management Objectives

The water quality and water quantity management objectives adopted for the SWMP are discussed in the following section.

4.2.1 Water Quality Control Objective

An accurate estimate of the existing water quality of the site is difficult to determine without long and detailed water quality monitoring records. Furthermore, it is possible that parts of the site in its current condition could have higher pollutant export loads than a stabilised developed catchment. As such, a more reasonable approach is to adopt long term water quality treatment targets recommended in current best management guidelines. Currently, the most stringent water quality treatment targets are in the *Draft Managing Urban Stormwater: Environmental Targets* (*DECC & CMA, October 2007*) document, which is currently in the consultation draft stage. The key water quality treatment targets are outlined below:-

- Suspended Solids (TSS) 85% retention of the developed average annual load
- Total Phosphorous (TP) 65% retention of the developed average annual load
- Total Nitrogen (TN) 45% retention of the developed average annual load

A water quality model (*MUSIC*) was used to estimate the likely pollutant loads and determine the water quality controls required to meet the objectives listed above. The following sections describe the modelling methodologies and report the estimated performance and minimum design parameters for the proposed water quality controls.

4.2.2 Water Quantity Control Objective

As discussed in **Section 3**, the increased hydraulic efficiencies typical of urban catchments can result in "*peak discharges corresponding to a 5 year ARI event in a rural catchment occurring on average twice a year following urban development of a catchment*" (ARQ, IEAust, 2006). The increased frequency of moderate flooding disturbs the natural flow cycle which is crucial to maintaining aquatic biodiversity.

Furthermore, increasing the flood frequency would result in an increase in the occurrence of stream forming flows (*typically defined as a 2 year ARI event*) resulting in increased erosion rates of downstream waterways. Hence, as discussed in **Section 3**, it is proposed to provide 20mm of retention storage per unit area of impervious surfaces in the proposed development. This would be integrated into water quality controls, which are to be located offline to the on-site water courses.

4.3 Proposed Water Quality Controls

The following water quality control options are proposed for the stormwater management plan:

- **Gross Pollutant Traps**: It is proposed to provide Proprietary Gross Pollutant Traps (*GPT's*) at the end of piped drainage systems. The GPT's would remove litter and coarse to medium sized sediment. It is proposed to install HumeGuard or equivalent units for all commercial areas. A SPEL STORMCEPTOR or equivalent is recommended for the road and rail intermodal freight handling facility. The SPEL STORMCEPTOR or equivalent is recommended as it has enhanced removal efficiencies for oil and grease contamination, which is typical in heavy industrial areas such as road and rail intermodal freight handling facilities.

  The GPT's would significantly reduce the sediment load entering into the downstream water quality controls. This would result in significantly increased lifespan of the downstream controls, reducing the long term maintenance costs. GPT's should be serviced on a 6 to 12 month frequency, depending on the unit sizing.

- **Bio-Retention Basins**: It is proposed to construct bio-retention basins downstream of the GPT's. Bio-retention basins would consist of vegetated areas with enhanced filtration media, which would typically be 500-600mm deep. Filtered stormwater would be collected in an underlying subsurface drainage system and directed into the main channel. The 20mm required retention storage would be provided above the filter media through temporarily ponding water up to 400 to 700mm deep over the filter media. Refer to **Figure 9** for a cross-section of a typical bio-retention basin.

- **Water Quality Control Pond**: It is proposed to construct a water quality control pond (*WQCP*) as part of the proposed development (*this will treat stormwater which doesn't get treated in bio-retention basins*). This pond would be offline to Raglan Creek and would provide water quality control for runoff from the adjacent proposed commercial areas. The WQCP would provide enhanced removal of sediment, nutrients and other contaminants through biological, chemical and physical processes. The WQCP would also provide the 20mm of retention storage required for water quantity control. GPT's would be installed upstream to remove litter and coarse to medium sized sediments.

Figure 8 indicates the proposed locality and indicative areas for the above water quality control measures. The following sections discuss the sizing of the above water quality controls. GPT's would be sized at the detail design stage when the pipe system configuration is known.

4.4 MUSIC Model

MUSIC is a continual-run conceptual water quality assessment model developed by the Cooperative Research Centre for Catchment Hydrology (*CRCCH*). *MUSIC* can be used to estimate the long-term annual average stormwater volume generated by a catchment as well as the expected pollutant loads. *MUSIC* is able to conceptually simulate the performance of a group of stormwater treatment measures (*treatment train*) to assess whether a proposed water quality strategy is able to meet specified water quality objectives.

To undertake the water quality assessment, a *MUSIC* model was established for the site. The model was used to estimate the pollutant load generated from the development and estimate the indicative size of water quality controls required to meet the water quality targets defined in **Section 4.5**.

4.4.1 Model Parameters

In order to establish a *MUSIC* model, rainfall and evaporation records in the vicinity of the site were sought and are discussed below.

Rainfall

The most comprehensive rainfall data record for Bathurst is from BoM station 063005 (*Bathurst Agricultural Station*), which has recorded rainfall from 1908 to present. Over this period, the average annual rainfall was 631mm.

In order to develop a model that could comprehensively assess the performance of the proposed SWMP, the use of 6 minute pluviograph data was considered necessary. Rainfall records obtained from a regional BoM station were used for MUSIC water quality simulations. A period was selected which represents five consecutive years of approximate average annual rainfall of 631mm.

Evaporation

Monthly areal potential evapotranspiration (*PET*) rates for the site were estimated from PET data provided by the Climate Atlas of Australia (BoM). The monthly average PET adopted for the *MUSIC* model are shown in **Table 4-1.**

Table 4-1.– Monthly Areal Potential Evapotranspiration

Month	Average Areal Potential Evapotranspiration (mm)
January	150
February	110
March	110
April	75
May	45
June	40
July	45
August	65
September	75
October	120
November	135
December	140

Catchment Parameters

MUSIC simulates the generation, mobilisation and removal of the following pollutants:-

- Total Suspended Solids (*TSS*)
- Total Phosphorus (*TP*)
- Total Nitrogen (*TN*)

The pollutant loadings for each catchment are proportional to the land use and the impervious area fraction. The following three general urban surfaces were adopted for the *MUSIC* modelling:-

- Urban Roads
- Urban Roofs
- Other Urban pervious areas

The event mean concentrations (*EMC's*) for each of these land uses were derived from Fletcher et al (2004). Adopted EMC's for each land use are detailed in **Appendix D.**

4.5 Results

An assessment was undertaken in *MUSIC* to determine the preliminary sizes of stormwater management controls required for the treatment systems discussed in **Section 4.2**. All calculations have been undertaken on a unit area basis, where-by the requirements of water quality controls are presented on a per hectare of development area basis. As water quality treatment rates are proportional to the hydraulic loading, the specific sizes of water quality controls for each catchment can be adjusted by applying the treatment size per catchment area ratio.

Water quality controls were based on the land use categories, and the corresponding ratios of road, roof and other pervious areas as defined in **Section 4.4.1**. The following scenarios were identified in the proposed development and assessed using the *MUSIC* model:

- **Bio-retention** controls for commercial areas - 90% impervious
- **Bio-retention** controls for industrial areas – 100% impervious
- **Water Quality Control Pond** control for commercial areas – 90% impervious

Table 4-5 presents the preliminary sizing of stormwater management control devices based on *MUSIC* model results. Detailed *MUSIC* results are attached in **Appendix D**.

Table 4-2 – Preliminary sizing of stormwater management control options per hectare of development area

Catchment Characteristics	Water Quality Control Requirements *(Size per ha)*	Water Quantity Control Requirements *(Size per ha)*	Governing Water Quality Controls *(Size per ha)*
Bio-Retention Basin **Commercial Areas** (90% impervious) (*all sizes for 1 ha catchment*)	▪ GPT – HumeGuard or equivalent ▪ Bio-Retention Basin with: 40m^2 of filter area 32m^3 storage above filter	▪ 180 m^3 of retention storage	▪ GPT– HumeGuard or equivalent ▪ Bio-Retention Basin with: 40m^2 of filter area and 180m^3 storage above filter
Bio-Retention Basin **Industrial Areas** (100% impervious) (*all sizes for 1 ha catchment*)	▪ GPT – HumeGuard or equivalent ▪ Bio-Retention Basin with: 40m^2 of filter area 32m^3 storage above filter	▪ 200 m^3 of retention storage	▪ GPT– HumeGuard or equivalent ▪ Bio-Retention Basin with: 40m^2 of filter area and 200m^3 storage above filter
Water Quality Control Pond **Commercial Areas** (90% impervious) (*all sizes for 1 ha catchment*)	▪ GPT – StormCeptor or equivalent ▪ Water Quality Control Pond with: Permanent pool volume 120m^3	▪ 180 m^3 of retention storage	▪ GPT- StormCeptor or equivalent ▪ Water Quality Control Pond with: Permanent pool volume 120m^3 and 180m^3 of extended detention

5. RIPARIAN CORRIDOR REHABILITATION

This section discusses the existing conditions of the onsite water courses and the proposed rehabilitation strategy.

5.1 Existing Water Courses

Both Raglan Creek and its tributary are significantly degraded water courses. The following observations were made during a recent site visit:

- Both channels are significantly incised with head cuts between 2 to 3 m deep. The channels appear to be in an advanced stage of bed lowering and widening through erosion of the toe of the channel banks. As the channel becomes wider, the velocities would reduce and the channel will eventually stabilise. During a site inspection the channel banks were observed to be near vertical and un-vegetated in places (*refer to **Photo 2***). This indicates that the channel is not currently stabilised and further widening is likely.

- The channels are densely vegetated with non-indigenous flora, particularly Willows and Blackberries. It is noted that the section of Raglan Creek upstream of the site is also densely vegetated with Willows.

- There were numerous cars bodies partially buried in the bed of the channel.

- Cattle regularly access the creek in some areas.

Refer to **Photos 1** to **6** for images of Raglan Creek and the Minor Watercourse.

5.2 Minor Water Course

The Minor Watercourse is a small ephemeral watercourse which was identified as a "blue line" on the 1 to 25,000 topographical map (*refer to **Figure 4***). Applying the Strahler System of stream classification, the Minor Watercourse would be classified as a first order stream. The contributing catchment for this watercourse is approximately 222ha and predominantly consists of cleared agricultural land.

The Minor Watercourse is located immediately adjacent to the Great Western Highway within the subject site. The channel is significantly incised and is considered unstable in its current condition (*refer to **Photo 3***). Rehabilitation measures, such as Willow removal, may exacerbate the channel instability, potentially risking the stability of the Great Western Highway.

The development proposal includes the widening of the Great Western Highway to provide a deceleration and turning lane for access into the proposed development. This would require road works up to the edge of the existing channel. Considering the channel instability, significant stabilisation works, such as construction of a gabion rock retaining wall, would be required.

An engineered open channel was considered, and it was estimated that it would require a 20-30m wide corridor. This would be unsightly and impose a significant constraint on the development proposal. Additionally, the 2 to 3 meter deep channel located between the Great Western Highway and the proposed development area would create a public safety hazard.

Considering the potential risk to critical infrastructure and public safety, as well as the significant constraints and costs imposed on the development proposal, it is proposed to pipe the Minor Watercourse over the majority of the site. The proposed piped drainage system would collect flow arriving upstream of the site and discharge directly into the proposed Raglan Creek Culverts. Refer to **Figure 7** for the proposed alignment and discharge location of the piped drainage system.

5.3 Raglan Creek Rehabilitation Strategy

Raglan Creek is an ephemeral watercourse which was identified as a "blue line" on the 1 to 25,000 topographical map (*refer to **Figure 4***). Applying the Strahler System of stream classification, Raglan Creek would be classified as a second order stream. The contributing catchment for this watercourse is approximately 330ha and consists of a variety of land-uses including, cleared rural land, industrial facilities and medium density residential areas. As discussed in **Section 5.1**, Raglan Creek is currently significantly degraded.

It is proposed to rehabilitate the section of Raglan Creek within the subject site as part of the development proposal. This section discusses the watercourse rehabilitation constraints, strategies and proposed riparian setbacks.

5.3.1 Rehabilitation Constraints

The following rehabilitation constraints or potential problems have been identified:

- Maintaining a Willow free watercourse may be difficult considering that the watercourse immediately upstream of the site is densely vegetated with Willows. To ensure the long term success of the proposed rehabilitation measures, an ongoing Willow management plan will have to be implemented.

- As the channel is significantly incised, the root systems of vegetation plantings on the top of the bank would not extend to the toe of the channel bed. Hence, where the channel banks are too steep to support riparian vegetation, the toe of the bank would be vulnerable to erosion. Accordingly, it is required to establish vegetation on the channel banks, in some cases, the channel bank batter slope would be required to be flattened to facilitate the establishment of vegetation.

- Disturbances to the channel during the rehabilitation works may exacerbate the channel instability, especially if a moderate to major flood event occurs prior to vegetation becoming established. Hence, one of the key objectives of the rehabilitation strategy will be to stage the rehabilitation works to minimise the total area of disturbance within the channel at any one time.

The effect of Willows on streams is highly complex, and depends on a number of factors, such as if the stream is aggrading (*building up*) or degrading, width of the channel and depth of the channel. For example, Willows play an important role in stabilising stream banks. This is particularly evident in large, deep degrading channels where Willows help to reduce channel velocities adjacent to the bank, subsequently reducing risk of scour and erosion.

However, in smaller, degraded streams *(<10m width*), Willows can completely block channels, reducing the conveyance capacity of the channel, in turn increasing risk of localised flooding (*Land and Water Resources Research and Development Corporation, 2000*).

If Willows are to be removed from the channel banks it is imperative that they are replaced with native vegetation. In addition, it would be necessary to leave the root system of the Willow in place in order to reduce the potential for erosion and scour whilst the native vegetation is at a juvenile stage of development.

5.3.2 Proposed Riparian Corridor

It is proposed to rehabilitate an approximate 40-50m wide riparian corridor along Raglan Creek through the subject site.

The proposed riparian corridor width has been defined using the following methodology:

- The existing channel base width is to be maintained;

- The top of bank of the channel is to be defined using the following methodology:

  - The existing top of bank will be maintained where the existing channel bank slope is less then 1V in 2H; or

  - Where the existing channel slope is stepper than 1V in 2H then the top of bank will be calculated based on a 1V in 2H batter projected from the base of the channel. Where the channel bank slope exceeds a 1V in 1H batter slope, the batter slope will be flattened to 1V in 2H to facilitate the establishment of riparian vegetation. Batter slopes greater than 1V in 2H but less than 1V in 1H will be maintained and revegetated to minimise disturbance.

- An additional 10m vegetated buffer is to be provided from the top of bank. This buffer strip would be revegetated with native vegetation and will not incorporate any infrastructure.

The proposed top of bank and vegetated buffer extents are presented in **Figure 7**. **Figure 9** presents an indicative channel cross section, demonstrating the methodology described above.

5.3.3 Proposed Creek Rehabilitation Works

As discussed in **Section 5.1**, Raglan Creek is currently a highly degraded watercourse. Accordingly, it is proposed to rehabilitate the majority of the watercourse as part of the development. The following creek rehabilitation works are proposed:

- Removal of all exotic flora from within the channel and designated riparian corridor. It is recommended that either a “chop and poison” or “kill and cut” willow removal method is adopted. Both of these removal techniques kill the willow but leave the extensive root system in the ground. The dead willow roots will remain intact for many years, providing crucial stability while the native vegetation establishes. Annual follow-up inspections will be required to ensure that all willows are effectively eradicated.

- Establishment of a riparian corridor with an approximate 40 to 50m width (*refer to **Section 5.3.2** for details on corridor width determination*). The corridor would be re-vegetated with indigenous plantings in the channel, channel banks and in the riparian buffer zones. As discussed above, root systems of vegetation established on the top of bank will not provide bank stability as the significantly incised channel is up to 3m deep in places. Hence, it is crucial that vegetation is established on the channel banks to provide long term stability. This will require the flattening of channel banks which are too steep for planting. A landscape design and vegetation management plan outlining the criteria for the establishment and management of the riparian corridor would be provided at the detailed design stage. The vegetation management plan would be in accordance with DWE Guidelines (*Guidelines for controlled activities: Vegetation Management Plans*).

- Provision of rock riffles at select locations along the Raglan Creek Channel. The rock riffles would be similar to the existing riffles located immediately upstream of the site (*refer to **Photo 6***). The objective of the rock riffles is to reduce the flood velocities and facilitate a control energy loss over the rock riffle, which would be armoured with appropriately sized cobbles and boulders. This would reduce the potential for further erosion of the channel bed and banks. The rock riffles would be designed to withstand the typical in-stream channel velocities, and would be located at existing channel inflection points. The rock riffles would use natural locally sourced rock, and would be designed to minimise any potential limitation to habitat movement along the creek line. Typical locations of proposed rock riffles are presented in **Figure 7**. The rock riffles would be designed at the detailed design stage.

- Public access would be restricted to the riparian zone to prevent vegetation from being disturbed by trampling.
- Removal of numerous car bodies and other non natural objects.
- Removal of cattle from the watercourse.
- The two proposed culverts would be designed in accordance with DWE Guidelines (*Guidelines for controlled activities: Water Crossings*). Details of the culverts and scour protection would be provided at the detailed design stage.
- Any piped discharge from the proposed stormwater system would be designed in accordance with DWE Guidelines (*Guidelines for controlled activities: Outlet Structures*) Details of outlet structures and associated scour protection would be provided at the detailed design stage.

Figure 7 details the proposed creek rehabilitation works. A detailed design of the proposed rehabilitation works described above would be undertaken as part of the detailed design stage of the proposed development.

The proposed rehabilitation measures are likely to minimise further stream bank erosion and significantly enhance the environmental and aesthetic qualities of Raglan Creek within the subject site.

5.4 Harvestable Rights Assessment

Currently two small farm dams exist on-site, both of which will be decommissioned as part of the development proposal. Hence, an assessment of the existing harvestable rights is not required. With reference to the DWE website (*Farm dams in NSW*), the following dams are exempt from harvestable rights calculations:

- Dams for flood detention and mitigation. This applies to all proposed detention basins.
- Dams for the capture, containment and recirculation of drainage and/or effluent. This applies to all proposed water quality controls.

It is noted that no extraction is proposed from water quality controls for irrigation or other uses.

As all existing farm dams within the proposed development area are to be decommissioned, and all proposed stormwater management controls are exempt from the harvestable rights, a harvestable rights assessment is not required for the proposed development.

As the development proposal would not include any online permanent water bodies, the removal of all existing online farm dams would result in no online permanent water bodies within the development area. When combined with the proposed rehabilitation of riparian vegetation, it is likely that the development proposal would enhance the existing environmental functions of the creek line corridors.

5.5 Erosion and Sediment Control Plan

During construction, sediment and erosion control structures would be designed and installed in accordance with the NSW Department of Housing "*Managing Urban Stormwater – Soils and Construction*" (*Blue Book*). Staging of the development will minimise impacts during construction. These controls will reduce any adverse impacts on receiving water quality during the construction stage. A detailed soil and water management plan will be required for each construction stage and will be issued as part of the detailed design.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Hydrologic Assessment

A hydrologic assessment was undertaken to determine the existing and developed state hydrological conditions and quantitatively assess the impact of the proposed development on the local and regional hydrology. The assessment considered the catchments holistically, and adopted the culverts under the Great Western Highway as a point of reference for comparison of pre and post development hydrological results. Refer to **Figure 4** for adopted catchment extents.

The key results from the hydrologic assessment were:

- Modelling indicates that the introduction of impervious surfaces could potentially increase peak flows from the proposed development area by an estimated 3.2m^3/s frequently occurring storm events (*i.e. 2 year ARI*) and approximately 6.0m^3/s for less frequent events (*i.e 100 year ARI*).

- 20mm of retention storage per unit area of impervious surfaces is required to mitigate the increase in peak runoff flow rates and volume during the high return period events, such as a 2 year ARI storm. This would contribute to maintaining the naturalised flow regime in Raglan Creek, reducing the potential for erosion of the water course.

- Comparison of peak flows at the Great Western Highway Culverts (*immediately downstream of the proposed development area*) indicates that the proposed development would result in a marginal increase in peak flows by approximately 1 to 2% for a range of return period storm events. This marginal increase in peak flows occurs because the proposed mitigation measures would hold water, releasing a small portion of it when the peak flow from the upstream catchment reaches the site. This situation is unavoidable given the proximity of the development site in the greater Raglan Creek Catchment. Notwithstanding, the benefits of the mitigation measures in managing low return period flows (*which would reduce the erosion potential in the downstream watercourse*) are considered paramount to a 1 to 2% increase in peak flows during a major storm event.

6.2 Flood Assessment

A flood assessment was undertaken to determine the 100 year ARI flood extent and flood planning levels within Raglan Creek. Hydraulic modelling indicates that the peak 100 year ARI flood level is generally 1 to 2m below the top of bank. Hence, no out of channel flooding would be expected. This is typical of water courses which are significantly incised. Average cross-sectional velocities ranged between 1 to 2m/s, depending on the channel grade and cross section geometry. Long sections of both the existing state and developed state models are presented in **Figure 6**.

Modelling indicates that the existing culverts under the Great Western Highway have an estimated 20 year ARI capacity and would likely overtop during a 100 year ARI event.

It is recommended that a minimum freeboard of 1m be applied above the predicted flood level. This freeboard is greater than the minimum freeboard of 500mm specified in the NSW Floodplain Development Manual. Recommended flood planning levels at each cross section are specified in **Figure 6**.

Additionally, it is recommended that overland flow paths be provided above the culverts. This would allow flood water to spill over the culverts in a controlled manner in the unlikely event of a significant culvert blockage or a flood in excess of a 1 in 100 year ARI flood event.

6.3 Stormwater Management

A stormwater management plan (*SWMP*) of the site was established with the objective of reducing the water quality and water quantity impacts of the proposed development on the downstream watercourse and receiving waters. The SWMP was developed in accordance with *Australian Runoff Quality* and current best management practice.

The SWMP would include the following stormwater controls:

- **Gross Pollutant Traps**: It is proposed to provide Proprietary Gross Pollutant Traps (*GPT's*) at the end of piped drainage systems. The GPT's would remove litter and coarse to medium sized sediment. The GPT's would significantly reduce the sediment load entering into the downstream water quality controls. This would result in significantly increased lifespan of the downstream controls, reducing the long term maintenance costs.

- **Bio-Retention Basins**: It is proposed to construct bio-retention basins downstream of the GPT's. Bio-retention basins would consist of vegetated areas with enhanced filtration media which would typically be 500-600mm deep. Filtered stormwater would be collected in an underlying subsurface drainage system and directed into the main channel. The 20mm required retention storage would be provided above the filter media through temporarily ponding water up to 400 to 700mm deep over the filter media.

- **Water Quality Control Pond**: It is proposed to construct a water quality control pond (*WQCP*) as part of the proposed development (*this will treat stormwater which doesn't get treated in bio-retention basins*). This pond would be offline to Raglan Creek and would provide water quality control for runoff from the adjacent proposed commercial areas. The WQCP would provide enhanced removal of sediment, nutrients and other contaminants through biological, chemical and physical processes. The WQCP would also provide the 20mm of retention storage required for water quantity control.

Refer to **Figure 8** for the proposed stormwater management plan.

6.4 Riparian Corridor Assessment

An assessment of Raglan Creek and its tributary was undertaken. The key findings were:

- Both channels are significantly incised with head cuts between 2 to 3m deep. During a site inspection the channel banks were observed to be near vertical and un-vegetated in places. This indicates that the channel is not currently stabilised and further bed lowering and widening is likely.
- The channels are densely vegetated with non-indigenous flora, particularly Willows and Blackberries.

Based on the assessment of existing conditions and considering the development proposal, it is proposed to pipe the Minor Watercourse (*tributary to Raglan Creek*) along the western boundary of the site. Maintaining an open channel watercourse would potentially risk the structural integrity of the Great Western Highway and impose possible public safety risks as well as significant constraining the development proposal.

A creek rehabilitation strategy was developed for Raglan Creek. The key features of this strategy are:

- Removal of all exotic flora from within the channel and designated riparian corridor in a staged manner, including the retention of poisoned willow root systems.
- Establishment of a riparian corridor with an approximate 40 to 50m width. The corridor would be fully re-vegetated with indigenous plantings in the channel, channel banks and in the riparian buffer zones.
- Provision of rock riffles at select locations along the Raglan Creek Channel. The objective of the rock riffles is to reduce the flood velocities and facilitate a controlled energy loss over the rock riffle, which would be armoured with appropriately sized cobbles and boulders. This would reduce the potential for further erosion of the channel bed and banks.
- Public and livestock access would be restricted to the riparian zone to prevent vegetation from being disturbed by trampling.

- The two proposed culverts would be designed in accordance with DWE Guidelines (*Guidelines for controlled activities: Water Crossings*). Details of the culverts and scour protection would be provided at the detailed design stage.

- Any piped discharge from the proposed stormwater system would be designed in accordance with DWE Guidelines (*Guidelines for controlled activities: Outlet Structures*) Details of outlet structures and associated scour protection would be provided at the detailed design stage.

The proposed rehabilitation measures are likely to minimise further stream bank erosion and significantly enhance the environmental and aesthetic qualities of Raglan Creek within the subject site.

Figure 7 details the proposed creek rehabilitation works.

6.5 Comparison to Previous Concept Plan

In August 2006, a Concept Plan Application was submitted for the development proposal. Subsequently, the Concept Plan was approved by the NSW Minister of Planning subject to conditions, which are defined in Schedule 2 of the Concept Plan Approval (*ref Application no 05-0047*). A *Hydraulics Services Masterplan Report* was prepared by *Whipps-Wood Consulting* as part of the Concept Plan Application (*ref: Whipps-Wood July, 2005*). This report included a qualitative assessment of the flood, stormwater and riparian corridor management requirements for the site. *Gateway Land Corporation* now wishes to seek approval for a section 75(w) modification to the Concept Plan Approval. The key modifications relevant to the stormwater, flooding and riparian corridor aspects of the development proposal are summarised in **Table 6-1**.

Table 6-1 – Comparison of modified development proposal to previous concept plan.

	Previous Concept Plan	Modified Development Proposal	Implications
Stormwater Management	Stormwater management comprised of 3 water quality control ponds with overlying detention storage. No quantitative water quality or hydrologic assessment was undertaken.	Proposed stormwater management measures consist of 10 evenly distributed bioretention areas and a single water quality control pond. Refer to **Figure 8** for the proposed stormwater management plan. Gross Pollutant Traps are provided upstream of the bioretention areas and the water quality control pond to provide pre-treatment.	The modified development proposal incorporates a Water Sensitive Urban Design approach which provides both water quality and quantity treatment consistent with current best practice guidelines.
Flood Management	No detailed flood assessment was undertaken as part of the original concept plan. However, advice obtained from Council confirmed that the site does not have a history of flooding.	A detailed flood assessment was undertaken which determined the flood behaviour within the subject site, confirming that a 100 year ARI flood would be contained within the existing channel as long as the proposed culverts were adequately sized. Preliminary culvert sizes are detailed in **Figure 7**.	The detailed flood assessment confirmed that flooding is contained within the channel and would not impose a constraint on development.
Raglan Creek Rehabilitation	The upper section of Raglan Creek would be rehabilitated, with provision of a 10m wide vegetated buffer either side of the existing water course. The lower section of Raglan Creek and its tributary were to be culverted.	A similar rehabilitation concept was adopted. However, the overall culvert lengths were reduced, and the adopted top of bank was widened (*refer to **Section 5.3.2***). This would result in a substantial increase in the area of rehabilitated riparian vegetated. Rock riffles and scour protection would be provided in the upper portion of Raglan Creek.	The increase in adopted top of bank width as well as reduced culverted lengths would result in a substantial increase in riparian vegetation in the modified development proposal. The addition of rock riffles and scour protection would reduce the potential for further erosion of the channel bed and banks.

6.6 Further Assessment

At the detailed design stage, documentation of the following assessments would be required:

- Detailed design of the proposed stormwater system and water quality controls.
- Detailed design of the proposed culvert crossings and associated scour protection.
- Detailed design of the proposed creek line rehabilitation works. This would include the establishment of both landscape and vegetation management plans.

7. REFERENCES

1) Institution of Engineers (*1987*), *'Australian Rainfall and Runoff – A Guide to Flood Estimation'*; edited by DH Pilgrim.

2) New South Wales Government (*2005*), *'Floodplain Development Manual: the management of flood liable land'* ISBN 07313 0370 9

3) Willing & Partners Pty Ltd (*1996*), *'RAFTS-XP User Manual'*.

4) Bureau of Meteorology Website (*www.Bom.gov.au*)

5) Duncan, H. P. (February, 1999) '*Urban Stormwater Quality: A Statistical Overview*'.

6) Institution of Engineers, Australia (2006) '*Australian Runoff Quality*'

7) NSW Department of Water and Energy, (2000), 'Water Management Act 2000

8) AUSTROADS, (1994), 'Waterway Design, A Guide to the Hydraulic Design of Bridges, Culverts and Floodways'

9) Whipps-Wood Consulting, (July 2005), Issue B 'Hydraulic Services Masterplan Report-Central West Regional Road/ Rail Terminal, Great Western highway, Bathurst'

10) Land and Water Resources Research and Development Corporation, (2000), 'A Rehabilitation Manual for Australian Streams-Volume 1'

11) Crawford Architects (*2008*), 'Architectural Drawings for the proposed Development'

FIGURE 1

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LOCALITY PLAN

N:\Drafting Jobs\7458.00 Gateway Enterprise Park Bathurst SW & Flooding Assessment\CAD\FINAL STORMWATER FIGURES\FIG 1_LOCALITY.dwg
04/12/2008

FIGURE 2

0 160m

1: 4000

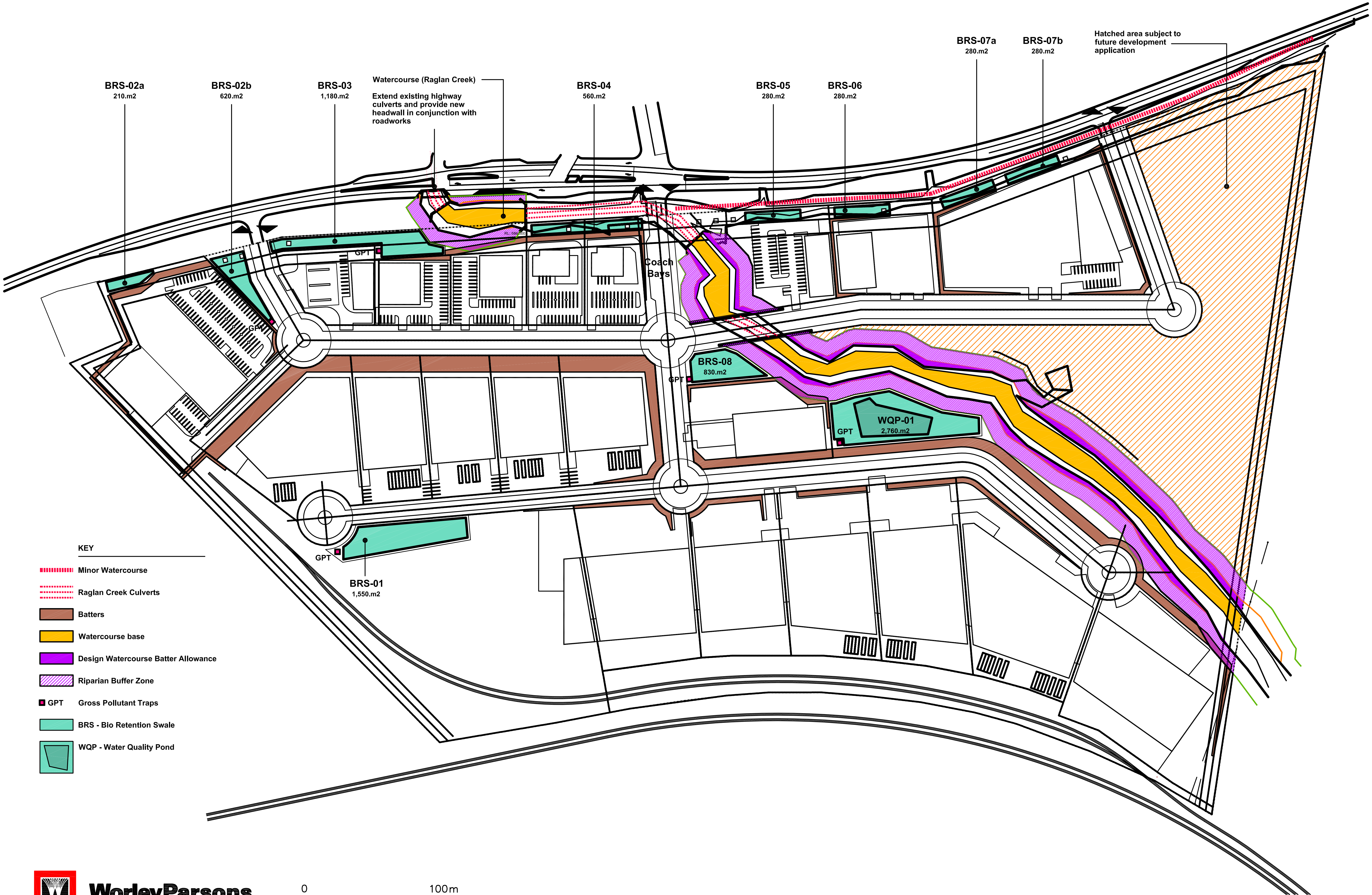
SOURCE: TABLELANDS & BUTTSWORTH SURVEYORS

WorleyParsons resources & energy

SITE SURVEY

N:\Drafting Jobs\7458.00 Gateway Enterprise Park Bathurst SW & Flooding Assessment\CAD\FINAL STORMWATER FIGURES\FIG 2_SURVEY.dwg 04/12/2008

FIGURE 3



WorleyParsons
resources & energy

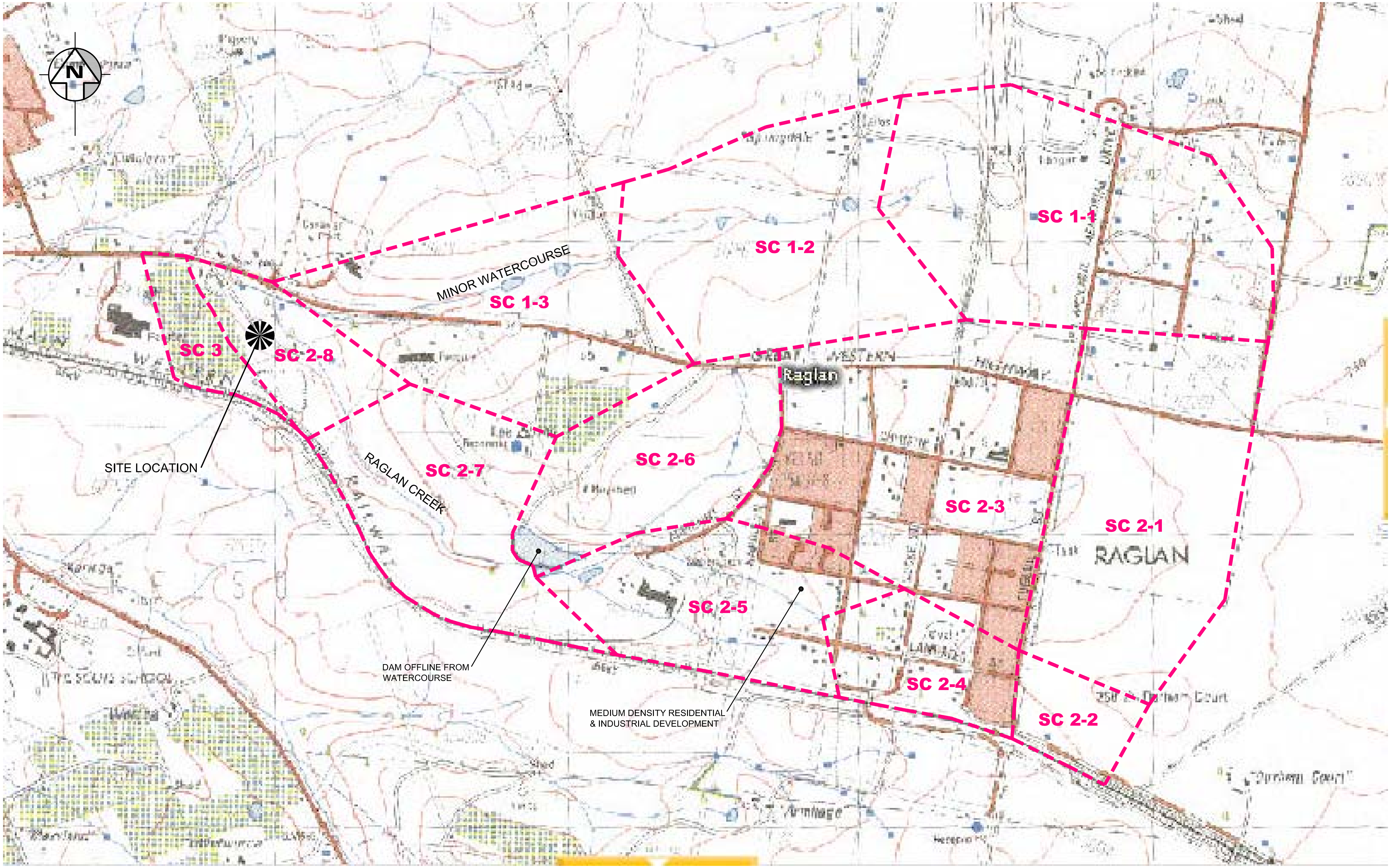
0 100m
1: 2500

SOURCE: CRAWFORD ARCHITECTS

PROPOSED DEVELOPMENT

N:\Drafting Jobs\7458.00 Gateway Enterprise Park Bathurst SW & Flooding Assessment\CAD\FINAL STORMWATER FIGURES\FIG 3_PROPOSED DEVELOPMENT.dwg 04/12/2008

FIGURE 4



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0 480m
1:12000

LEGEND

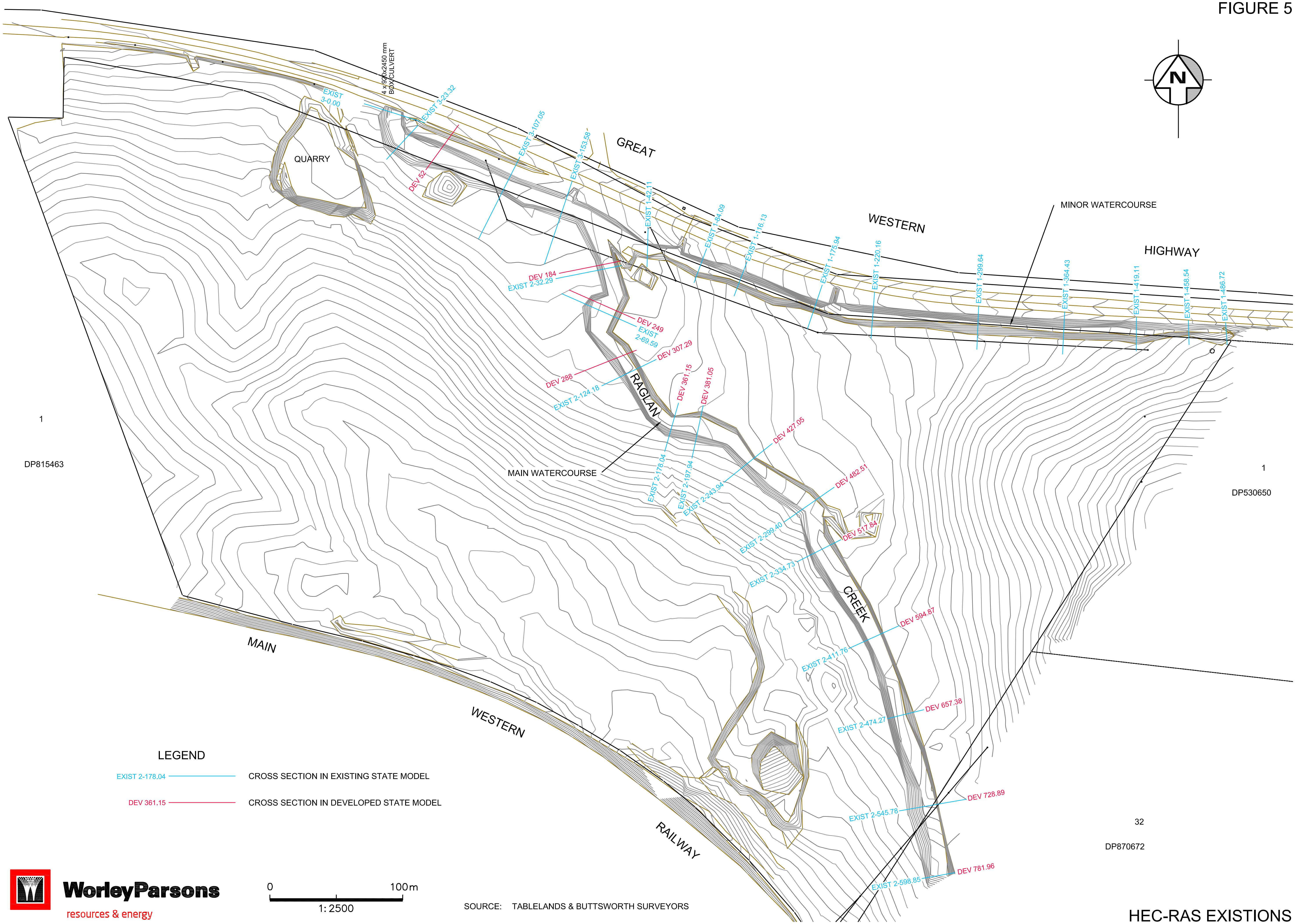
CATCHMENT BOUNDARY

SC 2-5 CATCHMENT NUMBER

CATCHMENT EXTENTS

N:\Drafting Jobs\7458.00 Gateway Enterprise Park Bathurst SW & Flooding Assessment\CAD\FINAL STORMWATER FIGURES\FIG 4_CATCHMENTS.dwg 04/12/2008

FIGURE 5



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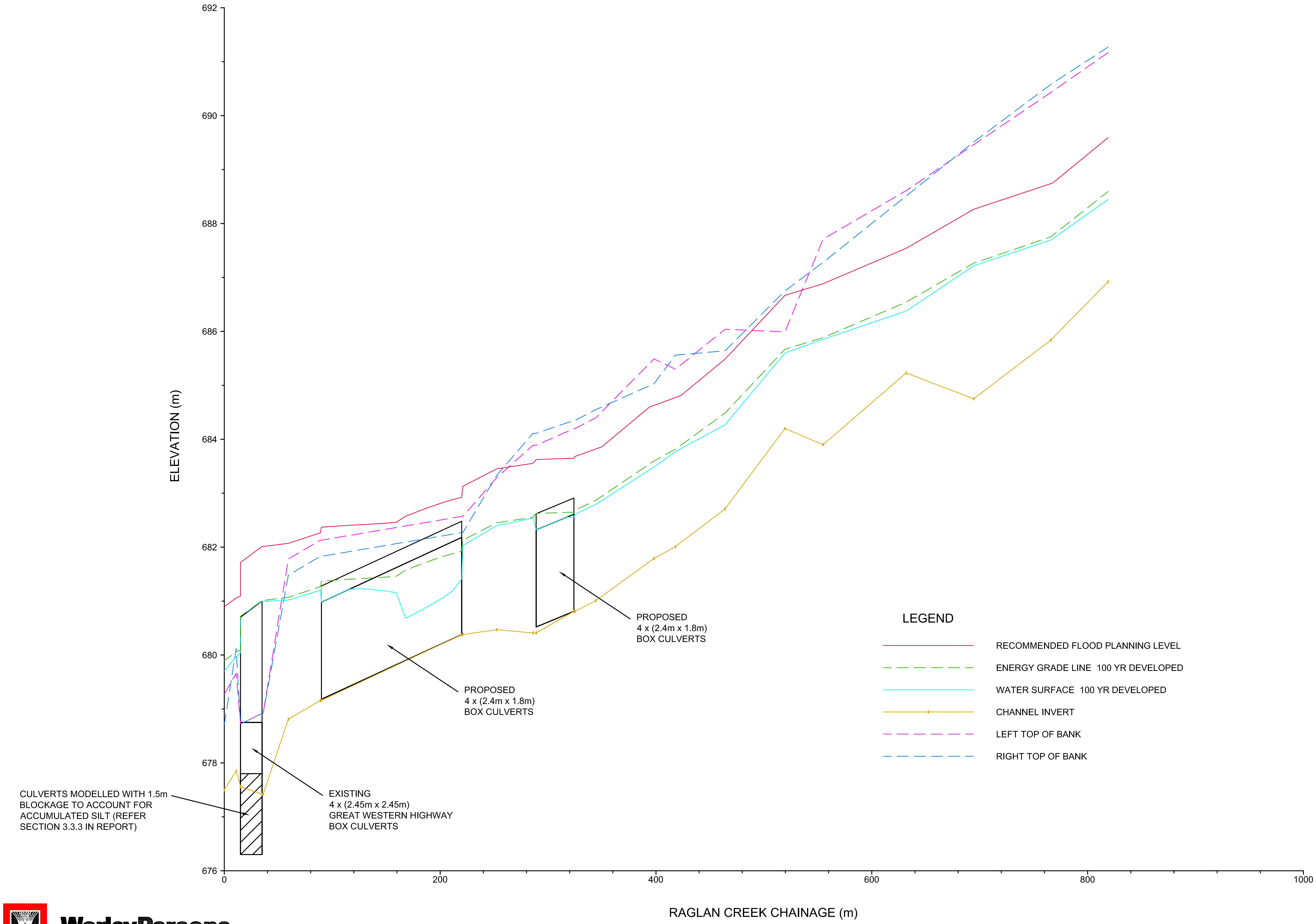
SOURCE: TABLELANDS & BUTTSWORTH SURVEYORS

HEC-RAS EXISTIONS

N:\Drafting Jobs\7458.00 Gateway Enterprise Park Bathurst SW & Flooding Assessment\CAD\FINAL STORMWATER FIGURES\FIG 5_HEC RAS SECTIONS.dwg 04/12/2008

FIGURE 6



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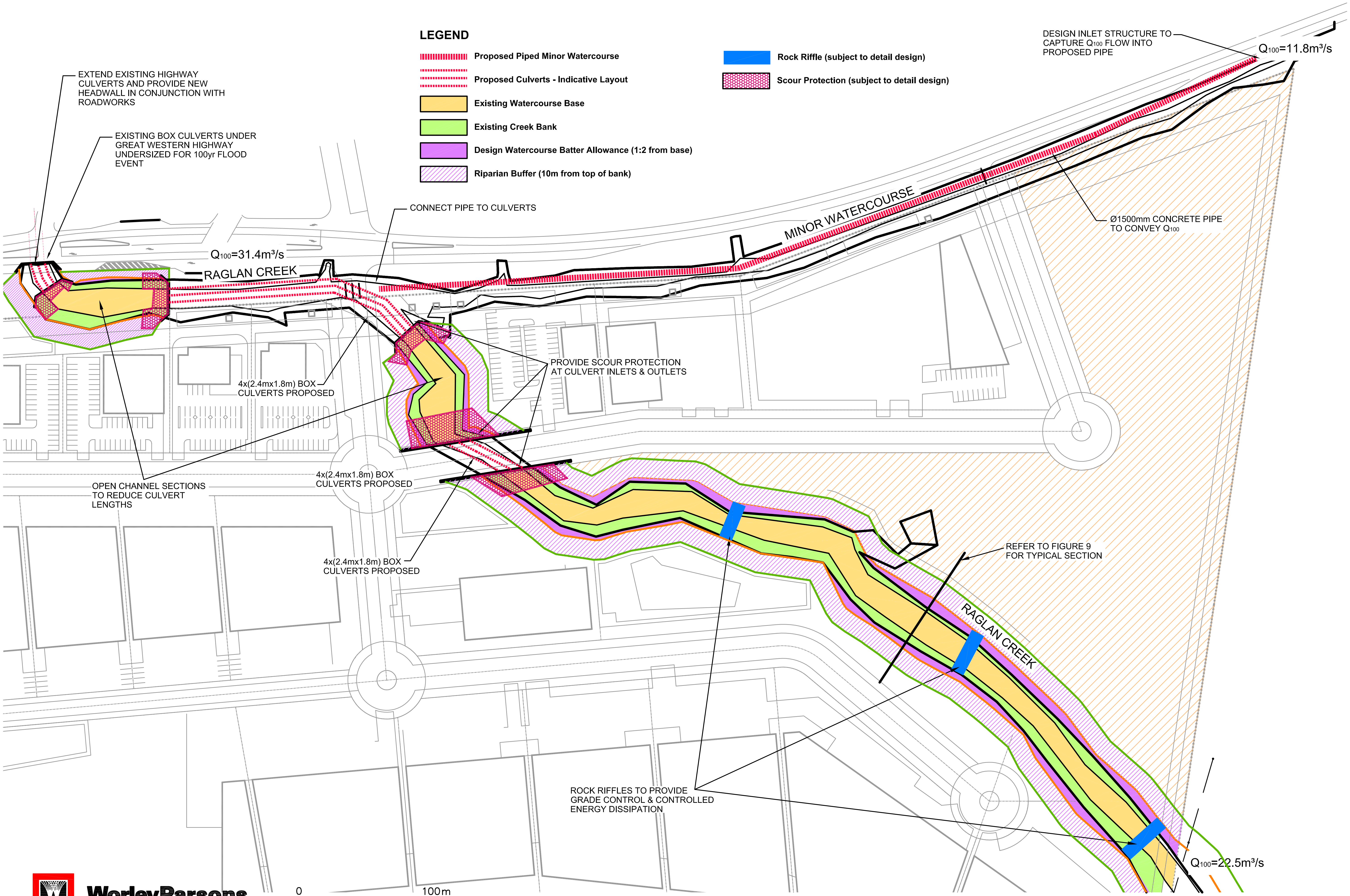
DEVELOPED FLOOD PROFILE

N:\Drafting Jobs\7458.00 Gateway Enterprise Park Bathurst SW & Flooding Assessment\CAD\FINAL STORMWATER FIGURES\FIG 6_DEVELOPED FLOOD PROFILE.dwg 04/12/2008



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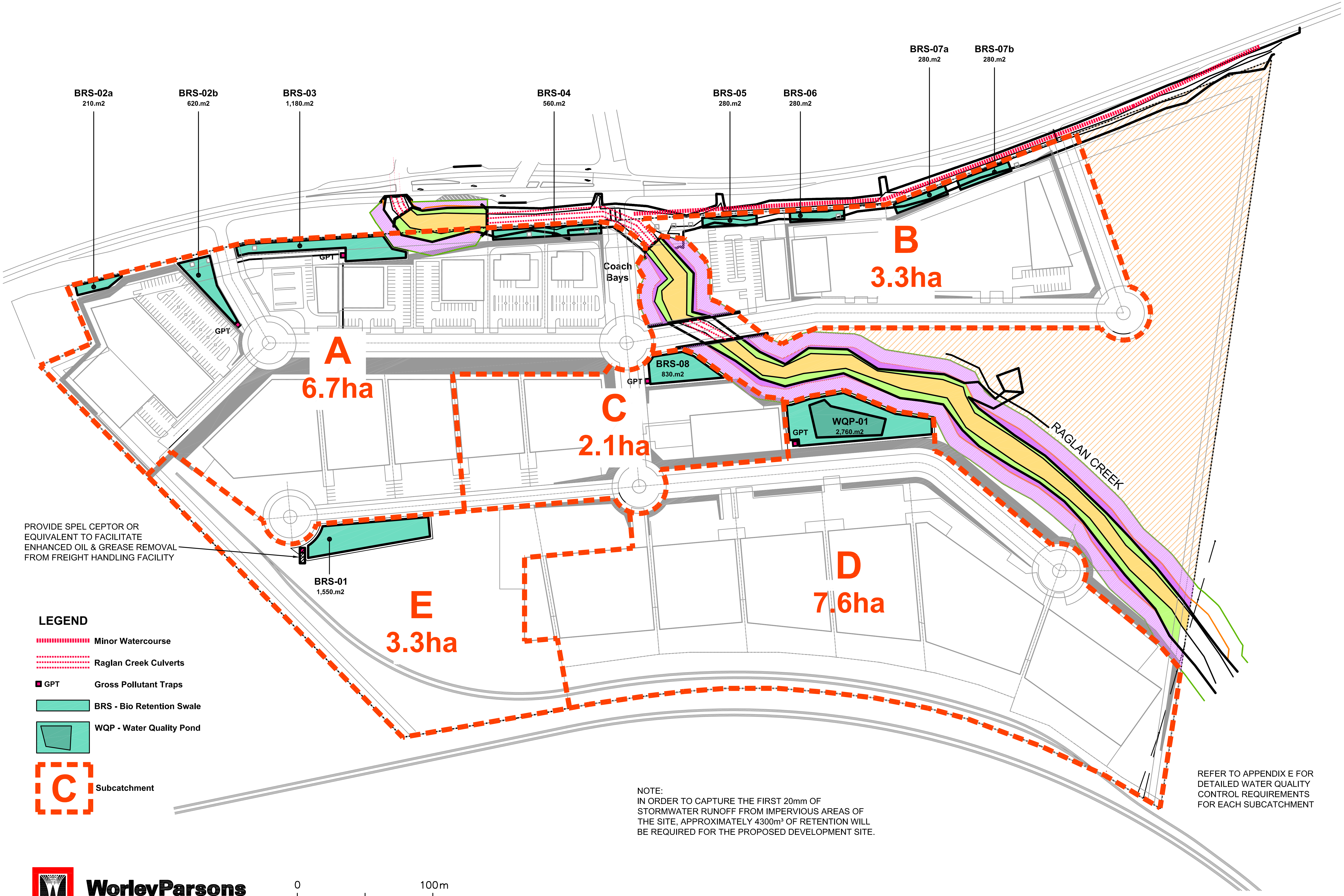
SOURCE: CRAWFORD ARCHITECTS

PRELIMINARY TRUNK DRAINAGE DESIGN & CHANNEL REHABILITATION WORKS



NOTE:
IN ORDER TO CAPTURE THE FIRST 20mm OF STORMWATER RUNOFF FROM IMPERVIOUS AREAS OF THE SITE, APPROXIMATELY 4300m³ OF RETENTION WILL BE REQUIRED FOR THE PROPOSED DEVELOPMENT SITE.

REFER TO APPENDIX E FOR DETAILED WATER QUALITY CONTROL REQUIREMENTS FOR EACH SUBCATCHMENT

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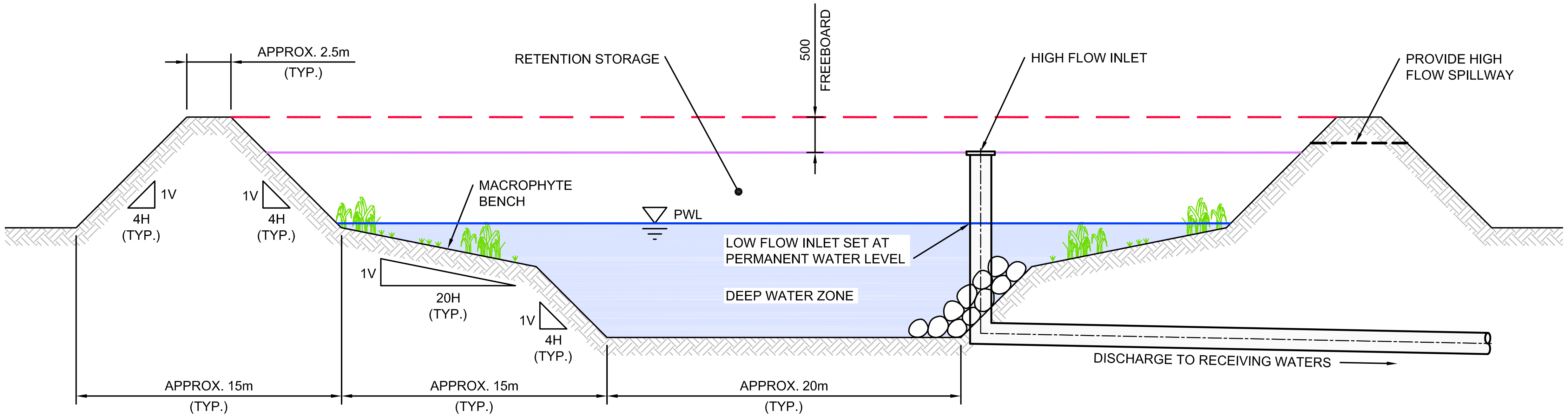
SOURCE: CRAWFORD ARCHITECTS

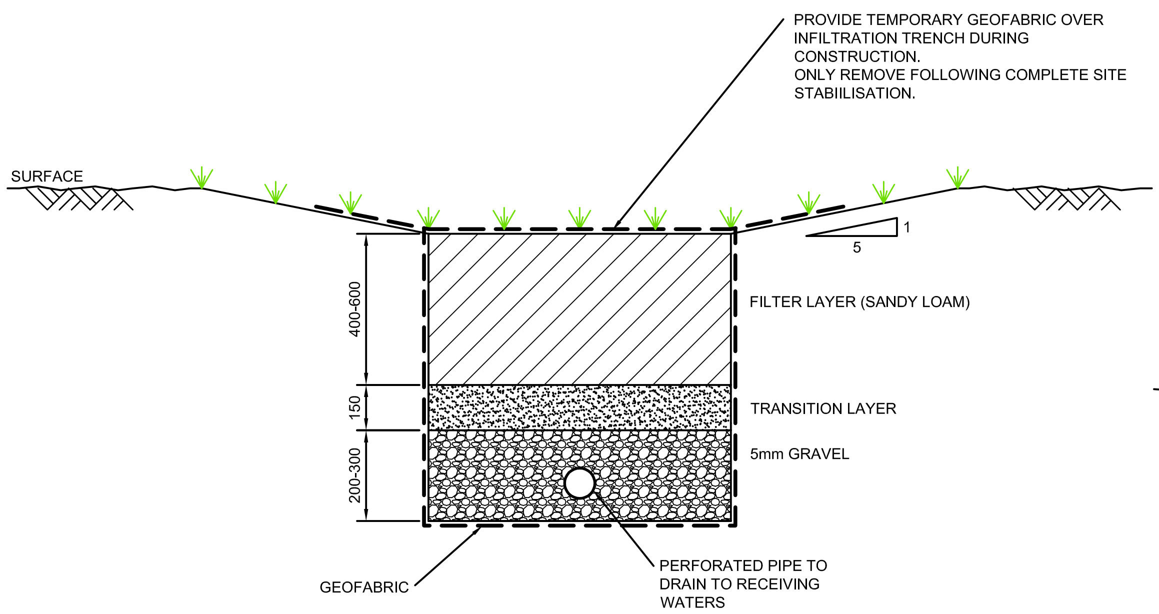
PROPOSED STORMWATER MANAGEMENT PLAN

N:\Drafting Jobs\7458.00 Gateway Enterprise Park Bathurst SW & Flooding Assessment\CAD\FINAL STORMWATER FIGURES\FIG 8_PROP SWATER MANAGEMENT PLAN.dwg 04/12/2008

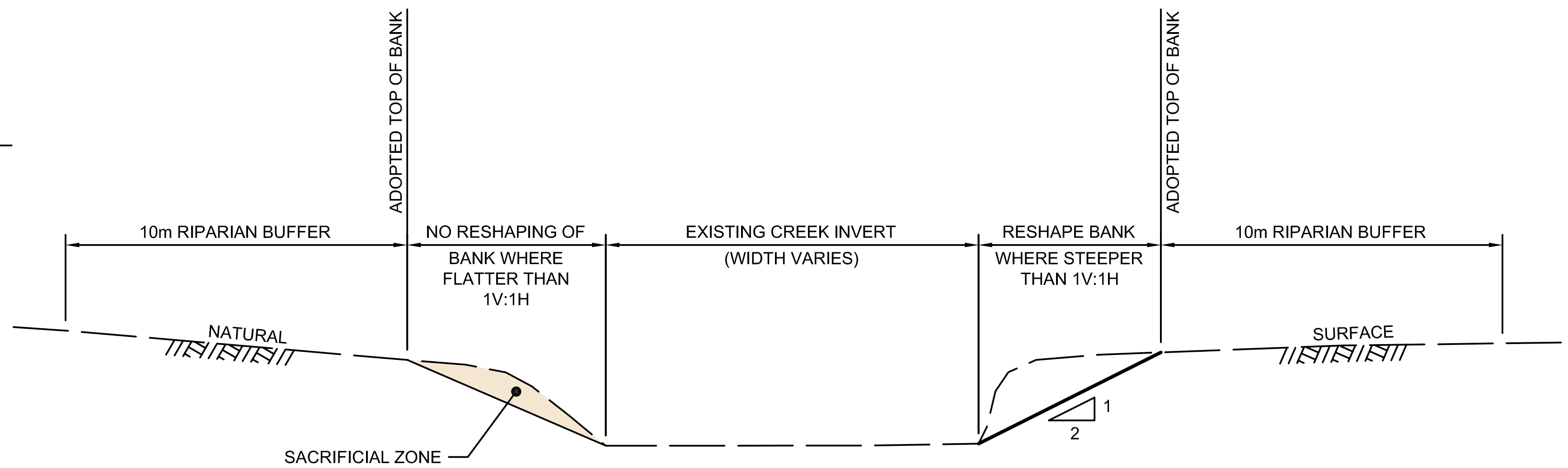
FIGURE 9



WATER QUALITY CONTROL POND DESIGN CONCEPT
NTS



VEGETATED BIO-RETENTION TYPICAL SECTION
NTS



TYPICAL SECTION - RAGLAN CREEK
1:200 NATURAL

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0 70 m
1:1750

TYPICAL CROSS SECTION & DETAILS

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PHOTOGRAPHS

Photo 1: Four box culverts under Great Western Highway

Photo 2: Raglan Creek with heavy Willow growth, and steeply incised channel

Photo 3: Minor Water Course, adjacent to the Great Western Highway

Photo 4: indicating the incised channel banks**.**

Photo 5: Partially buried car bodies in Raglan Creek

Photo 6: Rehabilitation works upstream of the site to prevent further head cuts.

Appendix A – RAFTS Parameters

Existing State RAFTS Parameters

Subcatchment ID	Catchment Area				Slope	Roughness		Initial Loss		Continuing Loss	
	Pervious surfaces	Impervious Surfaces	Total	Percentage Impervious		Pervious surfaces	Impervious Surfaces	Pervious surfaces	Impervious Surfaces	Pervious surfaces	Impervious Surfaces
	(ha)	(ha)	(ha)	(%)	(%)	(n)	(n)	(mm)	(mm)	(mm/h)	(mm/h)
1-1.	82.7	4.4	87.1	5	2.2	0.04	N/A	25	N/A	2.5	N/A
1-2.	67.9	0.0	67.9	0	1.9	0.04	N/A	25	N/A	2.5	N/A
1-3.	60.1	6.7	66.8	10	2.7	0.04	N/A	25	N/A	2.5	N/A
2-1.	74.7	0.0	74.7	0	2	0.04	N/A	25	N/A	2.5	N/A
2-2.	12.5	0.0	12.5	0	2.1	0.04	N/A	25	N/A	2.5	N/A
2-3.	60.6	26.0	86.6	30	2.8	0.04	0.025	25	1.5	2.5	0
2-4.	15.5	6.7	22.2	30	2.9	0.04	0.025	25	1.5	2.5	0
2-5.	35.5	8.9	44.4	20	2.5	0.04	0.025	25	1.5	2.5	0
2-6.	39.1	2.1	41.2	5	2.8	0.04	N/A	25	N/A	2.5	N/A
2-7.	45.4	2.4	47.8	5	4.2	0.04	N/A	25	N/A	2.5	N/A
2-8.	18.8	1.0	19.8	5	1.6	0.04	N/A	25	N/A	2.5	N/A
3	9.7	0.5	10.2	5	1.4	0.04	N/A	25	N/A	2.5	N/A
Total	**522.6**	**58.6**	**581.2**								

Developed State RAFTS Parameters

Subcatchment ID	Catchment Area				Slope	Roughness		Initial Loss		Continuing Loss	
	Pervious surfaces	Impervious Surfaces	Total	Percentage Impervious		Pervious surfaces	Impervious Surfaces	Pervious surfaces	Impervious Surfaces	Pervious surfaces	Impervious Surfaces
	(ha)	(ha)	(ha)	(%)	(%)	(n)	(n)	(mm)	(mm)	(mm/h)	(mm/h)
1-1.	82.7	4.4	87.1	5	2.2	0.04	N/A	25	N/A	2.5	N/A
1-2.	67.9	0.0	67.9	0	1.9	0.04	N/A	25	N/A	2.5	N/A
1-3.	60.1	6.7	66.8	10	2.7	0.04	N/A	25	N/A	2.5	N/A
2-1.	74.7	0.0	74.7	0	2	0.04	N/A	25	N/A	2.5	N/A
2-2.	12.5	0.0	12.5	0	2.1	0.04	N/A	25	N/A	2.5	N/A
2-3.	60.6	26.0	86.6	30	2.8	0.04	0.025	25	1.5	2.5	0
2-4.	15.5	6.7	22.2	30	2.9	0.04	0.025	25	1.5	2.5	0
2-5.	35.5	8.9	44.4	20	2.5	0.04	0.025	25	1.5	2.5	0
2-6.	39.1	2.1	41.2	5	2.8	0.04	N/A	25	N/A	2.5	N/A
2-7.	45.4	2.4	47.8	5	4.2	0.04	N/A	25	N/A	2.5	N/A
2-8&3per.	6.8	0.0	6.8	0	1.5	0.04	N/A	25	N/A	2.5	N/A
2-8&3imp.	2.0	21.2	23.2	91	1.5	0.035	0.015	15	1.5	2.5	0
Total	**503.0**	**78.2**	**581.2**								

Adopted Lagtimes

Flow Path		Lag Time (min)
From	To	Existing
1-1.	1-2.	11.7
1-2.	1-3.	11.1
1-3.	culvert.	4.1
2-1.	2-3.	10
2-3.	2-6.	9.2
2-2.	2-4.	7.2
2-4.	2-5.	11.1
2-5.	2-6.	0
2-6.	2-7.	7.2
2-7.	2-8.	10.6
2-8.	3	0

Appendix B – RAFTS Results

RAFTS RESULTS

		Raglan Creek			Raglan Creek-Tributary			Raglan Creek - Highway Culverts		
RAFTS Subcatchment		SC 2-7			SC 1-3			SC 2-8		
		Existing State	**Developed State**		**Existing State**	**Developed State**		**Existing State**	**Developed State**	
			No Controls	**With Controls**		**No Controls**	**With Controls**		**No Controls**	**With Controls**
Storm ARI	Duration *(min)*	Peak Flow *(m3/s)*	Peak Flow *(m3/s)*	Peak Flow *(m3/s)*	Peak Flow *(m3/s)*	Peak Flow *(m3/s)*	Peak Flow *(m3/s)*	Peak Flow *(m3/s)*	Peak Flow *(m3/s)*	Peak Flow *(m3/s)*
2 yr	30 min	0.0	0.0	0.0	6.7	6.7	6.9	6.7	6.7	6.9
2 yr	45 min	0.0	0.0	0.0	6.0	6.8	6.3	6.0	6.8	6.3
2 yr	60 min	0.0	0.0	0.0	6.3	6.8	6.6	6.3	6.8	6.6
2 yr	90 min	0.1	0.1	0.1	6.0	7.2	6.7	6.0	7.2	6.7
2 yr	120 min	0.4	0.4	0.4	5.9	7.0	6.3	5.9	7.0	6.3
2 yr	180 min	1.0	1.0	1.0	3.7	4.8	4.1	3.7	4.8	4.1
2 yr	270 min	1.4	1.4	1.4	3.3	4.0	3.6	4.0	4.2	4.2
2 yr	360 min	1.5	1.5	1.5	2.7	3.2	3.0	4.2	4.4	4.5
2 yr	540 min	3.4	3.4	3.4	6.1	6.3	6.4	**9.4**	9.7	**9.7**
2 yr	720 min	3.0	3.0	3.0	5.3	5.6	5.6	8.3	8.6	8.6
5 yr	30 min	0.0	0.0	0.0	8.8	8.8	9.1	8.8	8.8	9.1
5 yr	45 min	0.2	0.2	0.2	7.7	8.9	8.3	7.7	8.9	8.3
5 yr	60 min	0.9	0.9	0.9	8.0	9.0	8.9	8.2	9.3	9.1
5 yr	90 min	1.8	1.8	1.8	8.0	9.3	8.9	8.3	9.6	9.1
5 yr	120 min	2.4	2.4	2.4	7.9	9.0	8.3	8.0	9.2	8.5
5 yr	180 min	3.0	3.1	3.1	5.4	6.0	5.8	8.4	8.6	8.8
5 yr	270 min	3.0	3.0	3.0	5.1	5.3	5.4	8.0	8.3	8.4
5 yr	360 min	3.1	3.1	3.1	5.1	5.3	5.4	8.1	8.4	8.4
5 yr	540 min	5.8	5.8	5.8	10.0	10.2	10.3	15.7	16.0	16.1
5 yr	720 min	4.2	4.3	4.3	8.0	8.2	8.4	12.2	12.4	12.6
20 yr	30 min	1.1	1.1	1.1	12.5	12.5	12.9	13.1	13.2	13.6
20 yr	45 min	3.1	3.1	3.1	11.2	12.3	12.3	12.3	13.4	13.3
20 yr	60 min	4.3	4.3	4.3	13.2	13.9	14.2	15.5	16.1	16.5
20 yr	90 min	5.3	5.4	5.4	12.8	14.3	14.2	15.2	16.7	16.6
20 yr	120 min	5.7	5.8	5.8	12.0	13.3	13.0	15.7	15.9	16.1
20 yr	180 min	6.0	6.0	6.0	10.0	10.2	10.4	16.0	16.2	16.3
20 yr	270 min	5.5	5.5	5.5	9.0	9.3	9.4	14.5	14.7	14.8
20 yr	360 min	5.6	5.6	5.6	9.5	9.9	10.0	15.0	15.4	15.4
20 yr	540 min	8.8	8.8	8.8	14.8	15.0	15.2	23.5	23.8	24.0
20 yr	720 min	7.1	7.1	7.1	12.6	12.7	13.0	19.6	19.8	20.0
100 yr	30 min	5.8	5.8	5.8	19.4	19.2	20.0	23.3	23.0	23.9
100 yr	45 min	8.5	8.5	8.5	17.4	18.7	19.3	24.9	24.4	25.1
100 yr	60 min	10.2	10.2	10.2	**21.6**	22.2	22.6	29.0	29.2	29.6
100 yr	90 min	11.0	11.0	11.0	21.3	22.4	**22.5**	29.8	29.8	30.1
100 yr	120 min	11.2	11.2	11.2	18.8	20.0	19.9	29.6	29.7	30.0
100 yr	180 min	10.3	10.3	10.3	16.7	17.2	17.2	26.7	27.3	27.3
100 yr	270 min	9.0	9.0	9.0	14.3	14.7	14.8	23.3	23.7	23.8
100 yr	360 min	9.3	9.3	9.3	15.8	16.1	16.2	25.1	25.4	25.5
100 yr	540 min	**11.8**	11.8	**11.8**	19.3	19.4	19.7	**31.0**	31.1	**31.4**
100 yr	720 min	10.1	10.1	10.1	17.7	17.3	17.7	27.7	27.2	27.6

RAFTS RESULTS

RAFTS Parity Location		Proposed Development Area Prop Dev		
		Existing State	**Developed State**	
			No Controls	**With Controls**
Storm ARI	Duration *(min)*	Peak Flow *(m3/s)*	Peak Flow *(m3/s)*	Peak Flow *(m3/s)*
2 yr	30 min	0.0	4.0	0.2
2 yr	45 min	0.0	3.6	0.3
2 yr	60 min	0.0	3.8	0.3
2 yr	90 min	0.0	4.0	0.3
2 yr	120 min	0.1	3.8	0.4
2 yr	180 min	0.2	2.0	0.4
2 yr	270 min	0.2	1.7	0.4
2 yr	360 min	0.2	1.2	0.4
2 yr	540 min	**0.6**	1.2	**0.6**
2 yr	720 min	0.4	1.2	0.5
5 yr	30 min	0.0	5.3	0.3
5 yr	45 min	0.0	4.7	0.4
5 yr	60 min	0.1	5.0	0.5
5 yr	90 min	0.3	5.1	0.6
5 yr	120 min	0.4	4.8	0.7
5 yr	180 min	0.5	2.5	0.7
5 yr	270 min	0.5	2.1	0.6
5 yr	360 min	0.5	1.5	0.7
5 yr	540 min	1.0	1.5	1.1
5 yr	720 min	0.7	1.5	0.7
20 yr	30 min	0.2	7.1	0.6
20 yr	45 min	0.5	6.3	1.3
20 yr	60 min	0.8	6.6	1.5
20 yr	90 min	1.0	6.7	1.4
20 yr	120 min	1.0	6.3	1.5
20 yr	180 min	1.0	3.2	1.3
20 yr	270 min	0.9	2.7	1.2
20 yr	360 min	1.0	2.0	1.4
20 yr	540 min	1.5	1.9	1.6
20 yr	720 min	1.3	1.9	1.5
100 yr	30 min	1.0	8.8	2.8
100 yr	45 min	1.7	8.0	3.3
100 yr	60 min	**2.0**	8.3	**3.5**
100 yr	90 min	2.0	8.4	3.0
100 yr	120 min	2.0	7.7	3.1
100 yr	180 min	1.7	4.0	2.3
100 yr	270 min	1.3	3.4	2.5
100 yr	360 min	1.6	2.5	1.9
100 yr	540 min	1.9	2.3	2.3
100 yr	720 min	1.8	2.3	2.2

Appendix C - HEC-RAS output

HEC-RAS Output
Existing
Raglan Creek & Minor Watercourse

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
main	32	598.85	2 YR Exis	6.7	686.92	687.82	687.90	0.038	1.24	5	10.29	0.55
main	32	545.78	2 YR Exis	6.7	685.84	686.77	686.80	0.013	0.82	8	12.60	0.32
main	32	474.27	2 YR Exis	6.7	684.75	686.38	686.40	0.003	0.55	12	11.91	0.17
main	32	411.76	2 YR Exis	6.7	685.23	685.62	685.79	0.150	1.82	4	11.12	1.01
main	32	334.73	2 YR Exis	6.7	683.90	685.09	685.10	0.002	0.42	16	16.21	0.13
main	32	299.4	2 YR Exis	6.7	684.20	684.92	684.95	0.016	0.83	8	14.92	0.36
main	32	243.94	2 YR Exis	6.7	682.71	683.55	683.65	0.038	1.37	5	7.69	0.55
main	32	197.94	2 YR Exis	6.7	682.01	683.01	683.03	0.007	0.62	11	15.74	0.24
main	32	178.04	2 YR Exis	6.7	681.79	682.75	682.81	0.022	1.02	7	10.99	0.42
main	32	124.18	2 YR Exis	6.7	681.01	681.79	681.84	0.015	0.93	7	10.43	0.36
main	32	69.59	2 YR Exis	6.7	680.41	681.71	681.71	0.001	0.29	23	21.71	0.09
main	**32**	32.29	2 YR Exis	6.7	680.47	681.64	681.66	0.003	0.55	12	11.96	0.17
main	0	153.58	2 YR Exis	9.4	680.32	681.26	681.30	0.010	0.82	11	14.80	0.30
main	0	107.05	2 YR Exis	9.4	679.70	680.91	680.94	0.006	0.75	13	13.51	0.24
main	0	23.32	2 YR Exis	9.4	678.81	679.36	679.55	0.143	1.93	5	13.07	1.01
main	0	0	2 YR Exis	9.4	677.42	679.13	679.15	0.004	0.62	15	16.71	0.20
main	0	-11		Culvert								
main	0	-21	2 YR Exis	9.4	677.56	679.06	679.09	0.008	0.74	13	17.29	0.26
main	0	-25	2 YR Exis	9.4	677.85	679.01	679.05	0.011	0.91	10	12.58	0.32
main	0	-36	2 YR Exis	9.4	677.50	678.80	678.88	0.020	1.28	7	8.11	0.42
branch	42	486.72	2 YR Exis	3.4	693.69	694.58	694.62	0.019	0.88	4	7.26	0.38
branch	42	458.54	2 YR Exis	3.4	692.52	693.23	693.46	0.149	2.10	2	3.67	1.01
branch	42	419.11	2 YR Exis	3.4	690.16	690.80	690.84	0.022	0.93	4	6.93	0.41
branch	42	364.43	2 YR Exis	3.4	688.72	689.39	689.45	0.030	1.11	3	5.66	0.48
branch	42	299.64	2 YR Exis	3.4	686.94	687.83	687.88	0.020	0.98	3	5.44	0.39
branch	42	220.16	2 YR Exis	3.4	685.76	686.42	686.46	0.016	0.84	4	7.28	0.36
branch	42	175.94	2 YR Exis	3.4	684.24	685.26	685.36	0.042	1.41	2	3.36	0.53
branch	42	116.13	2 YR Exis	3.4	682.77	683.55	683.60	0.021	0.99	3	5.62	0.41
branch	42	84.09	2 YR Exis	3.4	682.37	682.93	682.96	0.018	0.81	4	8.73	0.37
branch	42	42.11	2 YR Exis	3.4	681.54	682.11	682.15	0.021	0.84	4	8.53	0.39

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
main	32	598.85	5 YR Exis	10	686.92	687.96	688.07	0.044	1.47	7	11.31	0.60
main	32	545.78	5 YR Exis	10	685.84	687.02	687.06	0.010	0.87	11	13.27	0.30
main	32	474.27	5 YR Exis	10	684.75	686.62	686.64	0.004	0.66	15	12.56	0.19
main	32	411.76	5 YR Exis	10	685.23	685.72	685.94	0.136	2.05	5	11.29	1.00
main	32	334.73	5 YR Exis	10	683.90	685.29	685.31	0.002	0.52	19	16.81	0.15
main	32	299.4	5 YR Exis	10	684.20	685.09	685.13	0.015	0.93	11	15.80	0.36
main	32	243.94	5 YR Exis	10	682.71	683.75	683.87	0.038	1.56	6	8.08	0.56
main	32	197.94	5 YR Exis	10	682.01	683.19	683.22	0.007	0.73	14	16.33	0.25
main	32	178.04	5 YR Exis	10	681.79	682.90	682.98	0.024	1.22	8	11.26	0.45
main	32	124.18	5 YR Exis	10	681.01	682.11	682.15	0.010	0.94	11	11.08	0.31
main	32	69.59	5 YR Exis	10	680.41	682.03	682.04	0.001	0.33	30	22.65	0.09
main	32	32.29	5 YR Exis	10	680.47	681.96	681.98	0.003	0.62	16	12.81	0.17
main	**0**	153.58	5 YR Exis	15.7	680.32	681.58	681.63	0.009	0.96	16	15.76	0.30
main	0	107.05	5 YR Exis	15.7	679.70	681.16	681.21	0.009	1.00	16	16.68	0.29
main	0	23.32	5 YR Exis	15.7	678.81	679.75	679.87	0.038	1.53	10	14.38	0.58
main	0	0	5 YR Exis	15.7	677.42	679.65	679.67	0.003	0.64	25	18.94	0.17
main	0	-11		Culvert								
main	0	-21	5 YR Exis	15.7	677.56	679.43	679.46	0.006	0.81	19	18.86	0.24
main	0	-25	5 YR Exis	15.7	677.85	679.37	679.42	0.010	1.04	15	13.73	0.32
main	0	-36	5 YR Exis	15.7	677.50	679.15	679.26	0.020	1.52	10	9.32	0.44
branch	42	486.72	5 YR Exis	5.8	693.69	694.81	694.86	0.018	1.02	6	8.42	0.39
branch	42	458.54	5 YR Exis	5.8	692.52	693.44	693.72	0.140	2.35	2	4.46	1.01
branch	42	419.11	5 YR Exis	5.8	690.16	691.01	691.07	0.023	1.12	5	7.62	0.43
branch	42	364.43	5 YR Exis	5.8	688.72	689.65	689.73	0.027	1.25	5	6.47	0.47
branch	42	299.64	5 YR Exis	5.8	686.94	688.07	688.15	0.022	1.19	5	6.21	0.43
branch	42	220.16	5 YR Exis	5.8	685.76	686.69	686.73	0.014	0.95	6	8.10	0.35
branch	42	175.94	5 YR Exis	5.8	684.24	685.58	685.71	0.042	1.61	4	3.99	0.54
branch	42	116.13	5 YR Exis	5.8	682.77	683.79	683.86	0.024	1.21	5	6.20	0.44
branch	42	84.09	5 YR Exis	5.8	682.37	683.10	683.16	0.020	1.01	6	9.19	0.41
branch	42	42.11	5 YR Exis	5.8	681.54	682.36	682.40	0.016	0.94	6	8.97	0.36

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
main	32	598.85	20 YR Exis	14.8	686.92	688.16	688.29	0.042	1.60	9	12.84	0.60
main	32	545.78	20 YR Exis	14.8	685.84	687.31	687.36	0.009	0.96	15	14.03	0.29
main	32	474.27	20 YR Exis	14.8	684.75	686.87	686.90	0.005	0.81	18	13.24	0.22
main	32	411.76	20 YR Exis	14.8	685.23	686.03	686.19	0.054	1.77	8	11.78	0.67
main	32	334.73	20 YR Exis	14.8	683.90	685.54	685.56	0.003	0.63	23	17.49	0.17
main	32	299.4	20 YR Exis	14.8	684.20	685.30	685.36	0.014	1.04	14	16.91	0.36
main	32	243.94	20 YR Exis	14.8	682.71	683.97	684.13	0.039	1.78	8	8.53	0.58
main	32	197.94	20 YR Exis	14.8	682.01	683.43	683.46	0.007	0.83	18	17.10	0.26
main	32	178.04	20 YR Exis	14.8	681.79	683.14	683.23	0.022	1.35	11	11.69	0.45
main	32	124.18	20 YR Exis	14.8	681.01	682.45	682.50	0.009	1.02	14	11.77	0.29
main	32	69.59	20 YR Exis	14.8	680.41	682.37	682.38	0.001	0.39	38	23.64	0.10
main	32	32.29	20 YR Exis	14.8	680.47	682.30	682.32	0.003	0.72	21	13.68	0.19
main	0	153.58	20 YR Exis	23.5	680.32	681.89	681.95	0.010	1.11	21	16.67	0.31
main	0	107.05	20 YR Exis	23.5	679.70	681.37	681.45	0.012	1.26	19	19.68	0.35
main	0	23.32	20 YR Exis	23.5	678.81	680.34	680.42	0.013	1.22	19	16.34	0.36
main	0	0	20 YR Exis	23.5	677.42	680.29	680.31	0.001	0.61	38	21.74	0.13
main	0	-11		Culvert								
main	0	-21	20 YR Exis	23.5	677.56	679.77	679.81	0.005	0.89	26	20.35	0.23
main	0	-25	20 YR Exis	23.5	677.85	679.71	679.78	0.010	1.18	20	15.02	0.32
main	0	-36	20 YR Exis	23.5	677.50	679.46	679.62	0.020	1.75	14	10.78	0.46
branch	42	486.72	20 YR Exis	8.8	693.69	695.03	695.10	0.018	1.14	8	9.47	0.41
branch	42	458.54	20 YR Exis	8.8	692.52	693.64	693.97	0.130	2.55	3	5.24	1.00
branch	42	419.11	20 YR Exis	8.8	690.16	691.23	691.31	0.023	1.27	7	8.35	0.44
branch	42	364.43	20 YR Exis	8.8	688.72	689.90	690.00	0.025	1.38	6	7.26	0.47
branch	42	299.64	20 YR Exis	8.8	686.94	688.31	688.41	0.024	1.37	6	6.97	0.45
branch	42	220.16	20 YR Exis	8.8	685.76	686.96	687.01	0.013	1.05	8	8.94	0.34
branch	42	175.94	20 YR Exis	8.8	684.24	685.89	686.05	0.041	1.77	5	4.71	0.55
branch	42	116.13	20 YR Exis	8.8	682.77	684.01	684.11	0.026	1.41	6	6.76	0.47
branch	42	84.09	20 YR Exis	8.8	682.37	683.29	683.36	0.021	1.17	8	9.68	0.42
branch	42	42.11	20 YR Exis	8.8	681.54	682.64	682.69	0.013	1.00	9	9.49	0.33

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
main	32	598.85	100 YR Exis	21.6	686.92	688.41	688.56	0.037	1.69	13	14.83	0.58
main	32	545.78	100 YR Exis	21.6	685.84	687.65	687.71	0.009	1.06	20	14.93	0.29
main	32	474.27	100 YR Exis	21.6	684.75	687.18	687.23	0.005	0.96	23	14.10	0.24
main	32	411.76	100 YR Exis	21.6	685.23	686.34	686.50	0.036	1.78	12	12.30	0.57
main	32	334.73	100 YR Exis	21.6	683.90	685.82	685.85	0.003	0.76	29	18.14	0.19
main	32	299.4	100 YR Exis	21.6	684.20	685.57	685.63	0.013	1.15	19	18.25	0.36
main	32	243.94	100 YR Exis	21.6	682.71	684.24	684.45	0.040	2.03	11	9.07	0.60
main	32	197.94	100 YR Exis	21.6	682.01	683.73	683.78	0.007	0.93	23	18.08	0.26
main	32	178.04	100 YR Exis	21.6	681.79	683.45	683.56	0.019	1.47	15	12.26	0.43
main	32	124.18	100 YR Exis	21.6	681.01	682.79	682.86	0.009	1.16	19	12.57	0.30
main	32	69.59	100 YR Exis	21.6	680.41	682.71	682.72	0.001	0.46	46	24.57	0.11
main	32	32.29	100 YR Exis	21.6	680.47	682.62	682.65	0.004	0.86	25	14.56	0.21
main	0	153.58	100 YR Exis	31	680.32	682.17	682.24	0.010	1.18	26	24.14	0.32
main	0	107.05	100 YR Exis	31	679.70	681.63	681.73	0.012	1.38	22	21.16	0.36
main	0	23.32	100 YR Exis	31	678.81	680.98	681.04	0.006	1.02	31	18.47	0.25
main	0	0	100 YR Exis	31	677.42	680.96	680.98	0.001	0.56	53	24.62	0.11
main	0	-11		Culvert								
main	0	-21	100 YR Exis	31	677.56	680.03	680.08	0.004	0.96	32	21.49	0.23
main	0	-25	100 YR Exis	31	677.85	679.96	680.05	0.010	1.30	24	17.00	0.33
main	0	-36	100 YR Exis	31	677.50	679.69	679.88	0.020	1.92	16	12.17	0.47
branch	42	486.72	100 YR Exis	11.8	693.69	695.22	695.29	0.018	1.24	10	10.34	0.41
branch	42	458.54	100 YR Exis	11.8	692.52	693.81	694.18	0.126	2.71	4	5.86	1.00
branch	42	419.11	100 YR Exis	11.8	690.16	691.41	691.51	0.022	1.38	9	8.97	0.45
branch	42	364.43	100 YR Exis	11.8	688.72	690.11	690.22	0.025	1.48	8	7.91	0.47
branch	42	299.64	100 YR Exis	11.8	686.94	688.51	688.62	0.025	1.50	8	7.62	0.47
branch	42	220.16	100 YR Exis	11.8	685.76	687.19	687.25	0.012	1.12	11	9.66	0.34
branch	42	175.94	100 YR Exis	11.8	684.24	686.15	686.33	0.041	1.89	6	5.31	0.56
branch	42	116.13	100 YR Exis	11.8	682.77	684.18	684.31	0.028	1.58	7	7.21	0.49
branch	42	84.09	100 YR Exis	11.8	682.37	683.48	683.56	0.020	1.26	9	10.15	0.42
branch	42	42.11	100 YR Exis	11.8	681.54	682.91	682.97	0.010	1.03	11	9.98	0.31

Developed

Raglan Creek

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
main	0	781.96	2 YR Dev	6.9	686.92	687.83	687.91	0.039	1.26	5	10.35	0.55
main	0	728.89	2 YR Dev	6.9	685.84	686.79	686.82	0.012	0.82	8	12.65	0.32
main	0	657.38	2 YR Dev	6.9	684.75	686.40	686.42	0.003	0.55	12	11.95	0.17
main	0	594.87	2 YR Dev	6.9	685.23	685.63	685.80	0.149	1.83	4	11.13	1.01
main	0	517.84	2 YR Dev	6.9	683.90	685.11	685.12	0.002	0.43	16	16.25	0.14
main	0	482.51	2 YR Dev	6.9	684.20	684.93	684.96	0.016	0.84	8	14.96	0.36
main	0	427.05	2 YR Dev	6.9	682.71	683.57	683.67	0.037	1.37	5	7.73	0.54
main	0	381.05	2 YR Dev	6.9	682.01	683.01	683.03	0.007	0.63	11	15.76	0.24
main	0	361.15	2 YR Dev	6.9	681.79	682.74	682.80	0.025	1.08	6	10.96	0.45
main	0	307.29	2 YR Dev	6.9	681.01	681.87	681.91	0.011	0.86	8	10.59	0.31
main	0	288	2 YR Dev	6.9	680.81	681.62	681.66	0.014	0.93	7	10.48	0.35
main	0	268.5		Culvert								
main	0	249	2 YR Dev	6.9	680.41	681.61	681.62	0.001	0.33	21	21.44	0.10
main	0	215.4	2 YR Dev	6.9	680.47	681.53	681.55	0.005	0.64	11	11.66	0.21
main	0	184	2 YR Dev	9.7	680.38	681.11	681.18	0.029	1.17	8	14.15	0.49
main	0	118		Culvert								
main	0	52	2 YR Dev	9.7	679.16	680.23	680.27	0.009	0.80	12	14.82	0.28
main	0	23.32	2 YR Dev	9.7	678.81	679.37	679.56	0.142	1.95	5	13.10	1.01
main	0	0	2 YR Dev	9.7	677.42	679.16	679.18	0.004	0.62	16	16.82	0.20
main	0	-11		Culvert								
main	0	-21	2 YR Dev	9.7	677.56	679.08	679.11	0.007	0.74	13	17.38	0.26
main	0	-25	2 YR Dev	9.7	677.85	679.03	679.07	0.011	0.91	11	12.64	0.32
main	0	-36	2 YR Dev	9.7	677.50	678.82	678.91	0.020	1.29	8	8.18	0.43

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
main	0	781.96	5 YR Dev	10.3	686.92	687.97	688.08	0.044	1.48	7	11.41	0.60
main	0	728.89	5 YR Dev	10.3	685.84	687.04	687.08	0.010	0.88	12	13.32	0.30
main	0	657.38	5 YR Dev	10.3	684.75	686.64	686.66	0.004	0.67	15	12.60	0.19
main	0	594.87	5 YR Dev	10.3	685.23	685.75	685.95	0.121	2.00	5	11.33	0.95
main	0	517.84	5 YR Dev	10.3	683.90	685.31	685.33	0.002	0.53	20	16.86	0.16
main	0	482.51	5 YR Dev	10.3	684.20	685.10	685.15	0.015	0.94	11	15.87	0.36
main	0	427.05	5 YR Dev	10.3	682.71	683.76	683.89	0.038	1.57	7	8.11	0.56
main	0	381.05	5 YR Dev	10.3	682.01	683.21	683.23	0.007	0.73	14	16.38	0.25
main	0	361.15	5 YR Dev	10.3	681.79	682.92	683.00	0.024	1.22	8	11.29	0.45
main	0	307.29	5 YR Dev	10.3	681.01	682.12	682.17	0.011	0.96	11	11.10	0.31
main	0	288	5 YR Dev	10.3	680.81	681.91	681.96	0.011	0.97	11	11.09	0.31
main	0	268.5		Culvert								
main	0	249	5 YR Dev	10.3	680.41	681.90	681.91	0.001	0.37	28	22.28	0.11
main	0	215.4	5 YR Dev	10.3	680.47	681.81	681.84	0.005	0.72	14	12.41	0.21
main	0	184	5 YR Dev	16.1	680.38	681.42	681.50	0.020	1.25	13	15.09	0.43
main	0	118		Culvert								
main	0	52	5 YR Dev	16.1	679.16	680.43	680.49	0.012	1.06	15	15.48	0.34
main	0	23.32	5 YR Dev	16.1	678.81	679.78	679.90	0.036	1.51	11	14.48	0.56
main	0	0	5 YR Dev	16.1	677.42	679.68	679.70	0.003	0.64	25	19.09	0.17
main	0	-11		Culvert								
main	0	-21	5 YR Dev	16.1	677.56	679.45	679.48	0.005	0.81	20	18.95	0.24
main	0	-25	5 YR Dev	16.1	677.85	679.39	679.44	0.010	1.05	15	13.80	0.32
main	0	-36	5 YR Dev	16.1	677.50	679.17	679.29	0.020	1.53	11	9.39	0.44

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
main	0	781.96	20 YR Dev	15.2	686.92	688.17	688.30	0.042	1.61	9	12.96	0.60
main	0	728.89	20 YR Dev	15.2	685.84	687.33	687.38	0.009	0.97	16	14.09	0.29
main	0	657.38	20 YR Dev	15.2	684.75	686.89	686.92	0.005	0.82	19	13.29	0.22
main	0	594.87	20 YR Dev	15.2	685.23	686.05	686.21	0.052	1.77	9	11.82	0.66
main	0	517.84	20 YR Dev	15.2	683.90	685.55	685.57	0.003	0.64	24	17.54	0.18
main	0	482.51	20 YR Dev	15.2	684.20	685.32	685.38	0.014	1.05	15	16.99	0.36
main	0	427.05	20 YR Dev	15.2	682.71	683.99	684.15	0.039	1.80	8	8.56	0.58
main	0	381.05	20 YR Dev	15.2	682.01	683.45	683.49	0.007	0.84	18	17.16	0.26
main	0	361.15	20 YR Dev	15.2	681.79	683.16	683.25	0.022	1.36	11	11.73	0.44
main	0	307.29	20 YR Dev	15.2	681.01	682.43	682.49	0.010	1.06	14	11.74	0.31
main	0	288	20 YR Dev	15.2	680.81	682.25	682.31	0.009	1.05	15	11.78	0.30
main	0	268.5		Culvert								
main	0	249	20 YR Dev	15.2	680.41	682.23	682.24	0.001	0.44	35	23.22	0.11
main	0	215.4	20 YR Dev	15.2	680.47	682.12	682.16	0.005	0.83	18	13.22	0.23
main	0	184	20 YR Dev	24	680.38	681.75	681.84	0.016	1.33	18	16.09	0.40
main	0	118		Culvert								
main	0	52	20 YR Dev	24	679.16	680.74	680.81	0.012	1.20	20	16.48	0.35
main	0	23.32	20 YR Dev	24	678.81	680.38	680.46	0.012	1.20	20	16.47	0.35
main	0	0	20 YR Dev	24	677.42	680.34	680.36	0.001	0.61	39	21.92	0.13
main	0	-11		Culvert								
main	0	-21	20 YR Dev	24	677.56	679.79	679.83	0.005	0.89	26	20.44	0.23
main	0	-25	20 YR Dev	24	677.85	679.72	679.80	0.010	1.19	20	15.17	0.32
main	0	-36	20 YR Dev	24	677.50	679.48	679.64	0.020	1.76	14	10.88	0.46

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl	Flood Planning Level m
main	0	781.96	100 YR Dev	22.5	686.92	688.45	688.59	0.036	1.69	13	15.08	0.58	689.59
main	0	728.89	100 YR Dev	22.5	685.84	687.69	687.75	0.008	1.07	21	15.04	0.29	688.75
main	0	657.38	100 YR Dev	22.5	684.75	687.22	687.26	0.006	0.97	23	14.20	0.24	688.26
main	0	594.87	100 YR Dev	22.5	685.23	686.38	686.54	0.035	1.78	13	12.36	0.56	687.54
main	0	517.84	100 YR Dev	22.5	683.90	685.85	685.88	0.003	0.77	29	18.22	0.20	686.88
main	0	482.51	100 YR Dev	22.5	684.20	685.60	685.67	0.013	1.16	19	18.41	0.36	686.67
main	0	427.05	100 YR Dev	22.5	682.71	684.27	684.49	0.040	2.06	11	9.13	0.60	685.49
main	0	381.05	100 YR Dev	22.5	682.01	683.77	683.82	0.007	0.94	24	18.20	0.26	684.82
main	0	361.15	100 YR Dev	22.5	681.79	683.49	683.60	0.019	1.49	15	12.32	0.43	684.60
main	0	307.29	100 YR Dev	22.5	681.01	682.79	682.87	0.010	1.20	19	12.57	0.31	683.87
main	0	288	100 YR Dev	22.5	680.81	682.61	682.68	0.009	1.19	19	12.62	0.31	683.68
main	0	268.5		Culvert									
main	0	249	100 YR Dev	22.5	680.41	682.54	682.55	0.001	0.53	42	24.12	0.13	683.55
main	0	215.4	100 YR Dev	22.5	680.47	682.40	682.45	0.006	1.02	22	13.96	0.26	683.45
main	0	184	100 YR Dev	31.4	680.38	682.03	682.13	0.014	1.39	23	17.08	0.38	683.13
main	0	118		Culvert									
main	0	52	100 YR Dev	31.4	679.16	681.20	681.27	0.007	1.12	28	18.04	0.29	682.27
main	0	23.32	100 YR Dev	31.4	678.81	681.02	681.07	0.006	1.01	31	19.00	0.25	682.07
main	0	0	100 YR Dev	31.4	677.42	680.99	681.01	0.001	0.56	54	24.77	0.11	682.01
main	0	-11		Culvert									
main	0	-21	100 YR Dev	31.4	677.56	680.04	680.09	0.004	0.96	32	21.54	0.23	681.09
main	0	-25	100 YR Dev	31.4	677.85	679.97	680.06	0.010	1.30	24	17.10	0.33	681.06
main	0	-36	100 YR Dev	31.4	677.50	679.71	679.90	0.020	1.93	16	12.27	0.47	680.90

Appendix D - MUSIC output

MUSIC Output
Source nodes

Location	Comm-Roads	Comm-Roofs	Comm-Other	Comm-Roads WQP	Comm-Roofs WQP	Comm-Other WQP	Ind-Roads
ID	2	3	4	9	10	11	15
Total Area (ha)	0.45	0.45	0.1	0.45	0.45	0.1	1
Area Impervious (ha)	0.45	0.45	0	0.45	0.45	0	1
Area Pervious (ha)	0	0	0.1	0	0	0.1	0
Field Capacity (mm)	80	80	40	80	80	40	80
Pervious Area Infiltration Capacity coefficient - a	200	200	100	200	200	100	200
Pervious Area Infiltration Capacity exponent - b	1	1	1	1	1	1	1
Impervious Area Rainfall Threshold (mm/day)	1	1	1	1	1	1	1
Pervious Area Soil Storage Capacity (mm)	120	120	60	120	120	60	120
Pervious Area Soil Initial Storage (% of Capacity)	30	30	30	30	30	30	30
Groundwater Initial Depth (mm)	10	10	10	10	10	10	10
Groundwater Daily Recharge Rate (%)	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Groundwater Daily Baseflow Rate (%)	5	5	5	5	5	5	5
Groundwater Daily Deep Seepage Rate (%)	0	0	0	0	0	0	0
Stormflow Total Suspended Solids Mean (log mg/L)	2.38	1.55	2.2	2.38	1.55	2.2	2.38
Stormflow Total Suspended Solids Standard Deviation (log mg/L)	0.4	0.39	0.32	0.4	0.39	0.32	0.4
Stormflow Total Suspended Solids Estimation Method	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Stormflow Total Suspended Solids Serial Correlation	0	0	0	0	0	0	0
Stormflow Total Phosphorus Mean (log mg/L)	-0.6	-0.92	-0.45	-0.6	-0.92	-0.45	-0.6
Stormflow Total Phosphorus Standard Deviation (log mg/L)	0.5	0.29	0.25	0.5	0.29	0.25	0.5
Stormflow Total Phosphorus Estimation Method	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Stormflow Total Phosphorus Serial Correlation	0	0	0	0	0	0	0
Stormflow Total Nitrogen Mean (log mg/L)	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Stormflow Total Nitrogen Standard Deviation (log mg/L)	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Stormflow Total Nitrogen Estimation Method	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Stormflow Total Nitrogen Serial Correlation	0	0	0	0	0	0	0
Baseflow Total Suspended Solids Mean (log mg/L)	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Baseflow Total Suspended Solids Standard Deviation (log mg/L)	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Baseflow Total Suspended Solids Estimation Method	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Baseflow Total Suspended Solids Serial Correlation	0	0	0	0	0	0	0
Baseflow Total Phosphorus Mean (log mg/L)	-0.82	-0.82	-0.82	-0.82	-0.82	-0.82	-0.82
Baseflow Total Phosphorus Standard Deviation (log mg/L)	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Baseflow Total Phosphorus Estimation Method	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Baseflow Total Phosphorus Serial Correlation	0	0	0	0	0	0	0
Baseflow Total Nitrogen Mean (log mg/L)	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Baseflow Total Nitrogen Standard Deviation (log mg/L)	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Baseflow Total Nitrogen Estimation Method	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Baseflow Total Nitrogen Serial Correlation	0	0	0	0	0	0	0
OUT - Mean Annual Flow (ML/yr)	2.43	2.43	4.18E-02	2.43	2.43	4.18E-02	5.4
OUT - TSS Mean Annual Load (kg/yr)	583	86.2	6.47	583	86.2	6.47	1.29E+03
OUT - TP Mean Annual Load (kg/yr)	0.61	0.292	1.46E-02	0.61	0.292	1.46E-02	1.36
OUT - TN Mean Annual Load (kg/yr)	6.39	6.39	0.109	6.39	6.39	0.109	14.2
OUT - Gross Pollutant Mean Annual Load (kg/yr)	83.5	83.5	0	83.5	83.5	0	186

MUSIC Output
Treatment Nodes

Location	Bio-Retention	Bio-Retention	Wetland
ID	7	8	14
Node Type	BioRetentionNode	BioRetentionNode	WetlandNode
Lo-flow bypass rate (cum/sec)	0	0	0
Hi-flow bypass rate (cum/sec)	100	100	100
Inlet pond volume			0
Area (sqm)	80	80	200
Extended detention depth (m)	0.4	0.4	0.7
Permanent pool volume (cum)			120
Proportion vegetated			0.5
Equivalent pipe diameter (mm)			60
Overflow weir width (m)	2	2	3
Notional Detention Time (hrs)			5.54
Orifice discharge coefficient			0.6
Weir coefficient	1.7	1.7	1.7
Number of CSTR cells	3	3	5
Total Suspended Solids k (m/yr)	8000	8000	1500
Total Suspended Solids C* (mg/L)	20	20	6
Total Suspended Solids C** (mg/L)			6
Total Phosphorus k (m/yr)	6000	6000	1000
Total Phosphorus C* (mg/L)	0.13	0.13	0.06
Total Phosphorus C** (mg/L)			0.06
Total Nitrogen k (m/yr)	500	500	150
Total Nitrogen C* (mg/L)	1.4	1.4	1
Total Nitrogen C** (mg/L)			1
Threshold hydraulic loading for C** (m/yr)			3500
Extraction for Re-use	Off	Off	Off
Filter area (sqm)	40	40	
Filter depth (m)	0.6	0.6	
Filter median particle diameter (mm)	0.8	0.8	
Saturated hydraulic conductivity (mm/hr)	150	150	
Voids ratio	0.3	0.3	
Seepage Rate (mm/hr)	0	0	0
Evap Loss as proportion of PET			1.5
Depth in metres below the drain pipe	0	0	
IN - Mean Annual Flow (ML/yr)	4.9	5.4	4.9
IN - TSS Mean Annual Load (kg/yr)	338	648	338
IN - TP Mean Annual Load (kg/yr)	0.736	1.09	0.736
IN - TN Mean Annual Load (kg/yr)	11.6	12.8	11.6
IN - Gross Pollutant Mean Annual Load (kg/yr)	167	186	167
OUT - Mean Annual Flow (ML/yr)	4.9	5.4	4.56
OUT - TSS Mean Annual Load (kg/yr)	64.9	114	70.6
OUT - TP Mean Annual Load (kg/yr)	0.344	0.438	0.353
OUT - TN Mean Annual Load (kg/yr)	6.94	7.7	6.87
OUT - Gross Pollutant Mean Annual Load (kg/yr)	0	0	0

Appendix E – Preliminary Stormwater Control Sizes

Raglan Creek Water Quality Control Requirements

Subcatchment ID	Land Use Category	Water Quality Control Option	Catchment Parameters		Per Hectare Requirements			Catchment Requirements			Estimated Footprint
			Total Area	Percentage Impervious	Retention Storage	Permanent Water Volume	Filter Area	Retention Storage	Permanent Water Volume	Filter Area	
			(ha)	*(%)*	*m3/ha*	*m3/ha*	*m2/ha*	*m3*	*m3*	*m2*	*m2*
A	Commercial	Bio-Retention	6.7	90	180.0	*NA*	40	1206	0	268	2412
B	Commercial	Bio-Retention	3.3	90	180.0	*NA*	40	594	0	132	1188
C	Commercial	Bio-Retention	2.1	90	180.0	*NA*	40	378	0	84	756
D	Commercial	WQCP	7.6	90	180.0	*120*	NA	1368	912	NA	2462
E	Industrial	Bio-Retention	3.3	100	200.0	NA	40	660	0	132	1430
Total			**23.0**					**4,206**	**912**	**616**	**8,248**