Bonnyrigg Partnerships

Bonnyrigg Living Communities Project Water Cycle Management

May 2008

Amendment 1

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1 Executive Summary

The Bonnyrigg Living Communities Project (BLCP) proposes to rejuvenate the existing NSW Department of Housing (DOH) Bonnyrigg Housing Estate by creating a new integrated community. The redevelopment creates an opportunity to assess and improve the water cycle management structures of the brownfield site.

Water cycle management opportunities incorporated into the redevelopment include water quality control pond, gross pollutant traps and bioretention devices while quantity control (i.e. flood retardation) is achieved by detention basins and the maximisation of discontinuities in the major / minor drainage system.

The entire spectrum of water management opportunities and constraints has been analysed for the project. The assessment has considered all levels of storm intensity from the low flows created during minor storm events through to the 1 in 100 year Average Recurrence Interval (ARI) storm event. Similarly, the impacts on water cycle management from the individual dwellings to the entire estate have been considered.

RAFTS software was used to evaluate the opportunities and constraints on both the minor/major system and storm event detention. The water cycle management devices proposed for the developed site include a number of detention basins and overland flow paths. Analysis of modelling has demonstrated that the 100yr ARI peak flows do not exceed those of the existing situation. An assessment of velocity-depth products was undertaken to identify areas of elevated flood hazard where an increased pipe design capacity could be used to reduce this risk at the detailed design stage.

HEC-RAS software was used to assess the 1 in 100yr ARI flow depths and extent of inundation in the existing and proposed scenarios. Models were created using *12d* (3-dimensional terrain modelling program) sections to represent both the existing and proposed scenarios. Analysis identified those areas in the proposed development which require elevated finished floor levels from the roadways to achieve sufficient flood protection. Analysis also confirmed that Fairfield City Council's standard 0.3m freeboard is achieved above the 100yr ARI flow levels to the existing private estate and that there is no adverse flooding effects experienced within the estate, upstream or downstream properties.

The proposed water quality treatment train for either the rainwater or stormwater has been assessed through the use of the MUSIC water quality model. The benefits of the rainwater reuse, bio-retention devices (swales and rain gardens) and Gross Pollutants Traps (GPT) have been assessed and incorporated in the future open space facilities. The proposal for numerous treatment facilities has enabled the system to be designed to ensure that the removal rate for pollutants is greater than the current benchmark industry standards.

1.1 Background & Project Understanding

The Bonnyrigg Living Communities Project (BLCP) presents opportunities and constraints for the all stakeholders. These issues include;

- Private and Public property ownership integration requirements for the community, are recognised as being crucial to the project's viability and character. The community's cultural ownership of Bonnyrigg must also be preserved during the entire renewal process.

- Through facility management and community building activities undertaken through the development shall ensure the level of amenity and opportunity for tenants and private owners in Bonnyrigg will be enhanced.
- Value adding in design is recognised and is achieved through continual improvement and application of affordable ESD principals. The use of infrastructure best management practises for water cycle management, water sensitive urban design and sustainable urban design principles with the recognition of whole life costs and the maximisation of community benefits is a foundation to the development's viability.
- Partnership with all stakeholders with particular focus on respecting resident and tenant rights, community service agencies, Fairfield City Council and other statutory authorities is appreciated as being imperative for the achievement of the best outcome for the Bonnyrigg community.
- Through the community consultation and social recognition the development will maintain the cultural diversity of the established Bonnyrigg community.
- The following project outcomes are recognised as being integral to the successful delivery of the renewal:
- Financial - the documentation, management and construction of the project stages must be delivered within the project budget and program.
- Marketing – the dwellings and community facilities must be functionally sound and aesthetically pleasing to ensure the project's commercial viability.
- Environmental – the end product must be in accordance with the legislative and statutory requirements, as well as the principles of ESD.
- Services / Infrastructure – due to the staged nature of the project within an existing community, all new infrastructure works must be carried out without disruption to existing users. To this end, the proposed services works may require lead in or lead out works, temporary diversions, etc. Further, it is recognised that much of the existing infrastructure may be retained with the current layout. The engineering designers will ensure that the proposed works take this into account and ensure that the extent of retained infrastructure is maximised.

The BLCP process must cater for the existing services and residents in the estate. As part of this underlying commitment, the retention of services to all residents is crucial to the development process. The utilisation of temporary services and lead-ins to provide live connections and uninterrupted service to the retained private dwellings or to facilitate the proposed staging, must be addressed as part of the works program.

The following stakeholders are involved in the Bonnyrigg Living Communities Project:

- Bonnyrigg Partnerships;
- Fairfield City Council;
- NSW Department of Housing;
- NSW Department of Planning;
- NSW Roads and Traffic Authority;
- Department of Environment and Conservation;

- Department of Natural Resources;
- NSW Fire Brigade;
- Utility service providers; and
- The local community.

The development works of the overall project will include:

- The demolition of structures, including dwellings, roads and services;
- the construction of a new subdivision including;
- bulk earthworks;
- new streets;
- retention of existing streets;
- stormwater management works;
- utility services;
- public domain improvements including new parks as part of a network of landscaped public open spaces and street trees; and
- a new community facility and improvements.

The Bonnyrigg Living Communities Project is about making the Bonnyrigg public housing estate a great place to live. The project aims to make Bonnyrigg safer and more appealing by:

- improving services and providing residents with better opportunities;
- supporting the local community to build its strengths, skills and overall capacity;
- renewing the housing and public areas and achieving better integration of social and private housing within the community;
- working side by side with Fairfield City Council, the Department has established a strong reputation in the community for its desire to listen to the views of residents; and
- engaging and involving the community in the project is fundamental to the success of the project because it ensures that the issues of importance to the community are recognised and respected.

Since the project was announced, the Department of Housing and Fairfield City Council have conducted over 65 public sessions and activities to find out what the local community thinks about the project and to inform local people about the project.

The emphasis on a partnership approach has also lead to the establishment of advisory groups including the Bonnyrigg Community Reference Group and the Bonnyrigg Network. The Bonnyrigg Residents Group has also provided support.

Through these forums, a number of important messages from the local community continue to shape the project. They provide valuable information to help guide the NSW Government as it takes the next step of choosing a private sector project company for the Bonnyrigg Living Communities Project.

2 Introduction

The Bonnyrigg Living Communities Project (BLCP) proposes to rejuvenate the existing NSW Department of Housing (DOH) Bonnyrigg Housing Estate by creating a new integrated community. The project will provide approximately 2,350 dwellings to both new and existing residents, providing a safer and more aesthetically pleasing environment for the community.

The redevelopment creates an opportunity to assess and improve the water cycle management structures of the brown field site.

This report will detail the procedures used and results obtained from analysis undertaken in developing a water cycle management plan that supports the Major Project approval for the BLCP.

The purpose of the investigation is to:

- Undertake a hydrologic, hydraulic and water quality assessment of the stormwater discharged from the site to demonstrate compliance with statutory requirements;
- Identify appropriate measures to achieve the water quality and quantity statutory requirements and determine the location and land area required to implement the recommendations; and
- Identify existing localised flood 'hot spots' and provide recommendations to rectify the situation.

The following analyses have taken into consideration the economical, engineering, environmental and social aspects of the works. Particular emphasis has been placed on protecting the environment and enhancing the bio-diversity of the receiving water bodies and environment by implementing water sensitive urban design and best management practices.

3 The Physical Environment

3.1 The Site

The BLCP site area is approximately 80 hectares in size and is located 30 km west of the Sydney CBD. It is adjacent to the suburbs of Edensor Park, St Johns Park, Bonnyrigg Heights and Mt Pritchard and lies within the Fairfield municipally. The master plan area is defined by Edensor Road to the north, Elizabeth Drive and Cabramatta Road to the south, Humphries Road to the east and Bonnyrigg Avenue to the west.

The subject site is best categorised by 3 primary catchment divisions; western, central (which also incorporate areas outside the site boundary of the BLCP) and eastern catchments, which occupy a combined area of about 90 Ha. The two smaller catchments (western and eastern) occupy approximately 4 and 19 hectares respectively while the larger, central catchment contributes to the remaining area.

The Western catchment grades towards Bonnyrigg Avenue from the a ridgeline (which runs in a north-south orientation) at grades of 3 – 5%. Runoff is collected via the low flow pipe system, and also makes use of the spaces and road corridors that direct flow out of the catchment.

The Central catchment of the master plan area is defined by the two natural ridgelines that run through the development site. Typically the catchment area grades towards a central reserve which runs south to north through the middle of the existing site. Grades within the catchment vary between 1% and 5%. The central reserve carries both minor and major events via low flow pipes and overload flow paths.

The Eastern catchment falls to the east with grades varying at 2 - 6%, until it reaches Humphries Road (which runs parallel to the ridgeline). Both minor flow pipes and overland flow paths within roadways then direct flow towards Green Valley Creek which runs north east of the development.

The topography of the existing site typically consists of New South Wales Department of Housing (DOH) dwellings, some medium density housing and open space areas, which are scattered throughout the site. The upgrade of the area into a new community is consequently classified as a “brown field” development.

The existing site also has a number of features that adjoin or are found within the development area. These including a mix of low and high density residential housing, a shopping centre, schools, temples, an electrical substation, a petrol station, a Croatian soccer club, a number of privately owned properties and a large private estate found in the centre of the BLCP site.

In terms of the geology of the site, the area sits on Bringelly Shale comprising of carbonaceous claystone, claystone, laminate, fine to medium grained lithic sandstone, rare coal and tuff. Sub surface strata encountered during intrusive investigations comprised of a variety of clay samples suggesting, given the nature of the materials and the site location, that the sub surface strata is likely to be residual soil that developed over Bringelly Shale. Geotechnical investigations conducted by Parsons Brinckerhoff indicate there was no evidence of contamination within the site and no free groundwater was encountered (Parsons Brinckerhoff 2005).

3.2 Data

3.2.1 Topography

Topographic information for the catchments was obtained from aerial contours and imagery undertaken by Sinclair Knight Merz Pty Ltd. Portions of the site were also subject to detailed survey by Vince Morgan Surveyors Pty. Ltd. in 2007.

3.2.2 Proposed Layout

The proposed road (including cross sections), lot and open spaces layout have been taken from the proposed master plan documentation.

3.2.3 Rainfall Data

3.2.3.1 Rainfall Records

The water quality analysis requires historical rainfall data recorded, by a pluviograph station. The closest available pluviograph recording station is located within the municipality of Liverpool, situated some 7km away from the development site. Historical rainfall records for the area were obtained from the Bureau of Meteorology from the following station:

Table 3.1 – Rainfall Data for Music

Station No.	Location	Records	Data Interval
067035	Liverpool	Feb 1962 – Feb 1998	Daily

3.2.3.2 Intensity-Frequency-Duration (IFD)

The design IFD data for the site was obtained from Fairfield Councils' Stormwater Drainage Policy (2002). Probable Maximum Precipitation (PMP) was derived using the Bureau of Meteorology's Generalised Short Duration Method (2003).

Summaries of the rainfall intensities derived are shown below in Tables 3.2 and 3.3

Table 3.2 – Bonnyrigg Rainfall Intensities (mm/hr)

Storm Duration (minutes)	Annual Recurrence Interval (years)		
	5	20	100
10	102.28	130.91	168.11
15	85.52	109.22	140.04
20	74.54	95.08	121.81
25	67.00	86.00	110.00
30	60.55	77.20	98.87
45	48.44	61.83	79.25
60	41.03	52.45	67.31
90	32.17	41.26	53.08
120	26.95	34.65	44.68
180	20.91	27.00	34.94
540	10.48	13.73	18.01

Table 3.3 – PMP Estimate (mm/hr)

PMP Values (mm)	
Duration (minutes)	Intensity (mm/hr)
15	680
30	480
45	400
60	350
90	300
120	260
150	232
180	213
240	180
300	160
360	140

3.2.4 Existing Utility Services

Existing utility service locations were derived from DOH infrastructure records and site survey information for gas, electricity, sewer, stormwater, telecommunications and water.

4 Design Controls

4.1 Australian Rainfall and Runoff – Volume 1 (2001)

Prepared by Engineers Australia, Australian Rainfall and Runoff – A Guide to Flood Estimation was written to “provide Australian designers with the best available information on design flood estimation”. It contains procedures for estimating stormwater runoff for a range of catchments and rainfall events and design methods for urban stormwater drainage systems.

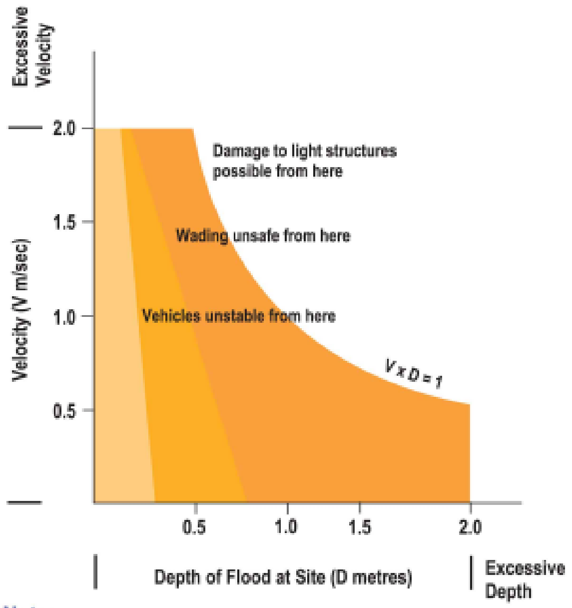
According to the document, good water management Master Planning should take into account:

- Hydrological and hydraulic processes;
- land capabilities;
- present and future land uses;
- public attitudes and concerns;
- environmental matters;
- costs and finances; and
- legal obligations and other aspects.

4.2 NSW Floodplain Development Manual (April 2005)

The NSW Government's Floodplain Development Manual – the Management of Flood Liable Land (2005) is concerned with the management of the consequences of flooding as they relate to the human occupation of urban and rural developments. The manual outlines the floodplain risk management process and assigns roles and responsibilities for the various stakeholders.

The manual applies to the development, in particular in Appendix L – Hydraulic and Hazard Categorisation for ensuring safe overland flow paths are provided (see Figure L1 below).



Notes

1. At velocities in excess of 2.0 m/s, the stability of foundations and poles can be affected by scour. Also, grass and earth surfaces begin to scour and can become rough and unstable
2. The velocity of floodwaters passing between buildings can produce a hazard, which may not be apparent if only the average velocity is considered. For instance, the velocity of floodwaters in a model test has risen from an average of 1 m/sec to 3 m/sec between houses.
3. Vehicle instability is initially by buoyancy.
4. At floodwater depths in excess of 2.0 meters and even at low velocities, there can be damage to light-framed buildings from water pressure, flotation and debris impact.

Derived from laboratory testing and flood conditions which caused damage.

FIGURE L1 - Velocity & Depth Relationships

Source: NSW Floodplain Development Manual, 2005 (Dept. of Infrastructure Planning & Natural Resources)

4.3 NSW Department of Environment and Climate Change

The NSW Department of Environment and Climate Change (DECC), formerly the NSW Environment Protection Authority (EPA) has developed a set of guidelines known as the Managing Urban Stormwater (MUS) series. The set of guidelines includes:

- Managing Urban Stormwater: Council Handbook
- Managing Urban Stormwater: Source Control
- Managing Urban Stormwater: Soils & Construction

4.3.1 Managing Urban Stormwater: Environmental Targets

The NSW Department of Environment and Climate Change (DECC) encourages the principle of no net deterioration of water quality. Under its former name, the NSWEPA, the DECC published Managing Urban Stormwater: Environmental Targets, outlines recommended environmental targets for stormwater management in new urban developments. Among its recommendations are the following stormwater treatment objectives:

Table 4.1– Stormwater Treatment Objectives for New Urban Areas from the Managing Urban Stormwater: Environmental Targets

Pollutant	Treatment Objective
Gross Pollutant	90% retention of the annual average load for particles 0.5mm or less
Suspended Solids	85% retention of the annual average load
Total Phosphorous	65% retention of the annual average load
Total Nitrogen	45% retention of the annual average load

4.3.2 Managing Urban Stormwater: Source Control

The DECC guide, Managing Urban Stormwater: Source Control recommends the control of stormwater pollution at the source, rather than more traditional “end of line” systems that are unsightly and require high levels of ongoing maintenance. In this document, Water Sensitive Urban Design (WSUD) is described as “minimising the impacts of development on the total water cycle and maximising the multiple benefits of a stormwater system”. It lists the main objectives of WSUD as:

- preservation of existing topographic and natural features;
- protection of surface water and groundwater sources;
- integration of public open space with stormwater drainage corridors, maximising public access; and
- passive recreational activities and visual amenity.

The broad principles of WSUD are listed as:

- minimising impervious area;
- minimising use of formal drainage systems (eg. pipes);
- encouraging infiltration (where appropriate); and

- encouraging stormwater re-use.

4.3.3 Managing Urban Stormwater: Soils and Construction

Managing Urban Stormwater – Soils and Construction (4th edition, March 2004) are guidelines produced by the NSW Department of Housing to help mitigate the impacts of land disturbance activities on landforms and receiving waters by focusing on the removal of suspended solids in stormwater runoff from construction sites.

According to the guide, effective soil and water management during construction involves the following key principles:

- Assess the soil and water implications of development at the subdivision or site planning stage (including salinity and acid sulphate soils);
- plan for erosion and sediment control concurrently with engineering design and before the land disturbance begins;
- minimise the area of soil disturbed;
- conserve topsoil for subsequent rehabilitation/revegetation;
- control surface runoff from upstream areas, as well as through the development site;
- rehabilitate disturbed lands as quickly as possible; and
- maintain soil and water management measures appropriately during, and after the construction phase until the disturbed land is fully stabilised.

4.4 WSROC Salinity Code of Practice

The Western Sydney Salinity Code of Practice was produced by the Western Sydney Regional Organisation of Councils (WSROC) to provide information on the current and best management practice for salinity management in the Western Sydney region. The document illustrates the methods used for assessing the salinity risk, recommended investigation methods and best management practices for managing salinity.

The guide lists the following key principles for salinity management:

- maintain natural water balance;
- maintain good drainage;
- avoid disturbance or exposure of sensitive soils;
- retain or increase vegetation in strategic areas; and
- implement building controls and/or engineering responses where appropriate.

4.5 BASIX

A water re-use assessment under the Building and Sustainability Index (BASIX) is outside of the scope of this report. Refer to the separate BASIX compliance assessment undertaken by Advanced Environmental as part of this submission for details.

4.6 ANZECC Water Quality Guidelines

The Australian and New Zealand Environment and Conservation Council (ANZECC) Paper No. 4 - Australian and New Zealand Guidelines for Fresh and Marine Water Quality (October 2000) includes a series of default pollutant concentrations that “trigger” the need to implement strategies to improve the water quality of the discharge. These trigger values have been set to highlight the risk of adverse effects due to excess nutrients - eutrophication, low dissolved oxygen and pH in a number of varying ecosystems. They should be used in lieu of site-specific data.

The relevant trigger values for this project (Sydney Basin) include:

- Total Phosphorous 0.025mg/L
- Total Nitrogen 0.35mg/L

4.7 Fairfield City Wide Development Control Plan 2006

An integral part of the Master Planning process for the BLCP, the Fairfield City Wide Development Control Plan 2006, provides the necessary controls for the redevelopment of the site. Particular water management requirements include:

- compliance with Fairfield City Councils Stormwater Drainage Policy 2002;
- compliance with the demands of the BASIX system;
- compliance with Fairfield City Councils On-Site Urban Areas Handbook for OSD requirements; and
- adoption of the principles of the FCWDCP Flood Risk Management Policy 2006 (including a Floodplain Risk Management Plan).

4.8 Fairfield City Council Stormwater Drainage Policy 2002

Council’s Stormwater Drainage Policy 2002 sets out their requirements for the design of stormwater drainage for urban and rural areas. The Stormwater Drainage Policy outlines the broad objectives of the policy regarding:

- Providing clear guidelines for the requirements of stormwater drainage and civil works.
- Ensuring that developments meet all relevant standards for the disposal of stormwater and that developments do not increase the hazard to persons or property.
- Catering for minor and major stormwater systems.

The policy also provides detailed requirements for the hydrologic and hydraulic design and analyses of the proposed water management system including standard calculation factors and drawings.

4.9 Environmental Management Plan for Fairfield City 2006 - 2016

The Environmental Management Plan (EMP) for Fairfield City 2006 – 2016, is a strategic plan containing a series of adopted targets and indicators that will be used to measure how well the Council is reaching its environmental targets and visions.

The plan provides a standard to which proposed actions should be tested and measured, as well as identifying actions that will help achieve these adopted targets. The EMP has been designed to contain targets, which focus on a ten-year timeframe, to be reviewed after five years.

The EMP identifies a number of environmental issues and provides targets for the Council to work towards. These issues, related more specifically to this Water Cycle report include:

- The design of open space areas;
- Permeable surfaces;
- Reducing financial damage from flooding;
- Rehabilitation of creek systems to their natural conditions; and
- Providing useable waterways.

4.10 Fairfield City Council WSUD Strategy

The Fairfield City Council Water Sensitive Urban Design (WSUD) report details a strategy and technical guidelines that facilitate the practical implementation of WSUD principles into Council policies and activities.

The report outlines a strategy tailored for Fairfield, involving implementing planning and management practices for sustainable water management within the local government area. Step by step guidelines and processes are described and are assisted by practical examples in the form of Case Studies. These studies provide examples of how WSUD can be integrated into typical Council projects, with the particular example of residential water management being focused on for this report.

The WSUD strategy also contains a number of fact sheets containing information regarding various water management strategies. The fact sheets offer design considerations, maintenance requirements and references for further information on the topic. Those topics within the WSUD relating to water cycle management include:

- Vegetation Swales and Buffer Strips;
- Bio-retention Systems;
- Gross Pollutant Traps; and
- Ponds.

5 Water Management Options

5.1 Water Quantity Management

5.1.1 Major/Minor Drainage System

The major/minor approach to street drainage is the recognised drainage concept for urban catchments within the Fairfield City Council local government area.

"The minor system is the gutter and pipe network capable of carrying runoff from minor storms. The major system comprises the many planned and unplanned drainage routes which convey runoff from major storm to trunk drains, sometimes causing damage along the way." [1] The major system also exists to cater for minor system failures.

"The overall aim of the major/minor approach is to ensure that hazardous situations do not arise on streets and footpaths, and that all buildings in urban areas are protected against floodwaters."[1]

5.1.2 Detention Basins

Detention basins temporarily detain stormwater runoff from urbanised catchments with the aim of reducing and attenuating the peak discharge at the outlet to reduce the risk of flooding to downstream lands as a result of a development. The storage volume may be above or below ground while discharges are accurately controlled via an orifice or throttled outlet pipe.

5.1.3 Stormwater Re-use

Negotiations are currently in progress for the proposed use of reticulated water mains to provide recycled water throughout the site. Should the use of this reticulated-recycled water system not proceed, an alternative source of recycled water will be ascertained from the nearby Sewerage Treatment Plant.

The NSW Department of Environment and Climate Change (DECC) has a number of statutory requirements regarding the reuse of stormwater. The DECC requires the following;

- As the site may be extracting water that would normally otherwise flow into the surrounding ecosystem, this loss of water must not disrupt or have adverse effects on downstream aquatic ecosystems;
- Should contamination occur, the collection of site water must be able to be stopped; and
- Recycled water must be treated to NSW Recycled Water Coordination Committee (RWCC) standards to achieve an acceptable quality.

F

[1] Australian Rainfall and Runoff 2001

The above requirements must be met when implementing a recycled water system on site, however if the recycled water was sourced from the nearby Sewerage Treatment Plant then the vast majority of requirements would be met by the service provider.

In consideration of both recycled reticulation options, a number of social, economic and environmental risks were evaluated. Whilst a recycled stormwater system may appear to be more desirable by some over conventional potable water reticulation, Table 5.1 demonstrates that in a majority of circumstances Sewerage Treatment Plant (STP) recycled water would be more desirable. Economically STP recycled water would be the most appropriate option, as design, construction and ongoing maintenance costs are minimal in comparison to on-site water treatment and reticulation facilities.

Table 5.1 – Potential Option Evaluation Considerations

Area	Consideration	Rainwater Tanks	Sewerage Treatment Plant recycled water
Social	Health and Safety	More efficient	Less efficient
	Aesthetic impacts	Size of tanks and treatment facilities would impede on the natural landscape	Minimal impact to visible landscape
	Improvements to community areas	As efficient	As efficient
Economic	Project costs (Design, construction, investigations, fees etc)	Much larger design and construction costs mainly due to tanks, retention and treatment facilities	Much less as majority of design and construction costs are associated with reticulation
	Ongoing costs (maintenance, power, monitoring	Very high maintenance and monitoring costs, typically 5-30% per annum of construction cost *	Much less as all maintenance, power and monitoring costs are included in rate provided by supplier.
Environmental	Mains Consumption	No mains water consumption	No mains water consumption
	Aquatic Ecosystem	Potential to disrupt downstream ecosystem if over extraction occurs	Minimal to no effect on site aquatic life.
	Greenhouse gas production	Ongoing Power generation associated with pumps, etc * greenhouse gases associated with extra construction	Only associated with construction of pipe reticulation.
	Groundwater	Minimal effect	Minimal effect

Department of Environment and Climate Change: Managing Urban Stormwater: Harvest and reuse; Maintenance costs

5.1.4 Effective Impervious Area

To obtain a more thorough analysis of how impervious area affects the drainage of the site, the catchment can be examined to obtain an 'effective impervious' area calculation.

Effective impervious area refers to the percentage of the total impervious area that is effective in directly connecting runoff from the sub-catchment to streams through pipe networks or other drainage systems.

The Fairfield City Council Environmental Management Plan 2006 – 2016 provides no quantifiable target for effective impervious areas within Fairfield municipal shire. An overland flow study conducted in 2004 for Fairfield City Council concluded that 41.2% of the study area (Prospect Creek catchment) was impervious. It is imperative that the post developed hydrology remains as close as possible to the pre-developed hydrology.

Due to a number of factors including the sites zoning classification, low infiltration and the relative imperviousness of the soil, an impervious value of approximately 76% is expected for the proposed development, which is a reasonable amount of impervious with thein the context of our site development. In an effort to reduce the effective impervious areas within the site, we have tried to add as many discontinuities as possible to aid in the retention of rainfall and reduce the percentage of impervious surfaces.

5.2 Water Quality Management

5.2.1 Infiltration Devices

Consisting of a gravel bed and usually greater than 600mm depth, an infiltration device primarily removes sediments and attached pollutants (including nutrients, metals and other soluble pollutants) by filtration. They may be installed as conventional below ground trenches backfilled with filter media or beneath permeable paving and are designed to capture and treat the "first flush" volume of a rainfall event.

5.2.2 Bio-Retention Systems

Bio-retention systems are similar to infiltration devices, but typically contain an extended detention zone above the gravel bed in the order of 100-300mm in depth and can contain water tolerant plant species to facilitate additional nutrient removal. Sediments and attached pollutants (including nutrients, metals and other soluble pollutants) are removed by filtration through the vegetative surface layer and filter media below.

They are often constructed as linear swales, but may also be designed as larger "rain gardens" and are designed to capture and treat the first flush volume.

5.2.2.1 Inspection and Monitoring

The Upper Parramatta River Catchment Trust (UPRCT) provides appropriate guidelines for inspection and monitoring of bio-retention systems

"Following construction, bioretention systems should be inspected every 1 to 3 months (or after each major rainfall event) for the initial vegetation establishment period to determine whether or not the bioretention zone requires maintenance or the media requires replacement. The following critical items should be monitored:

- ponding, clogging and blockage of the filter media;
- establishment of desired vegetation/plants and density; and
- blockage of the outlet from the bioretention system.

After the initial establishment period (typically 1 to 2 years), inspections may be extended to the frequencies shown in Maintenance and Inspection Checklist for bioretention systems." [2]

5.2.2.2 Maintenance

UPRCT provides guidelines for the maintenance of bio-retention systems and includes a recommended checklist for inspection and maintenance.

"If the bioretention system is not maintained frequently, the entire filter media may need to be replaced due to clogging of the media material with fine particles. This can result in frequent maintenance being more cost effective in the long-term. The following maintenance activities will be required with inspection frequencies shown in the Maintenance and Inspection Checklist:

- maintenance of flow to and through the system;
- maintaining the surface vegetation;
- preventing undesired overgrowth vegetation/weeds from taking over the area;
- removal of accumulated sediments; and
- debris removal." [2]

A copy of UPRCT's Bioretention System Maintenance and Inspection Checklist is located in *(Appendix F)*

5.2.3 Vegetative Filter Strip

Vegetative filter strips are relatively flat, open landscaped areas upstream of stormwater inlets that promote "sheet flows" reducing velocities and removing litter, vegetative matter and sediments by filtration through the vegetation. This filtration process also removes some nutrient and other pollutants that are bound onto sediment particles.

5.2.4 Gross Pollutant Traps

"Gross Pollutant Trap" is a term applied to either in-situ, or proprietary units that remove litter, vegetative matter and sediment. Although the numerous units fall under the under the one umbrella of gross pollutant traps, the actual mechanics of the different units vary, as do the achievable pollutant removal rates. GPTs come in a range of sizes, with the larger units able to effectively treat large catchment areas and high flow rates. They are usually sized based on their maximum treatable flow being equal to, or greater than the 3-month Annual Recurrence Interval (ARI) storm event (typically 50% of the 1-year ARI storm event) of the upstream catchment.

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[2] Upper Parramatta River Catchment Trust (May 2004)

Table 5.2 – Typical Pollution Removal Rates of Water Quality Treatment Devices

Device	Coarse Sediment	Fine Sediment	Free Oil & Grease	Nutrients	Metals
Infiltration Devices*	50-80%	30-50%	30-50%	30-50%	30-50%
Bio-Retention Systems*	80-100%	30-50%	30-50%	30-50%	30-50%
Vegetative Filter Strips	50-80%	10-50%	10-50%	10-50%	10-50%
Pit Inserts	80-100%	40-60%	40-60%	40-60%	40-60%
Gross Pollutant Traps	60-90%	10-50%	-	10-50%	10-50%

* Assumes pre-treatment of stormwater runoff to remove gross pollutants and to minimise ongoing maintenance.

Source: WSUD – *Technical Guidelines for Western Sydney* (2004)

In January of 2004, the Cooperative Research Centre for Catchment Hydrology released Structural Stormwater Quality BMP Cost – Size Relationship Information from the Literature, which compared the capital and ongoing costs of various water quality treatment devices. Table 5.2, below summarises the findings, which are nominated in cost per hectare of treated area unless noted otherwise.

Table 5.3 – Typical Costs of Water Quality Treatment Devices

Device	Capital Cost	Maintenance Cost (0-2yrs)	Maintenance Cost (+2yrs)	Land Take
Constructed Wetlands	$12,000 – $18,000	$250 - $400	$150 - $250	Large
Infiltration Devices	$100 - $140 [1]	$5 - $10 [1]	$5 - $10 [1]	Med. – Large
Bio-Retention Systems	$150 - $200 [1]	$2 - $5 [1]	$2 - $5 [1]	Med.
Vegetative Filter Strips	$20 - $50 [2]	$1 - $5 [2]	$1 - $5 [2]	Med.
Pit Inserts	$500 - $900 [3]	$200 - $300 [3]	$200 - $300 [3]	None
Gross Pollutant Traps	$4,500 – $7,000	$350 - $550	$350 - $550	Small

[1] Cost nominated is per linear metre of device (based on 1m wide x 1m deep) and does not include pre-treatment devices.
[2] Cost nominated is per square metre of area (costs vary, depending on type of vegetation selected)
[3] Cost nominated is per Insert.

6 Water Quantity Modelling

The assessment of water quantity was completed using both hydrological and hydraulic modelling. Here, computer based models of the existing and proposed catchments were constructed using *XP-RAFTS*. Design storms were applied to these models to give estimates of the 100-year ARI discharges, which are examined in the following sections. Assessment of these models then allowed the determination of basin sizes and requirements.

As an overall check, the existing 100-year ARI results from *XP-RAFTS* (at the outlet) were then compared with empirical estimation techniques (Rational Method) as recommended by the Australian Rainfall and Runoff (I.E Aust, 2001).

Computer based, one-dimensional, steady flow hydraulic models were then constructed to represent both the proposed and the existing networks using *HEC-RAS*. The 100-year ARI discharges from the hydraulic model were then input into the hydraulic model to determine the respective flood levels and extent.

The probable maximum precipitation (PMP) was estimated using the Bureau of Meteorology's Generalised Short Duration Method (2003). Using a similar process to the 100-year, probable maximum flows (PMF) were estimated in *XP-RAFTS*, with flood levels and extent determined in *HEC-RAS*.

6.1 Model Parameters

The user data inputs required by *XP-RAFTS* include catchment areas and slopes, pervious and impervious areas, IFD rainfall statistics and hydrological losses. Guidelines for determining these parameters are provided in the Australian Rainfall and Runoff (I.E Aust, 1987) and are broken up as follows:

6.1.1 Slopes

In accordance with ARR (I.E Aust, 2001), the slopes of the sub-catchments were generated using "equal area" method. The slopes for each of the catchments are listed in Tables B.1 to B.6 in Appendix B.

Proposed sub-catchment slopes for links and catchments were derived from the proposed master plan layout and grading (as at 31 Aug 2007), while the existing slopes were developed from aerial contours.

6.1.2 Impervious and Catchment areas

The extent of impervious area within the existing catchment was digitally measured from aerial imagery. Impervious and catchment areas for each of the sub-catchments are included in Tables B.1 to B.6 in Appendix B

Similarly, the impervious areas within the proposed catchments were based upon the master plan density sketches supplied by Urbis JHD, urban designers.

Fraction impervious values were based on estimated values shown in Table 6.1, which are considered to be acceptable industry values in engineering practice. These values were derived from an unpublished UPRCT report and are, in our opinion reasonable estimates from our site inspections.

Table 6.1 – Percentage Impervious Areas for Various Land Uses

Land Use	Adopted % Impervious
Roads and Industrial Areas	95%
Medium Density Housing	80%
Residential Housing	75%
Parks/Grass Land	5%

Source: Derived from UPRCT estimates

6.1.3 Intensity-Frequency-Duration (IFD)

Rainfall intensities were used as described in Section 3.2

6.1.4 Rainfall Losses

The loss model adopted to estimate rainfall excess in the development of design flow hydrographs was the Initial Loss-Continuing Loss model.

As advised by Council, (e-mail correspondence on the 9th August 2007), previous studies conducted by council in the area (Green Valley Creek, Clear Paddock Creek, and Orphan Creek) incorporated the following parameters:

- an IL of 15mm and a CL of 1.5mm/hr for pervious areas; and
- an IL of 1.5mm and CL of 0mm/hr for impervious areas.

6.1.5 Land Use

The land use within the existing catchments is considered to be predominantly urban. This type of land use does have some effect on the runoff by providing some "resistance" to the flow. The effect is simulated in *XP-RAFTS* by a storage delay coefficient called "PERN". The following typical values are in accordance with the *RAFTS* reference manual.

Table 6.2 – Adopted PERN 'n' values

Catchment Type	PERN 'n'
Developed (Impervious Portion)	0.015
Developed (Pervious Portion)	0.025
Undeveloped (Rural Pastures)	0.05

In accordance with Table 6.2, a PERN value of 0.025 was applied for all sub catchments.

6.1.6 Hydraulic Roughness Parameters

Hydraulic roughness parameters for the overland flow paths were estimated based upon site visits and were applied in accordance with those recommended in ARR. A Manning's roughness parameter of 0.04 was applied for all grassed areas (including verges) while 0.013 was applied for all road pavements. These also satisfy parameters set out in the Council guidelines (Stormwater Policy, 2002).

6.1.7 B-Multiplier

The b-multiplier (*b*) used in *RAFTS* is usually determined by calibration against recorded floods. As discussed in Section 6.1.8, the value for *b* is then used in the standard equation $S=bQ^n$. Previous council *RAFTS* models (e-mail correspondence 9th Aug 2007) in the area have incorporated a b-multiplier of 1.0. This value will consequently be used in this study.

6.1.8 *RAFTS* Catchments

Hydrologic modelling was carried out using the *XP-RAFTS* software package (Version 6.5, XP Software, 2001). *RAFTS* is a non-linear runoff routing model that generates runoff hydrographs from rainfall.

A catchment is divided into a network of sub-catchments joined by links. The links represent natural watercourses, artificial channels, or pipes. The model divides each sub-catchment into 10 sub-areas. A sub-area is treated as a cascading non-linear storage governed by the relationship $S=bQ^n$. The coefficient ‘b’ is calculated from catchment parameters but can be calibrated to fit observed rainfall and streamflow data.

Rainfall is applied to each sub-area. Losses (representing infiltration, interception, etc) are subtracted from the rainfall and the excess is then converted into an instantaneous flow. This instantaneous flow is then routed through the sub-area storages to develop local sub-catchment hydrographs. Total flow hydrographs at various nodes in the drainage network are calculated by combining local hydrographs. Hydrographs are transported through the drainage network by time lagging or channel routing. Hydrographs may also be routed through the storage basins such as dams or detention basins.

6.1.9 Existing Catchment

The existing catchment was defined from aerial contours and is divided into 3 main catchments:

- *Western catchment,* bounded by Bonnyrigg Avenue and the western ridgeline. The overland flow path drains towards the corner of Elizabeth Drive and Bonnyrigg Avenue;
- *Eastern catchment*, overland flow paths grade towards Humphries Road and eventually onto Green Valley Creek; and
- *Central catchment*, bounded by both the western and eastern ridgelines, overland flow paths allow runoff to be carried to the centralised overland flowpath, which runs South to North and bisects the proposed site. This catchment uses the existing stormwater infrastructure (both Council and DOH systems) as a low flow pipe to drain through the centre of site to the existing basin located at Tarlington Reserve and eventually downstream until flow reaches the 5 creek system.

The 3 primary catchments were further bisected into 58 sub catchments, 3 in the western catchment, 15 in the eastern and 40 in the central catchment. These sub catchments ranged in size from 0.4 to 12.7 hectares (Refer to Tables B.1 to B.6 in Appendix B). Each of these sub-catchments naturally adjoin the system at various points with the central catchment exiting the subject site and across Edensor Road, the eastern draining towards and across Humphries Road and the western catchment exiting at Bonnyrigg Avenue.

The subject site is 79.55 hectares, but also has contributing upstream areas, which give a total catchment size of 113.2 hectares.

Figure W03 in Appendix A shows the existing catchment divisions, while Figures B.1 to Figure B.6 in Appendix B represent the existing networks within *RAFTS*. The division of catchments was based upon the overland flow paths, using the existing road and drainage networks as a guide. Overland flow paths generally match those specified by council. Some consideration of the proposed catchments was taken into account when developing the existing catchment areas.

In the Central catchment, the existing stormwater infrastructure in the central reserve acts as a low flow pipe. It's size ranges from a diameter of 625mm near Cabramatta Road, to a 1500mm diameter pipe at its intersection with Edensor Road. This pipe allows for minor events to be transported while major events will travel as overland flow.

Detailed survey and site visits indicate that Tarlington Reserve acts as a basin. Discussions with Council (meeting 24th August) indicated that while the area may not have been designed as a basin, it does still function as one.

Both the eastern and western catchments do not appear to have existing detention structures. However, they do appear to have stormwater infrastructure in place to carry low flows to their respective outlets.

Most of the links between nodes were modelled as channel routing links and are representative of the existing road profiles and low flow pipes. Sections were input from 12d as “HEC-2” and Manning's ‘n’ values were estimated from site visits.

Dummy nodes were used where two or more existing sub catchments joined, which allowed both inflow and outflow hydrographs to be assessed. Diversion links with (no lag time) were used to combine these inflow hydrographs.

6.1.10 Proposed Catchment

The proposed BLCP development area is also divided into 3 main catchments (similar to existing).

In developing the post-developed *RAFTS* models, the overall catchment was subdivided into 70 sub-catchments, 4 from the western, 17 from the eastern and 49 from the central catchment. These sub-catchments ranged in size from 0.2 to 12.7 hectares. Each sub-catchment was determined from the proposed Master Plan road layout and site grading, while existing low flow pipes were retained wherever possible.

Figure W04 in Appendix A shows the sub-catchment division while Figures B.1 to B.6 in Appendix B illustrate the proposed *RAFTS* network.

As this project is primarily a brown field development, some catchment areas remain similar to existing with multiple roads and general catchment divisions remaining, retention of stormwater infrastructure and the like. While other regions within the catchments however have different layouts and increased housing density.

The area dedicated to Tarlington Reserve is reduced in the proposed scenario (in the vicinity of the soccer fields). Here a new entrance road is proposed on the Eastern side of the park to connect the new estate to Edensor Road. Node 5.1 is representative of the proposed basin which is discussed in Section 6.2.2.

Most of the links were modelled as channel routing links and are representative of the road sections in the proposed masterplan. Where considered practical, existing low flow pipes were maintained in the channel routing links while new pipes were also estimated / included along new roads where required.

A quality control pond is proposed in the new development adjacent to Edensor Road (Node P1.2). Conservatively this was not included in the *RAFTS* modelling as a basin (assumed steady water surface).

Catchment areas, slopes and percentage impervious portions are tabulated in Tables B.1 to B.6 Appendix B.

6.2 Management Strategies

6.2.1 Major/Minor System

The proposed drainage system will be major/minor system. The (minor) piped drainage system is to be designed to control nuisance flooding and enable effective stormwater management for the site. Council's standard requires that the minor system be designed for a minimum 5 year ARI.

The major drainage system incorporates overland flow routes through proposed roads and has been assessed against the 100 year ARI design storm event, with general safety and flooding issues being addressed for events in excess of the 100 year ARI storm. If the major system cannot meet the safety and flooding criteria, the capacity of the minor system will need to be increased.

Inlet and culvert blockages were considered in the modelling with a 50% blockage factor across all culverts being applied.

In order to assess the adequacy and safety of the major drainage system, channel routing links were used in *RAFTS* to model flow paths along roads and pathways, while lagging links were used elsewhere. Although negligible attenuation is expected along the roadways, channel routing was used in order to assess flow depths and velocities in major storm events. The channel cross-sections were based on the proposed road cross-sections in the Master Plan. Low flow pipes in channel links were based off 5year ARI and were assumed to operate at 100% during assessment. The proposed pipe drainage system may be designed with greater capacity than this if required. The capacity of the existing drainage system needs to be assessed at the detailed design stage.

6.2.2 Detention Basins

Detention Basins were included in the hydrologic model to ensure that the development does not increase downstream flows, which could potentially have adverse impacts on downstream properties. All basins were designed to be a maximum of 1.2 metres deep to avoid safety fencing and thus retain the recreational value of the open spaces that they occupy. All basins were modelled with a linear stage-storage relationship and used the default discharge equations within *RAFTS*. More detailed modelling of the basins can be undertaken at the design stage when sufficient details are available to derive more accurate stage-storage and stage-discharge relationships.

The volumes required were refined by manual iteration until results showed that flows from the post-developed scenario did not exceed those in the pre-developed. The proposed basins and their volumes are shown in Table 6.3.

Table 6.3 – Modelled Detention Basins

Location (Catchment)	*RAFTS* Node	Volume (m^3)
Central	P1.5	7,860
Eastern	PBasin	1,000
Western	P1.1	390

Site visits and detailed survey information indicated that the existing playing fields in the central catchment (at node C1.5) acts as an existing basin. Mounded surrounds ensure water is stored and released at a controlled rate from the large inlet structure.

A high level weir is estimated at a width of 40m (RL 35.3) and is situated above the primary outlet. The levels across the weir are slightly lower than those mounds at the existing cul-de-sac to the east (RL 35.5). The existing depth to TWL within the existing basin is 1.73m. This is generally considered excessive by current safety design requirements. The BLCP therefore presents an opportunity to improve the flood hazard category of the Tarlington Reserve detention basin.

Iterations were performed in *RAFTS* to restrict flows to the PSD (Permissible Site Discharge). These iterations indicated that a volume of 7860m^3 would be required for the central proposed scenario. Similar iterations were then performed on the eastern and western catchments.

An application has been made to the Dam Safety Committee (DSC) to determine whether they need to approve the Stage 1 basin design. To date, a response has not been received. However, discussions with the DSC indicate

As discussed with Council (meeting 24th August), the detention requirements for the eastern catchment is proposed to be situated at a point along Green Valley Creek or another suitable location within Fairfield council’s “5 creek system”. At this stage it is considered that the existing detention facility in Chisolm Park is a suitable location.

Council is currently finalising a detailed flood assessment of Green Valley Creek. Once this study has been completed and the results fully understood, a decision regarding the location and nature and location of off-site works can be agreed upon. Council have indicated that, if the results of the study show that the creek system is not under flooding stress then water quality works may be undertaken instead.

Stage 3 is the first stage to be constructed within the eastern catchment. It is expected that these issues are resolved in detail as part of the Stage 3 Development Application.

6.3 Results

6.3.1 Design Discharges

Design discharges were produced for a range of ARIs including the 5, 20 and 100-year ARI events. Storm durations ranging from 10 minutes to 3 hours were modelled for each ARI, using AR&R temporal patterns, in order to identify the peak flow for each sub-catchment node. The design discharges for all of these events are shown in Appendix C.

6.3.2 Comparison of Post-developed and Existing Flows

The 100-year ARI flows for the post-development scenario are compared with existing conditions. From analysis, the critical storm duration for the 100 year ARI event on the central catchment (at the outlet) was 2 hours. Using similar methodology, the critical storm durations on both the eastern and western catchments were found as 1.5hrs.

Comparative results are shown at various points in the site in Table 6.4 for the 100yr ARI event. Full results are included in Appendix C.

Table 6.4 - Comparison of Existing and Proposed 100 year ARI Flows

Existing		Location	Proposed	
Node	**Flow (m3/s)**		**Flow (m^3/s)**	**Node**
CENTRAL				
C1.14	6.1	Cabramatta Rd	6.1	P1.14
C1.9	17.6	Tarlington Pde	18.9	P1.9
C1.6	21.5	Soccer Fields	22.2	P1.6
C1.5	22.0	Basin	24.0	P1.5
C1.3	23.4	D/S of Basin	23.5	P1.3
C1.1	25.2	Edensor Rd (Outlet)	24.5	P1.1
EASTERN				
E1.1	3.4	Corner of Humphries Rd and	3.5	P1.1
E3.1	4.7	Humphries Road	5.0	P3.1
E5.1	2.3	Humphries Road	2.8	P5.1
EOutlet	8.7	Basin at Green Valley Creek (Outlet)	8.1	POutlet
WESTERN				
WOutlet	1.9	Bonnyrigg Ave (Outlet)	1.7	POutlet

The basin sizes shown in Table 6.3 have been applied to the proposed models, subsequently allowing post-developed flows to be lower than existing at the outlets of each catchment.

Analysis on the central catchment has identified some isolated areas of increased flows (by up to 9%) along the central overland flow path, while the total flow at the outlet has decreased by 1%. These areas are generally situated just upstream of the central playing field basin.

Analysis on both eastern and western catchments also restricted post developed flows below existing at the outlet.

The results indicate that the proposed development will not have an adverse impact on downstream property as a result of increased flows.

The flow rates shown in Table 6.4 are representative of stormwater runoff being carried in low flow pipes as well as those travelling along overland flow paths.

Hydraulic modelling is completed in Section 7 to assess the depth and extent of flood inundation in both the post developed and existing scenarios. For the purposes of this study, the low flows pipes are assumed to operate at full capacity (in both scenarios). Consequently the overland flow rates used in Section 7 are expressed in Table 6.5.

Table 6.5 - Existing and Proposed 100 year ARI Flows for HEC-RAS (Central Catchment)

Node	Equivalent Hec-ras Position (Ch)	Location	Total Flow A (m^3/s)	Low Flow B (m^3/s)	Overland Flow A - B (m^3/s)
EXISTING					
C1.14	1100	Cabramatta Rd	6.1	1.1	5.0
C1.12	900	Reserve	13.3	2.4	10.9
C1.9	772.5	Tarlington Pde	17.6	3.4	14.2
C1.6	500	Soccer Fields	21.5	5.1	16.4
C1.5	282.5	Basin	22.0	6.7	15.3
C1.3	250	D/S of Basin	23.4	6.7	16.7
C1.1	140	Edensor Rd (Outlet)	25.2	6.7	18.5
PROPOSED					
P1.14	1100	Cabramatta Rd	6.1	1.1	5.0
P1.12	900	Reserve	13.2	2.4	10.8
P1.9	767	Tarlington Pde	18.9	3.4	15.5
P1.6	500	Soccer Fields	22.2	5.1	17.1
P1.5	297	Basin	24.0	6.7	17.3
P1.3	250	D/S of Basin	23.5	6.7	16.8
P1.1	156.6	Edensor Rd (Outlet)	24.5	6.7	17.8

6.3.4 Comparison with other Results

The hydrologic model results were compared with a more approximate method described below to check that they were within the expected range.

6.3.4.1 Rational Method

The rational method is the most widely used empirical technique used for calculating design flow rates within Australia (as recommended in ARR87). The rational method calculates the peak flow rate corresponding to the particular time of concentration for the catchment. These estimated flow rates are not related to any one specific storm event.

The basin situated within Tarlington Reserve cannot be modelled using this empirical method. Consequently to make a fair comparison of results, the basin was excluded from the *RAFTS* model and simulation was re-run.

The position of the estimated peak flow rate was chosen as the outlet point of the central catchment (where the central reserve intersects Edensor Road). The result was then compared to the corresponding *RAFTS* node (C1.1), as shown below in Table 6.6.

Table 6.6: Comparative Results – Central Existing Catchment

Point / Node	Location	ARR Rational Method	*RAFTS*
C1.1	Central Catchment Outlet (Edensor Rd)	19.1m^3/s	25.9 m^3/s

6.3.4.2 Discussion

Comparisons of results indicated that those results given from the *RAFTS* model are within a reasonable order of magnitude, given the empirical nature of the rational method.

Although the Rational Method has estimated lower flow rates, we propose to use the more conservative *RAFTS* results. It is expected that the *RAFTS* results would be greater than the Rational Method estimate for the following reasons:

- Low flow pipes are not considered in the Rational Method. This influences the time of concentration and consequently the overall flow rate;
- Fraction impervious (and in turn the runoff coefficient) is a rough estimate within the Rational Method.

Council has indicated that suitable flow rate records are not available for comparison in this area (from council's *RAFTS* models).

6.3.5 Sensitivity Analysis

To increase confidence in results, a sensitivity analysis was completed with respect to both the b-multiplier and initial loss parameters.

6.3.5.1 B-multipliers

RAFTS allows the user to enter a multiplier to adjust the value of the coefficient 'b' in the sub-area storage equation. Usually this value involves calibration and validation against recorded storms. Discussions with council have indicated that Bx = 1.0 was applied on council *RAFTS* records. To test its sensitivity, B-multiplier values of 0.5 and 2.0 were trialed. It was found that halving the B-multiplier (less catchment storage) increased Central Catchment 100 year flows at P1.1 by up to 12% while doubling it (more catchment storage) decreased flows by up to 14%.

Similarly Western catchments showed increasing 100 year flows at Woutlet of up to 32% and decreasing flows by up to 32% for B-multipliers of 0.5 and 2.0 respectively. Similarly the Eastern Catchment flows increased by 11% and decreased by 10%, again for B-multipliers of 0.5 and 2.0 respectively. Refer to sensitivity analysis tables in Appendix C

6.3.5.2 Initial Loss (IL)

RAFTS allows the user to enter an initial loss parameter to represent both the impervious and pervious portions of a catchment. Variations typically simulate the ability of surface water to infiltrate into the ground at the start of the event. This acceptance is generally dependent upon both soil type and land use.

Council has indicated that their RAFTS model for the 5 creek system uses 15mm and 1.5mm IL for pervious and impervious portions respectively. To test its sensitivity, IL combinations of (a)10mm and 1mm; and (b) 20mm and 2mm were used (for pervious and impervious portions respectively).

It was found that by reducing the IL parameters, the Central Catchment 100 year flows were increased at P1.1 by up to 11%. While increasing the IL parameters decreased flows by up to 10%.

Similarly sensitivity on the western catchments showed increases in 100 year flows at Woutlet of up to 21% and decreasing flows by up to 18% for decreases and increases of IL parameters respectively. Similarly the Eastern Catchment flows increased by 6% and decreased by 4%. Refer to sensitivity analysis tables in Appendix C

6.3.6 Probable Maximum Flood

The 15 minute duration PMP storm produced the highest discharges. Estimated PMF discharges are up to 8 times the 100 year ARI flows. Detention Basin spillways will be designed at detailed construction certificated stage to convey half the PMF discharge.

While it is recognised that an appreciation of the impacts of the PMF must be considered during the development assessment stage the critical parameters are the provision for evacuation and the structural integrity and safety of houses or other buildings subjected to high depth and velocities. It is accepted that the SES regional evacuation plans would address any need for evacuation. The structural integrity of any building impacted upon by the PMF event, needs to be addressed as part of the development application for the individual buildings.

The simple channel routing in the RAFTS model is inadequate to accurately assess flood behaviour with such high flows. However, in order to assess the structural integrity of dwellings during this event, RAFTS software is expected to provide results within an acceptable order of magnitude.

6.3.7 Overland Flow Depths and Velocities

The 100-year ARI flow depths and velocities are tabulated in Table 6.7. These depths and velocities are based on the assumption that the minor, piped drainage system conveys 100% of the 5-year ARI. Table 6.7 also compares the depths and velocities against the following criteria:

- A velocity-depth product of 0.4 m^2/s as recommended in AR&R
- Figure L1 of the NSW Floodplain Development Manual

In instances where *RAFTS* presented zero data was for overland flow, pipes were then excluded and the model re-run to be conservative. These are highlighted in yellow in Table 6.7.

Generally the upstream links (and the majority of proposed road corridors) in the central catchment satisfy the limits set above. Typically links at the upstream end of the catchments easily satisfy the velocity-depth product limits, but as flows increase down catchments the product is increased and in some instances the safety limits are exceeded.

Some potential hazard areas are identified as follows:

- Link P6.2 to P6.1 (due to increased flows);
- Links P13.4 to P13.3 and P9.3 to P9.2 (results indicate excessive velocities, however, these are in areas where pipes were excluded)
- Links P16.4 through to P16.2 (these links convey flows from an upstream catchment and appear to present a problem)
- Links along the central reserve appear to exceed the depth and velocity limits set above. However it should be recognised that this reserve is designed to be clear of structures.

To enable the overland flows to be reduced in the areas mentioned above, the piped drainage system will need to be designed to a higher ARI than the 5 year ARI for the flow paths. The required ARI for the pipe drainage system at these locations will be confirmed at the detailed design stage. Refer to Figure W05 for positions.

Table 6.7 - 100 year ARI Overland Flow Depths and Velocities

Node	Location	Velocity (m/s)	Depth (m)	CRITERIA	
				AR&R D x V < 0.4	Fig. L1 of FMM
EASTERN					
P1.3 to P1.2	Palisade Cr	1.8	0.125	YES	YES
P1.2 to P1.1	Humphries Rd	1.8	0.1578	YES	YES
P2.3 to P1.1	Mason Pl	1.4	0.0805	YES	YES
P3.3 to P3.2	Easement from Garden Pl	1.0	0.1508	YES	YES
P3.2 to P3.1	Humphries Rd	1.0	0.1355	YES	YES
P4.4 to P4.3	Tarlington Pde	1.2	0.0582	YES	YES
P4.3 to P3.1	Tarlington Pde	1.2	0.0582	YES	YES
P5.3 to P5.2	Sandilands Rd	1.9	0.0838	YES	YES
P5.2 to P5.1	Sandilands Rd	1.9	0.1086	YES	YES
P6.3 to P6.2	Bishop Cr	1.2	0.0512	YES	YES
P6.2 to P6.1	Bishop Cr	1.7	0.0664	YES	YES
P6.1 to P5.1	Humphries Rd	1.0	0.1328	YES	YES
WESTERN					
P1.4 to P1.1	Park			YES	
CENTRAL					
P16.4 to P16.3	Monash Pl	0.9	0.27	YES	NO
P16.3 to P16.2	Harricks Pl	2.4	0.18	NO	NO
P16.6 to P16.5	Madson Pl	1.6	0.10	YES	YES
P16.5 to P16.2	Madson Pl	1.5	0.11	YES	YES
P13.4 to P13.3	Upton Pl	2.1	0.10	YES	NO
P13.3 to P13.2	Tarlington Pde	1.7	0.11	YES	YES
P13.2 to P13.1	Tarlington Pde	1.2	0.20	YES	YES
P12.6 to P12.5	Tarlington Pde	1.8	0.12	YES	YES
P12.4 to P12.2	Proposed	0.6	0.10	YES	YES
P12.2 to P12.1	Wall St	1.3	0.0725	YES	YES
P9.3 to P9.2	Cowdry Way	2.8	0.1336	YES	NO
P9.2 to P9.1	Park	0.7	0.1668	YES	YES
P7.4 to P7.3	Corlette Way	1.2	0.0592	YES	YES
P7.2 to P7.1	Park	0.1	0.1309	YES	YES
P6.11 to P6.8	Stroud Way	0.7	0.0229	YES	YES
P6.8 to P6.3	Reeves Cr	1.4	0.1133	YES	YES
P6.6 to P6.5	Barseden St	0.9	0.0387	YES	YES
P6.5 to P6.4	Reeves Cr	1.2	0.1012	YES	YES
P6.2 to P6.1	Driver Pl	2.1	0.1703	YES	NO
P3.2 to P3.1	Edensor Rd	0.6	0.0691	YES	YES
P2.4 to P2.3	Proposed	1.4	0.0709	YES	YES
P2.3 to P2.2	Edensor Rd	1.2	0.1316	YES	YES
P2.2 to P2.1	Edensor Rd	1.3	0.1891	YES	YES

6.3.7.1 Stage 1 DRAINS Analysis

To further assess overland flow depths and velocities, a DRAINS analysis was conducted as part of the Stage 1 submission. Here the pipe sizes and overland flow directed towards Driver Place (which was identified in Section 6.3.7 as a potential hazard area) and into the basin were assessed to ensure compliance with regulatory requirements. Refer to Figure 6.1 for the DRAINS network.

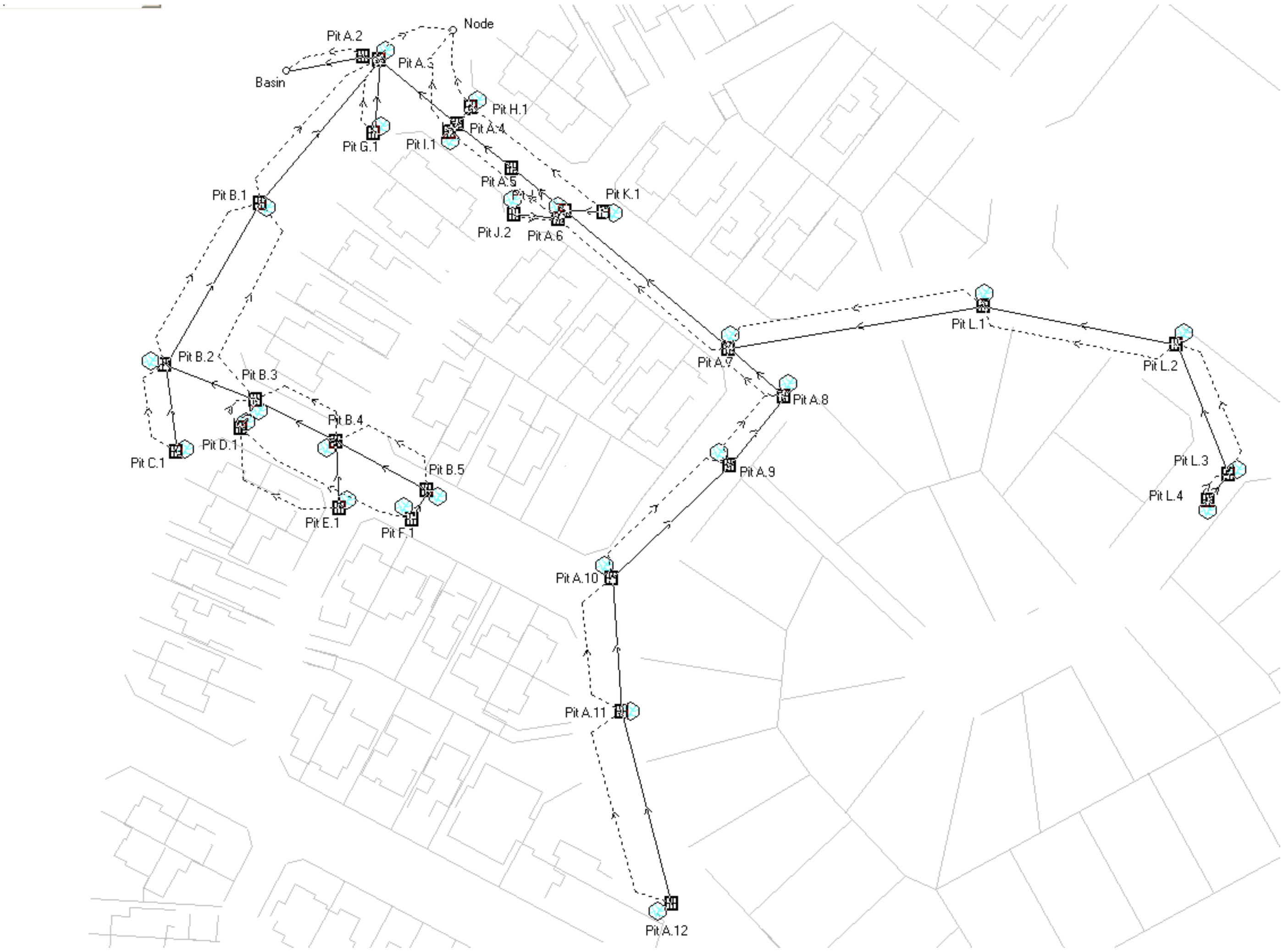


Figure 6.1 – DRAINS network

Results from the DRAINS analysis are tabulated in Table 6.8. Here results indicate that both sets of criteria used to assess overland flow are satisfied for the 100yr ARI event.

Further DRAINS analysis for the development will be submitted to council with each stage. As was discovered in this case, it is quite possible that areas identified in concept modelling as potential hazards are not so when subject to a more detailed analysis due to the conservative nature of the concept modelling.

Table 6.8 - 100 year ARI Overland Flow Depths and Velocities – Stage 1 DRAINS

Overland Link Name	Max Velocity (m/s)	Max Depth (m)	Max DxV	Criteria	
				DxV < 0.4	Fig L1 of FMM
OFL4-3	0.83	0.092	0.08	YES	YES
OF L3-2	0.99	0.08	0.08	YES	YES
OF L2-1	1.27	0.104	0.13	YES	YES
OF L1-A7	1.14	0.123	0.14	YES	YES
OF A7-6	1.51	0.1	0.15	YES	YES
OFA3-A0	1.22	0.068	0.08	YES	YES
OF A.2-Node	0	0	0	YES	YES
OF A12-11	0.71	0.061	0.04	YES	YES
OF A11-10	0.6	0.051	0.03	YES	YES
OF A10-9	0	0	0	YES	YES
OF A9-8	0	0	0	YES	YES
OF A8-7	0	0	0	YES	YES
OF G1-A3	0.23	0.011	0	YES	YES
OF F1-D1	0.35	0.022	0.01	YES	YES
OF B5-4	0.57	0.041	0.02	YES	YES
OF B4-3	0.76	0.081	0.06	YES	YES
OF B3-2	0.95	0.108	0.1	YES	YES
OF B2-1	0.64	0.065	0.04	YES	YES
OF B1-A3	0.95	0.104	0.1	YES	YES
OF E1-D1	0.34	0.015	0	YES	YES
OF D1-B3	0.47	0.032	0.02	YES	YES
OF C1-B2	0.23	0.011	0	YES	YES
OF I.1-A3	1.26	0.152	0.19	YES	YES
OF H1-A3	1.13	0.108	0.12	YES	YES
OF J2-1	0.2	0.011	0	YES	YES
OF J1-I1	1.18	0.143	0.17	YES	YES
OF K1-H1	0.88	0.088	0.08	YES	YES

7 Hydraulics

7.1 The Model

The *HEC-RAS* hydraulic analysis program was used to analyse the effect of flood flows on both flood levels and the extent of inundation. The *HEC-RAS* Version 3.1.1 (May 2003) hydraulic model, the latest windows-based release from US Army Corps of Engineers, Hydrologic Engineering Centre, is widely used for analysis of hydraulic conditions where floodplain storage effects are small.

HEC-RAS is an integrated package of hydraulic analysis programs capable of performing one-dimensional, steady or unsteady flow, water surface profile calculations. The model can handle a full network of channels, a dendritic system or a single river reach. It is capable of modelling subcritical, supercritical and mixed flow water surface profiles.

The basic computational procedure is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction (Manning's Equation). The effects of various obstructions such as bridges, culverts, weirs and obstructions in the floodplain are also considered in the computations.

7.2 Model Formulation

Formulating a *HEC-RAS* model involves defining river geometry, and boundary conditions.

HEC-RAS models were formulated to represent both the existing and proposed scenarios within the central catchment, subsequently allowing for assessment to be made on the extent of flood inundation, depths and the like. That is, the existing (pre-development) model is created to represent the extent of inundation and flood levels experienced by existing flows through the central reserve, while the proposed model is used to confirm that under the proposed development, future flood inundation is restricted to equal or less than that of the existing (current) flooding.

The two models presented in this study are representative of the central overland flow path which bisects the central catchment.

Within this study, *HEC-RAS* models were not completed for the western or eastern catchments. The western catchment is considered relatively small and will be assessed at a later stage. While as discussed with Council (meeting 24th August), the detention requirements for the eastern catchment is proposed to be situated at a point along Green Valley Creek or another suitable location within Fairfield council's "5 creek system". Options will be discussed at a later stage.

7.2.1 River Geometry

HEC-RAS models were formulated to represent the central reserve / overland flow path for both the existing and proposed central catchment scenarios.

The networks contain just one branch, but extend from its intersection with Cabramatta Rd, through Tarlington reserve, across Edensor Rd and finishes at a section 150m downstream from the subject site.

7.2.1.1 Existing

Surveyed cross-sections from 12d were used to model the existing surface profile of the reserve (and surrounding land) where overland flow will occur during peak events. Cross Sections were positioned at critical points, with other sections placed between at 50 metre intervals. Figure W12 in Appendix A shows the cross-section locations for the existing scenario. Additional cross-sections were interpolated at 10m intervals within *HEC-RAS* to more accurately model friction losses and contraction and expansion losses.

Resistance to flow is a function of the surface roughness in the channel and overbank areas, and is affected by vegetation, development etc. Roughness was represented by Manning's 'n' values. Guides for the estimations of roughness parameters are given in several standard publications such as Australian Rainfall and Runoff (1987) and *HEC-RAS* Hydraulic Reference Manual (2003). Values of Manning's 'n' were chosen on the basis of field inspection.

Along the existing river alignment, there are a number of houses that may impact on the effectiveness of overland flow. These buildings were incorporated into *the HEC-RAS* model as "obstructions", while paling or 'colourbond' fences were also incorporated into the model as "ineffective" areas. Refer Figure 7.1 for positions of all obstructions and ineffective areas considered in the existing model.

The existing network includes two piped road culverts (headwall or pit with pipe or culvert extending under road) and one existing basin (mounded surrounds with large inlet structure and 1.5m diameter outlet pipe). Dimensions included in the model were based on survey data.

The first road culvert (under Tarlington Parade) was modelled as a "bridge culvert" in accordance with the *HEC-RAS* user manual. This involved interpolation of cross sections just upstream and downstream, ineffective areas applied at 45deg from opening, decks extending for the surveyed width and level, contraction and expansion losses applied as recommended. Survey data indicated that there is one 2.44m x 0.6m box culvert crossing under the road, with a 1.05m dia low flow pipe separately diverting the minor flows. The decks (road above) were input from 12d sections.

The second road culvert (under Edensor Road) was modelled as an "inline structure" in accordance with the *HEC-RAS* user manual. The existing surface profile directs surface water to a pit offset from Edensor Road; here water is collected via a 0.375m dia pipe and directed into the trunk 1.5m dia low flow pipe which extends under Edensor Road. The low point of Edensor Road is situated above the 1.5m trunk pipe, consequently allowing flows across the existing roadway during Peak events. This involved interpolation of cross sections just upstream and downstream decks extending for the surveyed width and level, contraction and expansion losses applied as recommended. The models have assumed no piped outlet as a conservative approach. The decks (road above) were input from 12d sections.

The existing basin is situated at the playing fields within Tarlington Reserve. Here there is a mound which extends predominantly along the Northern end of the playing fields but also wraps onto the eastern and western sides. A large inlet structure appears to allow surface flows to be stored in the basin and discharged at a controlled rate into the 1.5m outlet pipe. Detailed survey information indicates a weir length of approximately 40m at a height of 1.53m. The mounded surround on the basin was modelled as a "bridge culvert" in accordance with the *HEC-RAS* user manual. This involved interpolation of cross sections just upstream and downstream, ineffective areas applied at 45deg from opening, decks extending for the surveyed width and level, contraction and expansion losses applied as recommended.

7.2.1.2 Proposed

The proposed model includes reshaping of the reserve surface profile, allowance for a rocked invert for low flows, modifications of park extents, introduction of a quality control pond and redefining the basin to achieve detention requirements set out in the hydrology section. As shown in Figure W12 in Appendix A and Figure 7.2, the alignment of the invert has been modified to suit new the masterplan layout and maximise space for the soccer fields.

The proposed model was formulated based upon the masterplan road hierarchy and preliminary grading as at 24th August 2007. A preliminary 12d model (digital terrain model) was created to ensure detention requirements could be achieved within the new basin area and to formulate a preliminary reserve profile. Cross sections were positioned at critical points, with the other sections placed at 50 metre intervals. Figure W12 in Appendix A and Figure 7.2 shows the cross section locations for the proposed scenario. Additional cross-sections were interpolated at 10m intervals within *HEC-RAS* to more accurately model friction losses and contraction and expansion losses.

Similar to the existing model, obstructions and ineffective areas were introduced where fences or houses could affect peak flows. Obstructions were introduced to represent the houses at the private estate (which is to remain) near Tarlington Parade (Ch550 to Ch767). By doing so, freeboard could be checked to check of the houses.

The existing road culverts under Tarlington Parade and Edensor Road were kept similar to existing, while the proposed basin was defined to represent those volumes set out in the hydrology section.

The proposed basin was modelled using a "bridge culvert". Here a wall height was set at 1.2m maximum and an outlet pipe (0.3m diameter) was introduced to allow surface water to enter the quality control pond at a controlled rate. An outlet structure was kept similar to existing to allow water to enter the 1.5m dia pipe outlet. A high level weir was redefined to a height which satisfies safety regulations (20m wide weir, RL34.77 to base of weir → 1m depth, RL 34.97 to top of weir → 1.2m depth).

The perimeter of the playing field and respective safety zones (on the western and northern edge) was modelled as tiered seating (0.6m high, 1.2m deep and maximum of 2 high)

7.2.2 Roughness Coefficients

Resistance to flow is a function of the surface roughness in the channel and overbank areas, and is affected by vegetation, development, etc. Roughness coefficients were represented by Manning's 'n' values. Guides for the estimations of roughness parameters are given in several standard publications such as Australian Rainfall and Runoff (1987) and *HEC-RAS* Hydraulic Reference Manual (2003). Values of Manning's ‘n’ were chosen on the basis of field inspection and are presented previously in Section 6.1.6 - Hydraulic Roughness Parameters.

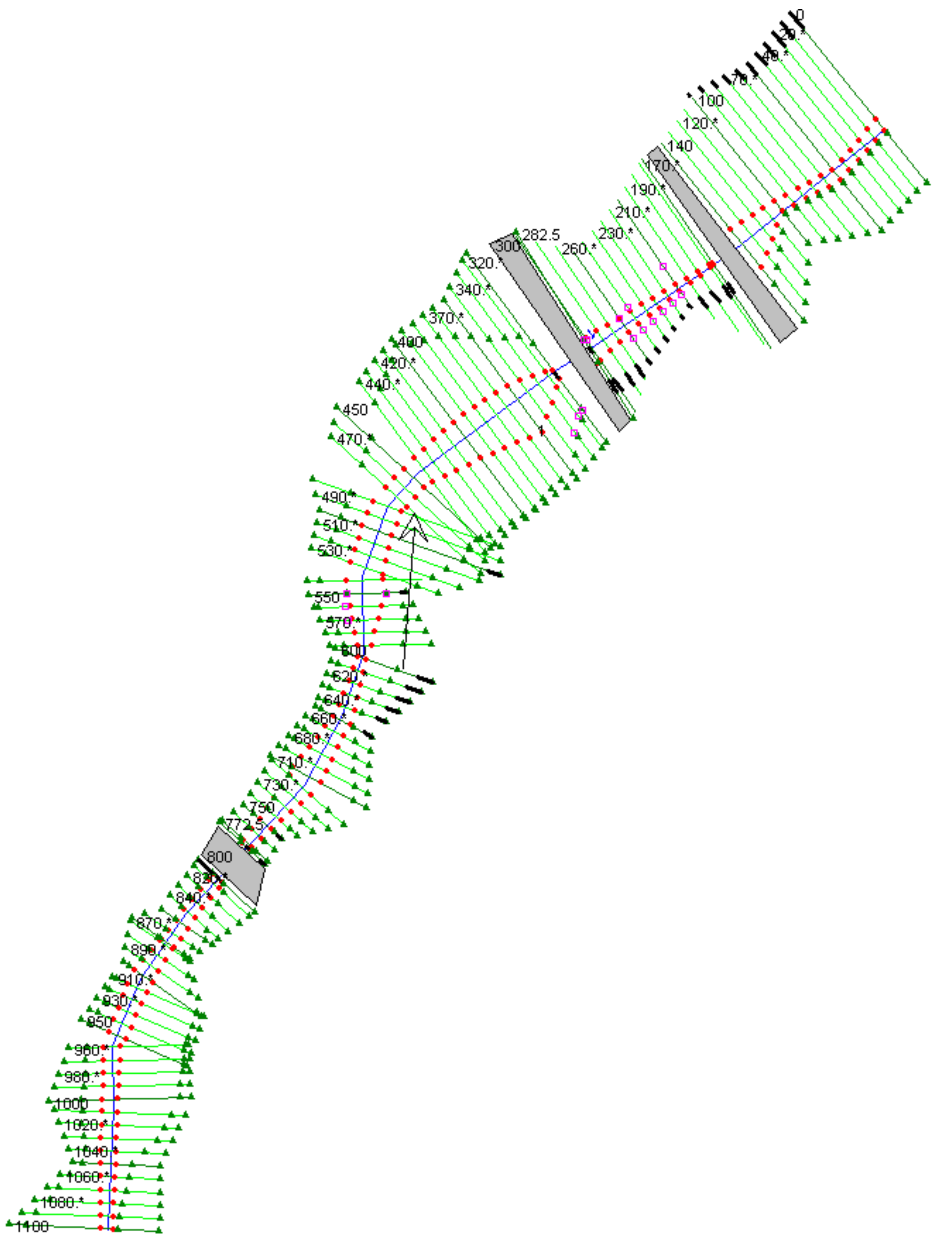
7.2.3 Boundary Conditions

Discharges calculated from hydrologic modelling in Sections 6 were incorporated into the model. These were inserted at upstream locations as well as additional inflows along the branches at cross-sections corresponding to the hydrologic model nodes that were considered critical. Normal depth was used as the upstream and downstream boundaries (1.6% and 0.9% respectively). Known water surface levels were also introduced within the existing and proposed basins (RL35.22 and RL34.97 respectively).

7.2.4 Inlet / Culvert Blockage Factors

As per councils standards (and discussions with Council, 9th August 2007), 50% blockages were considered on all culverts. This was applied to both the existing and proposed models where required.

Figure 7.1 *HEC-RAS* Existing Model Layout



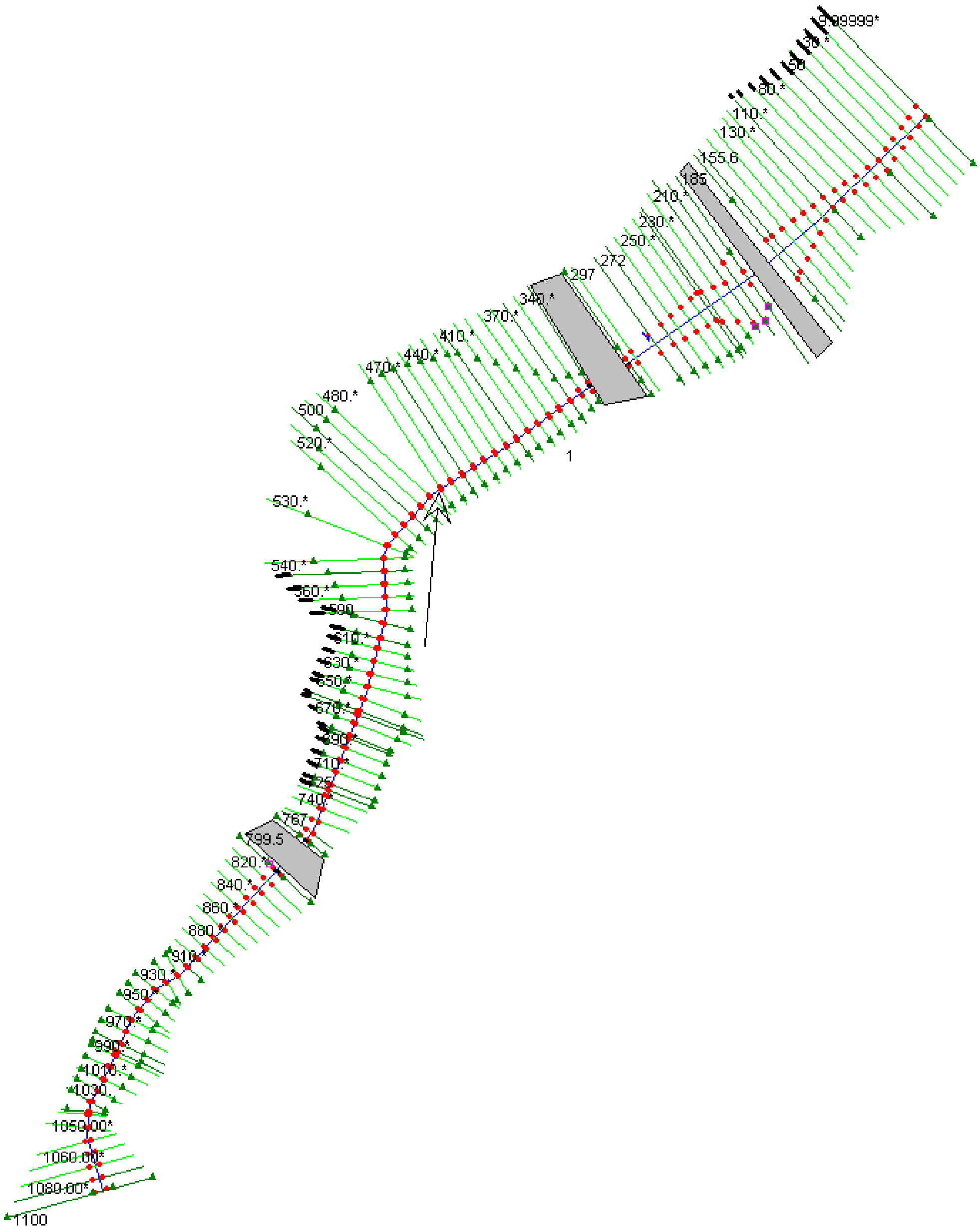


Figure 7.2 *HEC-RAS* Proposed Model Layout

7.3 Results

The discharges from the hydrological model (refer Table 6.5) were run through the *HEC-RAS* models using “steady flow” to produce design flood levels, flow depths, extent of inundation and velocities.

Appendix D shows full *HEC-RAS* results which includes (a) Summary table of velocities, peak flows, peak flood levels and extent of inundation; (b) flood profiles (both mixed and subcritical regimes); (c) Cross Sections at critical positions (with flow data); and (d) XYZ plots of the entire network.

Figures W12 and W13 in Appendix A shows the extent of flood inundation for the 100 year ARI. While the extent of inundation for the PMF will be considered at the design stage.

It should be noted that *HEC-RAS* is typically used to assess flow dynamics and open channel flow as opposed to modelling detention and stage / storage relationships.

The following table is provided to draw comparison between existing and proposed levels at critical positions:

Table 7.1 – Comparison of HEC-RAS 100year Results

Existing			Proposed	
Equivalent Hec-ras Position (Ch)	**W.S Elevation (m)**	**Location**	**W.S Elevation (m)**	**Equivalent Hec-ras Position (Ch)**
1100	43.31	Cabramatta Rd	43.28	1100
900	40.47	Southern Tarlington Reserve	40.24	900
805	39.40	U/S side of Tarlington Parade	39.33	799.5
772.5	38.91	D/S side of Tarlington Parade	38.95	767
750	38.53	Tarlington Reserve (adjacent private development)	38.75	750
700	38.03	Tarlington Reserve (adjacent private development)	38.24	700
650	37.58	Tarlington Reserve (adjacent private development)	37.77	650
600	37.15	Tarlington Reserve (adjacent private development)	37.27	602
550	36.74	Tarlington Reserve	36.37	550
500	36.09	Tarlington Reserve	35.51	500
450	35.71	Tarlington Reserve	35.15	450
400	35.22	Tarlington Reserve	34.97	400
350	35.23	Tarlington Reserve	34.97	350
315	35.22	U/S Basin Wall	34.97	331.4
200	33.56	D/S Basin – QCPond	33.48	201
166.787	33.21	U/S Edensor Rd	33.33	185
100	32.43	D/S properties	32.42	100
50	32.05	D/S properties	32.02	50
0	31.60	D/S properties	31.58	0

7.4 Discussion

The following comments are provided on the *HEC-RAS* results:

- **Supercritical and Subcritical Flows**

  Recent studies have shown that in areas of supercritical flows, full or partial blockages can cause flow to revert to the high level sub-critical state over a short period of time (Kandasamy and Beecham, 2004).

  Analysis of the existing model indicated areas of supercritical flows on the downstream side of culverts and some in the vicinity of downstream properties.

  Analysis on the proposed model seemingly indicated supercritical flows in a couple of additional areas. In light of recent studies, it does not seem practical to consider the modelled water surface profile as either the flood depth or extent of inundation. Consequently “subcritical” regimes were selected for both existing and proposed scenarios (as opposed to a “mixed” regime) to ensure the minimum water surface profile is no less then the critical depth.

- **Extent of Inundation and flow depths**

  Existing

  Hydraulic analysis on the existing *HEC-RAS* model indicated isolated areas of flood inundation within existing properties for the 100 year ARI event. Results are as follows:

  - Properties on the upstream side of Tarlington Parade (Ch910 to Ch805 LHS) appear to be inundated with half blockage factors being applied. Consequently 0.5m freeboard is not achieved in the area;
  - Properties on the downstream side of Tarlington Parade (Ch772.5 to Ch710 RHS) also appear to be inundated with 0.5m freeboard not being achieved on this side.
  - The existing private estate to be retained (adjacent to Tarlington Parade, Ch772.5 to Ch 600 LHS) appears to satisfy 0.5m freeboard;
  - Properties on the RHS of the main reserve (Ch570 to Ch420) do not appear to satisfy 0.5m freeboard and have some flood inundation.
  - Properties on the downstream side of the existing basin (Ch166.787 to Ch282.5 RHS) appear to be affected by flood inundation.
  - Downstream properties from the subject site also appear to be inundated (Ch120 to Ch 0 RHS).

  Proposed

  Hydraulic analysis on the proposed *HEC-RAS* model had the following results for the 100 year ARI event:

  - The extent of flood inundation does not affect roads or properties in the proposed model from Ch1100 to 880. Floor levels should however consider 0.5m freeboard from water surface levels;
  - The existing lowpoint within Tarlington Parade (Ch850 to Ch805 LHS) is situated at an intersection with a proposed road. Analysis indicates that the proposed road will be inundated during the 100 year ARI peak event. To achieve the desired 0.5m freeboard, the adjacent properties are modelled at a higher level;

- The channel profile adjacent to the existing private estate (Ch767 to Ch602 LHS) has been modified to include the rock-lined channel and new surface profile. The 0.5m freeboard appears to be maintained on all existing dwellings;
- The existing low point within Edensor Road is situated close to the new feature entrance and proposed road intersection (Ch240 to Ch185 RHS). Analysis indicates that the proposed road will be inundated during the 100year peak event. To achieve the desired 0.5m freeboard, the adjacent properties are modelled at a higher level;
- Downstream properties (Ch155.6 to Ch0) are subjected to less peak flows and consequently appear to have less flood inundation than in the existing scenario.

8 Water Quality Modelling

8.1 Model Parameters

The soil properties for the pervious areas of the catchment were taken from Council's Engineering Design Guide for Development, or in lieu of this, the recommended default values published in the MUSIC User Guide (version 3).

Table 8.1 - MUSIC Soil Parameters

Soil Properties:	Default Value
Impervious threshold (mm)	1.0
Soil storage capacity (mm)	125
Initial storage (% of capacity)	80
Field capacity (mm)	80
Infiltration coefficient 'a'	200
Infiltration coefficient 'b'	1.0
Initial groundwater depth (mm)	0
Daily recharge rate (%)	1.0
Daily base flow rate (%)	0.1
Daily deep seepage rate (%)	0.0

8.2 MUSIC Catchments

In order to measure the required pollutant removal rates against a "base line" a model was created based on the proposed development layout and grading without water quality treatment measures.

8.2.1 Base Catchment

The *RAFTS* model developed for detailed analysis and design of the proposed water management system divided the site into approximately 48 sub-catchments. This level of detail is required at the design stage for the site hydrologic and hydraulic analyses. However, this level of detail is not necessary for water quality modelling using MUSIC because the treatment devices capture runoff from large areas and sub-division of sub-catchments smaller than the treatment catchment will not achieve improved results.

The *RAFTS* sub-catchments were therefore consolidated into 7 sub-catchment areas based on the proposed drainage system layout (refer Figure W06).

Catchments were separated into three components for the purposes of the MUSIC model:

- Roof areas;
- pervious areas (including open space); and
- pavement areas (including roads, footpaths, etc.).

Roofed, pervious and impervious areas were measured as a percentage from the Master Plan documentation.

Table 8.2 - Area Breakdown per MUSIC Sub-Catchment

Sub-Catchment	Roof Area	Impervious Area[3]	Pervious Area	TOTAL AREA
M1	1.167 ha	0.389 ha	2.334 ha	3.89 ha
M2	1.800 ha	1.080 ha	4.320 ha	7.20 ha
M3	2.397 ha	0.799 ha	4.794 ha	7.99 ha
M4	1.800 ha	0.900 ha	1.800 ha	4.50 ha
M5	0.907 ha	0.518 ha	1.166 ha	2.59 ha
M6	3.934 ha	1.574 ha	2.361 ha	7.87 ha
M7	4.712 ha	1.571 ha	4.188 ha	10.47 ha
M8	0.184 ha	0.132 ha	2.315 ha	2.63 ha
M9	1.776 ha	1.184 ha	2.960 ha	5.92 ha
M10	2.963 ha	2.778 ha	3.519 ha	9.26 ha
M11	4.542 ha	3.785 ha	6.813 ha	15.14 ha
M12	2.018 ha	0.956 ha	2.018 ha	5.31 ha
			TOTAL	**82.77 ha**

8.2.2 Proposed Catchment

The proposed catchment model was identical to the base model in terms of catchment area and break-up of roof, paved and pervious areas, but included the water quality management strategies outlined below.

8.3 Management Strategies

Storm runoff generated on the BLCP site can be separated into 3 streams:

- Roof or rainwater runoff which can be captured and reused for toilet flushing or irrigation;
- road and pavement runoff can be treated by grassed swales or bio-retention swales; and
- pervious surfaces will have reduced runoff due to a portion of infiltration, and water "lost" to groundwater.

The proposed treatment train is as follows:

- bio-retention swales treating road, pavement and pervious surface runoff where permitted;
- gross pollutant traps; and
- Bio-Retention “raingardens”

The possibility of using the tree bays as at source stormwater bio-retention devices has not been considered as part of this proposal. The deviation of low flows from the road gutters into these tree bays would enable the at source water quality treatment of the low flows. This additional treatment would further improve any water quality results obtained during this modelling. The potential for this would be assessed as part of

F

[3] Impervious area refers to all other impervious areas contained in the sub-catchment including existing roof and existing and proposed roads, footpaths, pavements etc.

individual evaluation of each stage depending upon site parameters including road networks and grades.

8.3.1 BASIX Requirements

The opportunity for recycled water or rainwater reuse and the requirements of the BASIX (Building Sustainability Index) Certificates will be incorporated into the water cycle management appropriate for individual dwellings.

At present there is no recycled water supply within the Bonnyrigg estate and Sydney Water have not stated whether they will or will not be providing a reticulated supply within the foreseeable future.

Discussions however have taken place with a service provider who has indicated a desire to provide a recycled water supply to the development. Provision of supply would be made at the corner of Cabramatta Road and Humphries Road. This would then be connected to the purpose built recycled water reticulation within the development. Negotiations are currently in progress for the implementation of a recycled water supply, however should the proposed water treatment and reticulation not proceed, then the existing site reticulation will be temporarily attached to the town potable water mains.

8.3.2 Bio-Retention Devices

Bio-Retention “raingardens” are proposed for treating runoff from sub-catchments M5; M6; M7; M8 and M12. “Flow splitting” pits will direct flows up to and including the 3-month ARI runoff to the treatment facilities. Higher flows, up to and including the 100-year ARI runoff will by-pass the treatment facilities and drain to an OSD basin. Bio-retention swales have also been included for the entirety of the trunk line.

The following parameters were input to the MUSIC model:

Table 8.3 - Bio-Retention Swale MUSIC Parameters

Catchment	Length m	Surface Area m^2	Filter Depth mm	Filter Area m^2
M1	400	160	1000	80
M2	130	80	1000	40
M3	450	-	-	-
M4	180	120	1000	60
M5 & M6	340	200	1000	680
M7 & M8	250	200	1000	680
M9	200	-	-	-
M11	370	-	-	-
M12	300	80	1000	50

8.3.3 Gross Pollutant Traps

For the purposes of MUSIC modelling on the BLCP site, it was assumed that Gross Pollutant Traps (GPTs) would be located at the outflow from each sub-catchment. Additionally, GPTs are assumed upstream of any proposed water body or bio-retention devices.

Proposed positions of these Gross Pollutant Traps are shown in Figure W07 with their respective treatable flow rates shown in Table 8.6. Here positioning has taken into consideration proposed catchments as well as both existing and proposed stormwater infrastructure.

MUSIC requires that transfer functions for the reduction in pollutants be entered. The pollutant reductions vary for different types of GPTs, estimates were therefore applied to the average advertised removal rates of the Rocla's "Cleansall", the CDS Unit and Humes' "Humeceptor":

Table 8.4 - GPT Pollutant Reductions

Pollutant	Rocla [1]	CDS [2]	Humes [3]	Adopted Rate
Total Suspended Solids (mg/L)	70%	70%	87%	**70%**
Total Nitrogen (mg/L)	-	23%	45%	**25%**
Total Phosphorus (mg/L)	-	30%	30%	**20%**
Gross Pollutants (kg/ML)	100%	98%	-	**95%**

[1] *Rocla Water Quality – Cleansall Gross Pollutant Trap* (Rocla Pty. Ltd. 2002)
[2] *Removal of Suspended Solids and Associated Pollutants by a CDS Unit* (CRC Catchment Hydrology 1999)
[3] *Humeceptor case study – Seatac, Washington USA* (http://www.humes.com.au/products/StormwaterQuality/humeceptor/seattle.pdf)

Table 8.5 - MUSIC Input - GPT Pollutant Reductions

Pollutant	Input	Output
Total Suspended Solids (mg/L)	1000	300
Total Nitrogen (mg/L)	50	37.5
Total Phosphorus (mg/L)	5	4.0
Gross Pollutants (kg/ML)	15	0.8

In accordance with statutory requirements, the GPTs will need to treat the maximum flow rate from their upstream catchments for all flows up to and including the 3-month ARI storm event. The following flow rates have been extracted from the *RAFTS* model.

Table 8.6 - GPT-Treatable Flow Rates

GPT No	Catchment	Location	Node	Treatable Flow Rate (m^3/s) – 3 month
1	Central	Proposed Road near Basin	P6.1	0.49
2	Central	Proposed Road near Apartments	P7.3	0.23
3	Central	Tarlington Parade	P13.1	0.40
4	Central	Tarlington Parade	P12.5	0.35
5	Central	Proposed Road Southern Reserve	P16.2	0.81
6	Central	Existing		
7	Western	Bonnyrigg Avenue	P1.0	0.16
8	Eastern	Green Valley Creek	POutlet	1.01
9	Central	Proposed Near Basin	P8.1	0.13

8.3.4 Salinity

The 2002 Salinity Potential in Western Sydney map from the Department of Infrastructure, Planning and Natural Resources indicates that the development is located in a *High Salinity Potential* zone. Field soil borehole investigations undertaken by JBS Environmental Pty Ltd discovered that standing water levels in Stage 1 varied between 2.9m and 5.0m below the ground surface. It was noted that this level was affected by a slight pressure release from the bedrock. While drilling, water levels were observed between 5.0m and 7.5m below ground surface. Advice given by JBS Environmental was that unless operations and excavations exceeded 5m in depth it would be unlikely to affect groundwater on the site.

The soil was identified as Blacktown (bt) landscape from both bore holes and the Soil Conservation Service of NSW's Soil Landscapes of Penrith maps. Characteristics typical of Blacktown (bt) landscape include high plasticity with poor drainage qualities. As the maximum depth of cut proposed on site is not to exceed 1.5m and in conjunction with the Blacktown soil having poor drainage qualities, it is believed that the depth and amount of groundwater will be minimally effected and as a result will have negligible effect on salinity.

Specific salinity management requirements are called for due to the high salinity potential of our site. The WSROC Salinity Code of Practice outlines the following 'good practice' measures that should be adopted with regards to salinity.

- Practise good soil management techniques during construction;
- Use all soils and landscapes within their urban capacity;
- Minimise water inputs, maintain natural water balance, and use caution in implementing infiltration technique;
- Carefully manage areas of existing salinity or likely discharge areas; and
- Avoid clearing, retain and establish significant native vegetation.

8.4 Results

8.4.1 Base Model

In accordance with the industry standards and assessment processes the base water quality MUSIC model for the site was developed assuming that no water quality treatment measures would be installed. This model provides the basis for pollutant generation from the site and the measure for pollutant removal under "treated" conditions. The layout of this model is shown on Diagram 8.1.The results of the analysis are shown in Table 8.7.

8.4.2 Proposed Model

The "treated" site conditions model was developed incorporating the water quality treatment train as described above. Diagram 8.2 shows the layout of the model in MUSIC.

The results of the model are summarised in Table 8.7 below, and show that including a treatment train as described above, the water quality improvement objectives set out in

Council's Handbook for Managing Urban Stormwater by the Department of Environment and Climate Change for Development are achieved.

Diagram 8.1 – MUSIC Model for "Untreated" Development Site

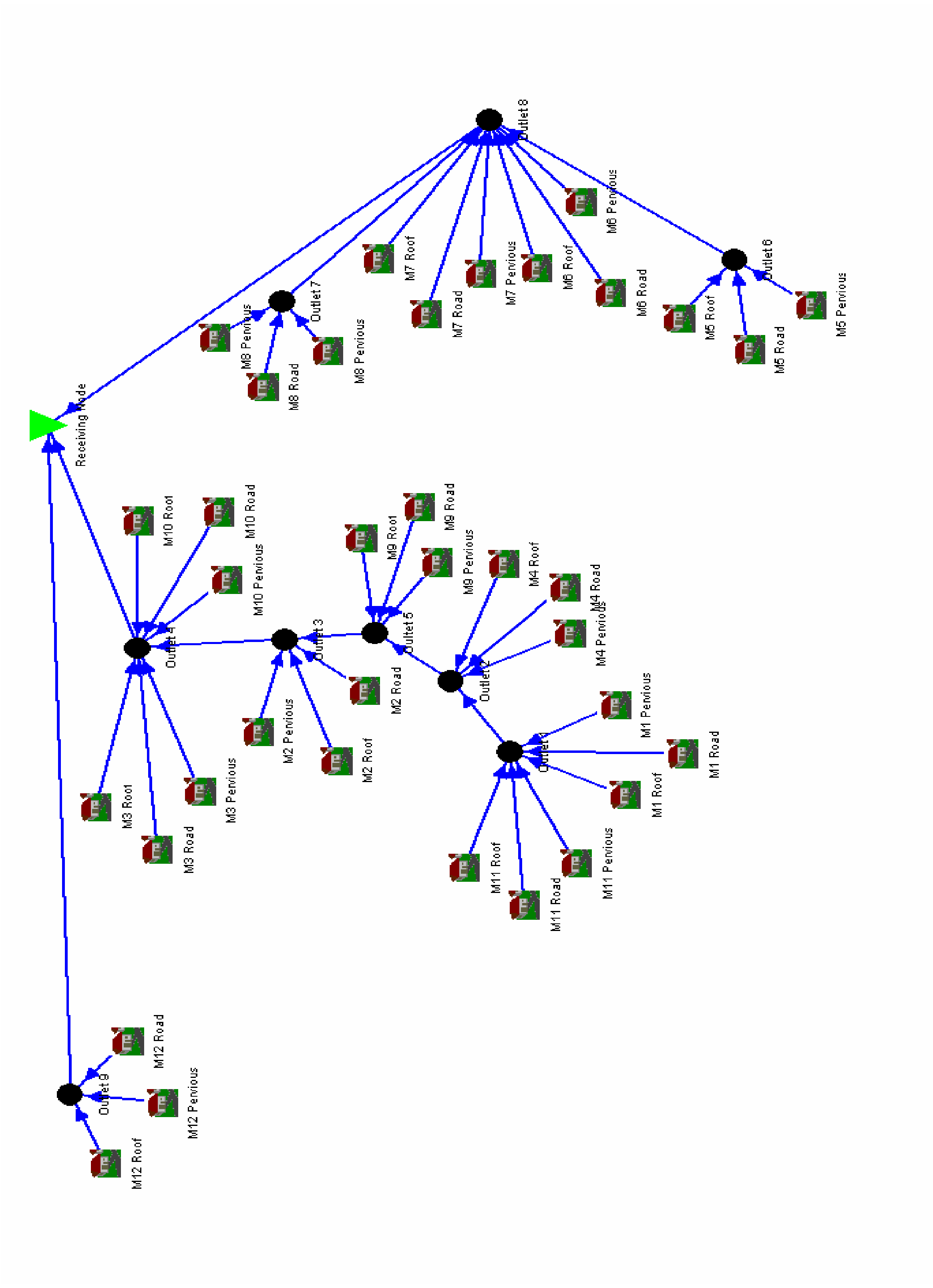


Diagram 8.2 – MUSIC Model for "Treated" Development Site

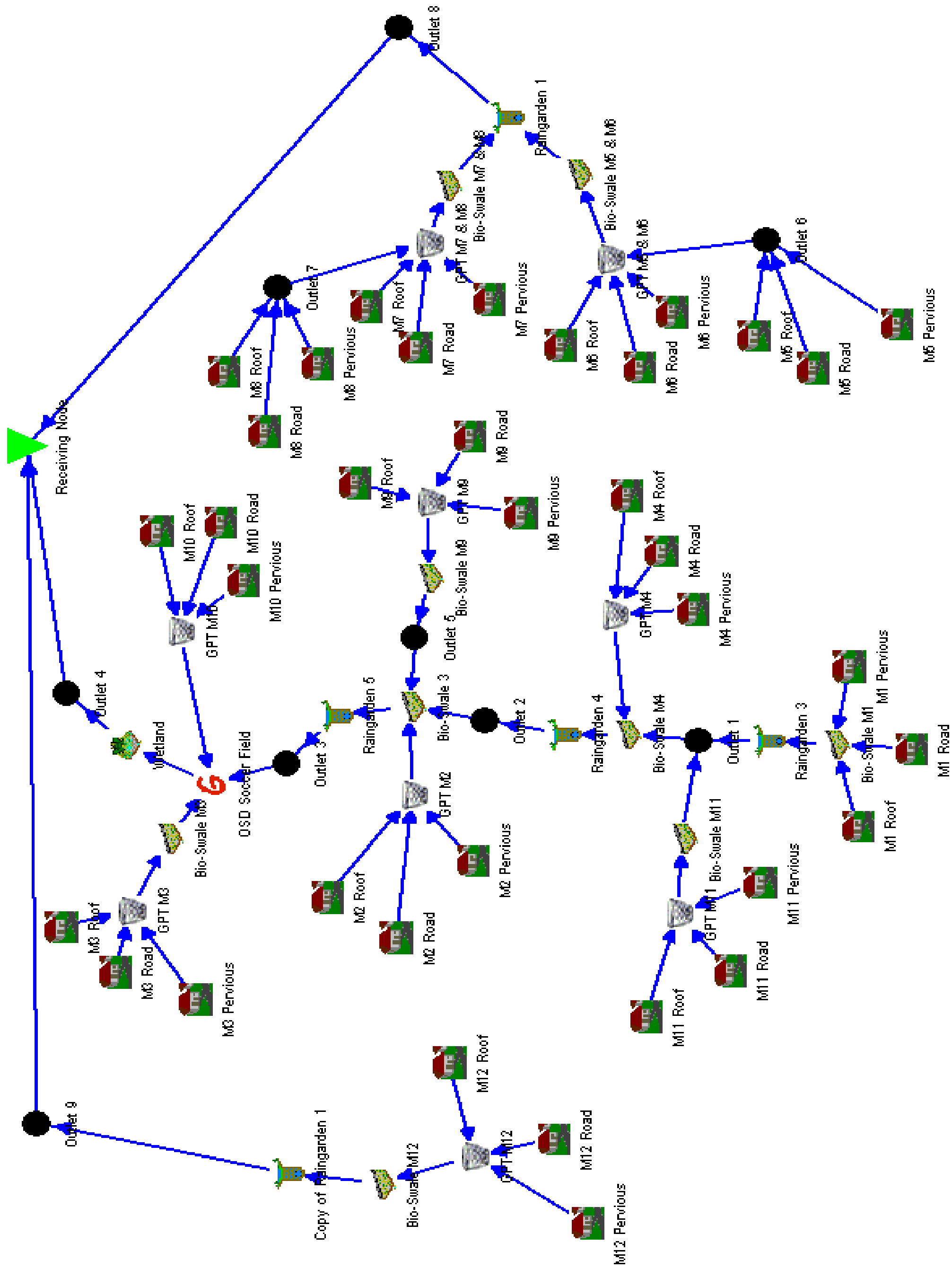


Table 8.7 – MUSIC Model Results Summary

	Flow (ML/yr)	TTSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	GPs (kg/yr)
UNTREATED					
M1	18.8	1,770	11.3	32.7	349
M2	34.8	3,800	19.3	67.5	646
M3	38.7	3,630	23.3	67.3	717
M4	28.0	2,720	17.0	48.6	606
M5	15.2	1,570	8.93	27.7	319
M6	65.2	5,550	42.0	103	1,410
M7	77.1	6,940	48.3	127	1,620
M8	10.7	1,630	357	29.3	29.4
M9	32.8	3,570	18.4	62.5	664
M10	59.0	6,980	31.9	118	1,290
M11	89.1	10,300	48.6	176	1,870
M12	31.6	3,050	19.2	54.8	667
TOTAL (receiving node)	**501**	**51.51E^3**	**291.8**	**914.4**	**10.19E^3**
TREATED					
M1	14.5	415	2.9	18.6	0
M2	32.4	592	7.64	39.3	0
M3	17.2	159	2.05	21.6	0
M4	25.2	304	5.11	26.1	0
M5	8.9	26.3	0.887	7.38	0
M6	55.0	338	10.2	43.6	0
M7	67.5	501	13.3	56.1	0
M8	4.52	18.2	0.399	4.51	0
M9	30.2	740	8.55	42..4	0
M10	34.2	353	4.29	43.2	0
M11	82.9	2,430	28.5	117	0
M12	27.6	393	6.31	30.1	0
TOTAL (receiving node)	**419**	**6.46E^3**	**97.1**	**478**	**0**
REDUCTIONS					
M1	22%	76.6%	74.3%	43.1%	100%
M2	6.9%	84.4%	60.4%	41.8%	100%
M3	61.8%	97.0%	91.2%	67.9%	100%
M4	10%	88.8%	69.9%	46.3%	100%
M5	41.4%	98.3%	90.1%	73.4%	100%
M6	15.6%	93.9%	75.7%	57.7%	100%
M7	12.5%	92.8%	72.5%	55.8%	100%
M8	57.8%	98.9%	99.9%	84.6%	100%
M9	7.9%	79.3%	53.5%	32.2%	100%
M10	42.0%	94.9%	86.6%	63.4%	100%
M11	7.0%	76.4%	41.3%	33.5%	100%
M12	12.7%	87.1%	67.1%	45.1%	100%
TOTALS (receiving node)	**83.6%**	**87.5%**	**66.7%**	**47.7%**	**100%**

Table 7.11 – MUSIC Model Results vs Objectives

	Flow	TTSS	TP	TN	GPs
REDUCTIONS	**83.6%**	**87.5%**	**66.7%**	**47.7%**	**100%**
OBJECTIVES		**80%**	**45%**	**45%**	**90%**

9 Conclusions

9.1 Water Quantity

RAFTS models of the proposed Bonnyrigg Living Communities Project were set up and run using design storms of various ARI's and durations. The model results were compared against the corresponding models used to represent the existing catchment development.

The model included detention basins on the eastern, western and central catchment having volumes of 1,000 m^3, 390m^3 and 7,860 m^3 respectively. It was found that these basins were sufficient to ensure that downstream flows and flood damage risk would not increase in the 100-year ARI event as a result of the proposed development.

HEC-RAS models were also created to determine both the level and extent of flood inundation for the 100-year ARI event. An assessment identified potential hot spot areas and indicated those regions which require dwellings to sit higher than adjacent road levels. Analysis also showed that there would be no effect on existing houses to be retained in the private estate and downstream properties.

An assessment of flow depths and velocities in the 100-year ARI was also undertaken. A number of areas were identified where minor piped drainage system links would need to be designed for an ARI greater than Council prescribed criteria (i.e. 5-year ARI) so that overland flows in a major storm meet the safety criteria.

9.2 Water Quality

The water quality model set up using the MUSIC software provides an indication of the pollutant removal rates expected when applying a treatment train of measures. However, the model is limited to concept analysis and the detailed size and removal rates for the different treatment components should be developed at the detailed design stage of the project.

According to the results of the MUSIC analysis, a treatment train consisting of rainwater reuse, bio-retention facilities (including swales and "raingardens") and GPTs will provide adequate treatment from the proposed development of the Bonnyrigg Living Communities site to exceed the statutory water quality objectives.

10 References

Commonwealth Bureau of Meteorology (2003). *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method*.

Duncan, H.P. (1999), *Urban Stormwater Quality: A Statistical Overview*, Report 99/3, Cooperative Research Centre for Catchment Hydrology, February 1999.

Institution of Engineers, Australia (2001*). Australian Rainfall and Runoff — A Guide to Flood Estimation*, Volumes 1 & 2, Institution of Engineers, Australia.

Department of Environment and Climate Change, EPA Resources. *Managing Urban Stormwater*

NSW Floodplain Development Manual (2005) *Dept. of Infrastructure Planning & Natural Resources*

Parsons Brinkerhoff (2005), Preliminary Environmental Site Assessment, Bonnyrigg Estate, Bonnyrigg, NSW. May 2005

XPSoftware, (1996). *XP-RAFTS* User Manual Version 5.

Wang, Q.J., Chiew, F.H.S., McConachy, F.L.N., James, R., de Hoedt, G.C., & Wright, W.J. (2001). *Climatic Atlas of Australia: Evapotranspiration*. Melbourne: Bureau of Meteorology and Cooperative Research Centre for Catchment Hydrology

US Army Corps of Engineers, Hydrologic Engineering Center (2003). *HEC-RAS River Analysis System — User's Manual, and Hydraulic Reference Manual*. US Army Corps of Engineers, Hydrologic Engineering Center

Kandasamy, J. and Beecham S. (2004), "*Experience of Flood Modelling in NSW, Australia*", HEC-RAS Workshop, University of Technology, Sydney

Upper Parramatta River Catchment Trust (2004), Water sensitive Urban Design, *Technical Guidelines for Western Sydney*

Appendix A: Drawings

bonnyrigg PARTNERSHIPS

LEGEND

SITE BOUNDARY

EXISTING OVERLAND FLOW PATH

EXISTING CREEK

RIDGE LINE

SCALE 1:5000 METRES
100 50 0 100
75 25

Bonnyrigg Living Communities Project

DATE
Aug 07

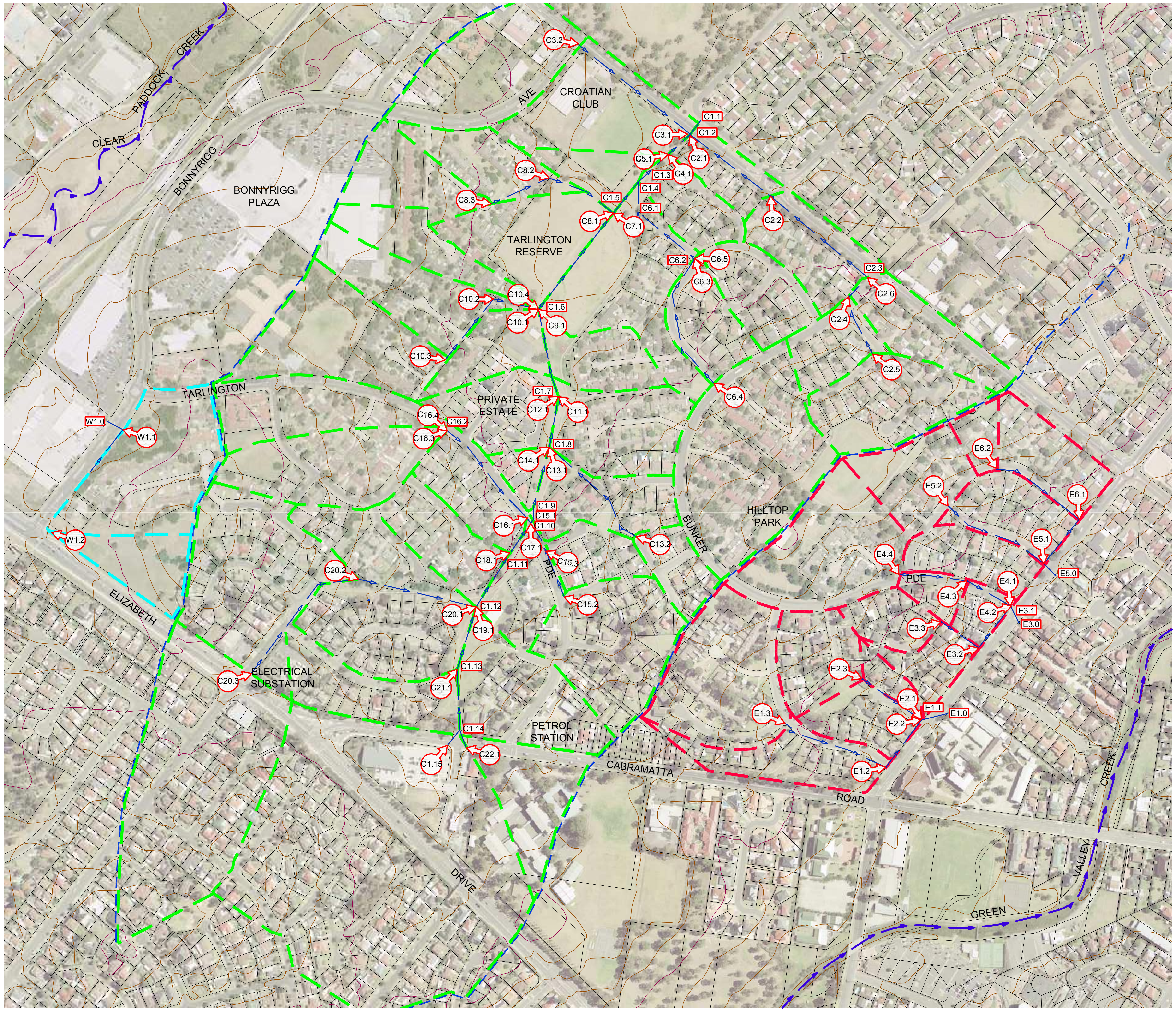
SCALE
1:5000 @ A3

DRAWING TITLE + DESCRIPTION
Existing Site Plan

DRAWING NO.
W01

REVISION
A

Water Cycle Report



bonnyrigg
PARTNERSHIPS

LEGEND

- EXISTING OVERLAND FLOW PATH
- EXISTING CREEK
- RIDGE LINE
- CENTRAL CATCHMENT BOUNDARY
- EASTERN CATCHMENT BOUNDARY
- WESTERN CATCHMENT BOUNDARY
- C1.2 RAFTS 'LINK' NODE
- C1.3 RAFTS CATCHMENT NODE

SCALE 1:5000 METRES
100 50 0 100
75 25

Bonnyrigg Living Communities Project

DATE
Aug 07

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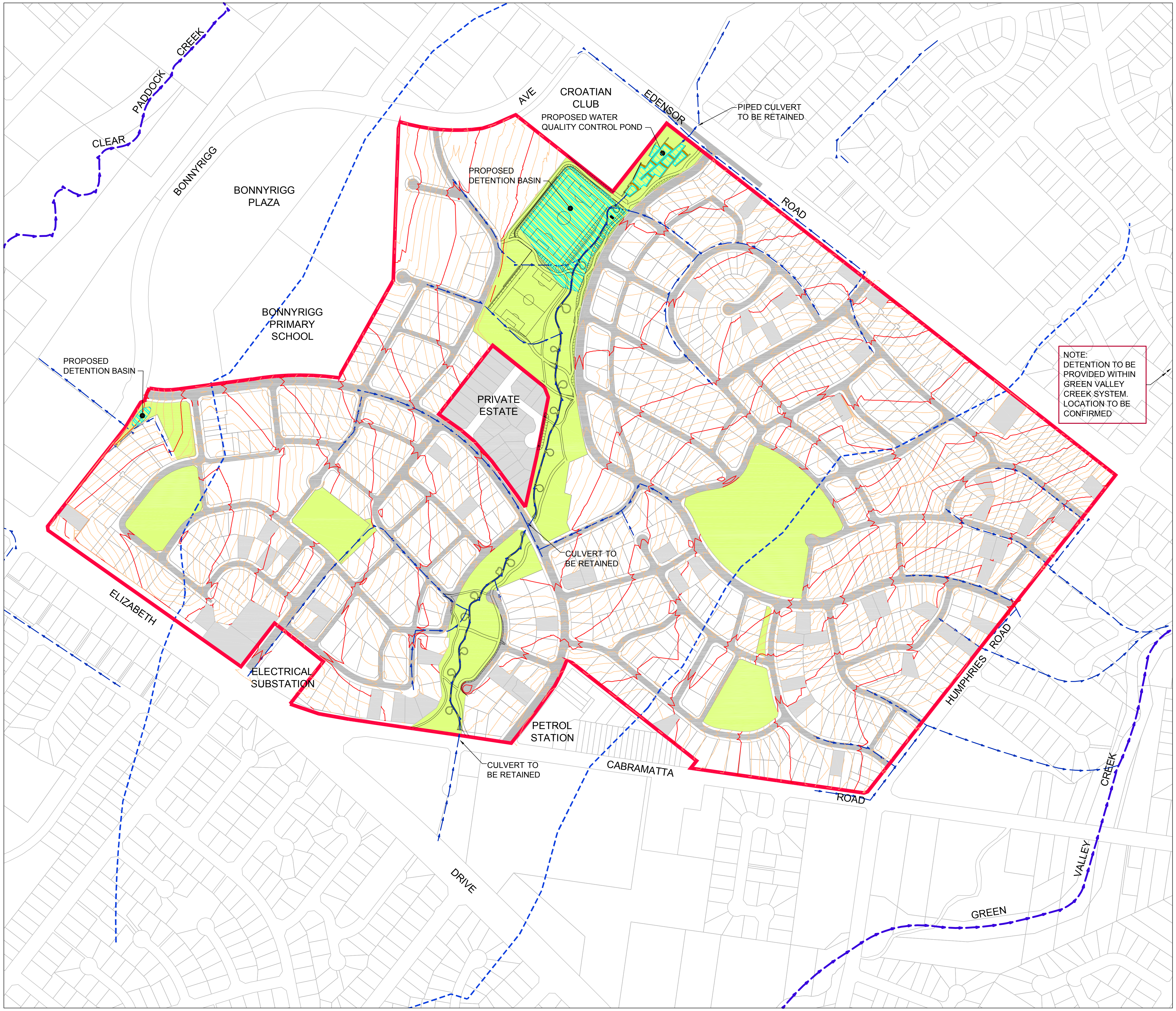
Existing Catchment Plan

DRAWING NO.
W02

REVISION
A

Water Cycle Report



bonnyrigg
PARTNERSHIPS

LEGEND

- SITE BOUNDARY
- PROPOSED OVERLAND FLOW PATH
- EXISTING CREEK
- RIDGE LINE
- PROPOSED ROAD
- PROPOSED DETENTION BASIN
- PROPOSED WATER QUALITY CONTROL POND
- PROPOSED OPEN SPACE

N SCALE 1:5000 METRES
100 50 0 100

Bonnyrigg Living Communities Project

DRAWING TITLE + DESCRIPTION
Proposed Site Plan

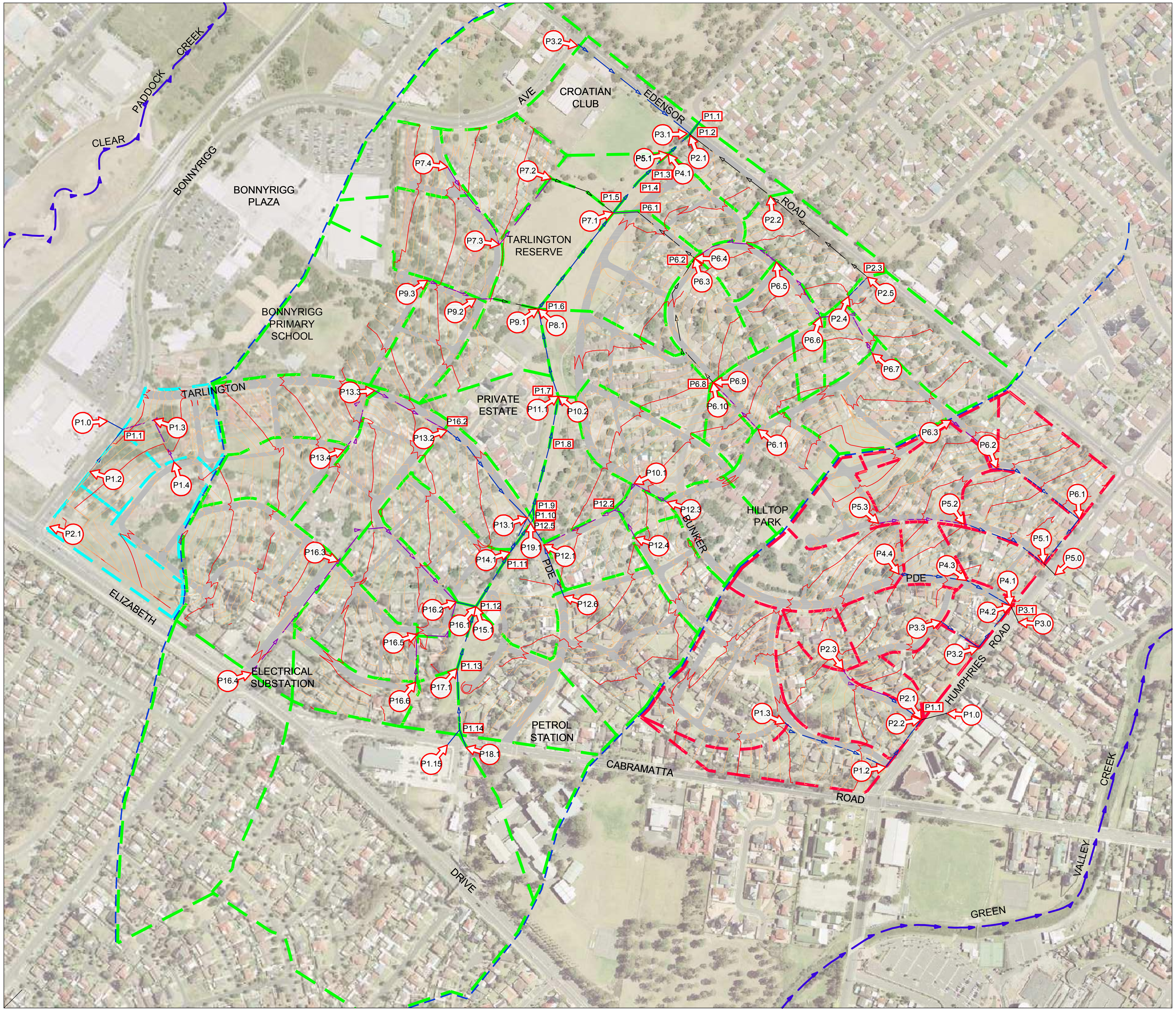
DATE
Aug 07

SCALE
1:5000 @ A3

DRAWING NO.
W03

REVISION
A

Water Cycle Report



bonnyrigg PARTNERSHIPS

LEGEND

- EXISTING OVERLAND FLOWPATH
- PROPOSED OVERLAND FLOWPATH
- EXISTING CREEK
- RIDGE LINE
- CENTRAL CATCHMENT BOUNDARY
- EASTERN CATCHMENT BOUNDARY
- WESTERN CATCHMENT BOUNDARY
- P1.2 RAFTS 'LINK' NODE
- P1.3 RAFTS CATCHMENT NODE

SCALE 1:5000 METRES
100 50 0 100
75 25

Bonnyrigg Living Communities Project

DATE
Aug 07

SCALE
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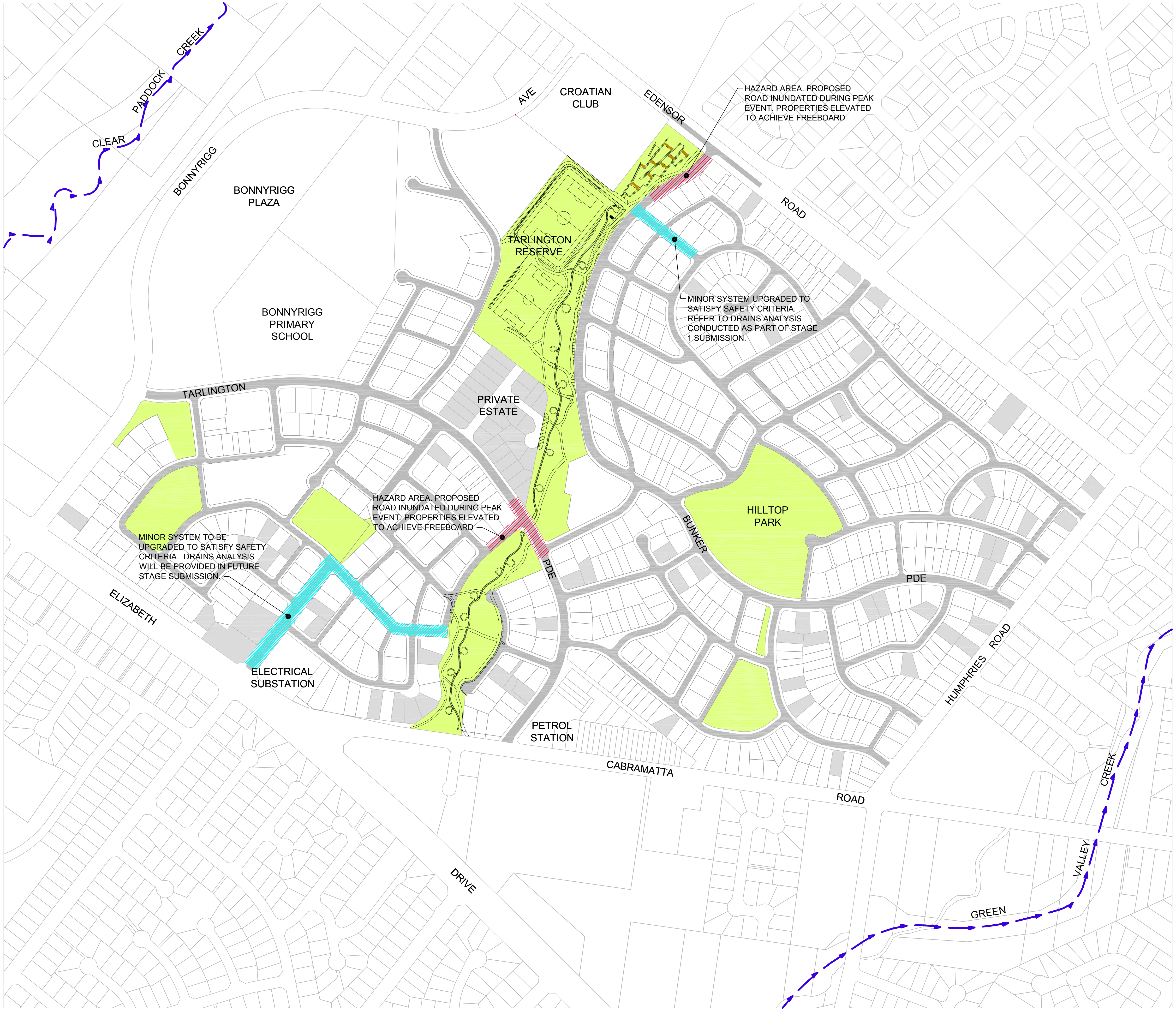
DRAWING TITLE + DESCRIPTION
Proposed Catchment Plan

DRAWING NO.
W04

REVISION
A



bonnyrigg
PARTNERSHIPS

LEGEND

- SITE BOUNDARY
- FLOW PATH REQUIRING MINOR SYSTEMS >5YR ARI TO MEET MAJOR SYSTEM SAFETY CRITERIA
- HAZARD AREA

SCALE 1:5000 METRES
100 50 0 100
75 25

Bonnyrigg Living Communities Project

DATE
Aug 07

SCALE
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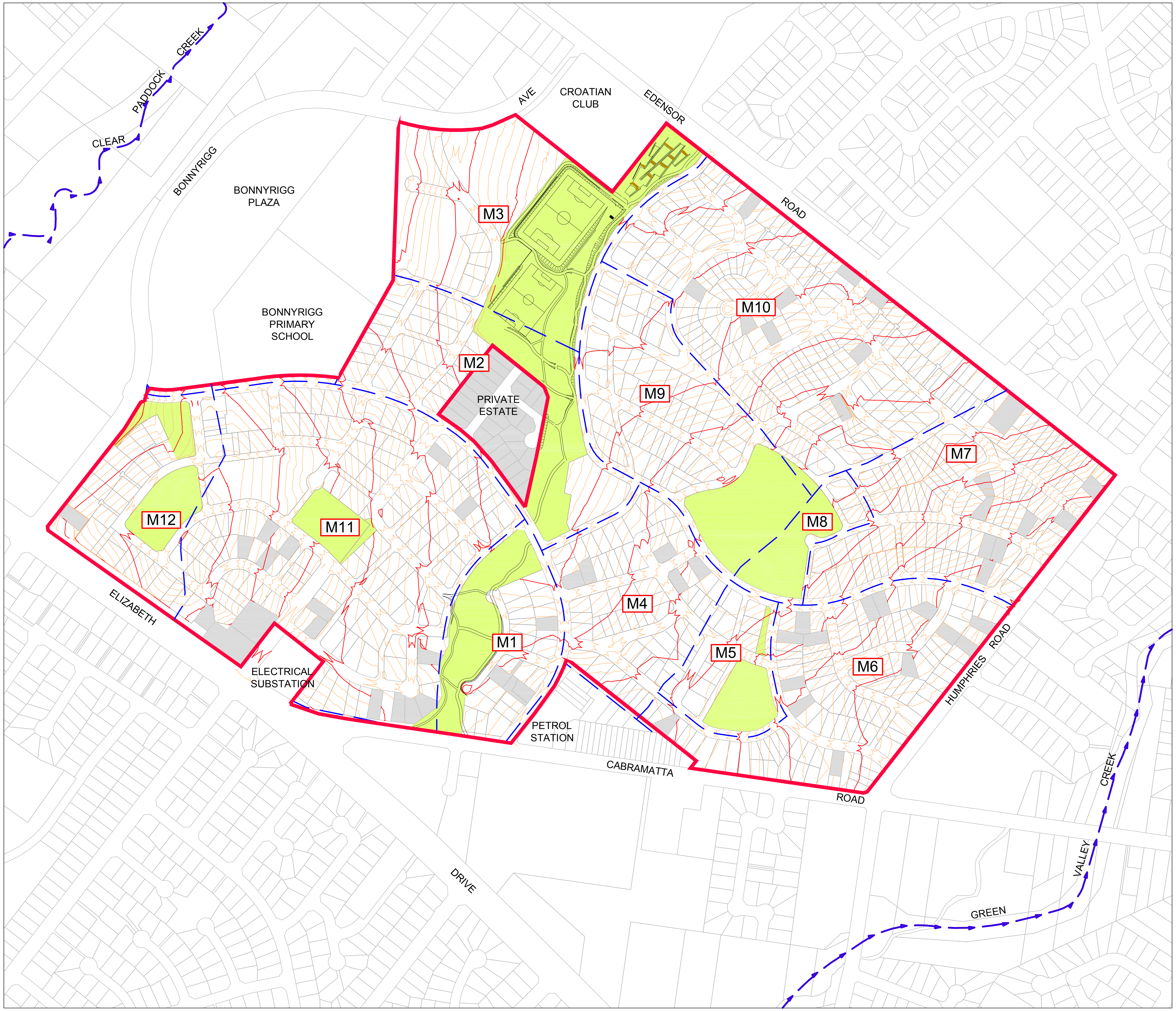
DRAWING TITLE + DESCRIPTION
Safety Assessment Plan

DRAWING NO.
W05

REVISION
A



bonnyrigg
PARTNERSHIPS

LEGEND

SITE BOUNDARY

M4 SUBCATCHMENT BOUNDARY WITH LABEL

SCALE 1:5000
METRES
100 50 0 100
75 25

Bonnyrigg Living Communities Project

DATE
Aug 07

SCALE
1:5000
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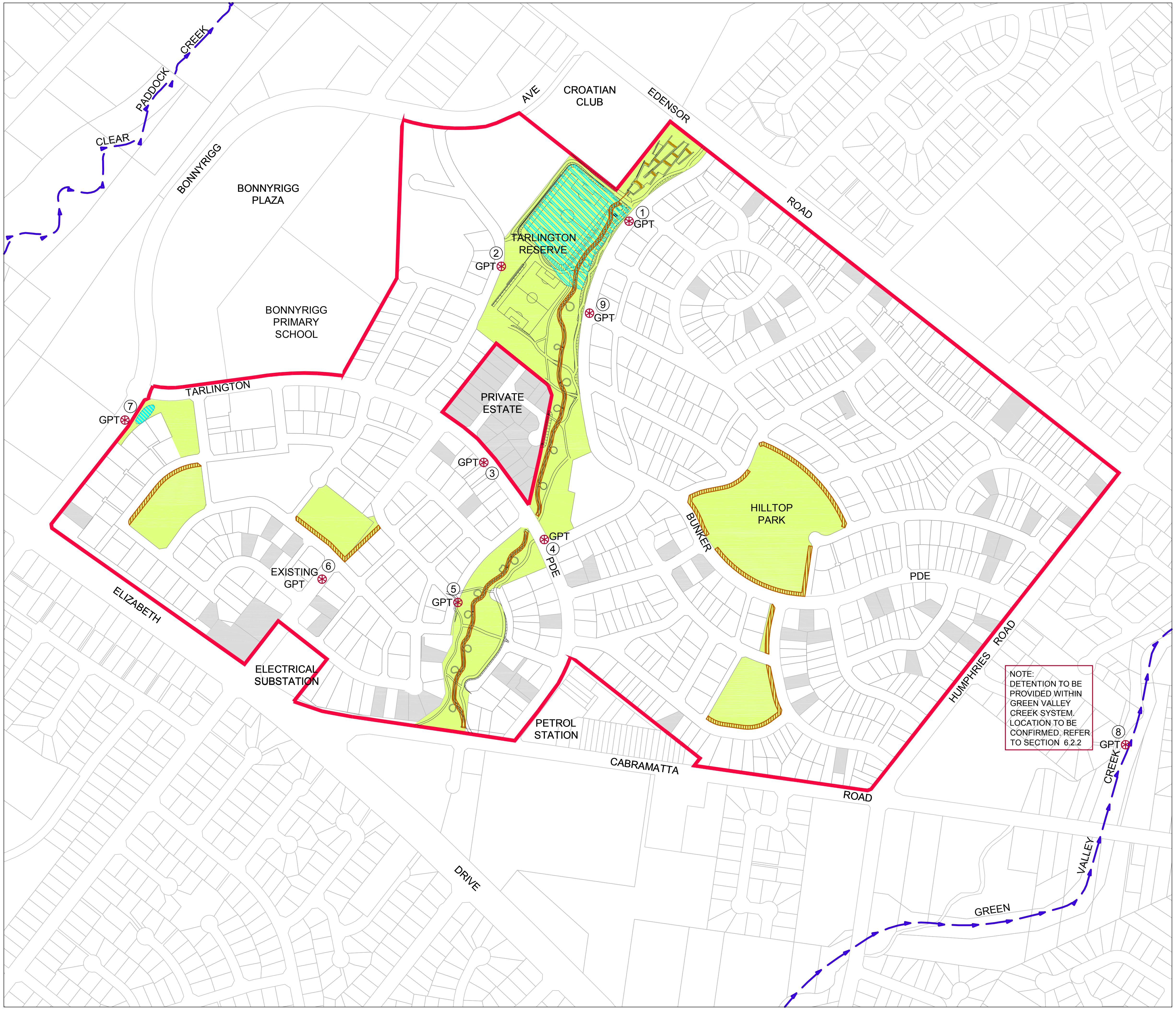
DRAWING TITLE + DESCRIPTION
Stormwater Quality (Music) - Catchment Plan

DRAWING NO.
W06

REVISION
A

Water Cycle Report



bonnyrigg PARTNERSHIPS

LEGEND

- SITE BOUNDARY
- PROPOSED DETENTION BASIN
- PROPOSED BIOSWALE
- GPT — GROSS POLLUTANT TRAP

SCALE 1:5000 METRES
100 50 0 100
75 25

Bonnyrigg Living Communities Project

DATE
Aug 07

SCALE
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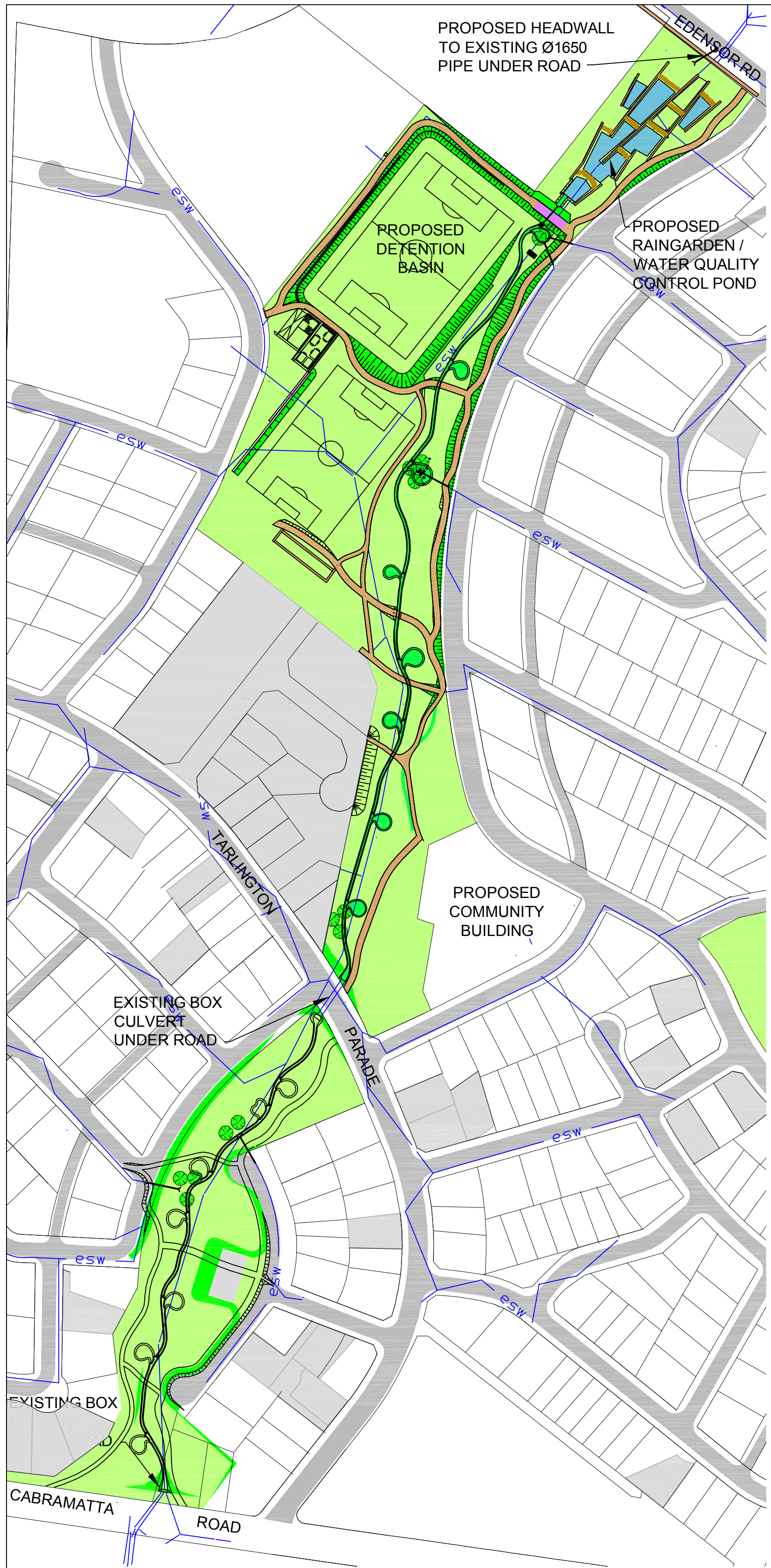
DRAWING TITLE + DESCRIPTION
Water Cycle Management Plan - Overall

DRAWING NO.
W07

REVISION
A



TARLINGTON RESERVE PLAN

SCALE 1:4000

DETENTION BASIN PLAN

SCALE 1:1000

bonnyrigg PARTNERSHIPS

SCALE 1:4000 METRES — 80 40 0 80 / 60 20

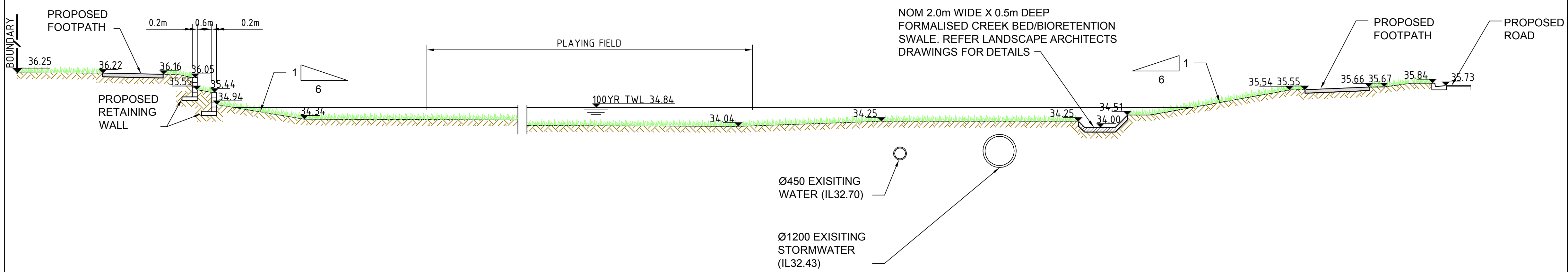
SCALE 1:1000 METRES — 20 10 0 20 / 15 5

N

Bonnyrigg Living Communities Project	DATE Aug 07
	SCALE AS SHOWN
DRAWING TITLE + DESCRIPTION **Tarlington Reserve Plan Sheet 1 of 2**	DRAWING NO. W08
	REVISION A

WATER QUALITY CONTROL POND PLAN

SCALE 1:500



SECTION 1/W08

1 : 200

bonnyrigg PARTNERSHIPS

Bonnyrigg Living Communities Project

DATE
Aug 07

SCALE
AS SHOWN

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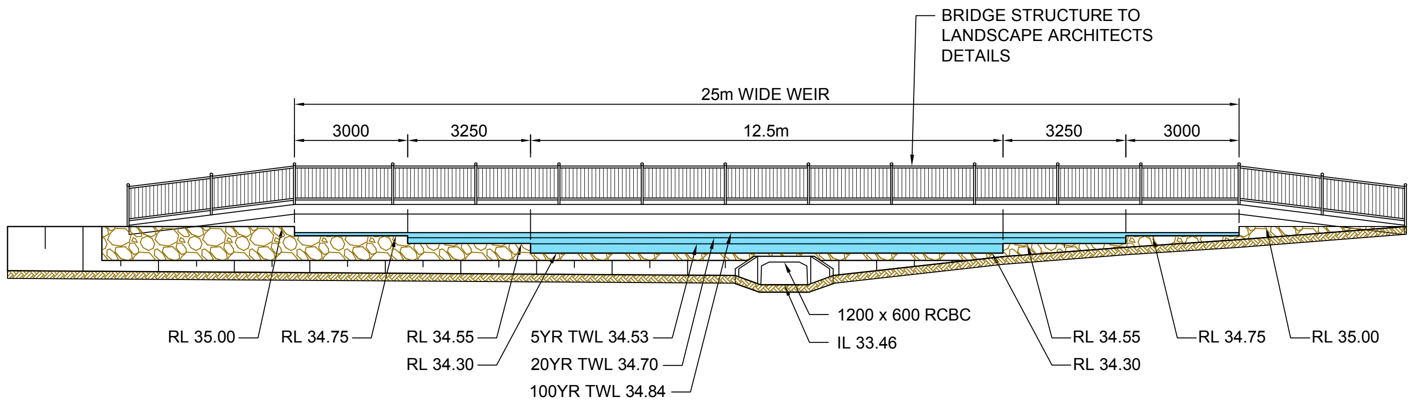
Tarlington Reserve Plan Sheet 2 of 2

DRAWING NO.
W09

REVISION
A



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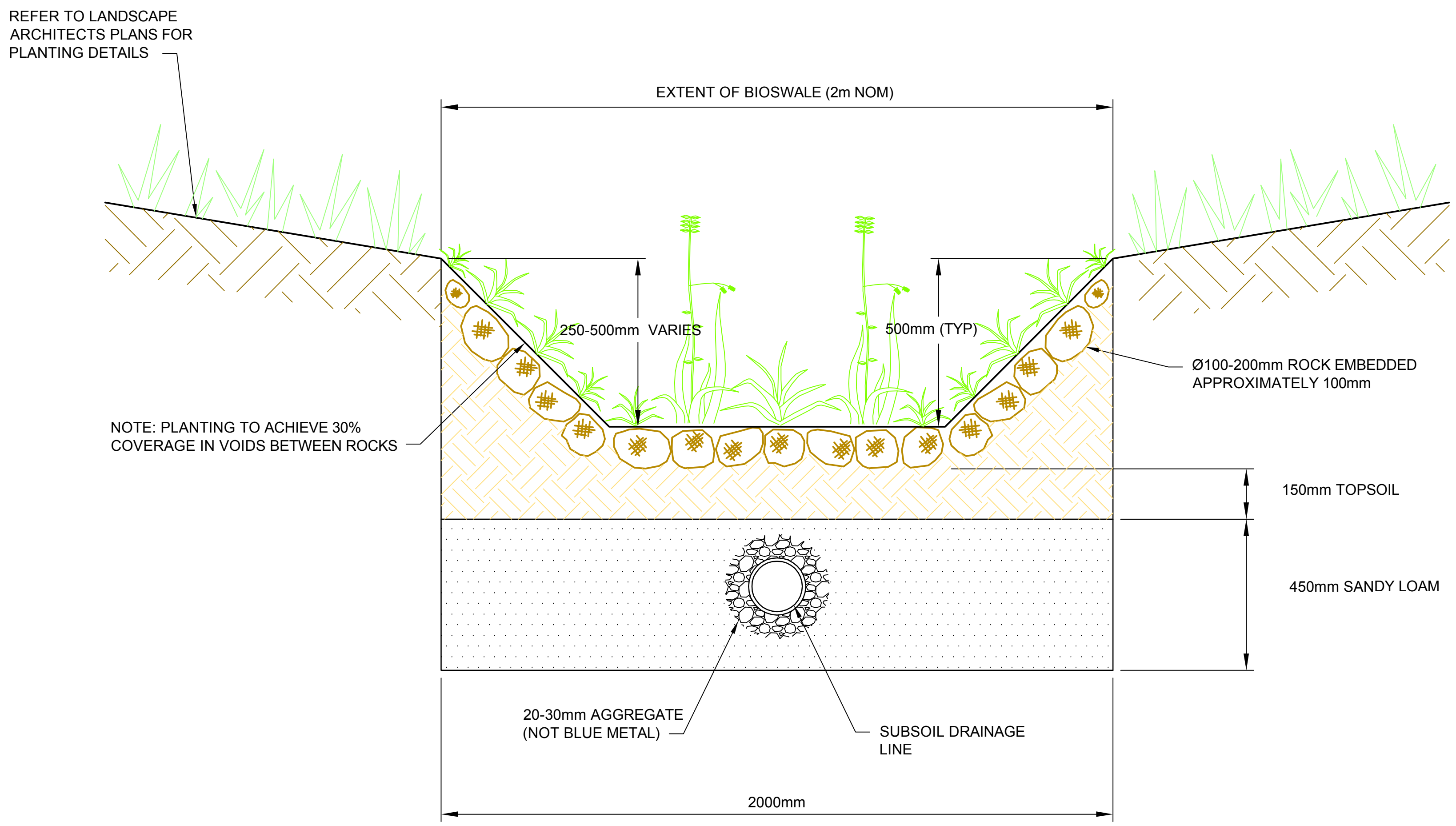

SECTION 3/W08
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bonnyrigg PARTNERSHIPS

N

Bonnyrigg Living Communities Project

DATE
Aug 07

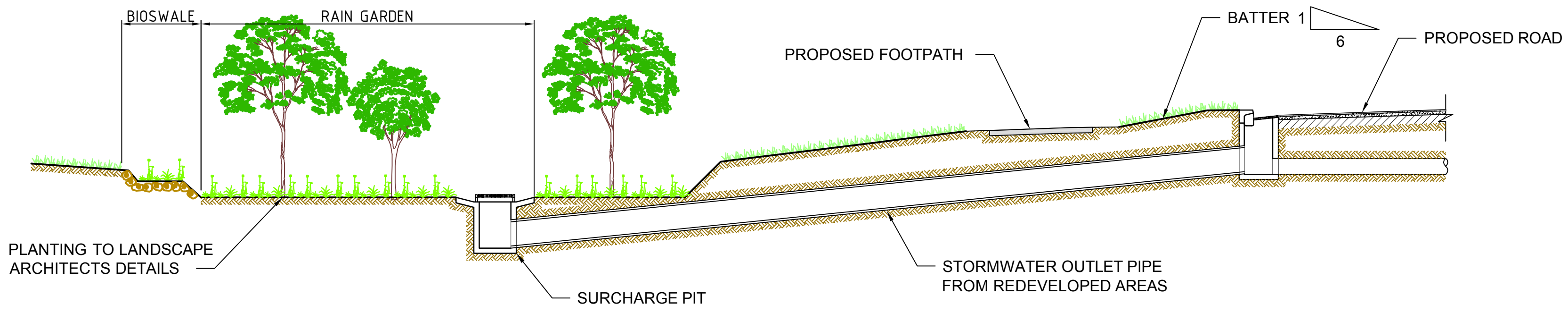
SCALE
AS SHOWN

DRAWING TITLE + DESCRIPTION
Tarlington Reserve Sections Sheet 1 of 2

DRAWING NO.
W10

REVISION
B

Water Cycle Report



SECTION 4/W08
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bonnyrigg PARTNERSHIPS

N

Bonnyrigg Living Communities Project

DATE
Aug 07

SCALE
AS SHOWN

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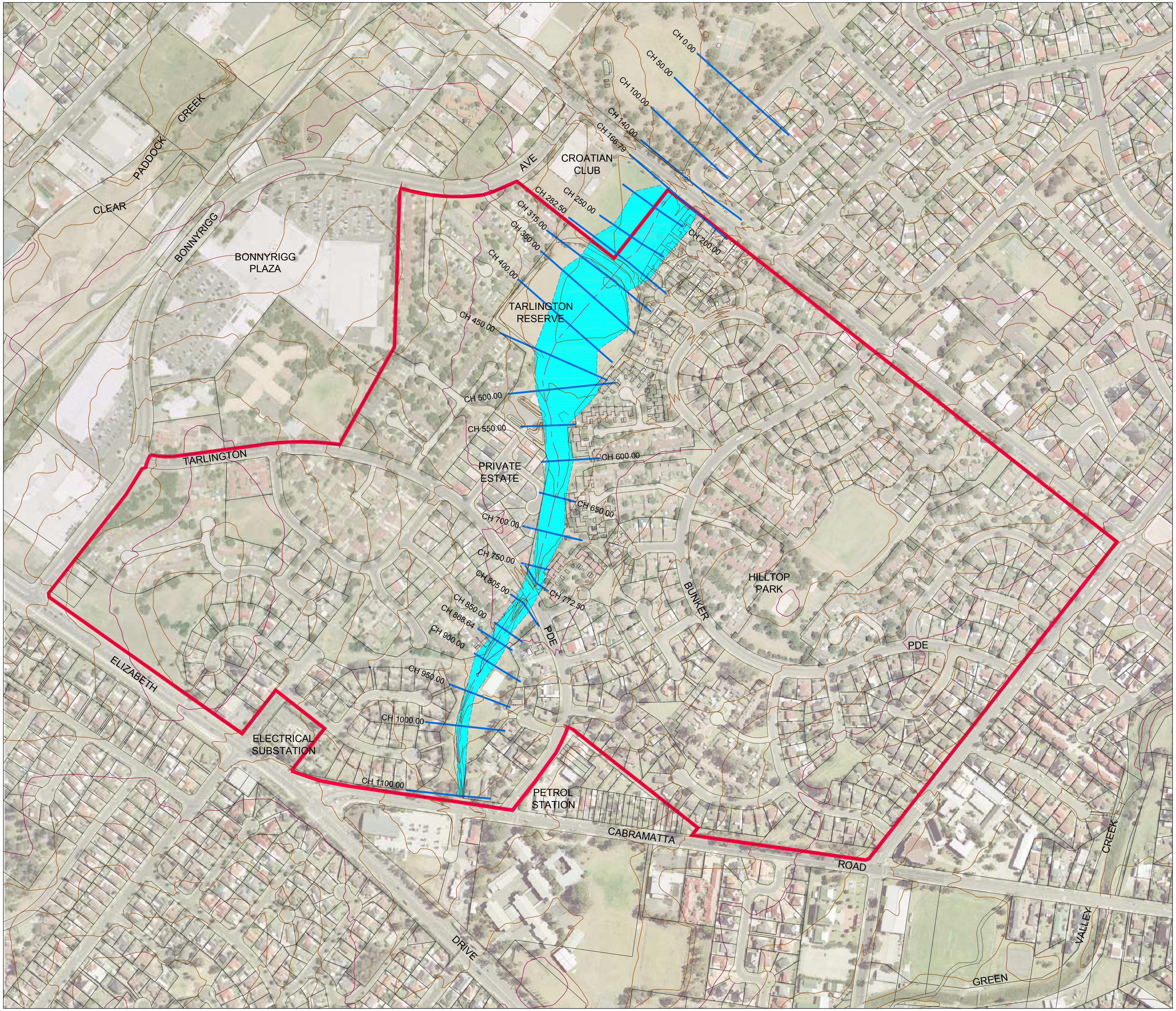
Tarlington Reserve Sections Sheet 2 of 2

DRAWING NO.
W11

REVISION
A



bonnyrigg
PARTNERSHIPS

LEGEND

- SITE BOUNDARY
- CREEK CENTRELINE
- HEC-RAS SECTIONS
- 100YR EXISTING FLOOD EXTENT

SCALE 1:5000
METRES
100 50 0 100
75 25

Bonnyrigg Living Communities Project

DATE
Aug 07

SCALE
1:5000
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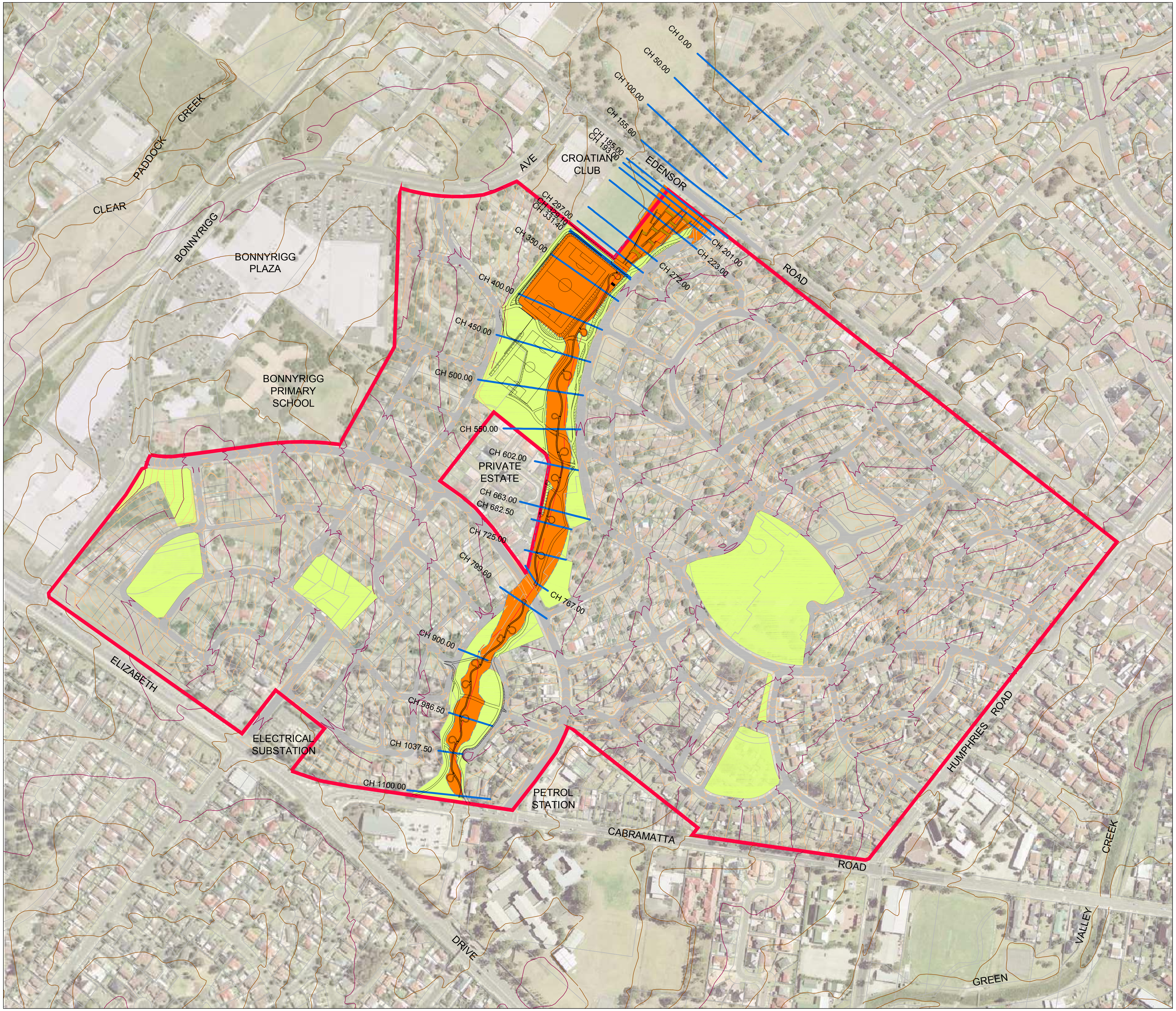
DRAWING TITLE + DESCRIPTION
Existing HEC-RAS Sections

DRAWING NO.
W12

REVISION
A



bonnyrigg
PARTNERSHIPS

LEGEND

- SITE BOUNDARY
- CREEK CENTRELINE
- HEC-RAS SECTIONS
- 100YR PROPOSED FLOOD EXTENT

SCALE 1:5000
METRES
100 50 0 100
75 25

Bonnyrigg Living Communities Project

DATE
Aug 07

SCALE
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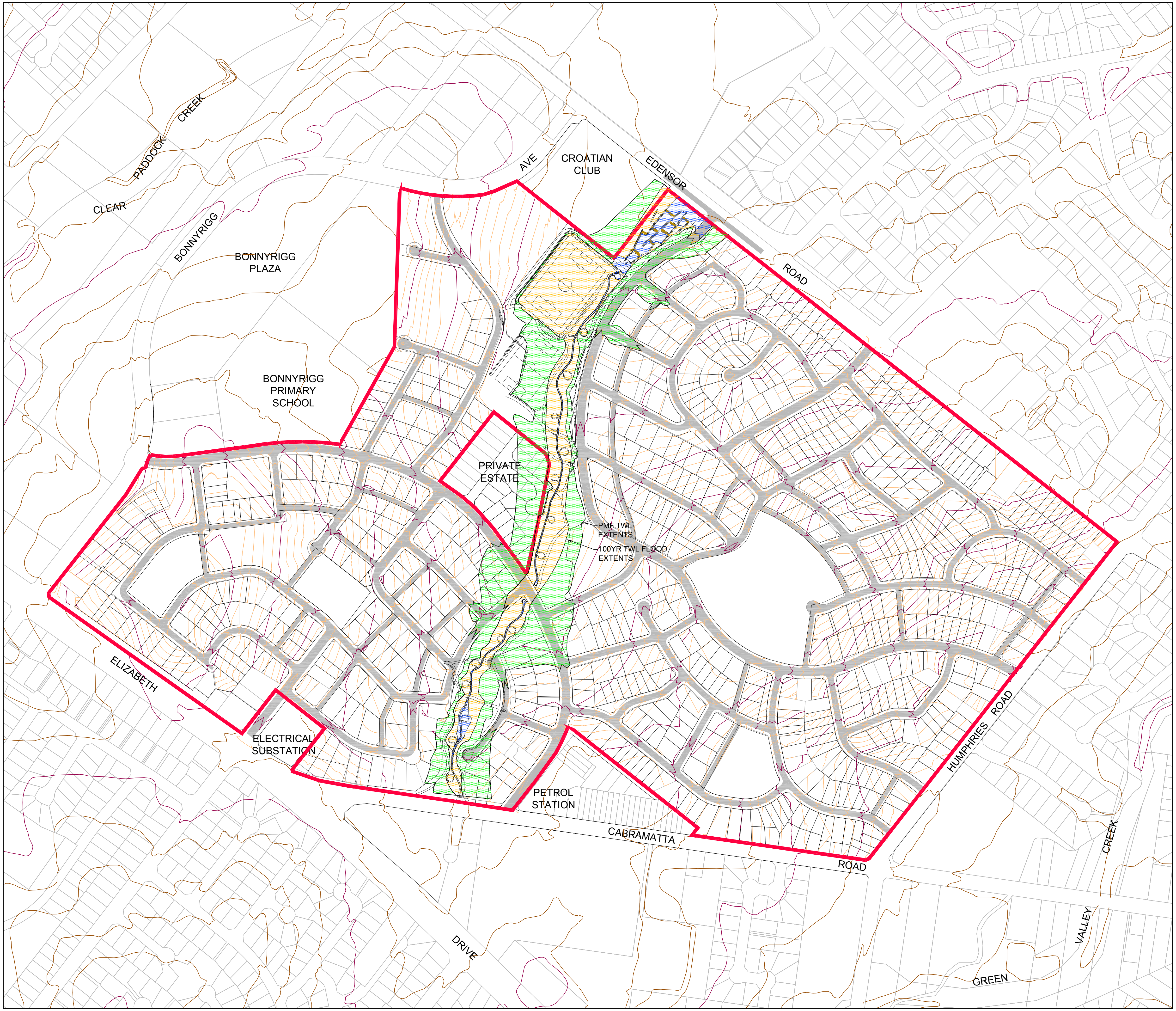
DRAWING TITLE + DESCRIPTION
Proposed HEC-RAS Sections

DRAWING NO.
W13

REVISION
A

Water Cycle Report



bonnyrigg PARTNERSHIPS

LEGEND

- SITE BOUNDARY
- HIGH FLOW RISK PRECINCT
- MEDIUM FLOW RISK PRECINCT
- LOW FLOW RISK PRECINCT

SCALE 1:5000 METRES
100 50 0 100
75 25

Bonnyrigg Living Communities Project

DATE
Aug 07

SCALE
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DRAWING TITLE + DESCRIPTION
Flood Risk Map

DRAWING NO.
W14

REVISION
A

Water Cycle Report

Appendix B: RAFTS model data

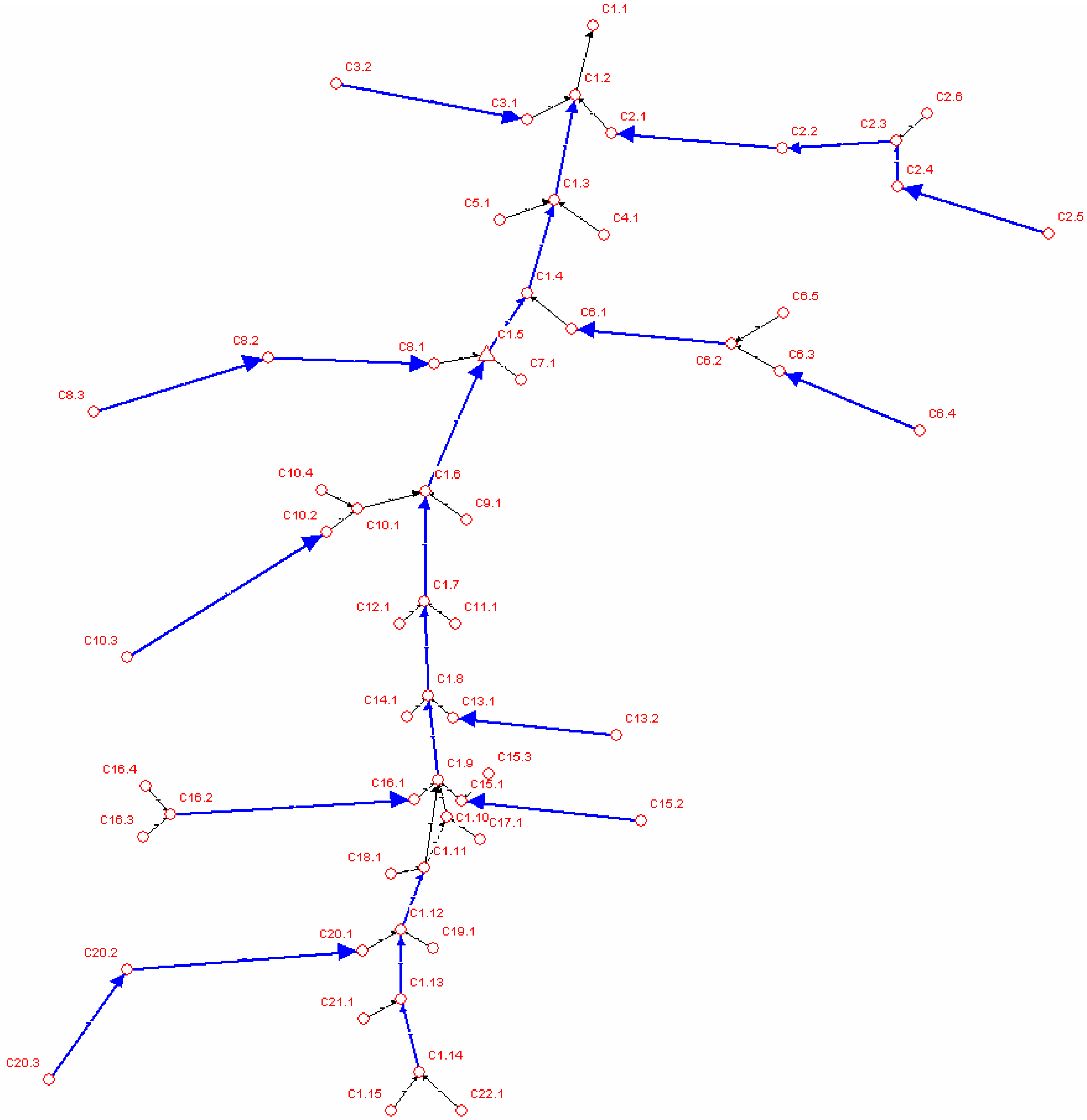

FIGURE B.1 – Existing RAFTS Model – Central Catchment

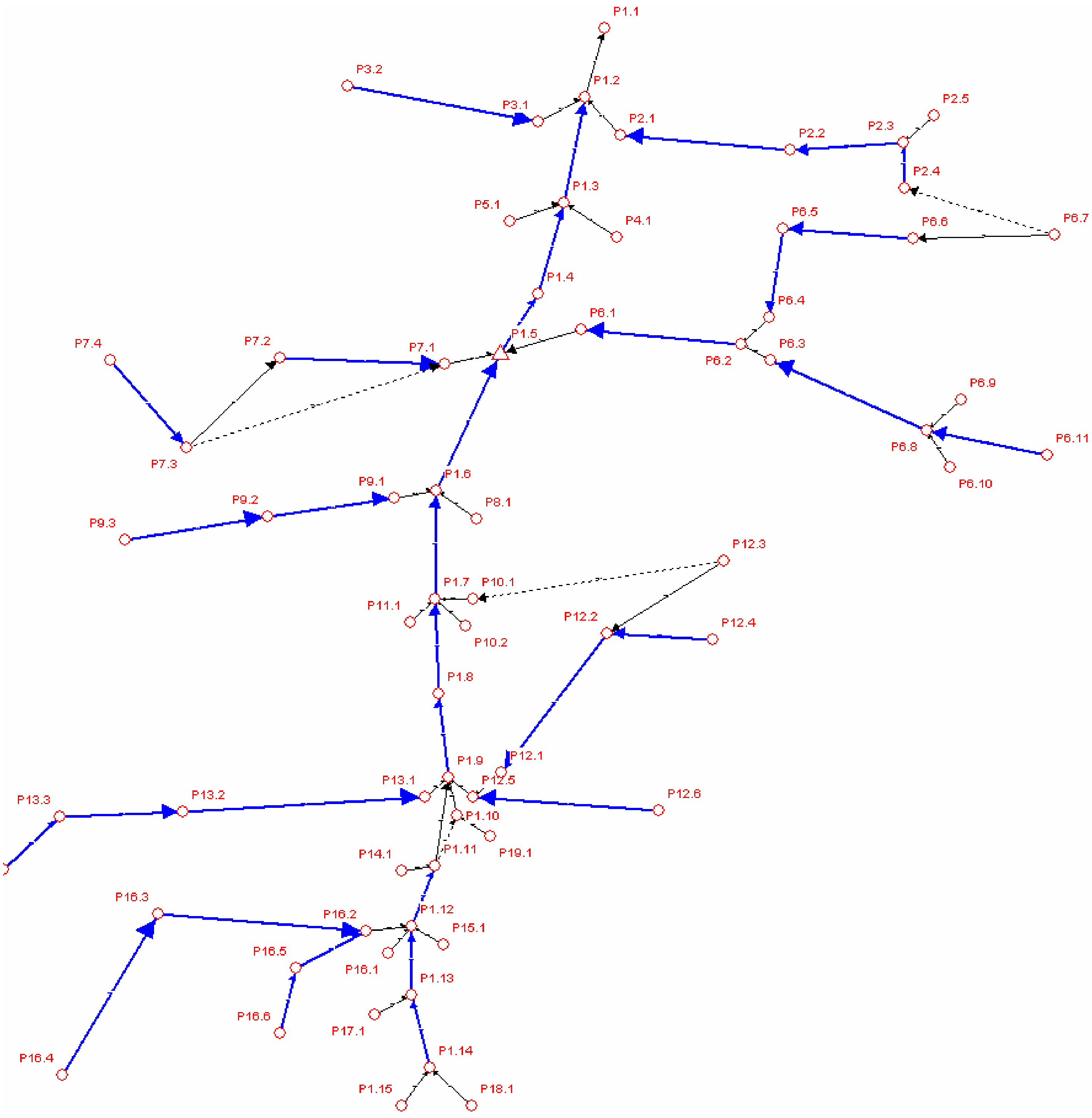

FIGURE B.2 – Proposed RAFTS Model – Central Catchment

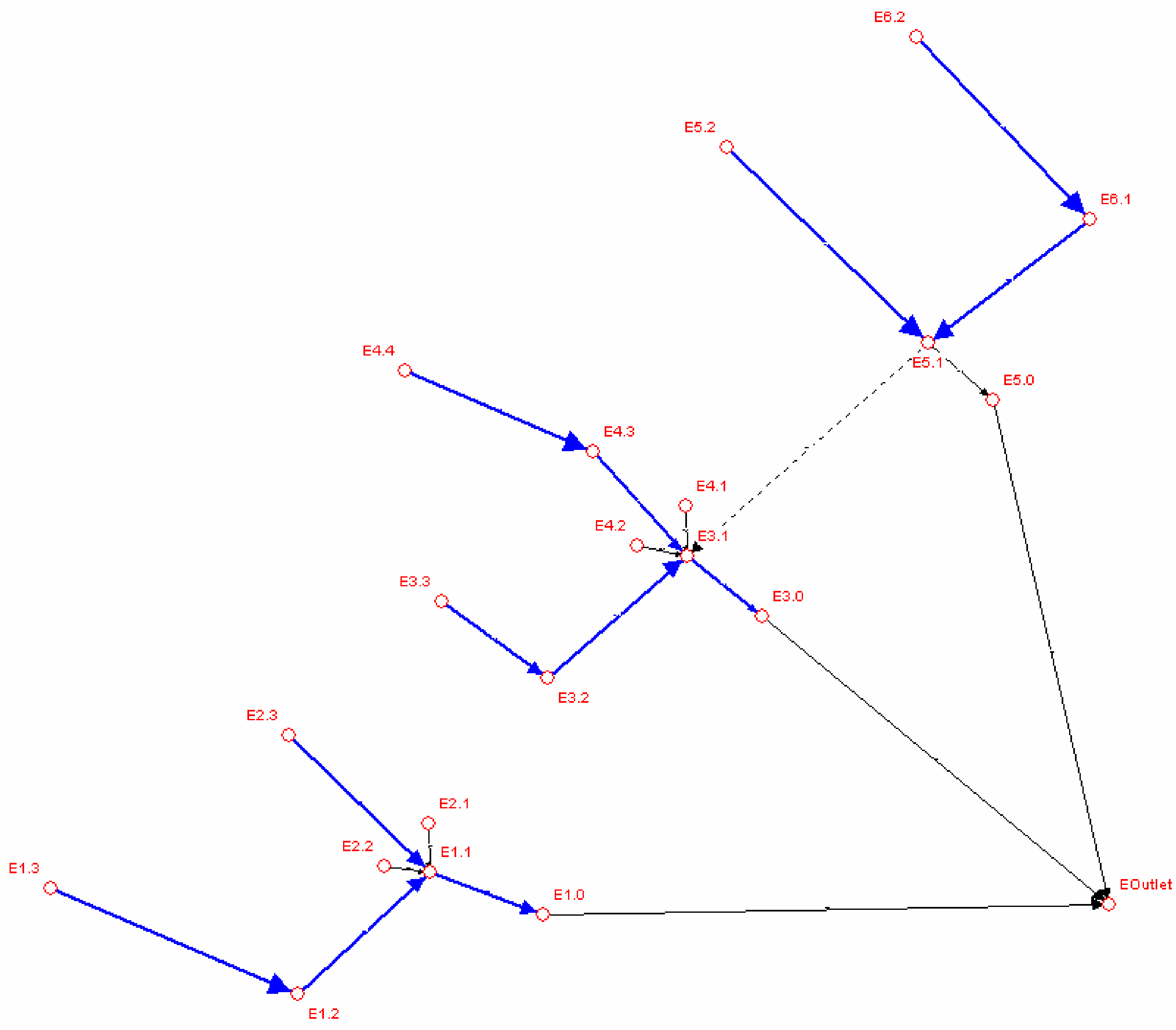

FIGURE B.3 – Existing RAFTS Model – Eastern Catchment

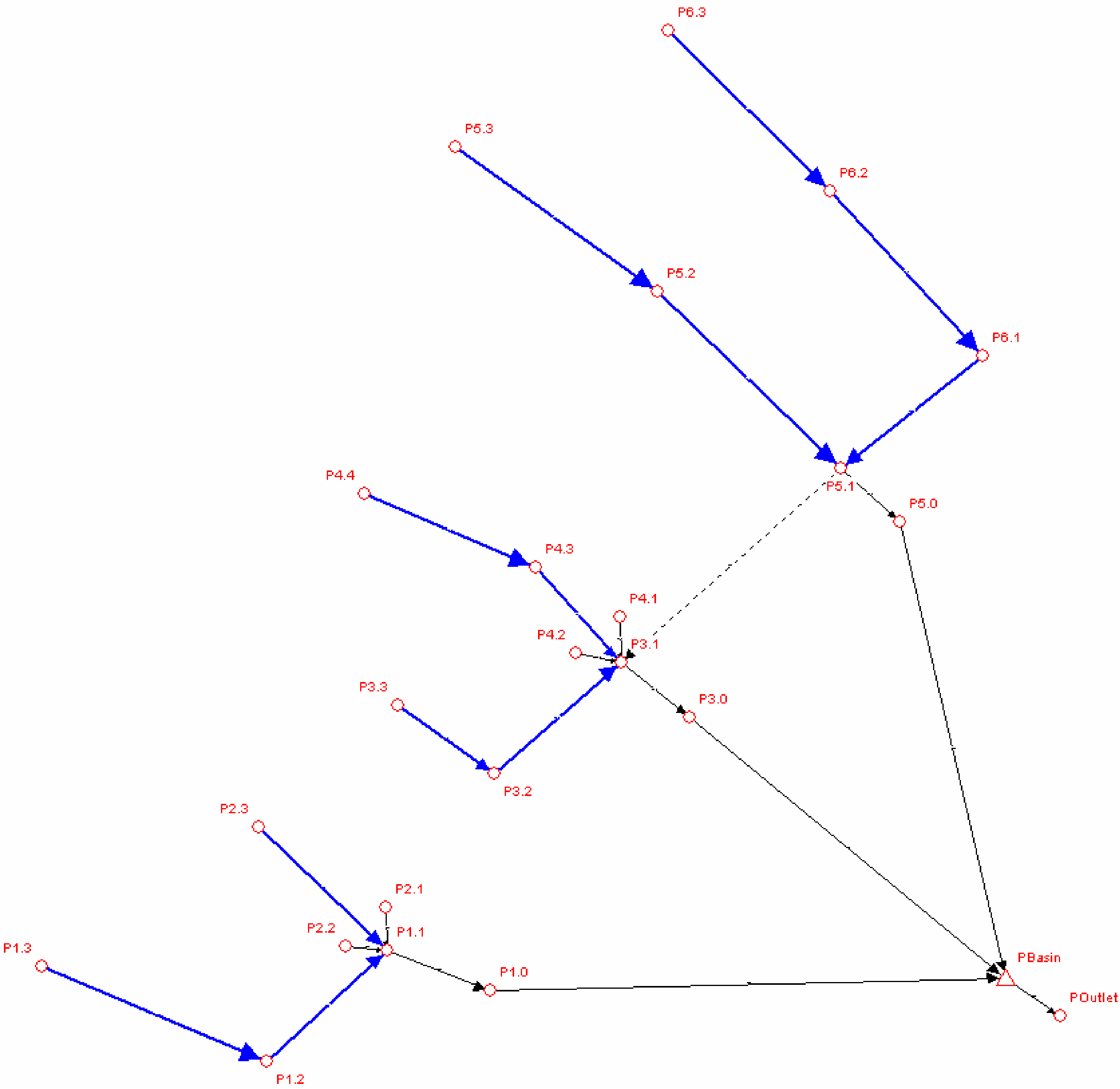

FIGURE B.4 – Proposed RAFTS Model – Eastern Catchment

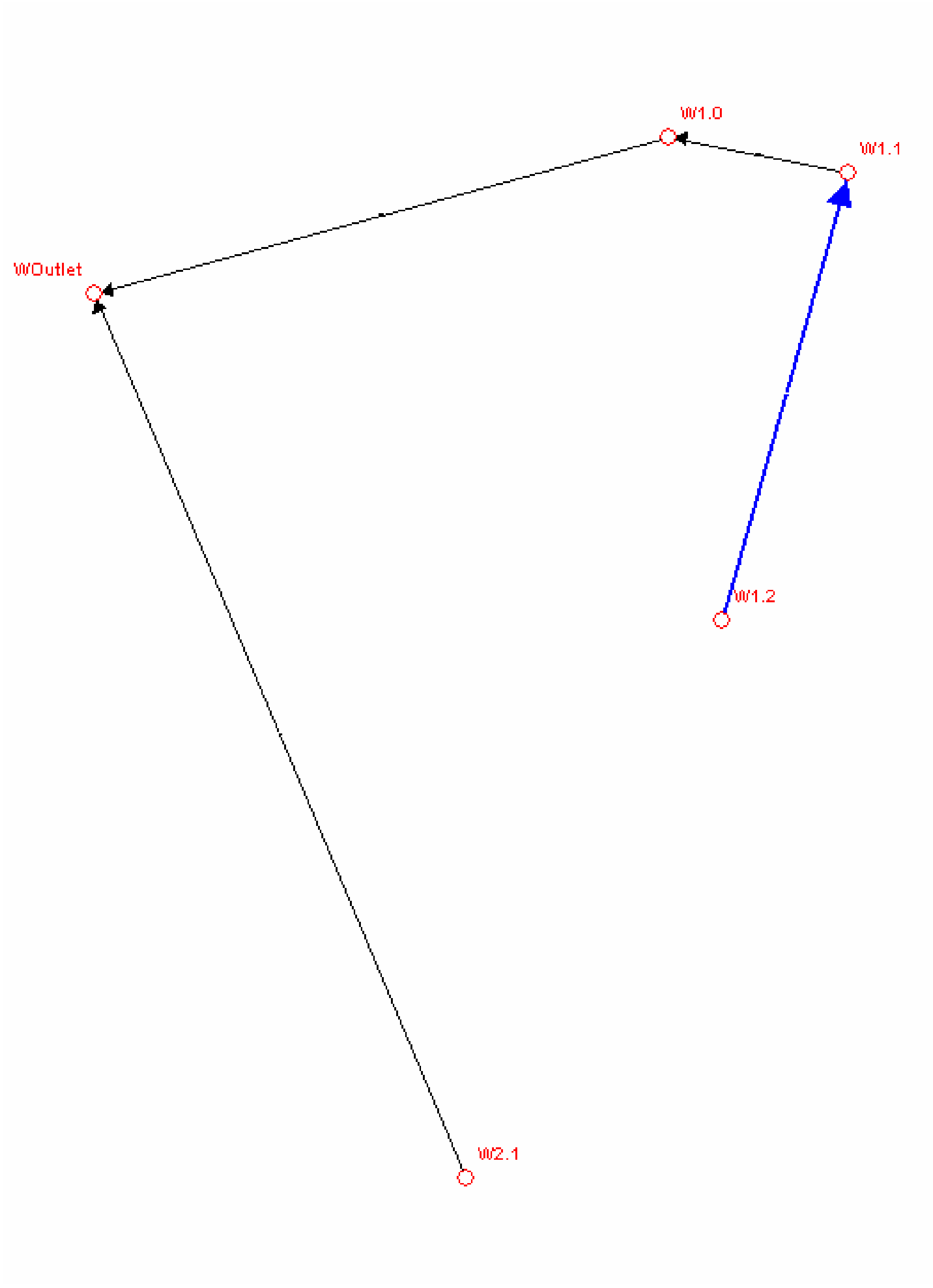

FIGURE B.5 – Existing RAFTS Model – Western Catchment

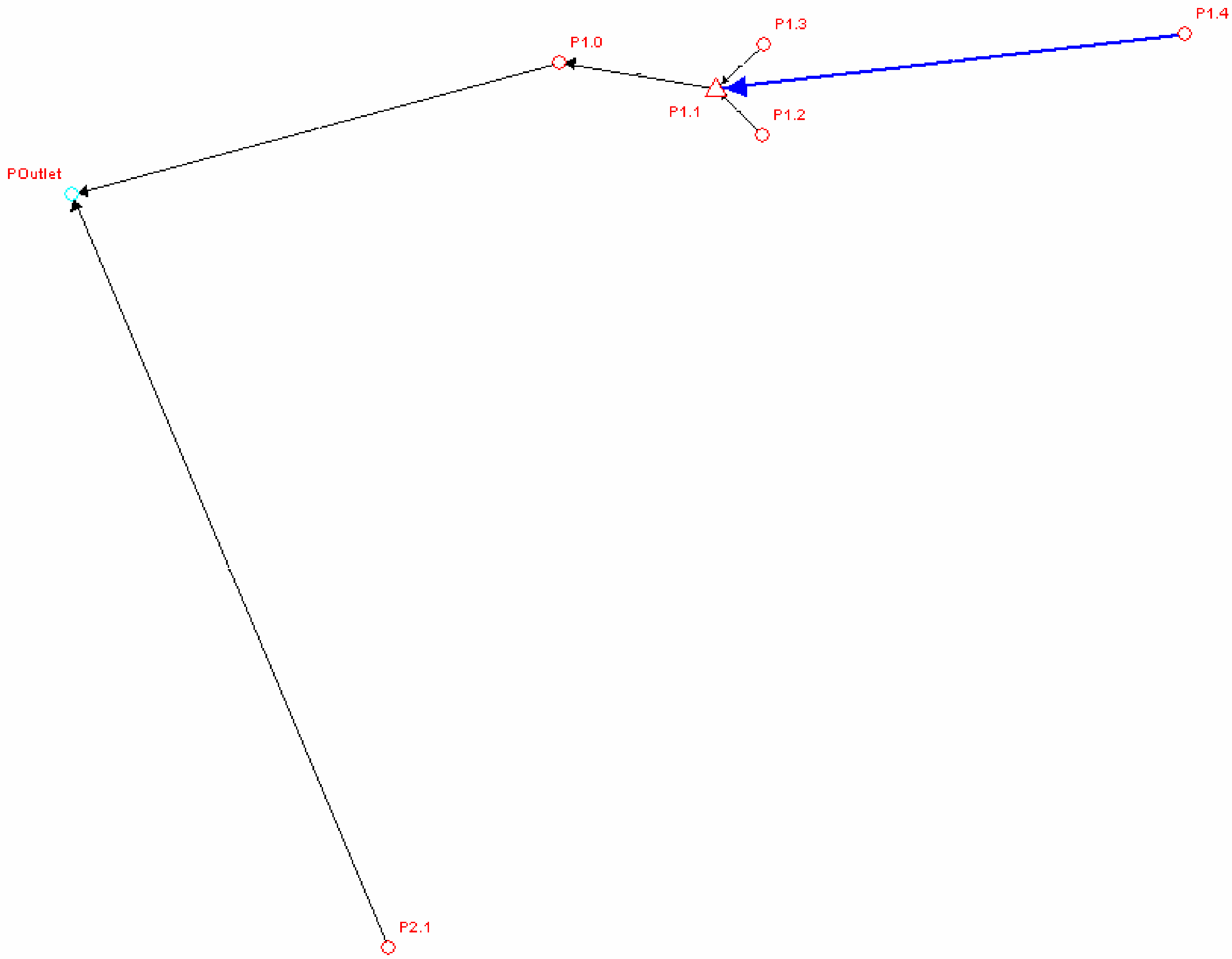

FIGURE B.6 – Proposed RAFTS Model – Western Catchment

GSDM CALCULATION SHEET

LOCATION INFORMATION

Catchment	Bonnyrigg	Area (km^2)	1.132
State	NSW	Duration Limit (hours)	6
Latitude	-33.883	Longitude	150.817

Portion of Area Considered:

Smooth, S=	0	Rough, R=	1

ELEVATION ADJUSTMENT FACTOR (EAF)

Mean Elevation 35 m

Adjustment for elevation (-0.05 per 300m above 1500m) 0.00

EAF= 1.00

MOISTURE ADJUSTMENT FACTOR (MAF)

MAF = 0.68

PMP VALUES (mm)

Duration (hours)	Initial Depth -Smooth	Initial Depth -Rough	PMP Estimate	Rounded PMP Estimate (nearest 10 mm)	Intensity mm/hr
0.25	245	245	167	170	680
0.5	350	350	238	240	480
0.75	440	440	299	300	400
1.0	510	510	347	350	350
1.5	580	655	445	450	300
2.0	647	770	524	520	260
2.5	690	850	578	580	232
3.0	727	940	639	640	213
4.0	793	1065	724	720	180
5.0	856	1175	799	800	160
6.0	900	1240	843	840	140

Time of Concentration

For 100yr

Time (min)	Intensity (mm/hr)	$t_c I^{0.4}$
5	219.4	*43*
6	205.9	*51*
10	168.1	*78*
11	161.3	*84*
15	140.0	*108*
20	121.8	*137*
30	98.9	*188*
45	79.3	*259*
60	67.3	*323*

Kinematic Wave Equation

Length of Flow Path	L	1410	m
Average Slope	S_o	0.014	m/m
Roughness Co-efficient	n	0.02	
	$t_c I^{0.4}$=	185.21	
	t_c=	**30**	**min**

Pilgram & McDermott method

Catchment Area	A	900000	m^2
	A	0.9	km^2
	t_c	0.730	hr
	t_c=	**43.8**	**min**

Bransby Williams formula

Time of concentration	**t_c=**	**48.8**	**min**

Average	41	min
Adopt	**40**	**min**

Estimation of Impervious Areas.
Bonnyrigg - Central Existing

Node	Total Area (Ha)	Impervious Portion (%)	Area Breakup (Ha)		Slope (%)
			Impervious	Pervious	
1.15	12.7	76	9.7	3.0	1.4
2.1	0.9	79	0.7	0.2	2.1
2.2	1.6	78	1.2	0.4	2.8
2.4	1.1	77	0.8	0.3	4
2.5	2.2	63	1.4	0.8	4.4
2.6	1.5	80	1.2	0.3	3
3.1	2.5	40	1.0	1.5	1.9
3.2	2.9	73	2.1	0.8	3.2
4.1	1	70	0.7	0.3	1.5
5.1	0.8	13	0.1	0.7	1.9
7.1	3	40	1.2	1.8	1.8
6.3	1.2	79	0.9	0.3	1.4
6.4	4.6	79	3.6	1.0	2.5
6.5	1.4	79	1.1	0.3	2
9.1	1.2	74	0.9	0.3	1.7
8.1	2.1	29	0.6	1.5	1.4
8.2	1.3	42	0.5	0.8	3
8.3	1.4	89	1.2	0.2	3.1
10.1	1.1	64	0.7	0.4	2.8
10.2	1.9	80	1.5	0.4	2.5
10.3	2.9	46	1.3	1.6	2.9
10.4	1.3	84	1.1	0.2	3
11.1	2	71	1.4	0.6	3.9
12.1	1.5	71	1.1	0.4	4.3
13.1	1.6	62	1.0	0.6	3.2
13.2	0.8	78	0.6	0.2	2.7
14.1	0.4	48	0.2	0.2	1.5
15.2	2.9	75	2.2	0.7	2.2
15.3	0.9	74	0.7	0.2	2.2
16.1	1.4	76	1.1	0.3	1.6
16.3	2.5	66	1.6	0.9	3.1
16.4	2.1	78	1.6	0.5	2.8
17.1	1.2	56	0.7	0.5	1.6
18.1	1.4	71	1.0	0.4	2.6
19.1	2.4	67	1.6	0.8	2.3
20.1	3.9	58	2.3	1.6	2.7
20.2	3.9	62	2.4	1.5	3.7
20.3	6.9	81	5.6	1.3	2.5
21.1	1.8	60	1.1	0.7	2.5
22.1	1.8	88	1.6	0.2	2.1
Total	90.0		61.4	28.6	

Estimation of Impervious Areas.
Bonnyrigg - Central Proposed

Node	Total Area (Ha)	Impervious Portion (%)	Area Breakup (Ha)		Slope (%)
			Impervious	Pervious	
1.15	12.7	81	10.3	2.4	1.4
2.1	0.9	71	0.6	0.3	1.8
2.2	1.6	85	1.4	0.2	2.6
2.4	0.5	85	0.4	0.1	4
2.5	2.0	85	1.7	0.3	3.5
3.1	2.3	83	1.9	0.4	2.1
3.2	2.9	72	2.1	0.8	3.2
4.1	1.2	69	0.8	0.4	1.6
5.1	0.7	35	0.2	0.5	1.1
6.1	2.2	70	1.5	0.7	1
6.3	1.3	85	1.1	0.2	1.9
6.4	0.5	85	0.4	0.1	1.2
6.5	0.8	85	0.7	0.1	3.1
6.6	0.4	85	0.3	0.1	2.6
6.7	1.9	85	1.6	0.3	3.4
6.9	0.9	85	0.8	0.1	3.5
6.10	0.4	85	0.3	0.1	3.5
6.11	1.4	42	0.6	0.8	3.7
7.1	1.7	5	0.1	1.6	1
7.2	1.6	95	1.5	0.1	2.2
7.3	2.2	94	2.1	0.1	3.9
7.4	1.3	95	1.2	0.1	2.9
8.1	2.2	68	1.5	0.7	1.7
9.1	1.2	39	0.5	0.7	2.2
9.2	1.4	85	1.2	0.2	2.3
9.3	3.3	94	3.1	0.2	2.7
10.1	1.8	85	1.5	0.3	3
10.2	1.3	37	0.5	0.8	1.6
11.1	1.8	71	1.3	0.5	2.1
12.1	0.9	85	0.8	0.1	2.6
12.2	0.3	85	0.3	0.0	3.8
12.3	1.2	27	0.3	0.9	2.2
12.4	0.9	85	0.8	0.1	2.6
12.6	2.7	85	2.3	0.4	2.8
13.1	1.4	85	1.2	0.2	1.5
13.2	2.2	64	1.4	0.8	2.6
13.3	1.8	85	1.5	0.3	2.9
13.4	1.4	95	1.3	0.1	3.6
14.1	1.5	72	1.1	0.4	2.3
15.1	2.5	74	1.8	0.7	1.8
16.1	0.4	42	0.2	0.2	1.3
16.2	1.4	85	1.2	0.2	2.7
16.3	3.7	85	3.1	0.6	3.9
16.4	6.9	79	5.4	1.5	2.5
16.5	1.6	85	1.4	0.2	2.4
16.6	1.2	83	1.0	0.2	1.9
17.1	0.5	25	0.1	0.4	2.6
18.1	1.8	79	1.4	0.4	2.1
19.1	1.3	64	0.8	0.5	1.6
Total	90		68.7	21.3	

Estimation of Impervious Area
Bonnyrigg - Eastern Existing

Node	Total Area	Impervious Portion (%)	Area Breakup		Slope (%)
			Impervious	Pervious	
1.2	1.5	55	0.8	0.7	2.5
1.3	3.1	72	2.2	0.9	3.1
2.1	0.4	75	0.3	0.1	3.3
2.2	1	58	0.6	0.4	2.4
2.3	1.4	69	1.0	0.4	4.4
3.2	0.8	75	0.6	0.2	3
3.3	0.8	77	0.6	0.2	3.2
4.1	1.2	76	0.9	0.3	4.1
4.2	0.5	79	0.4	0.1	2.8
4.3	0.4	81	0.3	0.1	2.4
4.4	3	42	1.2	1.8	5.9
5.1	1.3	77	1.0	0.3	4.5
5.2	1.6	43	0.7	0.9	5
6.1	1.4	78	1.1	0.3	5.8
6.2	0.5	63	0.3	0.2	3.3
Total	18.9		12.1	6.8	

Estimation of Impervious Area
Bonnyrigg - Eastern Proposed

Node	Total Area	Impervious Portion (%)	Area Breakup		Slope (%)
			Impervious	Pervious	
1.2	1.5	87	1.3	0.2	2.5
1.3	3.1	67	2.1	1.0	3.1
2.1	0.4	85	0.3	0.1	1.8
2.2	1.7	86	1.5	0.2	2.5
2.3	0.6	88	0.5	0.1	4.2
3.2	0.7	85	0.6	0.1	1.7
3.3	1.2	87	1.0	0.2	2.9
4.1	0.8	85	0.7	0.1	3.6
4.2	0.5	87	0.4	0.1	1.7
4.3	0.6	88	0.5	0.1	4.7
4.4	2	62	1.2	0.8	4.8
5.1	1.2	87	1.0	0.2	4.1
5.2	1.5	87	1.3	0.2	4.9
5.3	1	59	0.6	0.4	3.2
6.1	1.4	87	1.2	0.2	5.8
6.2	0.3	89	0.3	0.0	3.3
6.3	0.2	93	0.2	0.0	2.1
Total	18.7		14.8	3.9	

Estimation of Impervious Area
Bonnyrigg - Western Existing

Node	Total Area	Impervious Portion (%)	Area Breakup		Slope (%)
			Impervious	Pervious	
1.1	1.7	65	1.1	0.6	3.7
1.2	0.9	68	0.6	0.3	4.2
2.1	1.7	20	0.3	1.4	4.2
Total	4.3		2.1	2.2	

Estimation of Impervious Area
Bonnyrigg - Western Proposed

Node	Total Area	Impervious Portion (%)	Area Breakup		Slope (%)
			Impervious	Pervious	
1.2	0.6	83	0.5	0.1	3.4
1.3	1.2	55	0.7	0.5	5.1
1.4	1.3	50	0.6	0.7	4.1
2.1	1.2	87	1.0	0.2	3
Total	4.3		2.8	1.5	

Appendix C: Peak flows from RAFTS

Bonnyrigg 06P310

Central Catchment Modelling Results

100yr ARI peak flows at node C1.1

Storm	Existing (m^3/s)	Proposed (m^3/s)	
		No Basin	Basin
1	*15.613*	18.528	*15.345*
2	*20.261*	22.714	*19.608*
3	*23.49*	26.104	*22.69*
4	*25.7*	26.726	*24.832*
5	*25.113*	26.219	*24.511*
6	*25.086*	25.8	*24.713*
7	*25.746*	26.347	*25.46*
8	*25.074*	26.646	*24.26*
9	*25.612*	26.303	*25.125*
10	*19.984*	20.703	*18.684*
11	*13.614*	13.792	*13.458*

Existing Basin Parameters

Invert of basin =	33.77	m
Weir level =	35.3	m
Depth to weir =	1.53	m
Weir top level =	35.5	m
Depth to TWL =	1.73	m
Volume to weir =	6553	m^3
Volume to top =	7410	m^3
Outlet pipe size =	1.5	m
Outlet pipe grade =	0.91	%

Proposed Basin Parameters

Invert of basin =	33.77	m
Weir level =	34.77	m
Depth to weir =	1	m
Weir top level =	34.97	m
Depth to TWL =	1.2	m
Volume to weir =	6500	m^3
Volume to top =	7860	m^3
Outlet pipe size =	1.5	m
Outlet pipe grade =	0.91	%

Central Existing **100 year ARI**

Node	Duration (minutes)										
	10	15	20	25	30	45	60	90	120	180	540
C1.1	15.6	20.3	23.5	25.7	25.1	25.1	**25.7**	25.1	25.6	20.0	13.6
C1.2	15.6	20.3	23.5	25.7	25.1	25.1	**25.7**	25.1	25.6	20.0	13.6
C1.3	15.7	19.8	22.6	23.5	22.6	22.3	23.1	22.5	**23.7**	17.6	11.7
C1.4	15.3	19.8	22.6	23.3	22.3	21.9	22.7	22.1	**23.4**	17.3	11.5
C1.5	15.1	19.4	21.5	21.9	20.7	20.1	21.1	20.9	**22.1**	16.2	10.4
C1.6	17.0	20.7	**21.9**	21.1	19.8	19.3	20.2	20.3	21.8	15.4	9.4
C1.7	16.6	18.9	**19.8**	19.5	18.2	17.2	18.3	18.9	19.7	13.3	8.1
C1.8	16.3	18.2	18.8	**18.9**	17.5	16.3	17.6	18.5	18.8	12.5	7.5
C1.9	16.2	17.8	17.8	**18.5**	17.1	15.5	17.0	18.2	17.9	11.9	7.1
C1.10	9.0	10.2	10.4	10.6	9.5	8.5	9.8	**10.7**	10.5	5.4	1.7
C1.11	12.5	13.7	13.9	14.1	13.0	12.0	13.3	**14.2**	14.0	9.0	5.4
C1.12	12.0	13.5	13.4	13.9	12.8	11.6	13.0	**14.0**	13.5	8.6	5.2
C1.13	6.1	6.9	6.8	7.0	6.5	5.9	6.5	**7.1**	6.7	4.2	2.5
C1.14	5.6	6.4	6.3	6.5	6.0	5.4	6.1	**6.6**	6.2	3.7	2.2
C1.15	4.8	5.5	5.4	5.6	5.1	4.6	5.2	**5.7**	5.3	3.2	2.0
C2.1	2.7	2.9	3.0	3.3	2.9	2.6	3.0	**3.3**	3.1	2.0	1.1
C2.2	2.3	2.7	2.7	3.0	2.7	2.3	2.8	**3.0**	2.8	1.7	1.0
C2.3	1.8	2.1	2.0	**2.3**	2.2	1.8	2.2	2.3	2.2	1.3	0.8
C2.4	1.2	1.4	1.4	**1.6**	1.5	1.2	1.5	1.5	1.5	0.9	0.5
C2.5	0.8	1.0	0.9	**1.0**	1.0	0.8	1.0	1.0	1.0	0.6	0.3
C2.6	0.6	0.7	0.7	**0.8**	0.7	0.6	0.7	0.7	0.7	0.4	0.2
C3.1	1.7	1.9	1.8	2.0	1.9	1.7	2.0	**2.2**	2.1	1.4	0.8
C3.2	1.1	1.3	1.2	**1.4**	1.3	1.1	1.3	1.4	1.3	0.8	0.5
C4.1	0.4	0.4	0.4	0.4	0.4	0.4	0.4	**0.5**	0.4	0.3	0.2
C5.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3	**0.3**	0.3	0.2	0.1
C6.1	2.9	3.2	3.1	3.3	3.1	2.8	3.2	**3.4**	3.2	1.9	1.1
C6.2	2.9	3.2	3.2	3.4	3.1	2.7	3.2	**3.4**	3.2	1.9	1.1
C6.3	2.4	2.6	2.5	2.7	2.5	2.2	2.5	**2.7**	2.6	1.6	0.9
C6.4	1.9	2.1	2.1	2.2	2.0	1.8	2.0	**2.2**	2.1	1.2	0.7
C6.5	0.6	0.7	0.6	**0.7**	0.6	0.5	0.6	0.7	0.6	0.4	0.2
C7.1	0.7	0.8	0.8	0.9	0.9	0.7	1.0	**1.1**	1.0	0.7	0.5
C8.1	1.2	1.3	1.5	1.5	1.4	1.3	1.5	1.5	**1.7**	1.2	0.7
C8.2	0.9	1.1	1.1	1.2	1.1	1.0	1.1	**1.2**	1.1	0.7	0.4
C8.3	0.6	0.7	0.7	**0.7**	0.7	0.6	0.7	0.7	0.7	0.4	0.2
C9.1	0.5	0.5	0.5	0.6	0.5	0.4	0.5	**0.6**	0.5	0.3	0.2
C10.1	2.4	2.9	2.8	3.2	3.0	2.4	3.1	**3.3**	3.1	1.9	1.1
C10.2	1.5	1.8	1.7	2.0	1.9	1.5	2.0	**2.1**	2.0	1.3	0.7
C10.3	0.8	0.9	0.9	1.1	1.0	0.8	1.1	**1.2**	1.1	0.8	0.4
C10.4	0.6	0.7	0.6	**0.7**	0.6	0.5	0.6	0.7	0.6	0.4	0.2
C11.1	0.8	0.9	0.9	**1.0**	0.9	0.8	0.9	1.0	0.9	0.5	0.3
C12.1	0.6	0.7	0.7	**0.8**	0.7	0.6	0.7	0.7	0.7	0.4	0.2
C13.1	0.9	1.0	1.0	**1.1**	1.0	0.9	1.0	1.0	1.0	0.6	0.4
C13.2	0.3	0.4	0.4	**0.4**	0.4	0.3	0.4	0.4	0.4	0.2	0.1
C14.1	0.1	0.1	0.1	0.2	0.1	0.1	0.2	**0.2**	0.2	0.1	0.1
C15.1	1.6	1.7	1.6	1.8	1.7	1.4	1.7	**1.8**	1.7	1.0	0.6
C15.2	1.2	1.3	1.2	1.4	1.3	1.1	1.3	**1.4**	1.3	0.8	0.5
C15.3	0.4	0.4	0.4	**0.4**	0.4	0.4	0.4	0.4	0.4	0.2	0.1
C16.1	2.2	2.5	2.4	2.7	2.5	2.1	2.6	**2.8**	2.6	1.6	0.9
C16.2	1.7	2.0	1.9	2.1	2.0	1.7	2.0	**2.2**	2.0	1.2	0.7
C16.3	0.8	1.0	1.0	1.1	1.0	0.9	1.1	**1.1**	1.1	0.7	0.4
C16.4	0.8	1.0	0.9	**1.0**	0.9	0.8	1.0	1.0	1.0	0.6	0.3
C17.1	0.4	0.4	0.4	0.5	0.5	0.4	0.5	**0.5**	0.5	0.3	0.2
C18.1	0.5	0.6	0.6	**0.7**	0.6	0.5	0.6	0.7	0.6	0.4	0.2
C19.1	0.8	1.0	0.9	1.1	1.0	0.8	1.0	**1.1**	1.0	0.6	0.4
C20.1	5.2	5.8	5.8	6.1	5.5	5.0	5.9	**6.3**	6.1	3.9	2.3
C20.2	4.1	4.8	4.6	5.0	4.5	4.0	4.7	**5.1**	4.8	2.9	1.7
C20.3	2.9	3.2	3.2	3.3	3.0	2.7	3.1	**3.3**	3.2	1.9	1.1
C21.1	0.6	0.7	0.7	0.8	0.7	0.6	0.8	**0.8**	0.8	0.5	0.3
C22.1	0.8	0.9	0.9	**0.9**	0.8	0.8	0.9	0.9	0.9	0.5	0.3

Central Proposed **100 year ARI**

Node	Duration (minutes)										
	10	15	20	25	30	45	60	90	120	180	540
P1.1	12.8	16.6	20.7	22.9	22.7	23.0	24.3	23.6	**24.5**	18.0	13.5
P1.2	12.8	16.6	20.7	22.9	22.7	23.0	24.3	23.6	**24.5**	18.0	13.5
P1.3	12.7	17.0	20.4	22.3	21.3	21.0	22.9	22.3	**23.5**	17.1	12.0
P1.4	12.8	16.5	20.5	22.1	21.2	20.8	22.4	21.9	**23.1**	16.9	11.7
P1.5	17.3	21.2	23.6	23.8	22.9	22.2	23.1	22.6	**24.0**	17.5	12.0
P1.6	18.0	21.3	**22.4**	21.5	20.2	19.6	20.5	20.9	22.2	15.5	9.6
P1.7	17.2	19.8	**20.4**	20.2	18.9	17.5	18.8	19.8	20.2	13.5	8.3
P1.8	16.9	19.0	18.8	**19.5**	18.1	16.2	17.8	19.1	18.7	12.4	7.5
P1.9	17.2	19.2	19.0	**19.8**	18.4	16.3	18.1	19.5	18.9	12.4	7.6
P1.10	9.1	10.2	10.4	**10.6**	9.6	8.3	9.5	10.3	10.2	5.2	1.7
P1.11	12.6	13.7	13.8	**14.0**	13.1	11.8	13.0	13.8	13.7	8.7	5.3
P1.12	12.1	13.6	13.4	**13.8**	12.8	11.4	12.7	13.7	13.2	8.4	5.1
P1.13	5.6	6.3	6.2	6.4	5.9	5.3	5.9	**6.5**	6.1	3.7	2.3
P1.14	5.6	6.4	6.2	6.4	5.9	5.3	5.9	**6.5**	6.1	3.7	2.3
P1.15	4.8	5.5	5.3	5.5	5.0	4.6	5.1	**5.6**	5.2	3.2	2.0
P2.1	2.5	2.8	2.8	2.9	2.6	2.3	2.7	**3.0**	2.8	1.5	0.8
P2.2	2.3	2.6	2.5	2.6	2.4	2.1	2.5	**2.7**	2.5	1.3	0.6
P2.3	1.6	1.8	1.7	1.9	1.7	1.4	1.7	**1.9**	1.8	0.9	0.4
P2.4	0.7	0.8	0.8	**0.9**	0.8	0.6	0.8	0.9	0.8	0.3	0.1
P2.5	0.9	1.0	1.0	**1.0**	0.9	0.8	0.9	1.0	1.0	0.5	0.3
P3.1	2.1	2.2	2.2	2.3	2.2	1.9	2.2	**2.4**	2.2	1.4	0.8
P3.2	1.1	1.2	1.2	1.3	1.2	1.0	1.3	**1.4**	1.3	0.8	0.5
P4.1	0.4	0.5	0.4	0.5	0.5	0.4	0.5	**0.5**	0.5	0.3	0.2
P5.1	0.1	0.1	0.1	0.2	0.1	0.2	0.2	**0.2**	0.2	0.2	0.1
P6.1	3.2	3.5	3.5	3.7	3.4	3.1	3.6	**3.9**	3.7	2.4	1.5
P6.2	2.5	2.7	2.6	2.9	2.7	2.3	2.8	**3.0**	2.8	1.9	1.2
P6.3	1.4	1.6	1.6	1.7	1.6	1.3	1.7	**1.8**	1.7	1.1	0.6
P6.4	1.1	1.1	1.1	1.2	1.1	1.0	1.1	**1.2**	1.1	0.8	0.6
P6.5	0.8	0.9	0.9	0.9	0.9	0.8	0.9	**0.9**	0.9	0.7	0.5
P6.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	**0.5**	0.5	0.4	0.4
P6.7	0.8	0.9	0.9	1.0	0.9	0.8	0.9	**1.0**	0.9	0.5	0.3
P6.8	0.9	1.1	1.0	1.2	1.1	0.9	1.2	**1.2**	1.2	0.7	0.4
P6.9	0.4	0.5	0.4	**0.5**	0.4	0.4	0.4	0.5	0.4	0.2	0.1
P6.10	0.2	0.2	0.2	**0.2**	0.2	0.2	0.2	0.2	0.2	0.1	0.1
P6.11	0.4	0.4	0.5	0.5	0.5	0.4	0.6	**0.6**	0.5	0.4	0.2
P7.1	2.0	2.3	2.3	**2.6**	2.4	2.0	2.4	2.5	2.3	1.7	1.1
P7.2	1.2	1.2	**1.2**	1.2	1.2	1.1	1.2	1.2	1.2	0.8	0.7
P7.3	1.7	**1.8**	1.8	1.8	1.7	1.5	1.7	1.8	1.7	1.0	0.6
P7.4	0.6	**0.7**	0.7	0.7	0.6	0.6	0.6	0.7	0.6	0.4	0.2
P8.1	0.8	0.9	0.8	0.9	0.9	0.7	0.9	**1.0**	0.9	0.6	0.3
P9.1	2.5	2.7	2.7	2.8	2.6	2.3	2.7	**2.9**	2.7	1.6	0.9
P9.2	2.3	**2.4**	2.4	2.4	2.2	2.0	2.2	2.4	2.3	1.3	0.7
P9.3	1.6	**1.7**	1.7	1.7	1.6	1.5	1.6	1.7	1.6	0.9	0.5
P10.1	0.8	0.9	0.8	0.9	0.8	0.7	0.8	**0.9**	0.9	0.5	0.3
P10.2	0.3	0.3	0.3	0.4	0.4	0.3	0.4	**0.5**	0.4	0.3	0.2
P11.1	0.7	0.8	0.7	0.8	0.7	0.6	0.8	**0.8**	0.8	0.5	0.3
P12.1	1.1	1.3	1.2	1.3	1.2	1.1	1.3	**1.5**	1.3	0.9	0.5
P12.2	0.7	0.8	0.8	0.9	0.8	0.7	0.9	**1.0**	0.9	0.6	0.4
P12.3	0.2	0.2	0.3	0.3	0.3	0.3	0.4	**0.4**	0.4	0.3	0.2
P12.4	0.4	0.5	0.4	**0.5**	0.4	0.4	0.4	0.5	0.4	0.2	0.1
P12.5	2.4	2.6	2.5	2.7	2.4	2.2	2.6	**2.8**	2.6	1.6	0.9
P12.6	1.2	1.3	1.3	**1.3**	1.2	1.1	1.3	1.3	1.3	0.7	0.4
P13.1	2.7	3.0	3.0	3.1	2.8	2.6	2.9	**3.2**	3.1	1.8	1.1
P13.2	2.3	2.4	2.4	2.5	2.3	2.0	2.4	**2.6**	2.5	1.5	0.9
P13.3	1.5	1.6	1.6	1.6	1.5	1.3	1.5	**1.6**	1.5	0.9	0.5
P13.4	0.7	0.7	0.7	**0.7**	0.7	0.6	0.7	0.7	0.7	0.4	0.2
P14.1	0.6	0.6	0.6	0.7	0.6	0.5	0.7	**0.7**	0.7	0.4	0.2
P15.1	0.9	1.0	1.0	1.1	1.0	0.9	1.0	**1.1**	1.1	0.7	0.4
P16.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	**0.2**	0.1	0.1	0.1
P16.2	5.7	6.5	6.3	**6.6**	6.1	5.3	6.1	6.5	6.2	3.9	2.3
P16.3	4.1	4.7	4.6	**4.8**	4.4	3.8	4.4	4.7	4.5	2.8	1.7
P16.4	2.9	3.2	3.1	3.2	3.0	2.7	3.0	**3.3**	3.1	1.8	1.1
P16.5	1.3	1.4	1.3	1.4	1.3	1.1	1.3	**1.4**	1.3	0.8	0.4
P16.6	0.5	0.6	0.6	0.6	0.5	0.5	0.5	**0.6**	0.6	0.3	0.2
P17.1	0.1	0.1	0.2	0.2	0.1	0.1	0.2	**0.2**	0.2	0.1	0.1
P18.1	0.8	0.9	0.9	0.9	0.8	0.8	0.8	**0.9**	0.9	0.5	0.3
P19.1	0.4	0.5	0.5	0.5	0.5	0.4	0.5	**0.6**	0.5	0.3	0.2

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Eastern Catchment Modelling Results

100yr ARI peak flows at node EOutlet

		Proposed (m^3/s)	
Storm	**Existing (m^3/s)**	**No Basin**	**Basin**
1	*6.486*	7.582	*6.369*
2	*7.74*	8.758	*7.418*
3	*7.31*	8.497	*7.271*
4	*8.703*	9.213	*8.302*
5	*7.997*	8.481	*7.708*
6	*6.603*	7.435	*6.523*
7	*8.263*	8.542	*7.665*
8	*8.73*	9.09	*8.098*
9	*8.142*	8.552	*7.589*
10	*5.081*	5.053	*5.01*
11	*2.947*	2.935	*2.932*

Proposed Basin Parameters

Invert of basin =	0	m
Weir level =	0.8	m
Depth to weir =	0.8	m
Weir top level =	1	m
Depth to TWL =	1	m
Volume to weir =	800	m^3
Volume to top =	1000	m^3
Outlet pipe size =	0.6	m
Outlet pipe grade =	0.7	%

Eastern Existing **100 year ARI**

Node	Duration (minutes)										
	10	**15**	**20**	**25**	**30**	**45**	**60**	**90**	**120**	**180**	**540**
E1.0	2.6	3.0	2.9	3.3	3.1	2.6	3.2	**3.4**	3.2	2.0	1.2
E1.1	2.6	3.0	2.9	3.3	3.1	2.6	3.2	**3.4**	3.2	2.0	1.2
E1.2	1.6	1.9	1.8	2.0	1.9	1.6	1.9	**2.1**	2.0	1.2	0.7
E1.3	1.2	1.4	1.3	1.4	1.3	1.1	1.4	**1.4**	1.4	0.8	0.5
E2.1	0.2	0.2	0.2	**0.2**	0.2	0.2	0.2	0.2	0.2	0.1	0.1
E2.2	0.3	0.4	0.4	0.5	0.4	0.3	0.4	**0.5**	0.4	0.3	0.2
E2.3	0.6	0.7	0.6	**0.7**	0.7	0.6	0.6	0.7	0.6	0.4	0.2
E3.0	3.4	4.1	3.8	**4.7**	4.3	3.4	4.4	4.7	4.3	2.5	1.2
E3.1	3.4	4.1	3.8	**4.7**	4.3	3.4	4.4	4.7	4.3	2.5	1.2
E3.2	0.6	0.8	0.7	**0.8**	0.7	0.6	0.7	0.8	0.7	0.4	0.3
E3.3	0.3	0.4	0.4	**0.4**	0.4	0.3	0.4	0.4	0.4	0.2	0.1
E4.1	0.5	0.6	0.5	**0.6**	0.6	0.5	0.6	0.6	0.6	0.3	0.2
E4.2	0.2	0.2	0.2	**0.3**	0.2	0.2	0.2	0.2	0.2	0.1	0.1
E4.3	1.0	1.2	1.3	1.4	1.3	1.2	1.4	**1.5**	1.4	0.9	0.5
E4.4	0.9	1.1	1.1	1.3	1.2	1.0	1.3	**1.3**	1.2	0.8	0.5
E5.0	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
E5.1	1.8	2.1	1.9	**2.3**	2.1	1.8	2.1	2.3	2.1	1.3	0.7
E5.2	0.5	0.6	0.6	**0.7**	0.7	0.6	0.7	0.7	0.7	0.4	0.2
E6.1	0.8	0.9	0.9	**1.0**	0.9	0.8	0.9	1.0	0.9	0.5	0.3
E6.2	0.2	0.2	0.2	**0.3**	0.2	0.2	0.2	0.2	0.2	0.1	0.1
EOutlet	6.5	7.7	7.3	8.7	8.0	6.6	8.3	**8.7**	8.1	5.1	2.9

Eastern Proposed **100 year ARI**

Node	Duration (minutes)										
	10	**15**	**20**	**25**	**30**	**45**	**60**	**90**	**120**	**180**	**540**
P1.3	1.1	1.3	1.2	1.3	1.2	1.0	1.3	**1.4**	1.3	0.8	0.5
P1.2	1.8	1.9	1.9	2.1	1.9	1.6	2.0	**2.2**	2.0	1.2	0.7
P2.3	0.3	0.3	0.3	**0.3**	0.3	0.2	0.3	0.3	0.3	0.2	0.1
P2.2	0.8	0.8	0.8	0.9	0.8	0.7	0.8	**0.9**	0.8	0.5	0.3
P2.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	**0.2**	0.2	0.1	0.1
P1.1	2.9	3.3	3.2	3.4	3.1	2.8	3.2	**3.5**	3.3	2.0	1.2
P1.0	2.9	3.3	3.2	3.4	3.1	2.8	3.2	**3.5**	3.3	2.0	1.2
P4.4	0.7	0.8	0.7	0.9	0.8	0.7	0.9	**0.9**	0.9	0.5	0.3
P4.3	0.9	1.1	1.0	1.1	1.1	0.9	1.1	**1.2**	1.1	0.7	0.4
P3.3	0.5	0.6	0.6	0.6	0.5	0.5	0.6	**0.6**	0.6	0.3	0.2
P3.2	0.8	0.9	0.9	0.9	0.9	0.8	0.9	**0.9**	0.9	0.5	0.3
P4.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	**0.2**	0.2	0.1	0.1
P4.1	0.4	0.4	0.4	**0.4**	0.4	0.3	0.4	0.4	0.4	0.2	0.1
P5.3	0.3	0.4	0.4	0.4	0.4	0.3	0.4	**0.5**	0.4	0.3	0.2
P5.2	1.0	1.1	1.1	1.2	1.1	0.9	1.2	**1.2**	1.2	0.7	0.4
P6.3	0.1	0.1	**0.1**	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
P6.2	0.3	0.3	**0.3**	0.3	0.3	0.2	0.2	0.3	0.3	0.1	0.1
P6.1	0.9	1.0	1.0	**1.0**	0.9	0.8	0.9	1.0	0.9	0.5	0.3
P5.1	2.5	2.6	2.6	2.8	2.5	2.2	2.7	**2.8**	2.8	1.5	0.9
P3.1	4.1	4.6	4.4	4.8	4.4	3.8	4.6	**5.0**	4.7	2.5	1.2
P3.0	4.1	4.6	4.4	4.8	4.4	3.8	4.6	**5.0**	4.7	2.5	1.2
P5.0	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
PBasin	7.5	8.5	8.2	8.8	8.2	7.1	8.4	**9.1**	8.5	5.1	2.9
Poutlet	6.0	7.1	6.9	7.9	7.4	6.2	7.5	**8.0**	7.5	5.0	2.9

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Western Catchment Modelling Results

100yr ARI peak flows at node WOutlet

		Proposed (m^3/s)	
Storm	**Existing (m^3/s)**	**No Basin**	**Basin**
1	*1.312*	1.548	*1.101*
2	*1.557*	1.855	*1.217*
3	*1.592*	1.768	*1.566*
4	*1.868*	2.035	*1.602*
5	*1.716*	1.879	*1.41*
6	*1.43*	1.582	*1.278*
7	*1.81*	1.894	*1.613*
8	*1.908*	1.995	*1.819*
9	*1.756*	1.86	*1.584*
10	*1.149*	1.159	*0.984*
11	*0.66*	0.671	*0.66*

Proposed Basin Parameters

Invert of basin =	0	m
Weir level =	1	m
Depth to weir =	1	m
Weir top level =	1.2	m
Depth to TWL =	1.2	m
Volume to weir =	320	m^3
Volume to top =	384	m^3
Outlet pipe size =	0.525	m
Outlet pipe grade =	3	%

Western Existing **100 year ARI**

Node	Duration (minutes)										
	10	**15**	**20**	**25**	**30**	**45**	**60**	**90**	**120**	**180**	**540**
W1.0	1.0	1.1	1.1	**1.3**	1.2	1.0	1.2	1.2	1.2	0.7	0.4
W1.1	1.0	1.1	1.1	**1.3**	1.2	1.0	1.2	1.2	1.2	0.7	0.4
W1.2	0.3	0.4	0.4	**0.5**	0.4	0.3	0.4	0.4	0.4	0.2	0.1
W2.1	0.4	0.5	0.6	0.6	0.6	0.5	0.7	**0.7**	0.6	0.4	0.3
WOutlet	1.3	1.6	1.6	1.9	1.7	1.4	1.8	**1.9**	1.8	1.1	0.7

Western Proposed **100 year ARI**

Node	Duration (minutes)										
	10	**15**	**20**	**25**	**30**	**45**	**60**	**90**	**120**	**180**	**540**
P2.1	0.5	0.6	**0.6**	0.6	0.5	0.5	0.6	0.6	0.6	0.3	0.2
P1.4	0.4	0.4	0.5	0.5	0.5	0.4	0.5	**0.6**	0.5	0.4	0.2
P1.3	0.4	0.5	0.5	0.6	0.5	0.4	0.5	**0.6**	0.5	0.3	0.2
P1.2	0.3	0.3	**0.3**	0.3	0.3	0.2	0.3	0.3	0.3	0.2	0.1
P1.1	1.0	1.2	1.2	1.4	1.3	1.0	1.4	**1.5**	1.3	0.8	0.5
P1.0	0.6	0.7	1.1	1.1	0.8	0.7	1.1	**1.3**	1.1	0.7	0.5
POutlet	1.1	1.2	1.4	1.3	1.2	1.1	1.4	**1.7**	1.6	1.0	0.7

Sensitivity Analysis - Proposed Central Flows 100yr

		Bx multiplier				
Node	**Duration**	1	0.5	Increase %	2	Decrease %
P1.1	10	14.173	15.366	8.4	12.217	13.8
	15	18.206	20.315	11.6	15.679	13.9
	20	21.669	23.716	9.4	18.941	12.6
	25	23.902	26.614	11.3	20.909	12.5
	30	23.762	25.683	8.1	20.956	11.8
	45	24.033	26.084	8.5	21.341	11.2
	60	25.09	26.646	6.2	22.594	9.9
	90	24.121	25.138	4.2	21.967	8.9
	120	24.937	26.16	4.9	22.437	10.0
	180	18.534	19.105	3.1	17.24	7.0
	540	13.387	13.775	2.9	12.56	6.2

Sensitivity Analysis - Proposed Western Flows 100yr

		Bx multiplier				
Node	**Duration**	1	0.5	Increase %	2	Decrease %
Woutlet	10	1.101	1.169	6.2	1.052	4.5
	15	1.217	1.565	28.6	1.167	4.1
	20	1.64	1.716	4.6	1.185	27.7
	25	1.602	1.823	13.8	1.198	25.2
	30	1.41	1.859	31.8	1.147	18.7
	45	1.278	1.53	19.7	1.059	17.1
	60	1.613	1.889	17.1	1.155	28.4
	90	1.819	2.084	14.6	1.239	31.9
	120	1.584	1.758	11.0	1.352	14.6
	180	0.9841	1.001	1.7	0.941	4.4
	540	0.6679	0.669	0.2	0.656	1.8

Sensitivity Analysis - Proposed Eastern Flows 100yr

		Bx multiplier				
Node	**Duration**	1	0.5	Increase %	2	Decrease %
Eoutlet	10	6.369	6.909	8.5	5.912	7.2
	15	7.418	8.21	10.7	6.876	7.3
	20	7.271	7.935	9.1	6.764	7.0
	25	8.302	8.947	7.8	7.502	9.6
	30	7.708	8.302	7.7	6.985	9.4
	45	6.523	7.113	9.0	6.05	7.3
	60	7.665	8.034	4.8	6.905	9.9
	90	8.098	8.416	3.9	7.381	8.9
	120	7.589	7.933	4.5	6.971	8.1
	180	5.01	5.052	0.8	4.75	5.2
	540	2.932	2.935	0.1	2.89	1.4

Sensitivity Analysis - Proposed Central Flows 100yr

		Initial Loss (Pervious and Impervious areas)				
Node	**Duration**	15 and 1.5	10 and 1.0	Increase %	20 and 2.0	Decrease %
P1.1	10	12.839	14.191	10.5	11.558	10.0
	15	16.566	18.232	10.1	15.792	4.7
	20	20.67	21.706	5.0	19.387	6.2
	25	22.856	23.948	4.8	21.636	5.3
	30	22.69	23.809	4.9	21.598	4.8
	45	22.971	24.079	4.8	22.08	3.9
	60	24.32	25.137	3.4	23.48	3.5
	90	23.614	24.183	2.4	23.089	2.2
	120	24.513	25	2.0	23.773	3.0
	180	17.96	18.594	3.5	17.471	2.7
	540	13.459	13.459	0.0	13.459	0.0

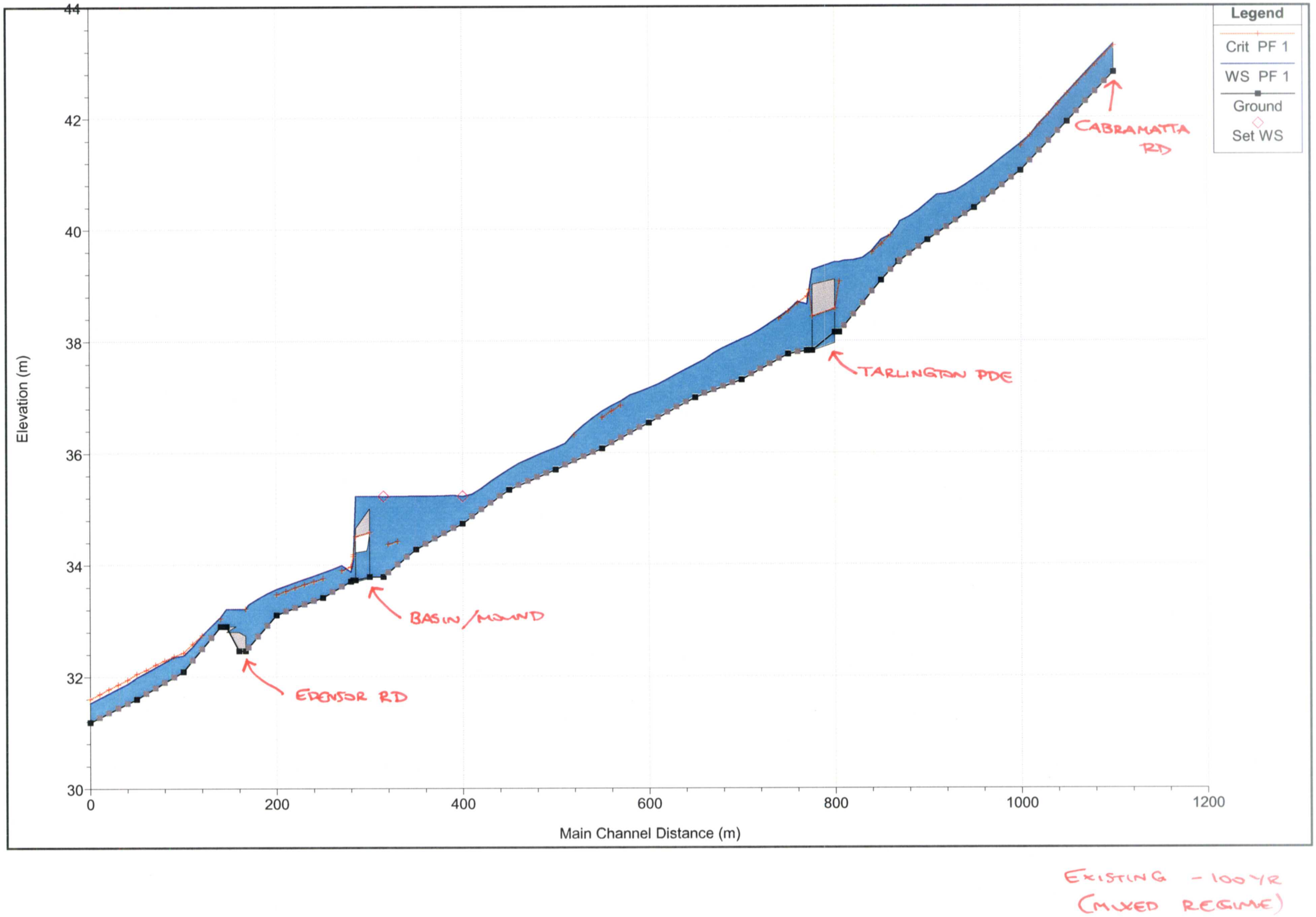
Sensitivity Analysis - Proposed Western Flows 100yr

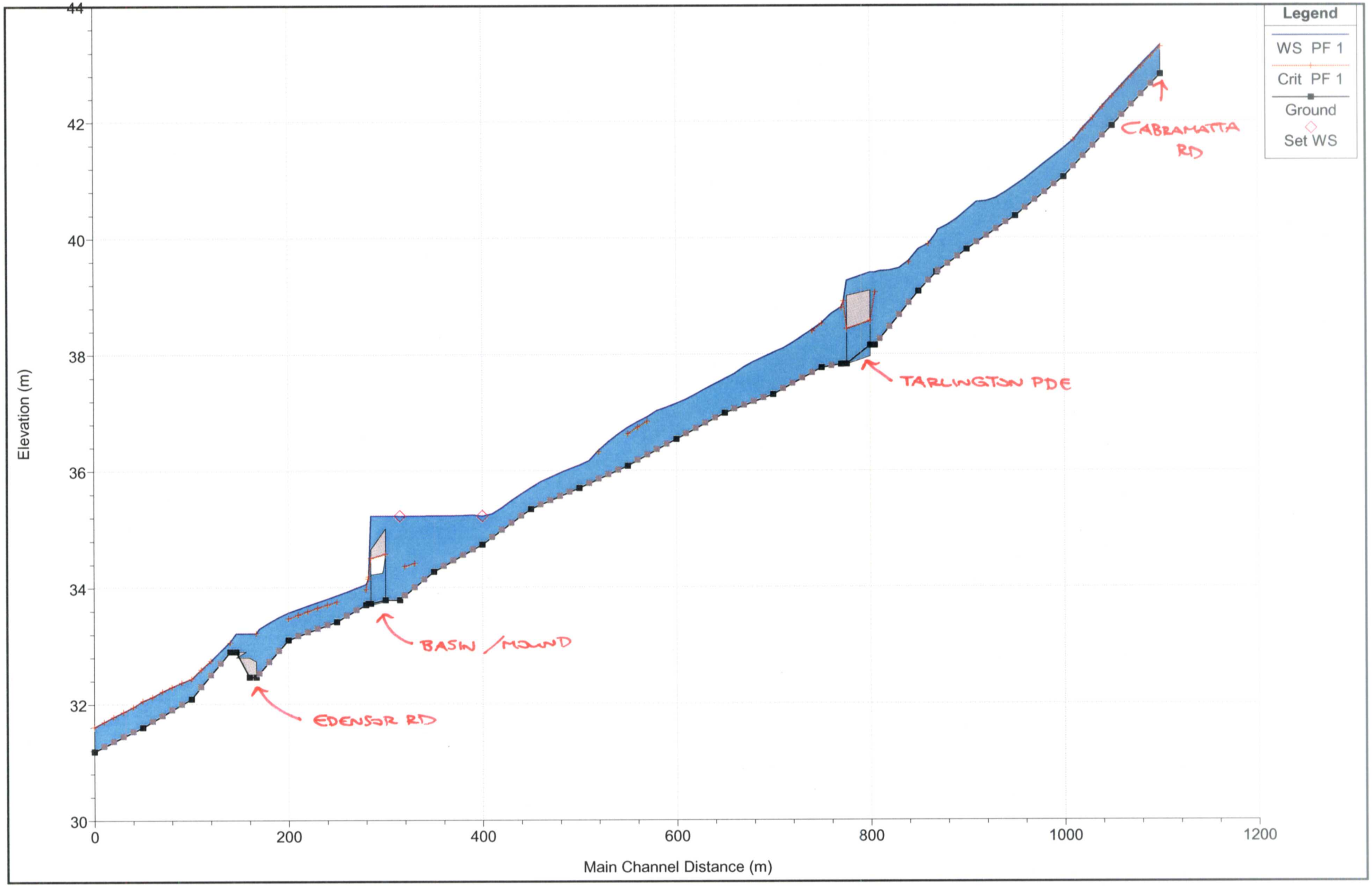
		Initial Loss (Pervious and Impervious areas)				
Node	**Duration**	15 and 1.5	10 and 1.0	Increase %	20 and 2.0	Decrease %
Woutlet	10	1.068	1.102	3.2	1.044	2.2
	15	1.186	1.217	2.6	1.167	1.6
	20	1.393	1.646	18.2	1.179	15.4
	25	1.346	1.609	19.5	1.205	10.5
	30	1.185	1.419	19.7	1.149	3.0
	45	1.067	1.287	20.6	1.048	1.8
	60	1.441	1.628	13.0	1.177	18.3
	90	1.72	1.829	6.3	1.498	12.9
	120	1.572	1.595	1.5	1.543	1.8
	180	0.9777	0.986	0.8	0.963	1.5
	540	0.6716	0.672	0.1	0.672	-0.1

Sensitivity Analysis - Proposed Eastern Flows 100yr

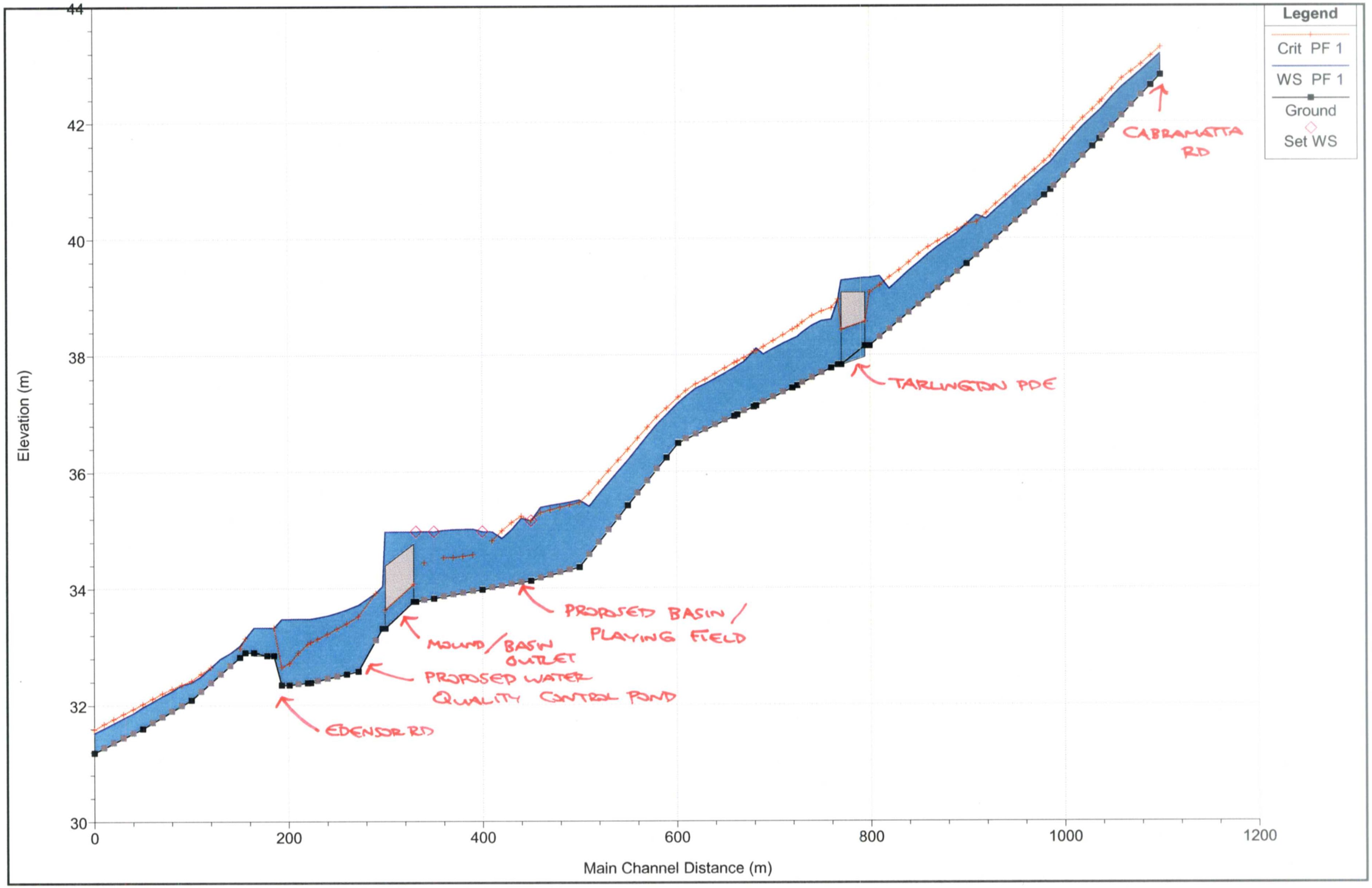
		Initial Loss (Pervious and Impervious areas)				
Node	**Duration**	15 and 1.5	10 and 1.0	Increase %	20 and 2.0	Decrease %
Eoutlet	10	6.043	6.375	5.5	5.78	4.4
	15	7.09	7.423	4.7	6.831	3.7
	20	6.929	7.277	5.0	6.636	4.2
	25	7.948	8.311	4.6	7.607	4.3
	30	7.359	7.72	4.9	7.046	4.3
	45	6.193	6.532	5.5	5.921	4.4
	60	7.493	7.679	2.5	7.198	3.9
	90	8.041	8.111	0.9	7.9	1.8
	120	7.518	7.604	1.1	7.336	2.4
	180	5	5.022	0.4	4.936	1.3
	540	2.944	2.944	0.0	2.944	0.0

Appendix D: HEC-RAS Results

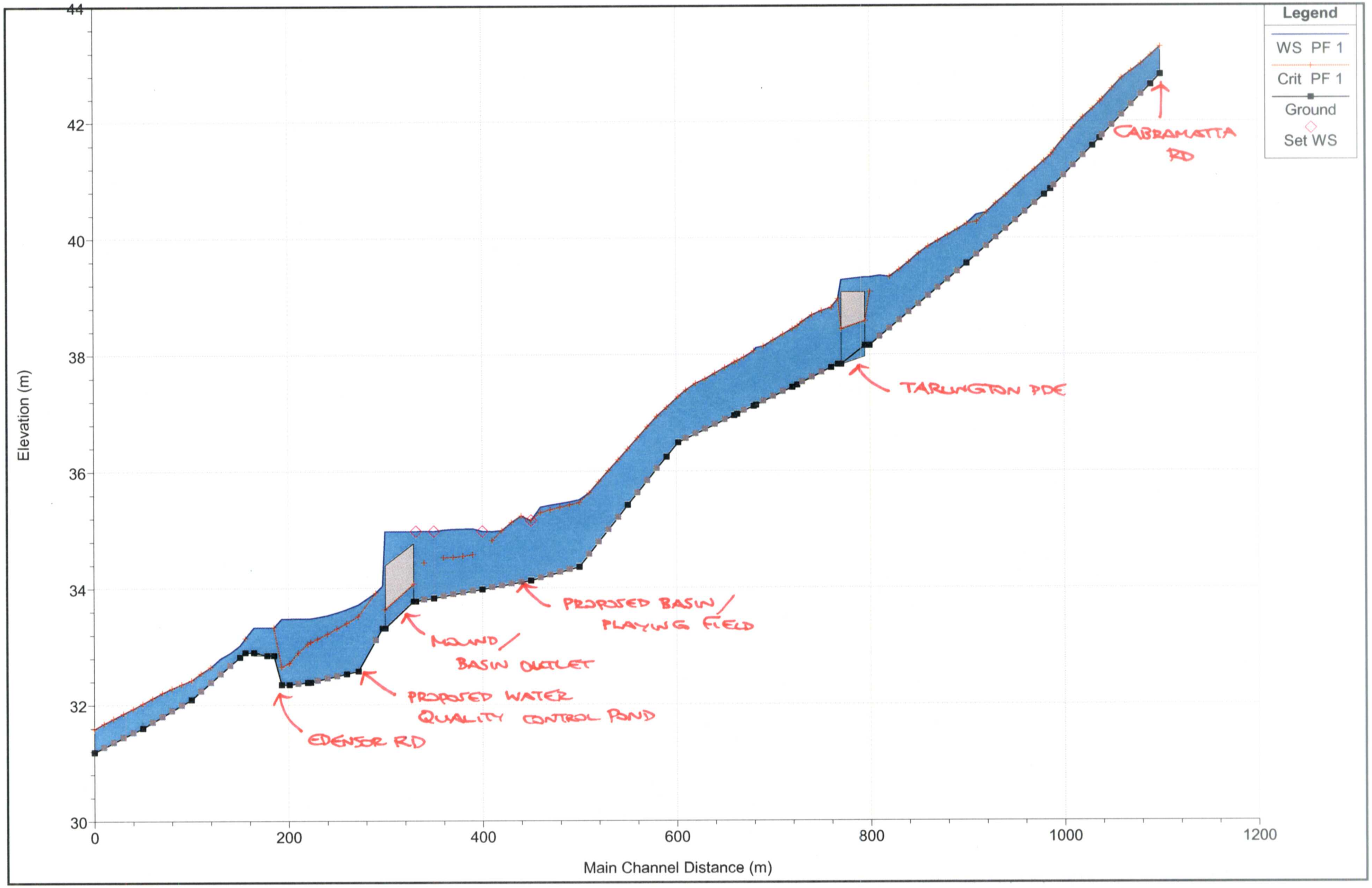

Legend
Crit PF 1
WS PF 1
Ground
Set WS
Elevation (m)
Main Channel Distance (m)
CABRAMATTA RD
TARLINGTON PDE
BASIN/MOUND
EDENSOR RD
EXISTING - 100YR (MIXED REGIME)



EXISTING - 100YR
(SUBCRITICAL REGIME)



PROPOSED - 100YR
(MIXED REGIME)



PROPOSED -100YR
(SUBCRITICAL REGIME)

HEC-RAS Plan: Q100 extg River: 1 Reach: 1 Profile: PF 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	1100	PF 1	5.00	42.82	43.31	43.28	43.46	0.017830	1.69	2.95	8.05	0.89
1	1090.*	PF 1	5.00	42.64	43.14	43.11	43.28	0.017791	1.65	3.03	8.64	0.89
1	1080.*	PF 1	5.00	42.46	42.97	42.94	43.10	0.017862	1.61	3.12	9.39	0.88
1	1070.*	PF 1	5.00	42.28	42.79	42.76	42.92	0.018263	1.59	3.18	10.98	0.89
1	1060.*	PF 1	5.00	42.11	42.62	42.59	42.74	0.017880	1.54	3.33	12.77	0.88
1	1050	PF 1	5.00	41.93	42.43	42.42	42.55	0.019320	1.54	3.38	14.21	0.90
1	1040.*	PF 1	5.00	41.75	42.25	42.23	42.36	0.017716	1.50	3.51	14.80	0.87
1	1030.*	PF 1	5.00	41.58	42.05	42.05	42.17	0.019894	1.56	3.35	14.54	0.92
1	1020.*	PF 1	5.00	41.40	41.88	41.86	41.99	0.016876	1.47	3.58	15.34	0.85
1	1010.*	PF 1	5.00	41.23	41.67	41.67	41.80	0.020918	1.59	3.28	14.54	0.94
1	1000	PF 1	5.00	41.05	41.53		41.62	0.012781	1.34	3.99	16.77	0.75
1	990.*	PF 1	5.00	40.92	41.40		41.49	0.012950	1.33	3.93	16.46	0.75
1	980.*	PF 1	5.00	40.78	41.27		41.36	0.013148	1.32	3.87	15.62	0.75
1	970.*	PF 1	5.00	40.65	41.14		41.23	0.013182	1.31	3.87	14.02	0.75
1	960.*	PF 1	5.00	40.51	41.01		41.09	0.013249	1.29	3.89	13.71	0.75
1	950	PF 1	5.00	40.38	40.89		40.97	0.011462	1.21	4.13	13.95	0.70
1	940.*	PF 1	5.00	40.27	40.78		40.85	0.011514	1.19	4.21	14.76	0.70
1	930.*	PF 1	5.00	40.15	40.68		40.74	0.009987	1.11	4.52	16.03	0.65
1	920.*	PF 1	5.00	40.04	40.63		40.67	0.005005	0.89	5.87	22.17	0.47
1	910.*	PF 1	5.00	39.92	40.61		40.63	0.001918	0.64	8.79	34.69	0.31
1	900	PF 1	10.90	39.81	40.47		40.57	0.010934	1.46	8.28	30.62	0.72
1	890.*	PF 1	10.90	39.68	40.33		40.45	0.012452	1.58	7.38	29.39	0.77
1	880.*	PF 1	10.90	39.56	40.22		40.33	0.010993	1.56	7.67	29.36	0.73
1	870.*	PF 1	10.90	39.43	40.13		40.23	0.008209	1.46	8.37	31.92	0.65
1	868.639	PF 1	10.90	39.42	40.08		40.22	0.011593	1.67	6.97	24.70	0.76
1	860.*	PF 1	10.90	39.26	39.89	39.89	40.08	0.019740	1.98	5.73	22.92	0.97
1	850	PF 1	10.90	39.09	39.81		39.91	0.009381	1.50	8.29	23.68	0.68
1	840.*	PF 1	10.90	38.88	39.60	39.58	39.78	0.015514	1.92	5.97	20.89	0.88
1	830.*	PF 1	10.90	38.68	39.48		39.64	0.011598	1.82	6.40	21.26	0.78
1	820.*	PF 1	10.90	38.47	39.44		39.55	0.005748	1.49	8.05	27.16	0.57
1	810.*	PF 1	10.90	38.26	39.43		39.50	0.002845	1.21	10.28	32.87	0.41
1	805	PF 1	10.90	38.16	39.40	39.06	39.48	0.003668	1.26	9.18	21.09	0.42
1	800		Culvert									
1	772.5	PF 1	14.20	37.84	38.91	38.91	39.18	0.020699	2.36	6.36	31.33	0.90
1	770.	PF 1	14.20	37.83	38.80	38.79	39.03	0.012643	2.19	7.32	28.17	0.83
1	760.*	PF 1	14.20	37.80	38.69		38.90	0.012030	2.05	7.62	22.50	0.81
1	750	PF 1	14.20	37.77	38.53	38.52	38.76	0.016443	2.13	7.00	18.22	0.92
1	740.*	PF 1	14.20	37.68	38.42	38.39	38.59	0.013732	1.86	8.23	21.73	0.83
1	730.*	PF 1	14.20	37.59	38.31		38.45	0.012658	1.70	8.96	25.32	0.79
1	720.*	PF 1	14.20	37.50	38.20		38.32	0.011753	1.59	9.52	28.05	0.76
1	710.*	PF 1	14.20	37.41	38.10		38.21	0.010414	1.48	10.24	31.12	0.71
1	700	PF 1	14.20	37.32	38.03		38.11	0.007761	1.30	11.74	35.46	0.62
1	690.*	PF 1	14.20	37.25	37.95		38.03	0.007634	1.30	11.78	34.11	0.61
1	680.*	PF 1	14.20	37.19	37.87		37.96	0.007228	1.33	11.58	31.12	0.60
1	670.*	PF 1	14.20	37.12	37.78		37.88	0.007951	1.43	10.84	29.61	0.64
1	660.*	PF 1	14.20	37.06	37.66		37.79	0.010901	1.63	9.86	31.26	0.74
1	650	PF 1	14.20	37.00	37.58		37.68	0.009048	1.52	10.75	31.43	0.68
1	640.*	PF 1	14.20	36.90	37.49		37.59	0.008842	1.53	11.06	32.57	0.67
1	630.*	PF 1	14.20	36.81	37.40		37.50	0.009190	1.57	11.25	33.61	0.69
1	620.*	PF 1	14.20	36.73	37.31		37.40	0.009317	1.59	11.38	34.64	0.69
1	610.*	PF 1	14.20	36.64	37.22		37.31	0.009011	1.59	11.69	35.53	0.69
1	600	PF 1	14.20	36.55	37.15		37.23	0.007128	1.46	12.49	37.72	0.61
1	590.*	PF 1	14.20	36.45	37.09		37.16	0.006448	1.35	13.33	41.86	0.58
1	580.*	PF 1	14.20	36.36	37.03		37.09	0.005917	1.26	14.09	46.80	0.55
1	570.*	PF 1	14.20	36.27	36.92	36.84	37.02	0.009191	1.43	10.87	34.42	0.67
1	560.*	PF 1	14.20	36.18	36.83	36.74	36.93	0.009066	1.35	11.08	33.49	0.66
1	550	PF 1	14.20	36.09	36.74	36.63	36.83	0.009696	1.32	10.76	33.66	0.67
1	540.*	PF 1	14.20	36.01	36.62		36.72	0.012461	1.41	11.06	44.81	0.75
1	530.*	PF 1	14.20	35.93	36.49		36.58	0.015268	1.42	11.63	58.12	0.81
1	520.*	PF 1	14.20	35.86	36.35	36.32	36.42	0.016498	1.28	12.42	71.83	0.81
1	510.*	PF 1	14.20	35.78	36.17		36.24	0.019201	1.10	11.94	74.70	0.83
1	500	PF 1	16.40	35.71	36.09		36.13	0.006338	0.59	19.49	94.52	0.47
1	490.*	PF 1	16.40	35.64	36.03		36.06	0.006931	0.67	19.90	107.05	0.50
1	480.*	PF 1	16.40	35.56	35.96		35.99	0.007150	0.77	20.73	94.87	0.52
1	470.*	PF 1	16.40	35.49	35.88		35.92	0.007531	0.87	20.24	95.45	0.55
1	460.*	PF 1	16.40	35.42	35.81		35.84	0.007815	0.96	19.97	94.32	0.57
1	450	PF 1	16.40	35.35	35.71		35.75	0.010024	1.13	18.38	91.67	0.65
1	440.*	PF 1	16.40	35.23	35.60		35.65	0.010395	1.18	17.87	91.00	0.67
1	430.*	PF 1	16.40	35.11	35.49		35.55	0.010642	1.21	17.29	89.08	0.68
1	420.*	PF 1	16.40	34.98	35.37		35.43	0.011947	1.27	16.00	82.48	0.72
1	410.*	PF 1	16.40	34.86	35.26		35.32	0.010130	1.20	16.53	80.28	0.67
1	400	PF 1	16.40	34.74	35.22		35.25	0.003972	0.87	22.85	87.99	0.43
1	390.*	PF 1	16.40	34.65	35.24		35.25	0.001391	0.60	33.41	100.42	0.27
1	380.*	PF 1	16.40	34.56	35.23		35.24	0.000715	0.47	42.29	108.22	0.20
1	370.*	PF 1	16.40	34.46	35.23		35.24	0.000392	0.38	51.95	113.51	0.15
1	360.*	PF 1	16.40	34.37	35.23		35.23	0.000232	0.32	62.07	118.00	0.12
1	350	PF 1	16.40	34.28	35.23		35.23	0.000146	0.27	72.62	122.25	0.09
1	340.*	PF 1	16.40	34.14	35.23		35.23	0.000131	0.29	70.71	119.01	0.09
1	330.*	PF 1	16.40	34.00	35.22	34.41	35.23	0.000125	0.31	65.28	94.47	0.09
1	320.*	PF 1	16.40	33.86	35.22	34.36	35.23	0.000134	0.35	59.15	84.23	0.10
1	315	PF 1	16.40	33.80	35.22		35.23	0.000212	0.34	48.73	80.29	0.10
1	300		Culvert									
1	282.5	PF 1	15.30	33.73	34.18	34.18	34.39	0.023993	2.05	7.45	93.88	1.01

HEC-RAS Plan: Q100 extg River: 1 Reach: 1 Profile: PF 1 (Continued)

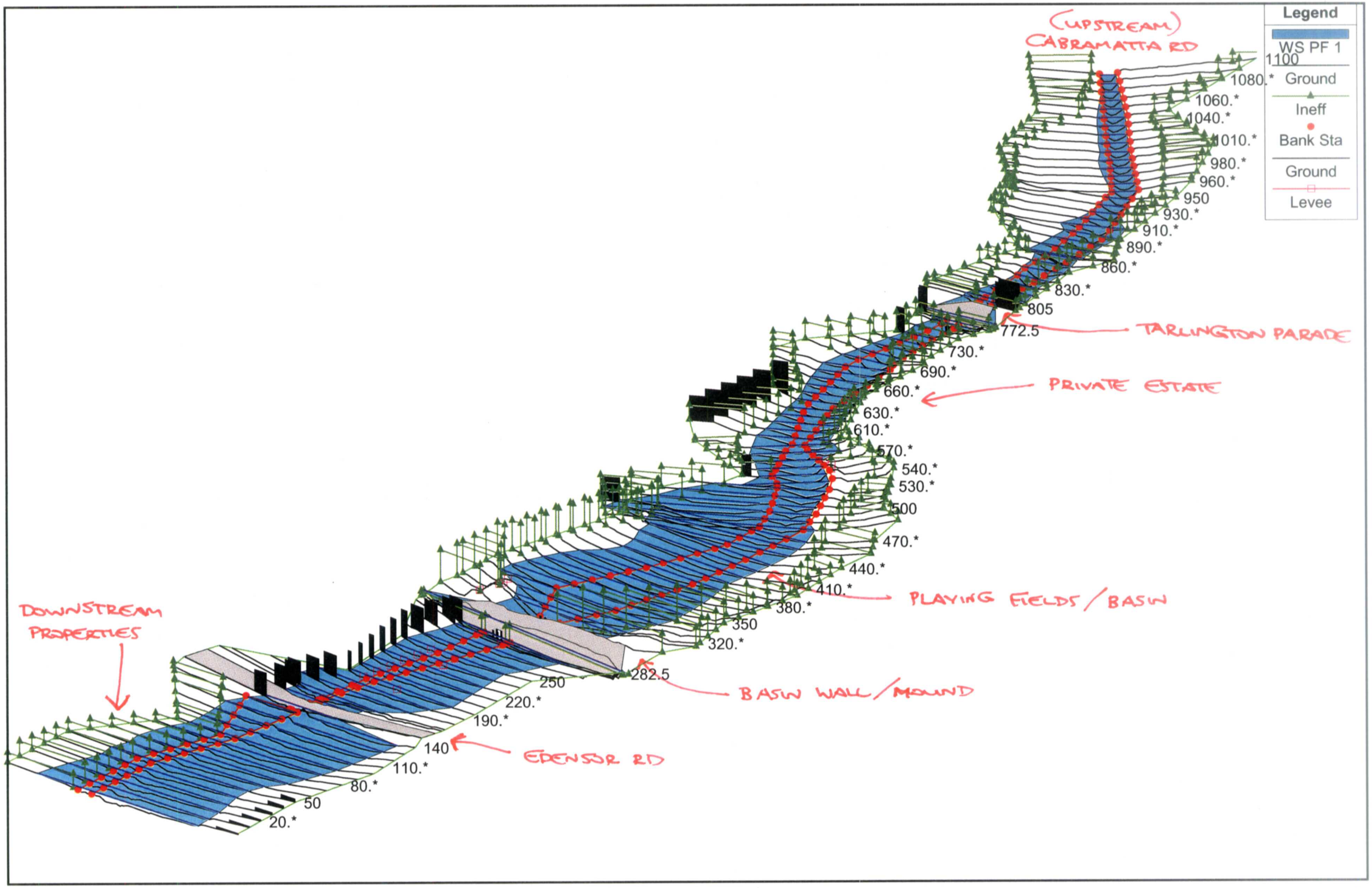
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	282.4	PF 1	15.30	33.73	34.14	34.14	34.34	0.021243	1.95	7.84	88.81	0.99
1	280.	PF 1	15.30	33.71	34.05	33.96	34.08	0.006013	0.91	20.01	83.28	0.51
1	270.*	PF 1	15.30	33.61	33.99		34.02	0.006453	0.97	19.20	80.07	0.54
1	260.*	PF 1	15.30	33.52	33.92		33.96	0.006680	1.02	18.87	79.30	0.55
1	250	PF 1	16.70	33.42	33.86	33.75	33.90	0.005571	0.97	20.71	76.85	0.51
1	240.*	PF 1	16.70	33.36	33.80	33.70	33.84	0.005757	1.00	20.61	77.36	0.52
1	230.*	PF 1	16.70	33.30	33.74	33.64	33.78	0.005930	1.02	20.53	77.92	0.52
1	220.*	PF 1	16.70	33.23	33.68	33.59	33.72	0.006085	1.04	20.49	78.51	0.53
1	210.*	PF 1	16.70	33.17	33.62	33.53	33.66	0.006153	1.05	20.56	79.20	0.54
1	200	PF 1	16.70	33.11	33.56	33.46	33.60	0.006003	1.04	20.87	80.06	0.53
1	190.*	PF 1	16.70	32.92	33.49		33.53	0.007124	1.35	19.07	78.75	0.60
1	180.*	PF 1	16.70	32.72	33.39		33.45	0.008238	1.64	17.14	74.49	0.66
1	170.*	PF 1	16.70	32.53	33.29		33.37	0.009248	1.87	15.92	61.35	0.70
1	166.787	PF 1	16.70	32.47	33.21	33.21	33.32	0.015788	2.35	12.83	53.53	0.89
1	150		Inl Struct									
1	140	PF 1	18.50	32.90	33.07	33.05	33.13	0.016486	0.69	17.06	95.60	0.70
1	130.*	PF 1	18.50	32.70	32.91		32.97	0.016745	0.83	17.61	106.00	0.74
1	120.*	PF 1	18.50	32.50	32.74	32.74	32.85	0.007722	2.04	17.99	104.02	1.60
1	110.*	PF 1	18.50	32.30	32.59	32.59	32.70	0.006296	2.16	19.07	105.81	1.50
1	100	PF 1	18.50	32.09	32.43	32.43	32.55	0.006555	2.42	19.39	107.29	1.57
1	90.*	PF 1	18.50	31.99	32.36	32.36	32.48	0.004975	2.33	20.67	109.46	1.40
1	80.*	PF 1	18.50	31.90	32.29	32.29	32.41	0.004243	2.30	21.33	109.93	1.32
1	70.*	PF 1	18.50	31.80	32.21	32.21	32.33	0.003780	2.28	21.75	109.02	1.26
1	60.*	PF 1	18.50	31.70	32.12	32.12	32.25	0.004126	2.38	20.52	99.39	1.31
1	50	PF 1	18.50	31.61	32.05	32.05	32.17	0.003347	2.25	21.80	99.48	1.20
1	40.*	PF 1	18.50	31.52	31.94	31.94	32.07	0.003803	2.33	20.17	97.95	1.27
1	30.*	PF 1	18.50	31.44	31.86	31.86	31.99	0.003709	2.31	20.50	103.72	1.25
1	20.*	PF 1	18.50	31.36	31.77	31.77	31.90	0.003597	2.27	20.99	109.70	1.23
1	9.99999*	PF 1	18.50	31.27	31.69	31.69	31.81	0.003649	2.25	21.21	113.93	1.24
1	0	PF 1	18.50	31.19	31.60	31.60	31.71	0.003922	2.26	21.08	116.97	1.27

HEC-RAS Plan: Q100 prop   River: 1   Reach: 1   Profile: PF 1

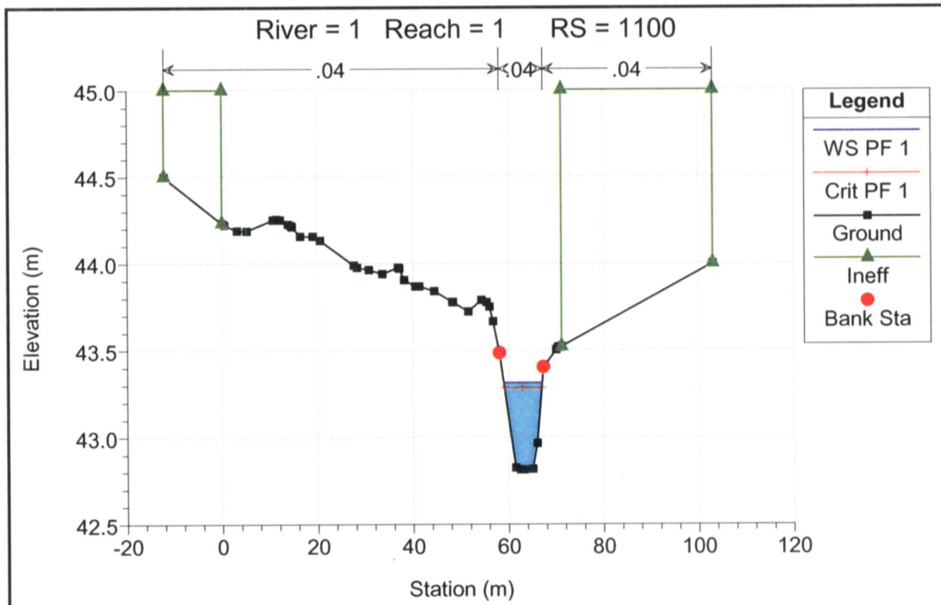
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	1100	PF 1	5.00	42.82	43.28	43.28	43.46	0.005773	1.86	2.69	7.78	1.01
1	1090.	PF 1	5.00	42.64	43.13	43.13	43.31	0.005669	1.88	2.66	7.42	1.00
1	1080.00*	PF 1	5.00	42.46	42.98	42.98	43.17	0.005502	1.93	2.61	7.74	1.00
1	1070.00*	PF 1	5.00	42.29	42.86	42.86	43.04	0.004168	1.88	3.07	14.17	0.89
1	1060.00*	PF 1	5.00	42.11	42.74	42.74	42.87	0.002880	1.73	4.73	22.71	0.76
1	1050.00*	PF 1	5.00	41.93	42.56	42.56	42.69	0.003365	1.88	4.89	19.09	0.81
1	1040.00*	PF 1	5.00	41.76	42.37	42.37	42.52	0.004532	2.17	4.51	14.73	0.93
1	1037.5	PF 1	5.00	41.71	42.33	42.33	42.48	0.004889	2.25	4.39	13.59	0.95
1	1030.	PF 1	5.00	41.59	42.21	42.21	42.34	0.004450	2.16	4.81	16.48	0.91
1	1020.*	PF 1	5.00	41.42	42.06	42.06	42.17	0.003694	2.02	5.46	24.15	0.84
1	1010.*	PF 1	5.00	41.24	41.88	41.88	42.00	0.003948	2.06	5.68	25.56	0.87
1	1000.*	PF 1	5.00	41.07	41.70	41.70	41.79	0.003784	1.98	6.34	30.44	0.84
1	990.*	PF 1	5.00	40.90	41.49	41.49	41.58	0.003954	1.92	6.63	31.21	0.84
1	986.5	PF 1	5.00	40.84	41.42	41.42	41.50	0.004170	1.93	6.65	31.41	0.86
1	980.	PF 1	5.00	40.75	41.32	41.32	41.41	0.004128	1.93	6.63	30.88	0.86
1	970.*	PF 1	5.00	40.60	41.17	41.17	41.26	0.004197	1.95	6.51	30.06	0.87
1	960.*	PF 1	5.00	40.45	41.03	41.03	41.12	0.004227	1.97	6.42	29.32	0.88
1	950.*	PF 1	5.00	40.30	40.88	40.88	40.97	0.004236	1.98	6.36	28.69	0.88
1	940.*	PF 1	5.00	40.16	40.73	40.73	40.83	0.004356	2.00	6.24	28.08	0.89
1	930.*	PF 1	5.00	40.01	40.59	40.59	40.68	0.003958	1.93	6.46	33.28	0.85
1	920.*	PF 1	5.00	39.86	40.43	40.43	40.52	0.004093	1.94	6.42	31.10	0.86
1	910.*	PF 1	5.00	39.71	40.40	40.27	40.43	0.001193	1.20	9.97	30.45	0.48
1	900	PF 1	10.80	39.57	40.24	40.24	40.38	0.006019	2.67	9.47	27.69	1.07
1	890.*	PF 1	10.80	39.43	40.16	40.16	40.30	0.004543	2.46	10.15	29.84	0.96
1	880.*	PF 1	10.80	39.29	40.07	40.07	40.22	0.003742	2.31	10.50	31.88	0.89
1	870.*	PF 1	10.80	39.15	39.98	39.98	40.13	0.003126	2.17	10.74	33.90	0.82
1	860.*	PF 1	10.80	39.01	39.89	39.89	40.03	0.002648	2.05	10.86	36.61	0.76
1	850.	PF 1	10.80	38.87	39.78	39.78	39.93	0.002378	1.96	10.72	42.77	0.73
1	840.*	PF 1	10.80	38.73	39.59	39.59	39.81	0.003551	2.24	7.68	28.26	0.87
1	830.*	PF 1	10.80	38.59	39.46	39.46	39.67	0.003329	2.14	7.66	29.33	0.84
1	820.*	PF 1	10.80	38.45	39.36	39.36	39.53	0.002706	1.95	8.39	32.17	0.76
1	810.*	PF 1	10.80	38.31	39.37		39.44	0.001042	1.36	13.11	35.22	0.49
1	800.*	PF 1	10.80	38.17	39.39		39.42	0.000445	0.98	18.82	40.16	0.33
1	799.6	PF 1	10.80	38.16	39.33	39.07	39.42	0.001201	1.36	9.67	37.96	0.48
1	799.5	PF 1	10.80	38.16	39.33	39.07	39.42	0.001202	1.36	9.66	37.95	0.48
1	794.5		Culvert									
1	767	PF 1	15.50	37.84	38.95	38.95	39.27	0.005689	2.57	6.81	33.07	0.95
1	760.	PF 1	15.50	37.78	38.80	38.80	39.01	0.003034	2.29	11.33	30.77	0.82
1	750.*	PF 1	15.50	37.69	38.75	38.75	38.96	0.002864	2.38	12.44	33.42	0.81
1	740.*	PF 1	15.50	37.61	38.67	38.67	38.87	0.002956	2.52	13.54	35.40	0.83
1	730.*	PF 1	15.50	37.53	38.56	38.56	38.75	0.003519	2.76	14.00	35.20	0.90
1	725	PF 1	15.50	37.48	38.48	38.48	38.67	0.004251	2.96	13.76	34.53	0.97
1	720.	PF 1	15.50	37.44	38.44	38.44	38.62	0.004225	2.94	13.94	35.32	0.96
1	710.*	PF 1	15.50	37.36	38.34	38.34	38.52	0.004304	2.93	14.14	36.80	0.97
1	700.*	PF 1	15.50	37.28	38.24	38.24	38.41	0.004324	2.90	14.47	38.75	0.97
1	690.*	PF 1	15.50	37.20	38.14	38.14	38.30	0.004400	2.88	14.70	40.35	0.97
1	682.5	PF 1	15.50	37.14	38.11		38.22	0.002982	2.43	17.29	43.16	0.81
1	680.	PF 1	15.50	37.12	38.06	38.06	38.21	0.004195	2.81	14.96	41.42	0.95
1	670.*	PF 1	15.50	37.04	37.95	37.95	38.12	0.004753	2.93	13.38	33.67	1.01
1	663	PF 1	15.50	36.98	37.89	37.89	38.06	0.004669	2.90	13.65	34.61	1.00
1	660.	PF 1	15.50	36.96	37.86	37.86	38.03	0.004725	2.91	13.58	34.43	1.00
1	650.*	PF 1	15.50	36.88	37.77	37.77	37.94	0.004881	2.92	13.37	33.93	1.02
1	640.*	PF 1	15.50	36.80	37.68	37.68	37.84	0.005038	2.93	13.18	33.48	1.03
1	630.*	PF 1	15.50	36.72	37.57	37.57	37.75	0.005507	3.01	12.72	32.90	1.07
1	620.*	PF 1	15.50	36.64	37.50	37.50	37.66	0.004983	2.88	13.75	37.99	1.02
1	610.*	PF 1	15.50	36.56	37.38	37.38	37.53	0.005196	2.85	13.50	36.00	1.03
1	602	PF 1	15.50	36.50	37.27	37.27	37.43	0.005874	2.91	12.85	33.32	1.09
1	590.	PF 1	15.50	36.25	37.08	37.08	37.24	0.005220	2.89	13.50	34.93	1.04
1	580.*	PF 1	15.50	36.05	36.93	36.93	37.08	0.004564	2.82	14.31	37.22	0.98
1	570.*	PF 1	15.50	35.84	36.75	36.75	36.92	0.004693	2.92	14.11	38.18	1.00
1	560.*	PF 1	15.50	35.63	36.57	36.57	36.74	0.004665	2.95	13.69	35.64	1.00
1	550	PF 1	15.50	35.43	36.37	36.37	36.55	0.004646	2.97	13.39	33.85	1.00
1	540.*	PF 1	15.50	35.22	36.19	36.19	36.38	0.004465	2.98	13.36	33.01	0.99
1	530.*	PF 1	15.50	35.00	36.01	36.01	36.20	0.004271	2.98	13.38	32.34	0.97
1	520.*	PF 1	15.50	34.79	35.82	35.82	36.01	0.004184	2.99	13.28	31.58	0.96
1	510.*	PF 1	15.50	34.58	35.62	35.62	35.82	0.004068	2.99	13.23	30.91	0.96
1	500	PF 1	17.10	34.37	35.51	35.46	35.67	0.003209	2.82	15.67	33.07	0.86
1	490.*	PF 1	17.10	34.32	35.47	35.42	35.64	0.003157	2.82	15.81	33.64	0.86
1	480.*	PF 1	17.10	34.28	35.44	35.38	35.61	0.003030	2.79	16.18	34.81	0.84
1	470.*	PF 1	17.10	34.23	35.42	35.34	35.58	0.002888	2.75	16.72	36.88	0.82
1	460.*	PF 1	17.10	34.18	35.39	35.29	35.55	0.002818	2.74	17.38	41.07	0.81
1	450	PF 1	17.10	34.14	35.15	35.15	35.49	0.006553	3.72	11.01	25.08	1.20
1	440.*	PF 1	17.10	34.11	35.23	35.23	35.39	0.003271	2.82	18.91	58.30	0.87
1	430.*	PF 1	17.10	34.08	35.12	35.12	35.25	0.003303	2.69	21.09	72.33	0.86
1	420.*	PF 1	17.10	34.05	34.98	34.98	35.09	0.003645	2.62	22.64	87.01	0.89
1	410.*	PF 1	17.10	34.02	34.97	34.81	34.99	0.000975	1.37	36.53	101.49	0.46
1	400	PF 1	17.10	33.99	34.97		34.98	0.000334	0.82	50.67	105.91	0.27
1	390.*	PF 1	17.10	33.96	35.02	34.57	35.02	0.000267	0.77	51.46	105.62	0.24
1	380.*	PF 1	17.10	33.93	35.01	34.54	35.02	0.000296	0.83	46.81	104.45	0.26
1	370.*	PF 1	17.10	33.89	35.00	34.52	35.02	0.000358	0.92	40.96	103.21	0.29
1	360.*	PF 1	17.10	33.87	34.99	34.52	35.01	0.000488	1.09	33.95	101.92	0.33
1	350	PF 1	17.10	33.83	34.97		35.00	0.000806	1.41	25.74	100.52	0.43
1	340.*	PF 1	17.10	33.81	34.97	34.43	35.01	0.000485	1.20	25.84	101.53	0.36

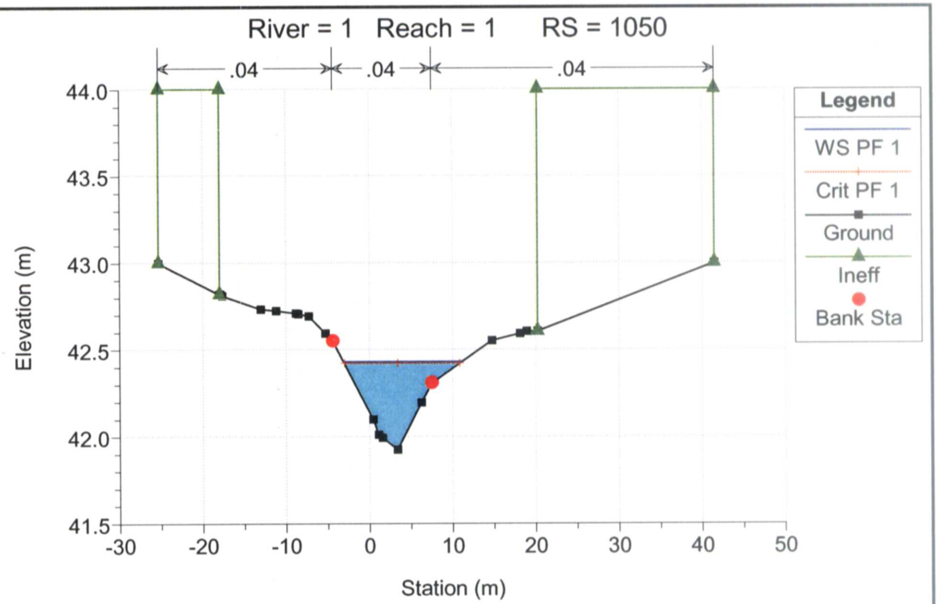
HEC-RAS Plan: Q100 prop River: 1 Reach: 1 Profile: PF 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	331.4	PF 1	17.10	33.78	34.97		35.01	0.000431	1.06	24.12	102.03	0.31
1	329.1		Culvert									
1	297	PF 1	17.30	33.32	34.04		34.16	0.018174	1.57	11.12	59.20	0.69
1	290.*	PF 1	17.30	33.11	33.92	33.92	34.03	0.017901	1.79	12.85	54.39	0.77
1	272	PF 1	17.30	32.58	33.71	33.51	33.80	0.007555	1.35	15.25	50.69	0.52
1	260.	PF 1	17.30	32.53	33.63	33.39	33.71	0.006889	1.27	15.79	53.16	0.49
1	250.*	PF 1	17.30	32.49	33.57	33.30	33.64	0.006010	1.18	16.72	56.52	0.46
1	240.*	PF 1	17.30	32.46	33.53	33.21	33.58	0.004934	1.08	18.30	64.72	0.42
1	230.*	PF 1	17.30	32.42	33.49	33.13	33.54	0.003733	0.96	20.92	73.01	0.37
1	223	PF 1	17.30	32.39	33.48	33.07	33.51	0.002958	0.87	23.47	81.38	0.33
1	210.*	PF 1	17.30	32.37	33.48	32.89	33.49	0.000747	0.49	40.28	109.92	0.17
1	201	PF 1	17.30	32.35	33.48	32.71	33.48	0.000370	0.38	52.97	119.86	0.12
1	193	PF 1	17.30	32.35	33.47	32.64	33.48	0.000244	0.31	60.54	123.32	0.10
1	185	PF 1	17.30	32.85	33.33	33.33	33.46	0.004723	2.03	15.20	111.13	0.96
1	167.8		Inl Struct									
1	155.6	PF 1	17.80	32.90	33.14	33.14	33.23	0.023463	1.14	14.17	119.64	0.90
1	150.	PF 1	16.80	32.82	33.01		33.06	0.011883	0.66	18.42	108.92	0.61
1	140.*	PF 1	16.80	32.68	32.89		32.94	0.012930	0.76	18.03	106.28	0.65
1	130.*	PF 1	16.80	32.53	32.80		32.83	0.008318	0.75	20.94	109.25	0.55
1	120.*	PF 1	16.80	32.39	32.64	32.64	32.75	0.006807	2.01	17.67	102.51	1.52
1	110.*	PF 1	16.80	32.24	32.54	32.54	32.64	0.005742	2.08	19.16	105.64	1.44
1	100	PF 1	16.80	32.09	32.42	32.42	32.53	0.006671	2.34	18.15	104.91	1.56
1	90.*	PF 1	16.80	31.99	32.35	32.35	32.45	0.004679	2.19	20.93	107.07	1.35
1	80.*	PF 1	16.80	31.90	32.28	32.28	32.38	0.003949	2.16	21.58	107.43	1.26
1	70.*	PF 1	16.80	31.80	32.20	32.20	32.31	0.003565	2.16	21.73	105.86	1.21
1	60.*	PF 1	16.80	31.70	32.11	32.11	32.23	0.003665	2.22	20.72	97.91	1.23
1	50	PF 1	16.80	31.61	32.02	32.02	32.15	0.003985	2.31	19.08	89.09	1.28
1	40.*	PF 1	16.80	31.52	31.93	31.93	32.05	0.003690	2.23	19.52	93.03	1.24
1	30.*	PF 1	16.80	31.44	31.85	31.85	31.96	0.003485	2.19	20.27	99.68	1.21
1	20.*	PF 1	16.80	31.36	31.76	31.76	31.87	0.003460	2.17	20.80	105.64	1.20
1	9.99999*	PF 1	16.80	31.27	31.67	31.67	31.78	0.003510	2.15	21.24	109.99	1.20
1	0	PF 1	16.80	31.19	31.58	31.58	31.69	0.004049	2.21	19.45	112.22	1.28



XYZ PLOT - EXISTING 100YR ARI


River = 1 Reach = 1 RS = 1100
.04
.04
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta


River = 1 Reach = 1 RS = 1050
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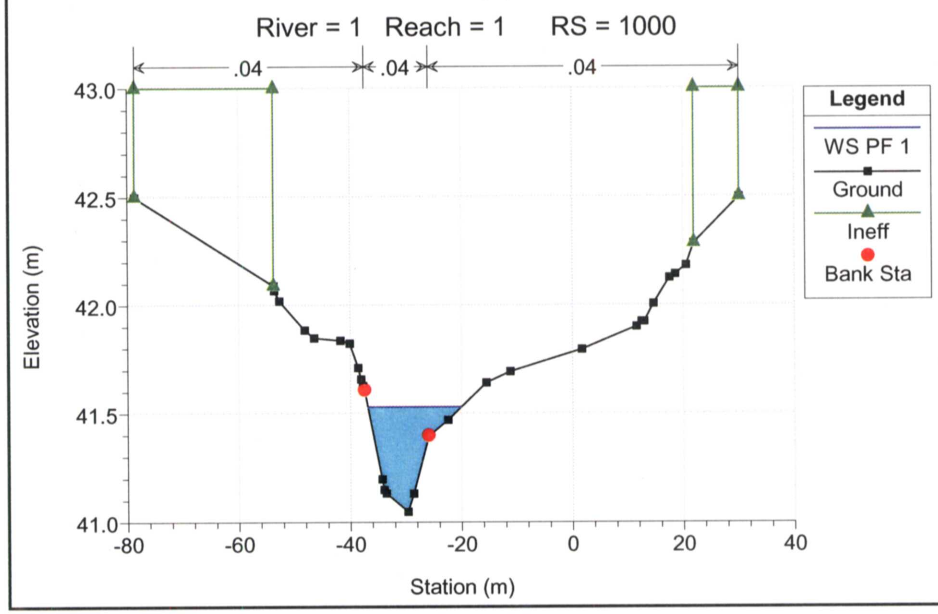
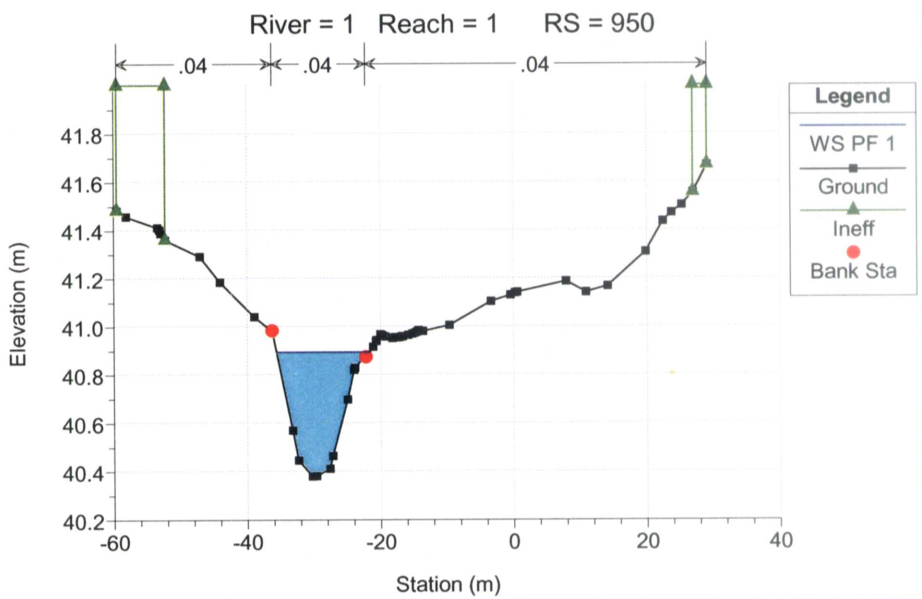
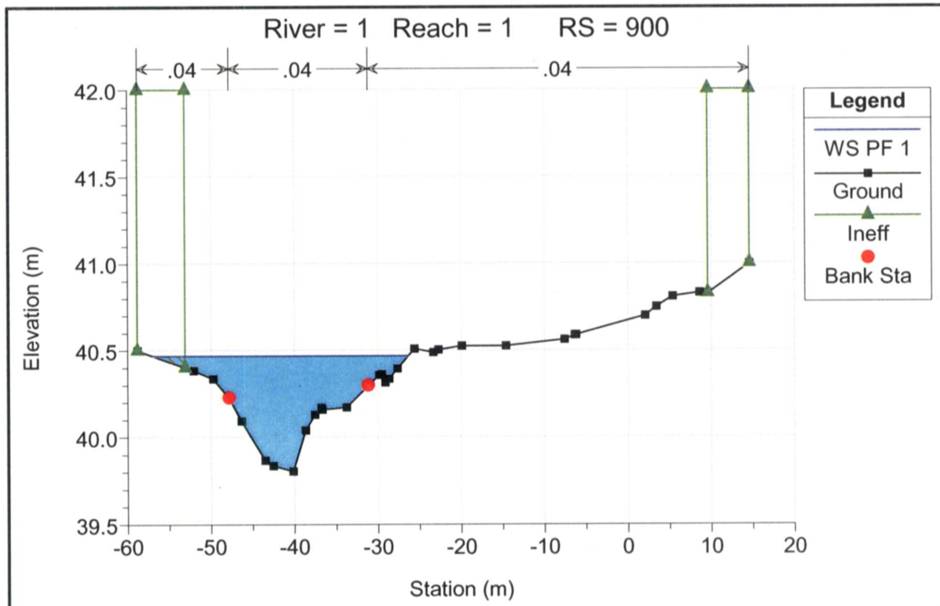
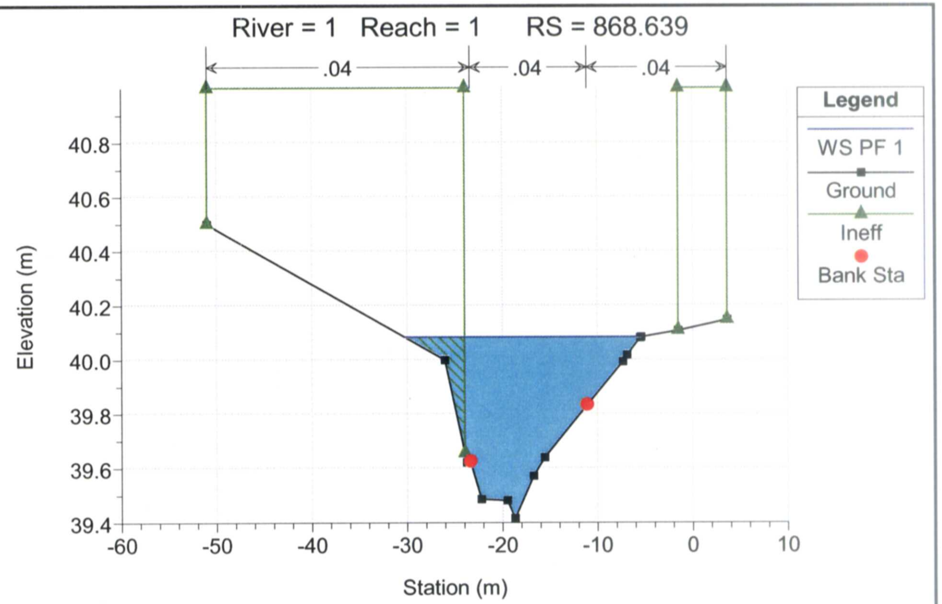
.04
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta

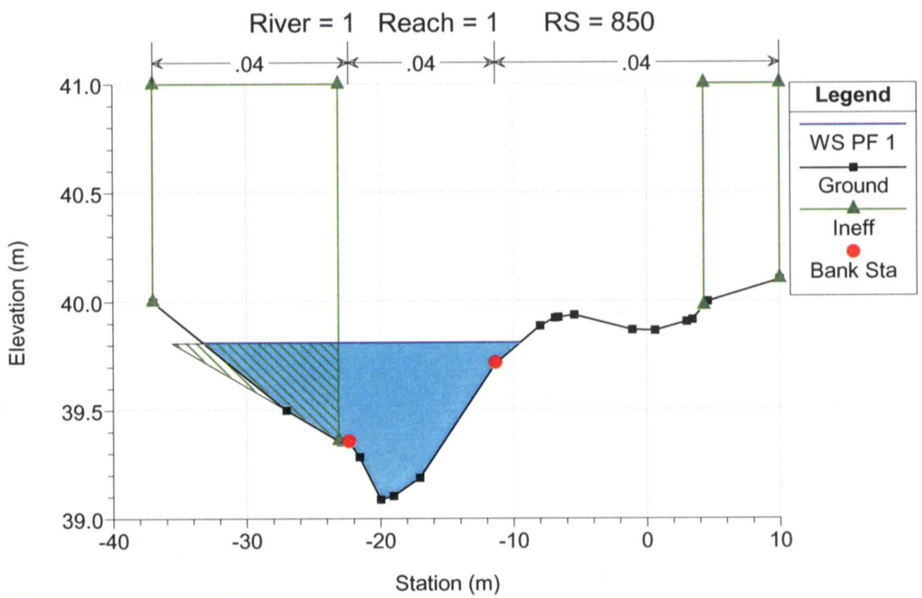

River = 1 Reach = 1 RS = 1000
.04
.04
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Ground
Ineff
Bank Sta

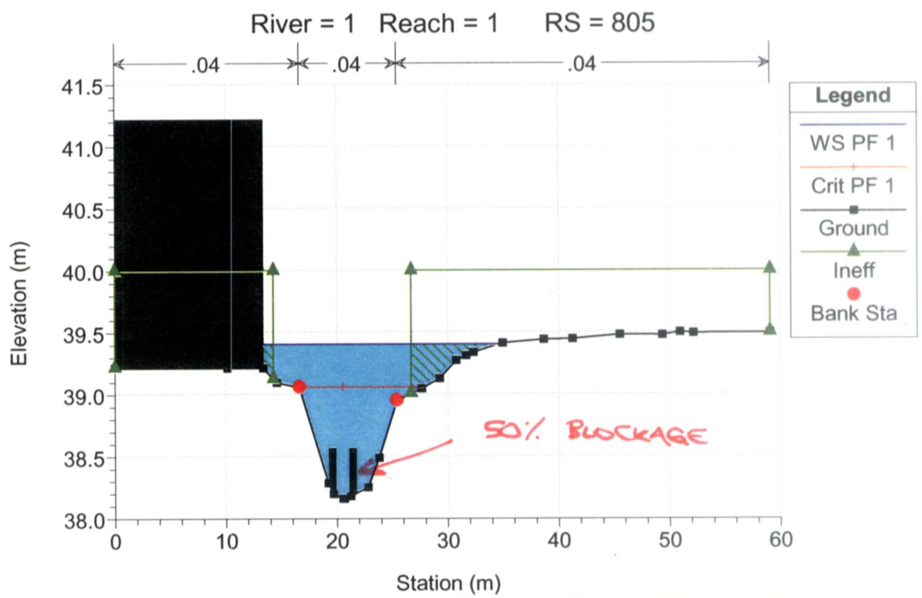

River = 1 Reach = 1 RS = 950
.04
.04
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Ground
Ineff
Bank Sta

EXISTING

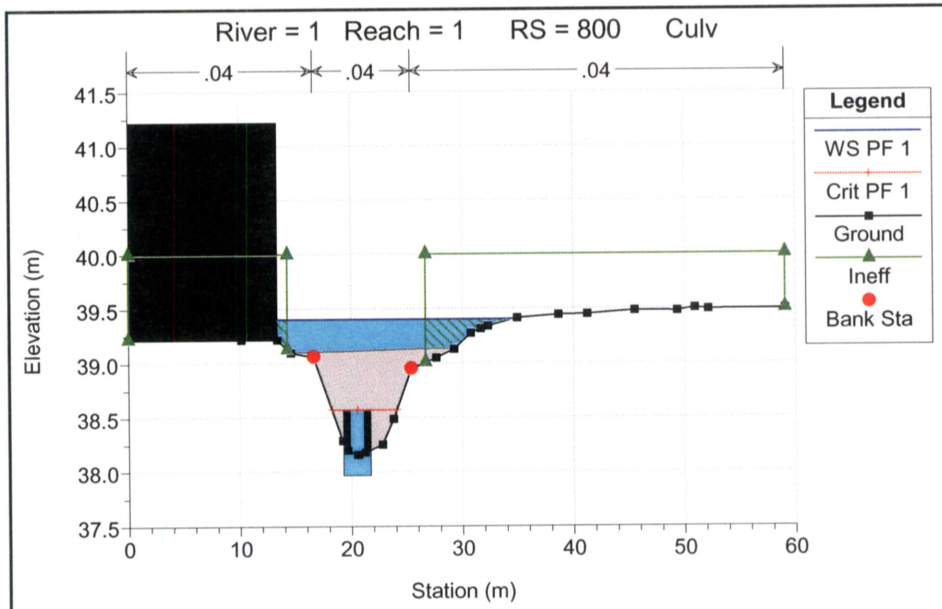

River = 1 Reach = 1 RS = 900
.04
.04
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Ground
Ineff
Bank Sta

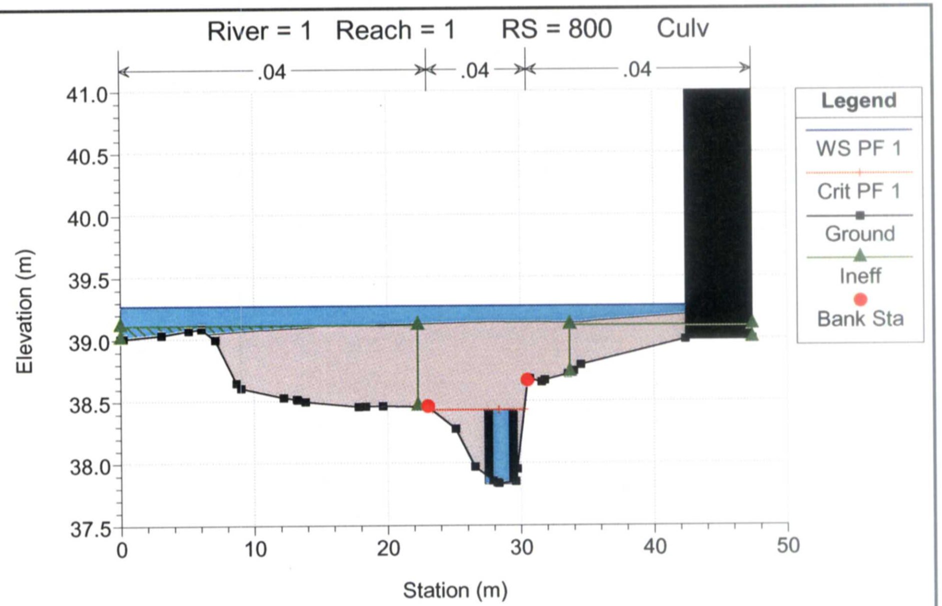

River = 1 Reach = 1 RS = 868.639
.04
.04
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Ground
Ineff
Bank Sta

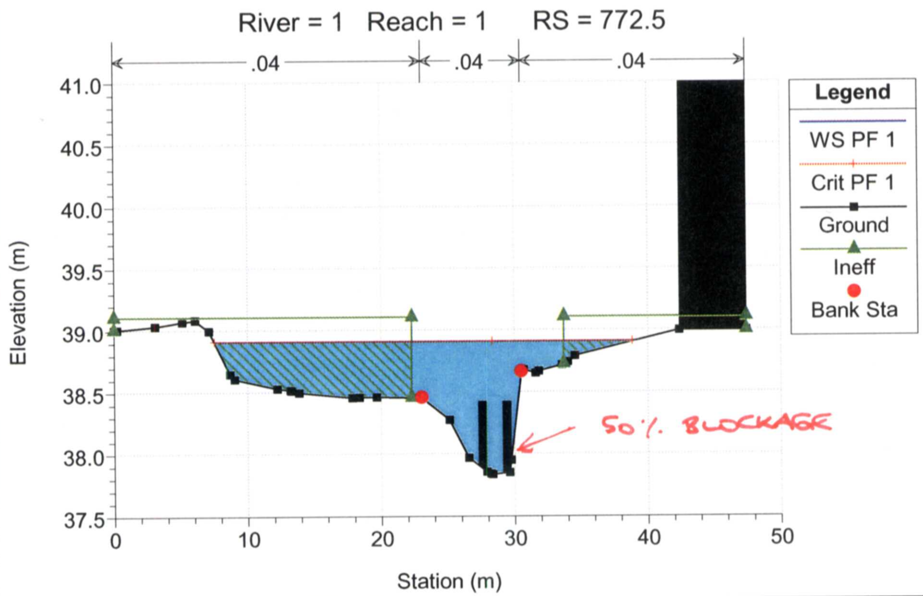

River = 1 Reach = 1 RS = 850
.04
.04
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Ground
Ineff
Bank Sta

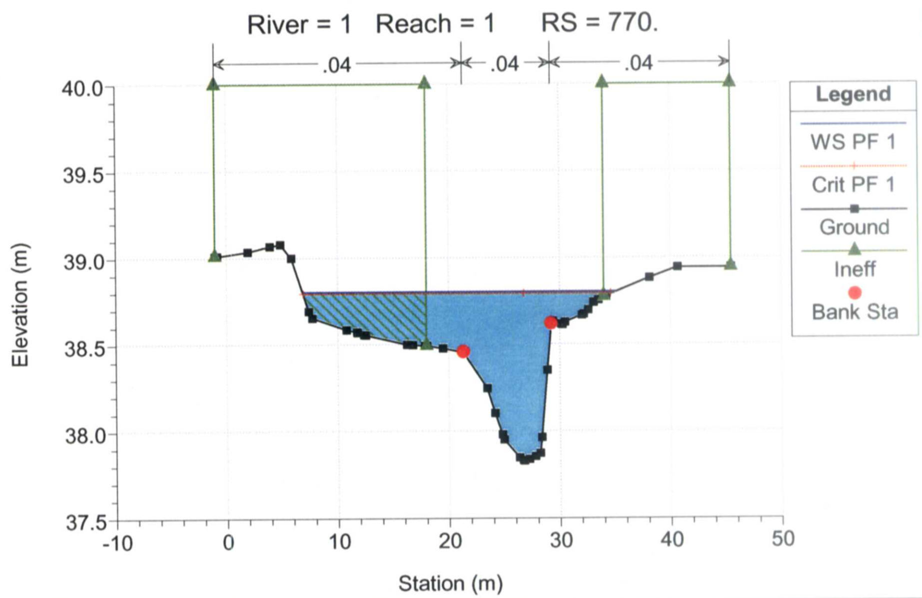

River = 1 Reach = 1 RS = 805
.04
.04
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
50% BLOCKAGE

EXISTING

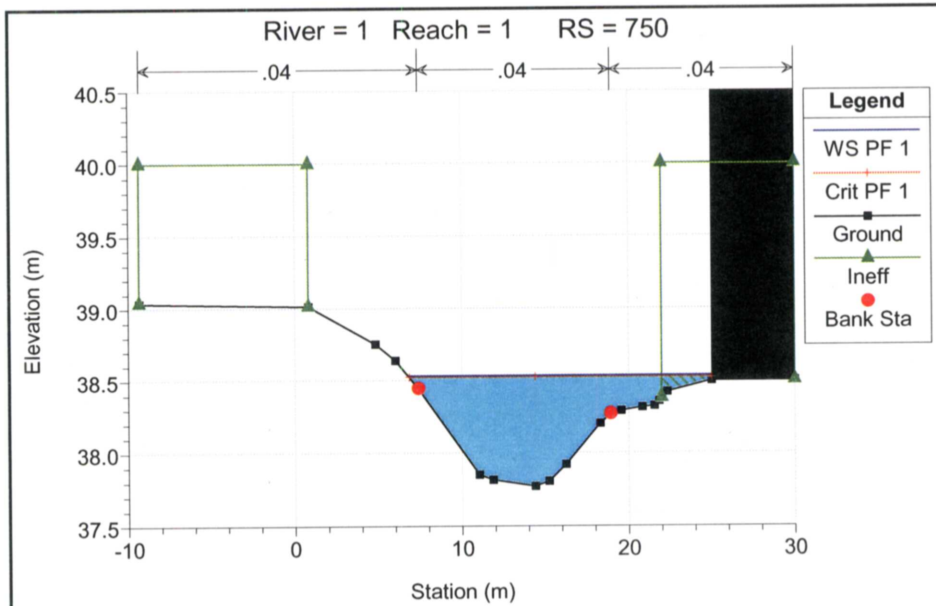

River = 1 Reach = 1 RS = 800 Culv
.04
.04
.04
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)

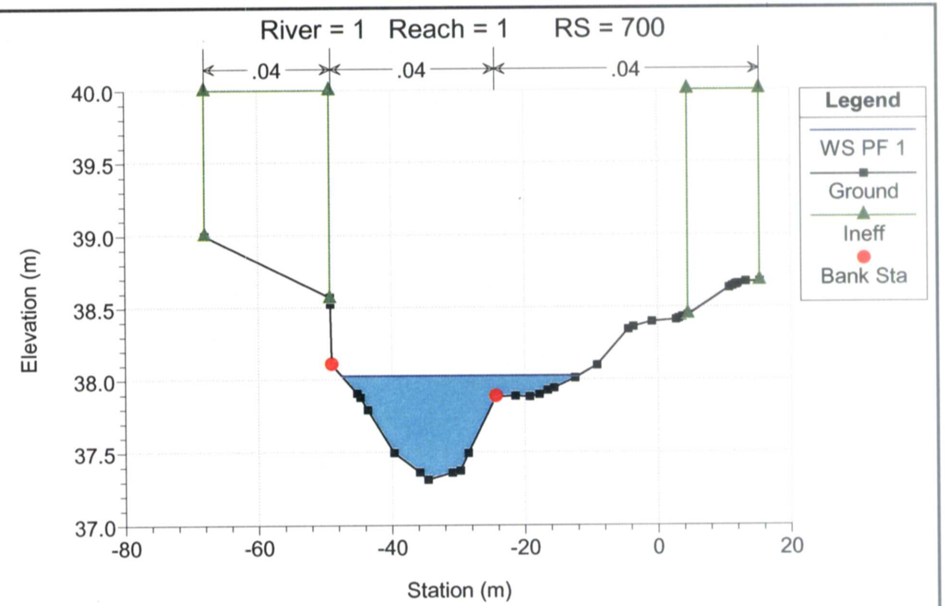

River = 1 Reach = 1 RS = 800 Culv
.04
.04
.04
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)

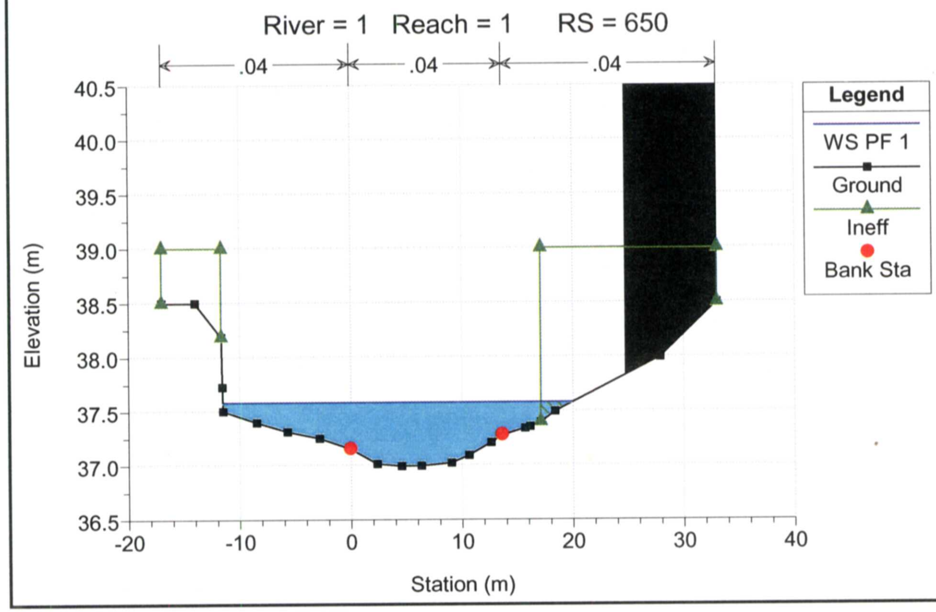

River = 1 Reach = 1 RS = 772.5
.04
.04
.04
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
50% BLOCKAGE
Elevation (m)
Station (m)

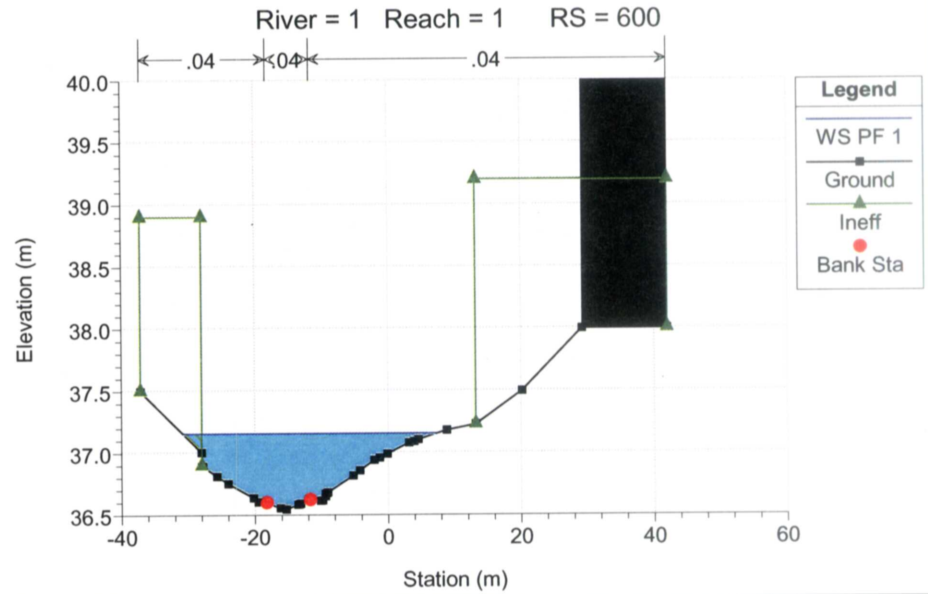

River = 1 Reach = 1 RS = 770.
.04
.04
.04
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)

EXISTING

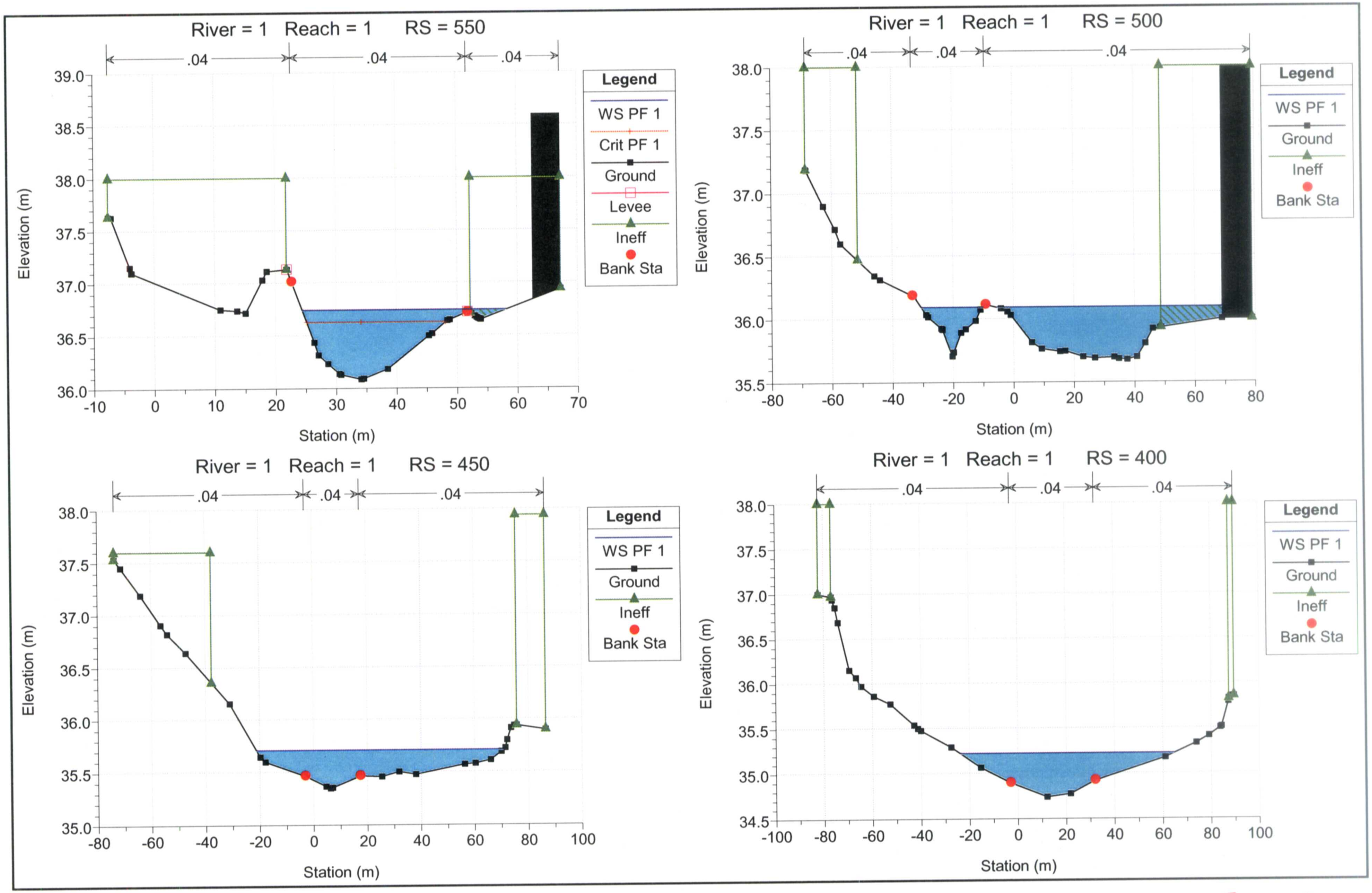

River = 1 Reach = 1 RS = 750
.04
.04
.04
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (m)
40.5
40.0
39.5
39.0
38.5
38.0
37.5
-10
0
10
20
30
Station (m)


River = 1 Reach = 1 RS = 700
.04
.04
.04
Legend
WS PF 1
Ground
Ineff
Bank Sta
Elevation (m)
40.0
39.5
39.0
38.5
38.0
37.5
37.0
-80
-60
-40
-20
0
20
Station (m)


River = 1 Reach = 1 RS = 650
.04
.04
.04
Legend
WS PF 1
Ground
Ineff
Bank Sta
Elevation (m)
40.5
40.0
39.5
39.0
38.5
38.0
37.5
37.0
36.5
-20
-10
0
10
20
30
40
Station (m)

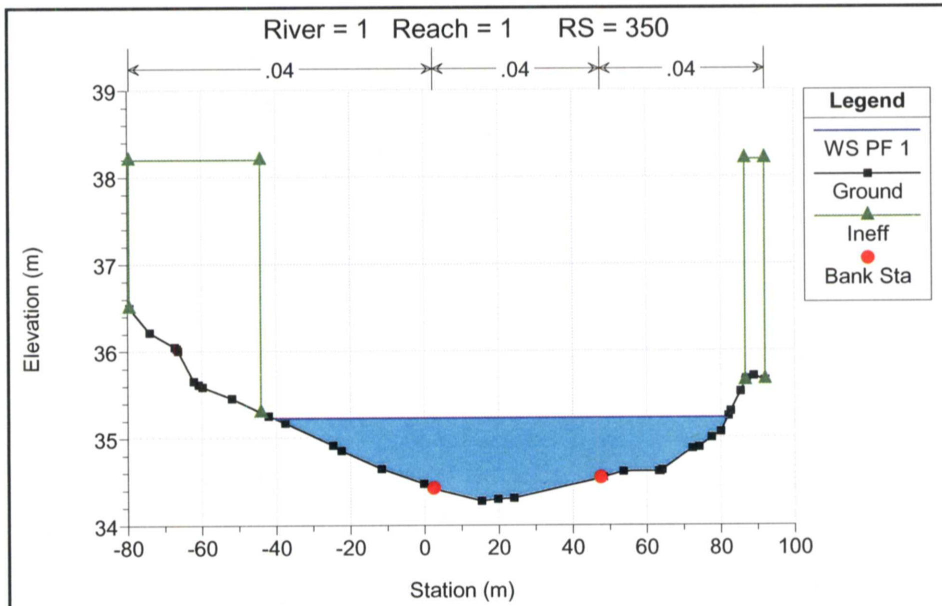

River = 1 Reach = 1 RS = 600
.04
.04
.04
Legend
WS PF 1
Ground
Ineff
Bank Sta
Elevation (m)
40.0
39.5
39.0
38.5
38.0
37.5
37.0
36.5
-40
-20
0
20
40
60
Station (m)

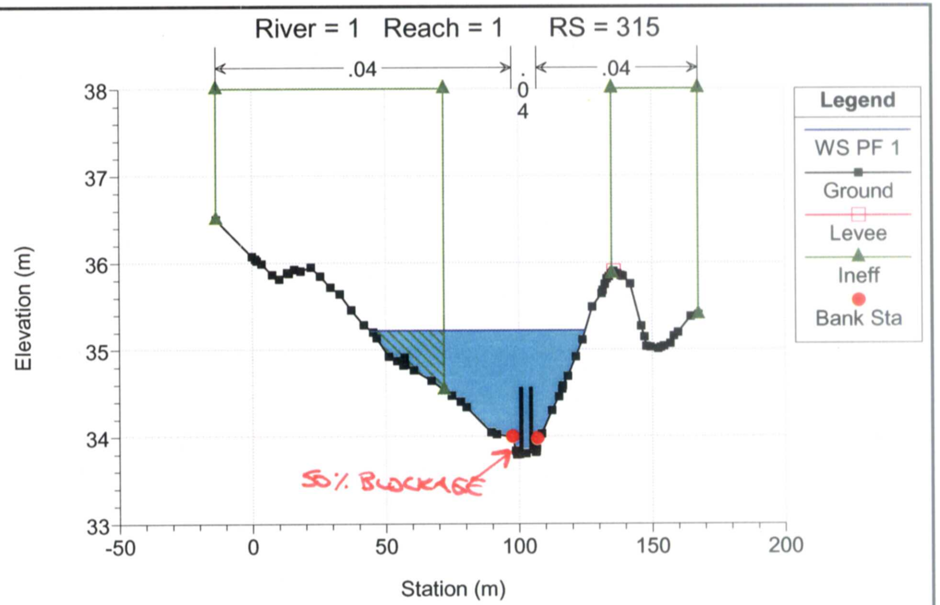
EXISTING

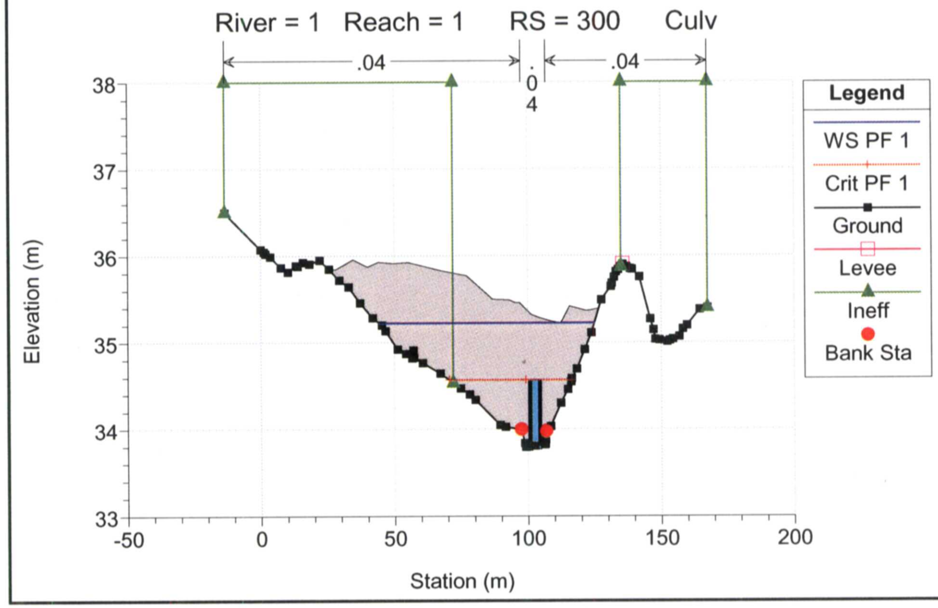


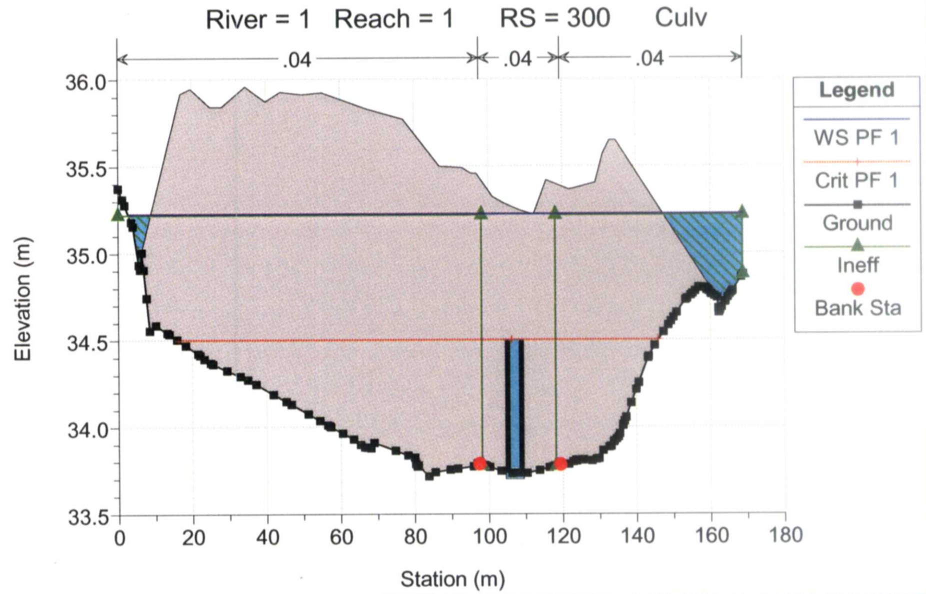
River = 1 Reach = 1 RS = 550
.04
.04
.04
Legend
WS PF 1
Crit PF 1
Ground
Levee
Ineff
Bank Sta
Elevation (m)
Station (m)
River = 1 Reach = 1 RS = 500
.04
.04
.04
Legend
WS PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)
River = 1 Reach = 1 RS = 450
.04
.04
.04
Legend
WS PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)
River = 1 Reach = 1 RS = 400
.04
.04
.04
Legend
WS PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)

EXISTING

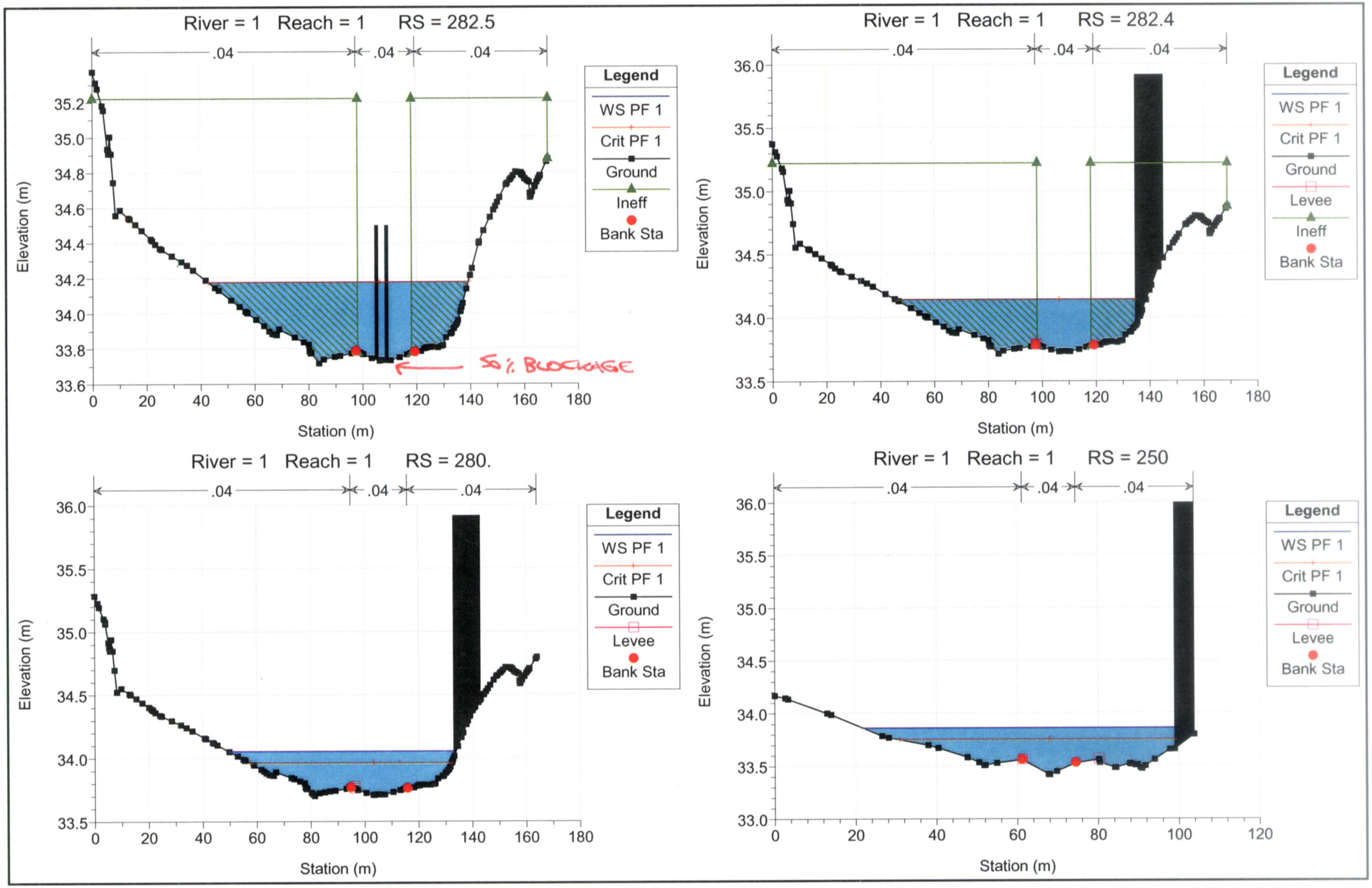

River = 1 Reach = 1 RS = 350
.04
.04
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Ground
Ineff
Bank Sta


River = 1 Reach = 1 RS = 315
.04
.04
Elevation (m)
Station (m)
50% BLOCKAGE
Legend
WS PF 1
Ground
Levee
Ineff
Bank Sta

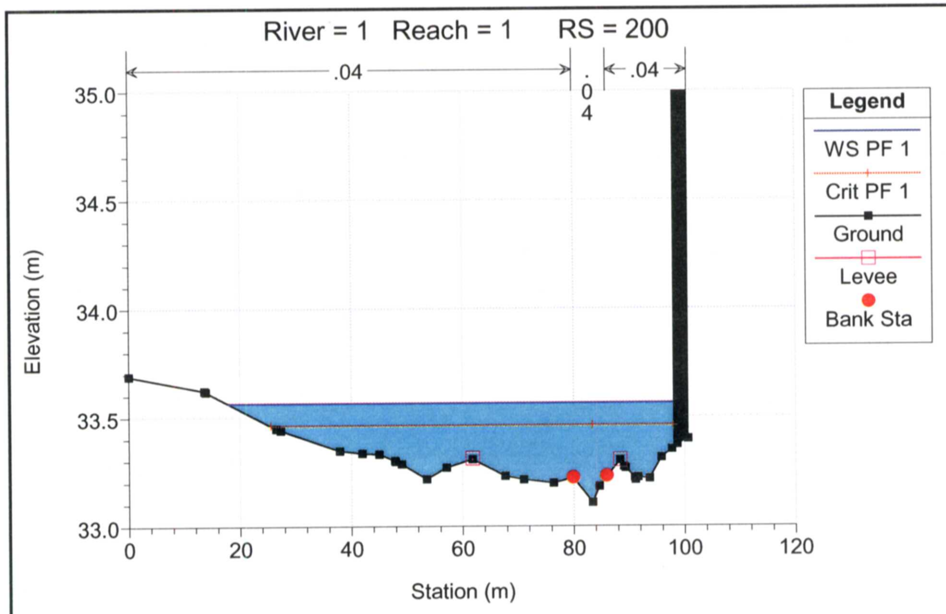

River = 1 Reach = 1 RS = 300 Culv
.04
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Levee
Ineff
Bank Sta

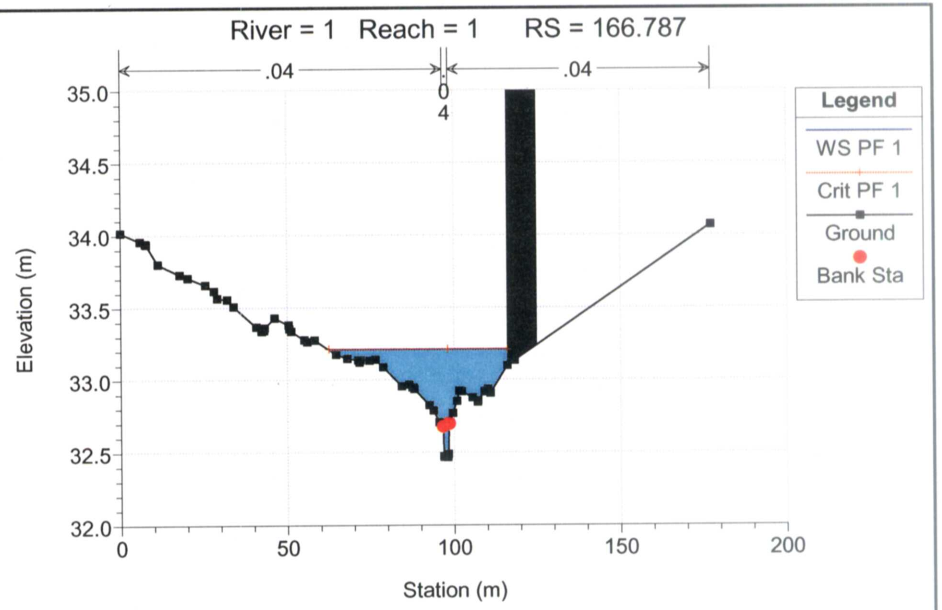

River = 1 Reach = 1 RS = 300 Culv
.04
.04
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta

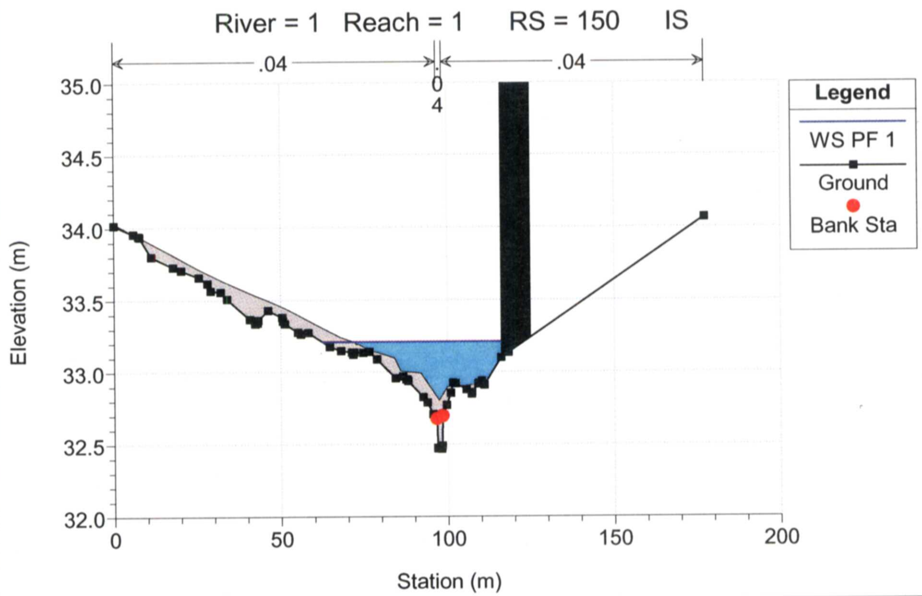
EXISTING

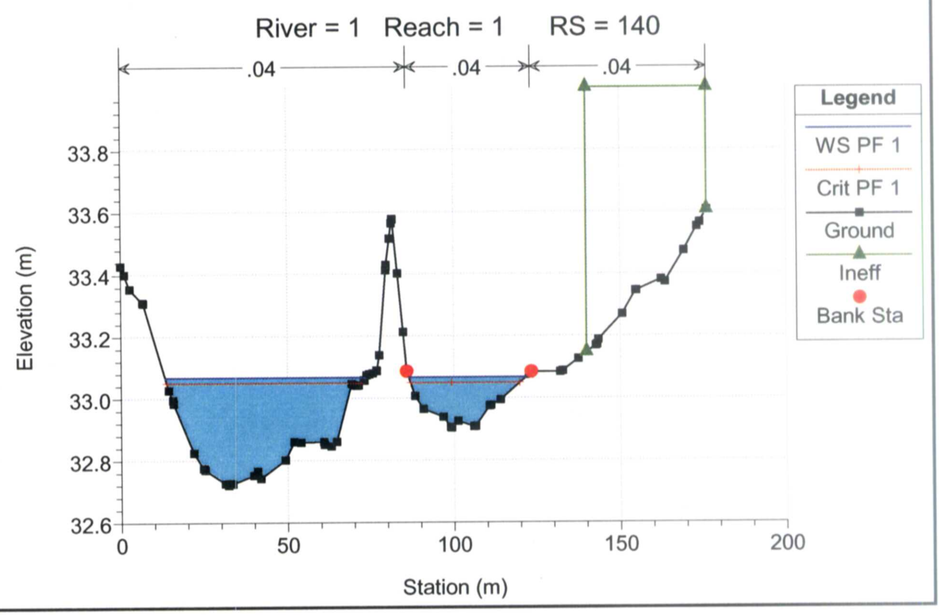

River = 1 Reach = 1 RS = 282.5
.04 .04 .04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
50% BLOCKAGE
River = 1 Reach = 1 RS = 282.4
.04 .04 .04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Levee
Ineff
Bank Sta
River = 1 Reach = 1 RS = 280.
.04 .04 .04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Levee
Bank Sta
River = 1 Reach = 1 RS = 250
.04 .04 .04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Levee
Bank Sta

EXISTING

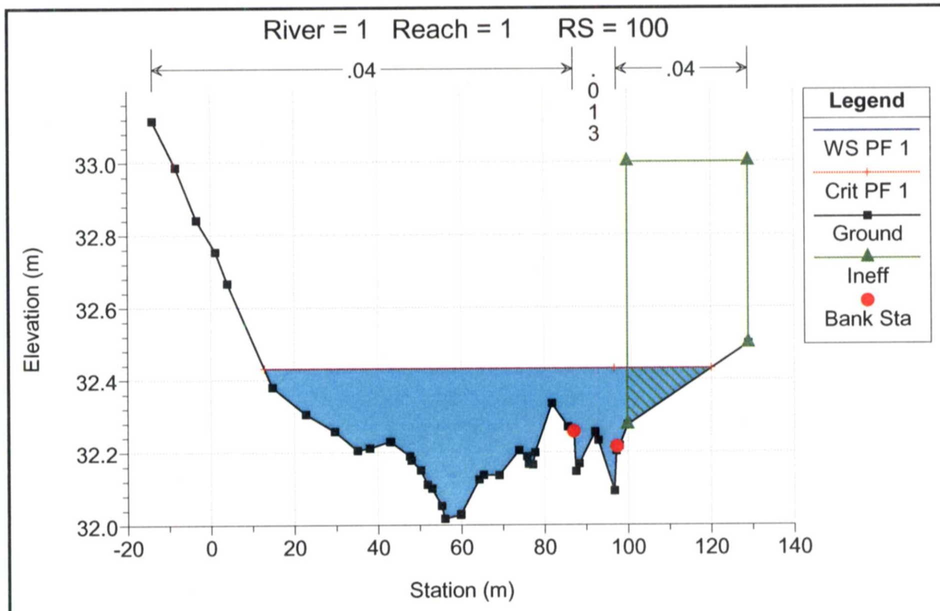

River = 1 Reach = 1 RS = 200
.04
0
4
.04
Legend
WS PF 1
Crit PF 1
Ground
Levee
Bank Sta
Elevation (m)
35.0
34.5
34.0
33.5
33.0
0
20
40
60
80
100
120
Station (m)

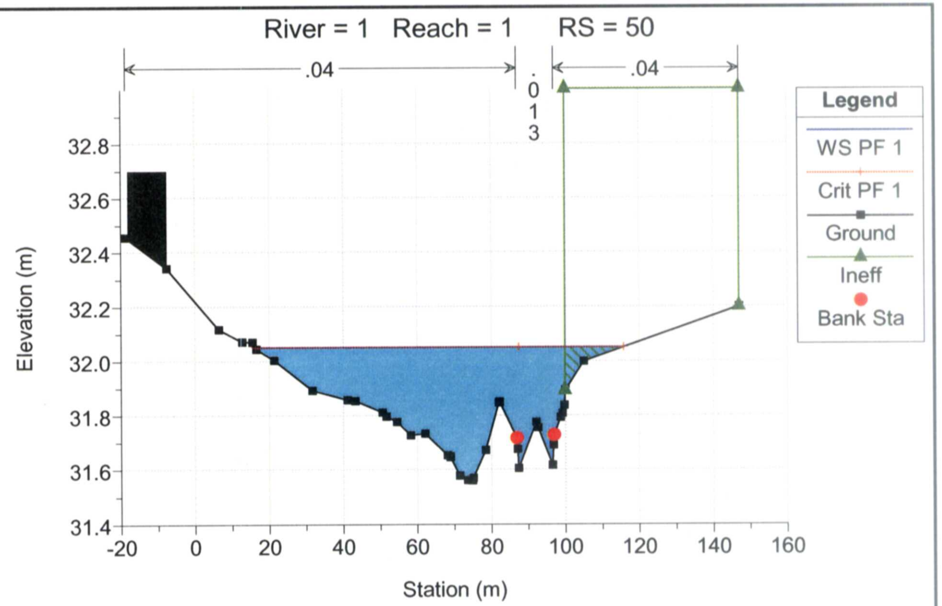

River = 1 Reach = 1 RS = 166.787
.04
0
4
.04
Legend
WS PF 1
Crit PF 1
Ground
Bank Sta
Elevation (m)
35.0
34.5
34.0
33.5
33.0
32.5
32.0
0
50
100
150
200
Station (m)

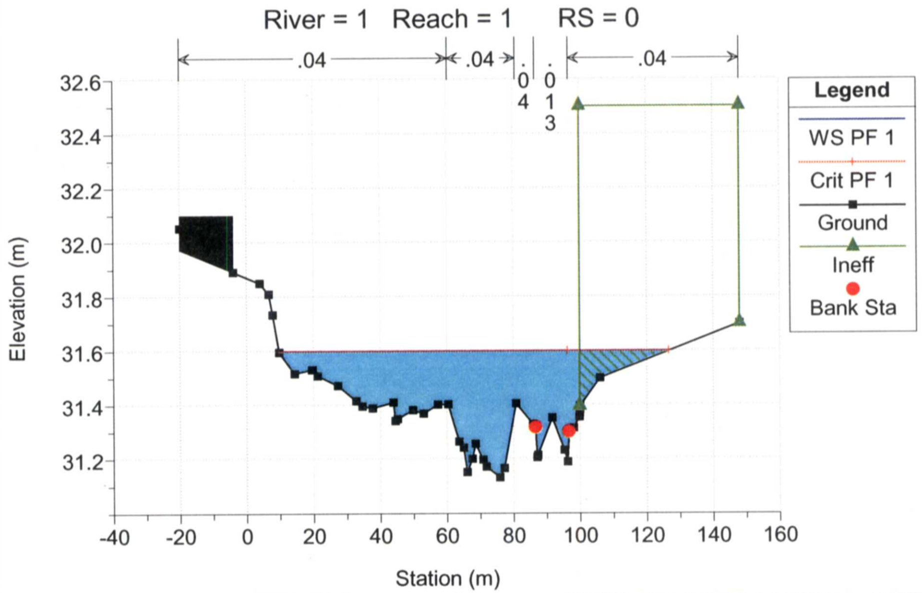

River = 1 Reach = 1 RS = 150 IS
.04
0
4
.04
Legend
WS PF 1
Ground
Bank Sta
Elevation (m)
35.0
34.5
34.0
33.5
33.0
32.5
32.0
0
50
100
150
200
Station (m)


River = 1 Reach = 1 RS = 140
.04
.04
.04
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (m)
33.8
33.6
33.4
33.2
33.0
32.8
32.6
0
50
100
150
200
Station (m)

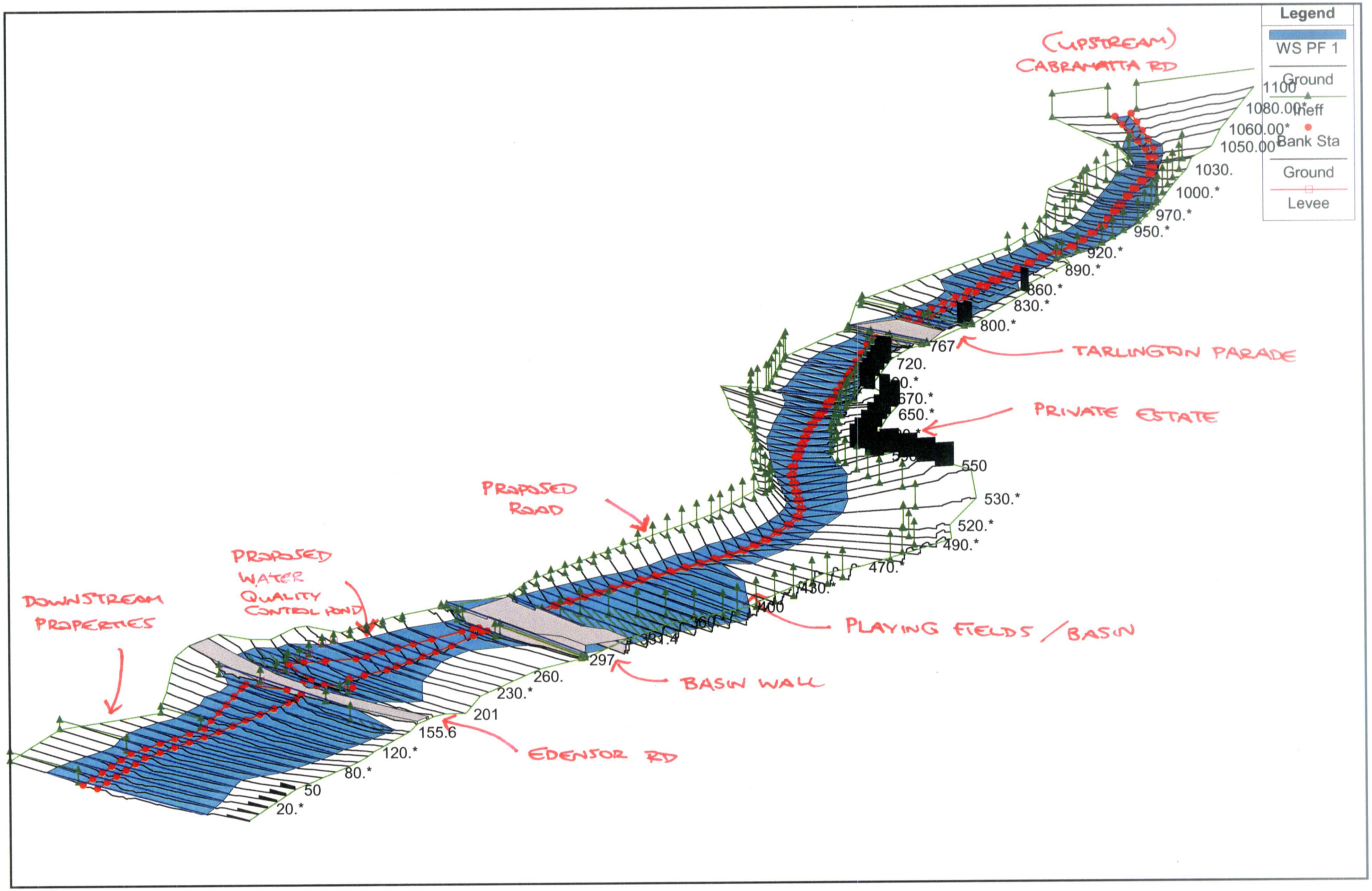
EXISTING


River = 1 Reach = 1 RS = 100
.04
.013
.04
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)

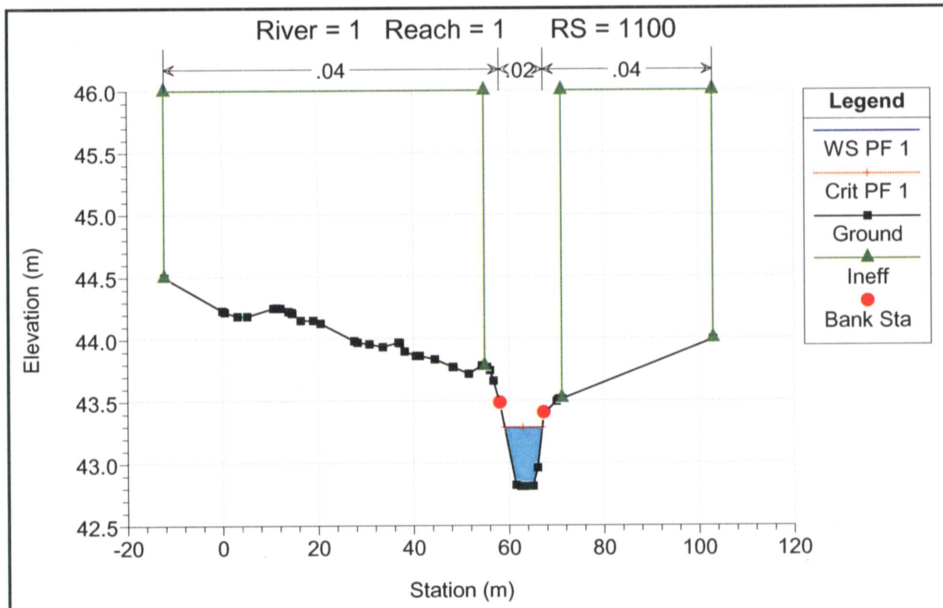

River = 1 Reach = 1 RS = 50
.04
.013
.04
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)


River = 1 Reach = 1 RS = 0
.04
.04
.04
.013
.04
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)

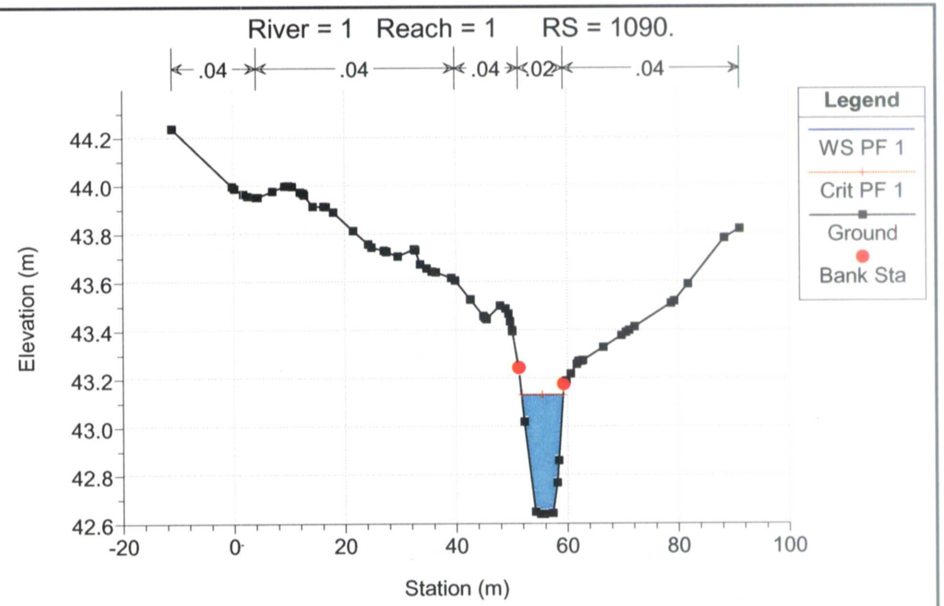
EXISTING



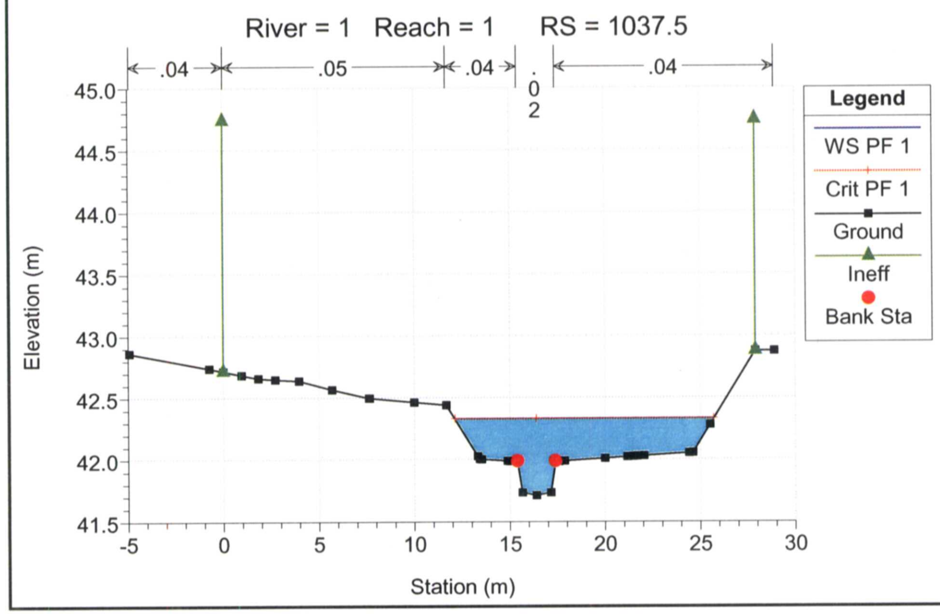
XYZ PLOT – PROPOSED 100YR ARI



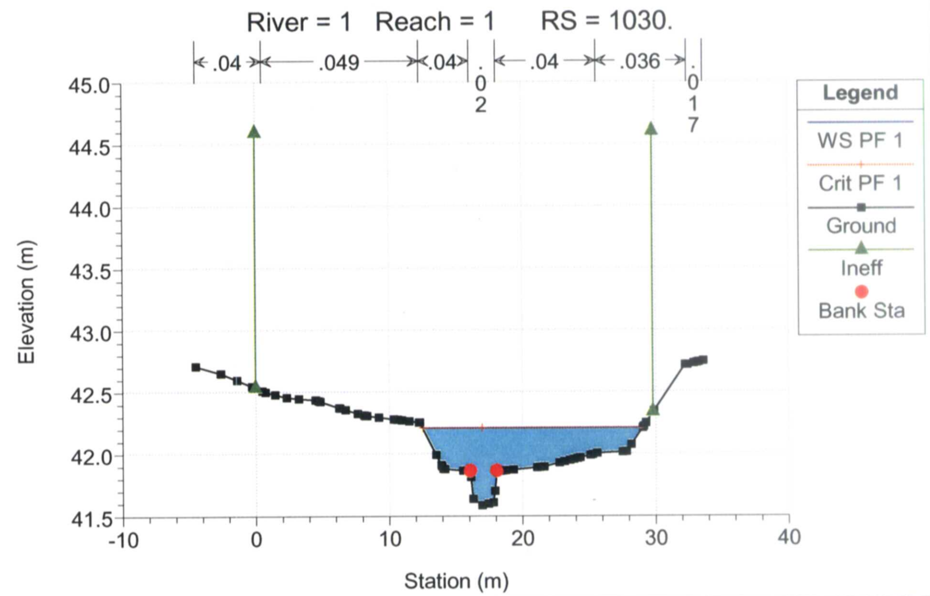
River = 1 Reach = 1 RS = 1100
.04
.02
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta



River = 1 Reach = 1 RS = 1090.
.04
.04
.04
.02
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Bank Sta

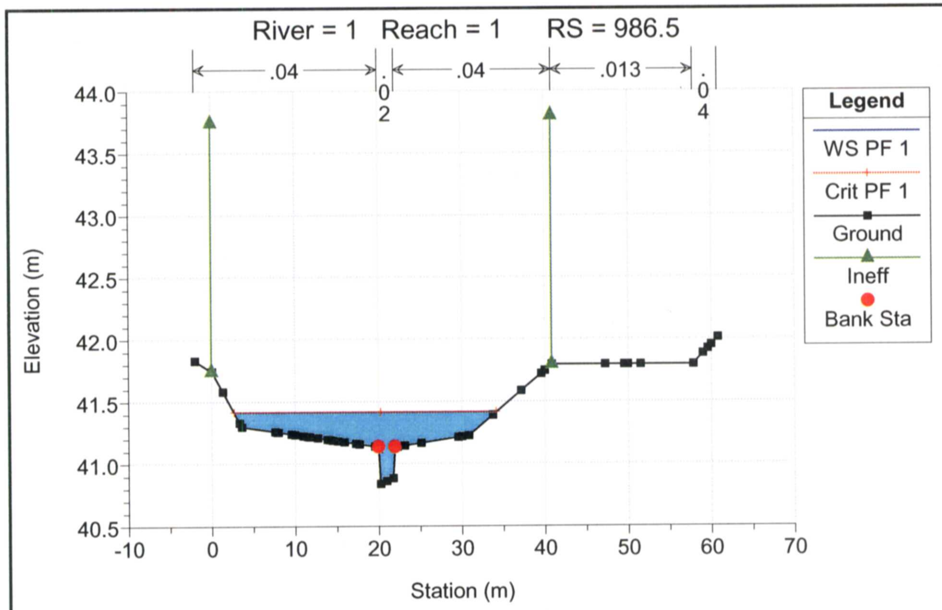


River = 1 Reach = 1 RS = 1037.5
.04
.05
.04
.02
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta

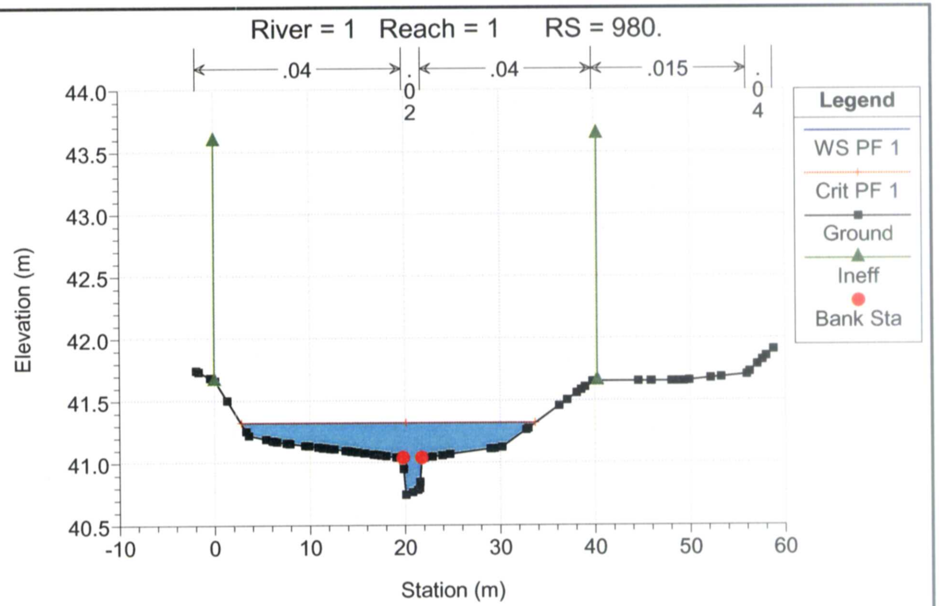


River = 1 Reach = 1 RS = 1030.
.04
.049
.04
.02
.04
.036
.017
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta

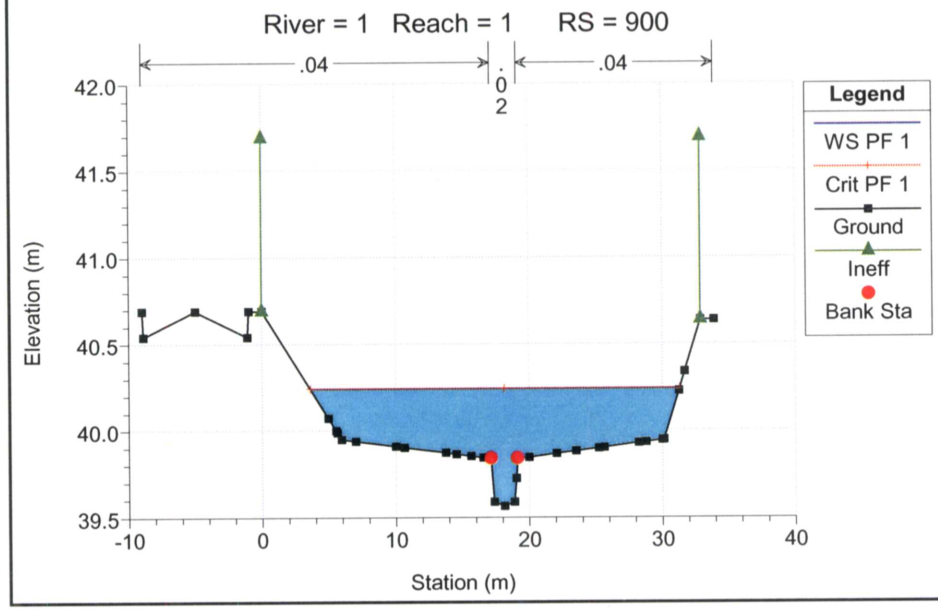
PROPOSED



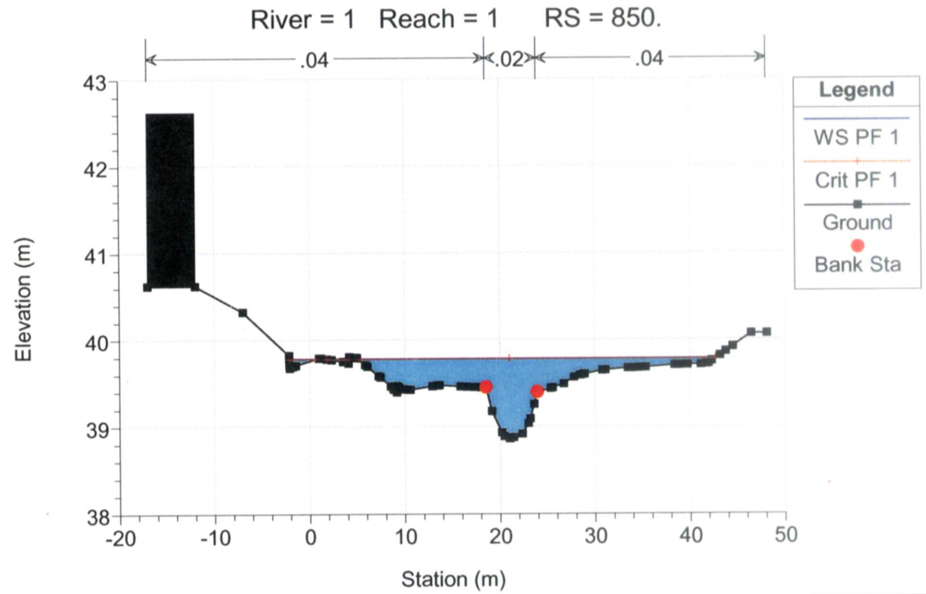
River = 1 Reach = 1 RS = 986.5
.04
.02
.04
.013
.04
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)



River = 1 Reach = 1 RS = 980.
.04
.02
.04
.015
.04
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)

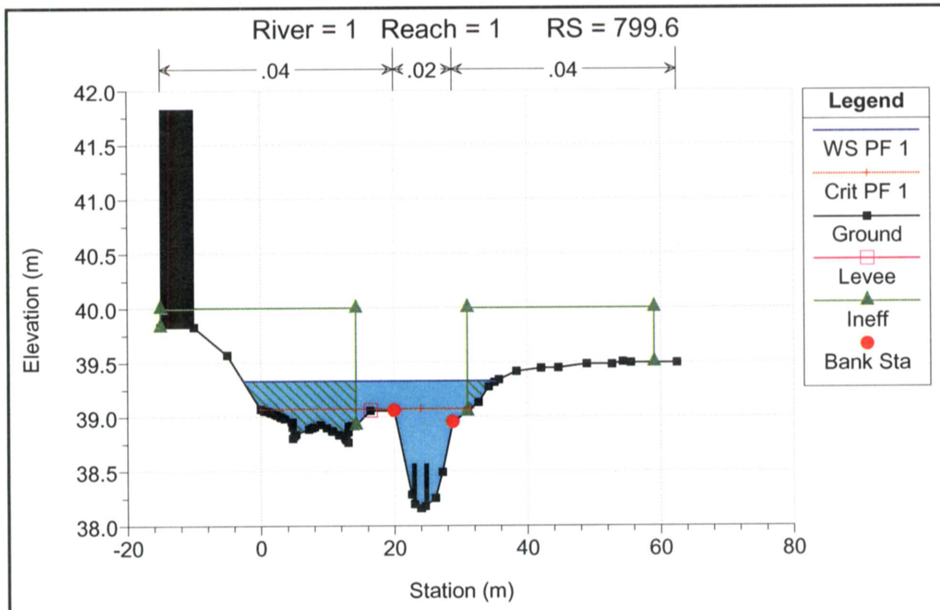


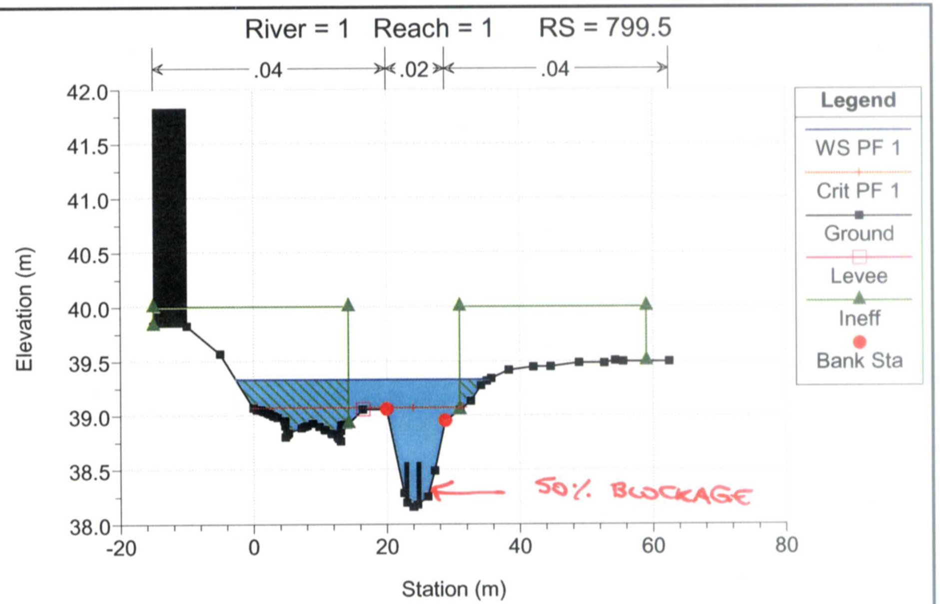
River = 1 Reach = 1 RS = 900
.04
.02
.04
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)

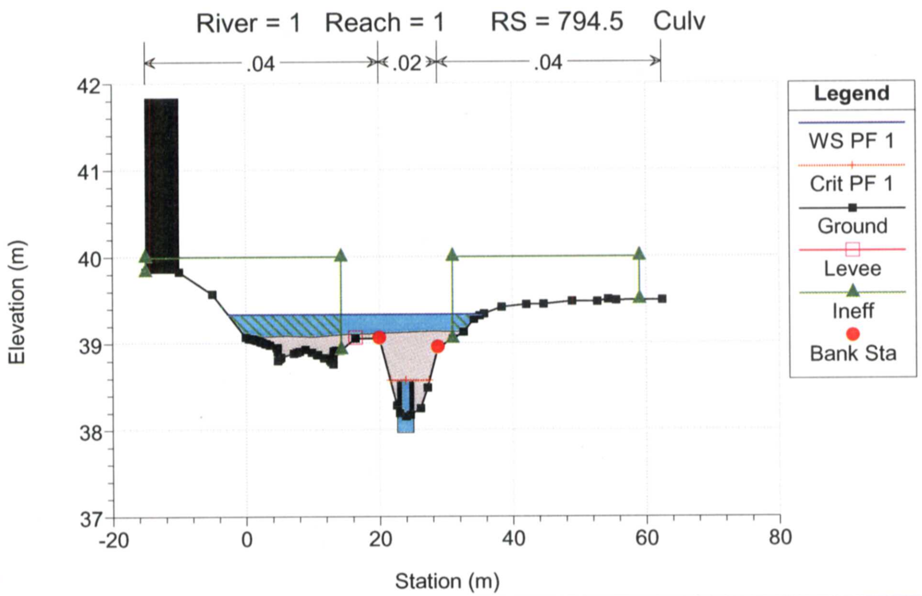


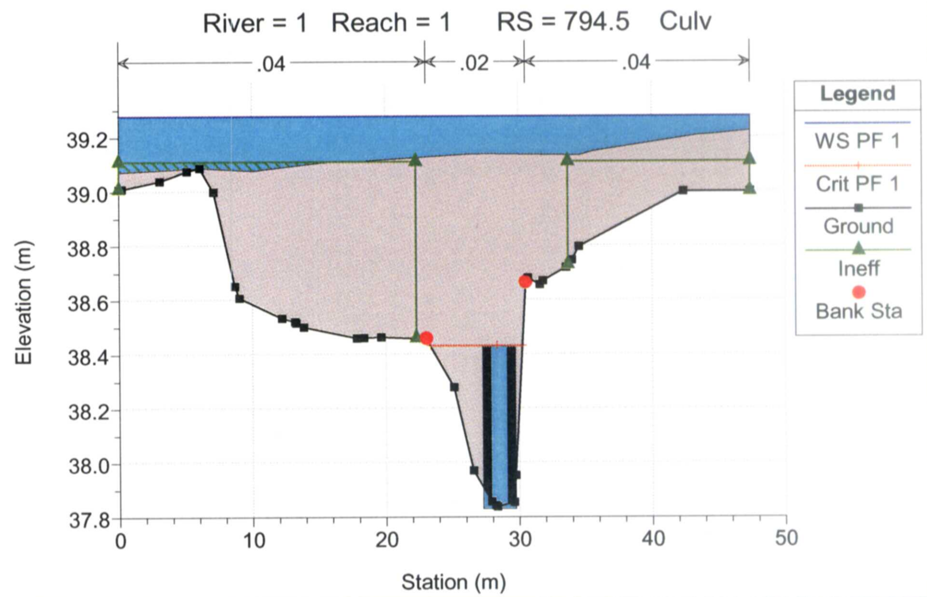
River = 1 Reach = 1 RS = 850.
.04
.02
.04
Legend
WS PF 1
Crit PF 1
Ground
Bank Sta
Elevation (m)
Station (m)

PROPOSED

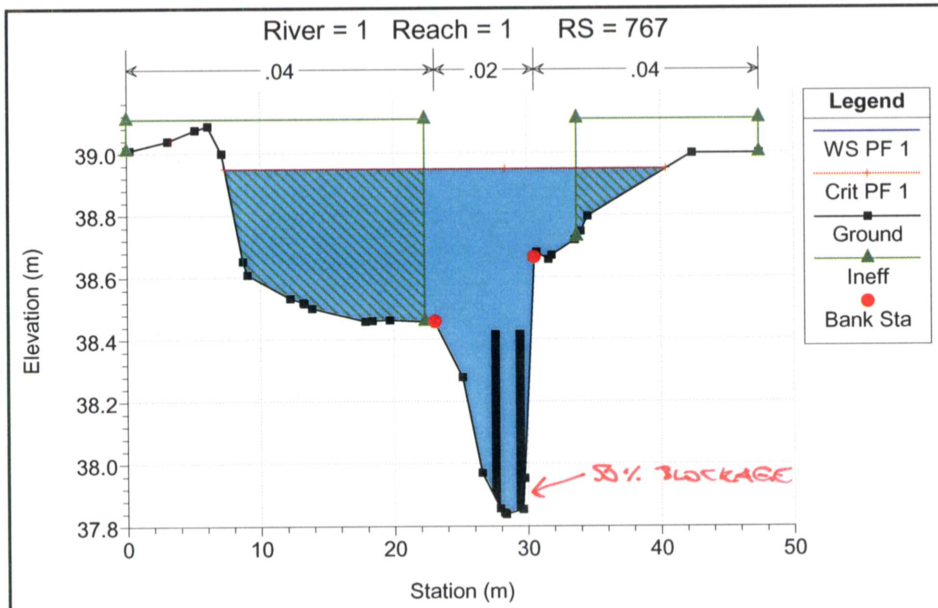

River = 1 Reach = 1 RS = 799.6
.04
.02
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Levee
Ineff
Bank Sta

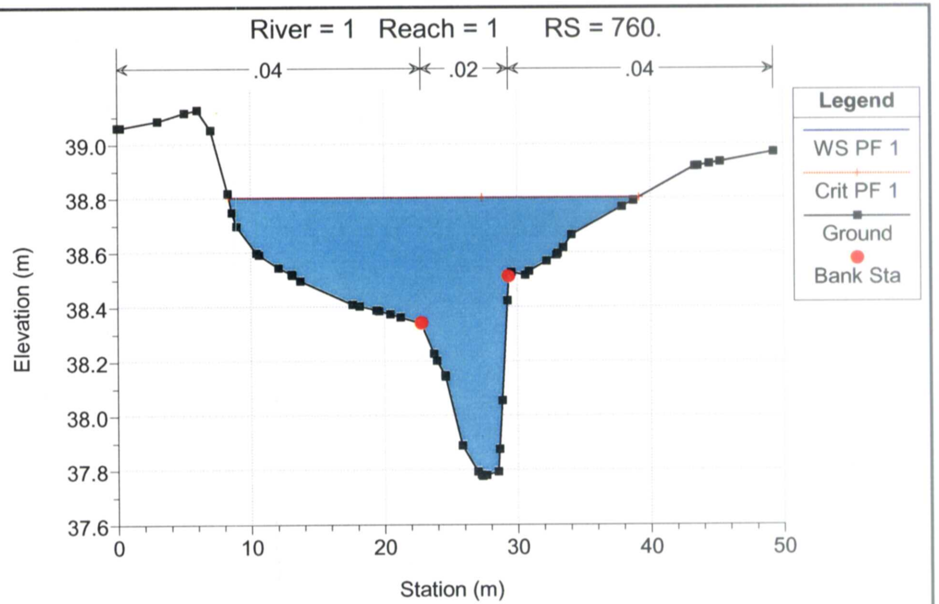

River = 1 Reach = 1 RS = 799.5
.04
.02
.04
Elevation (m)
Station (m)
50% BLOCKAGE
Legend
WS PF 1
Crit PF 1
Ground
Levee
Ineff
Bank Sta

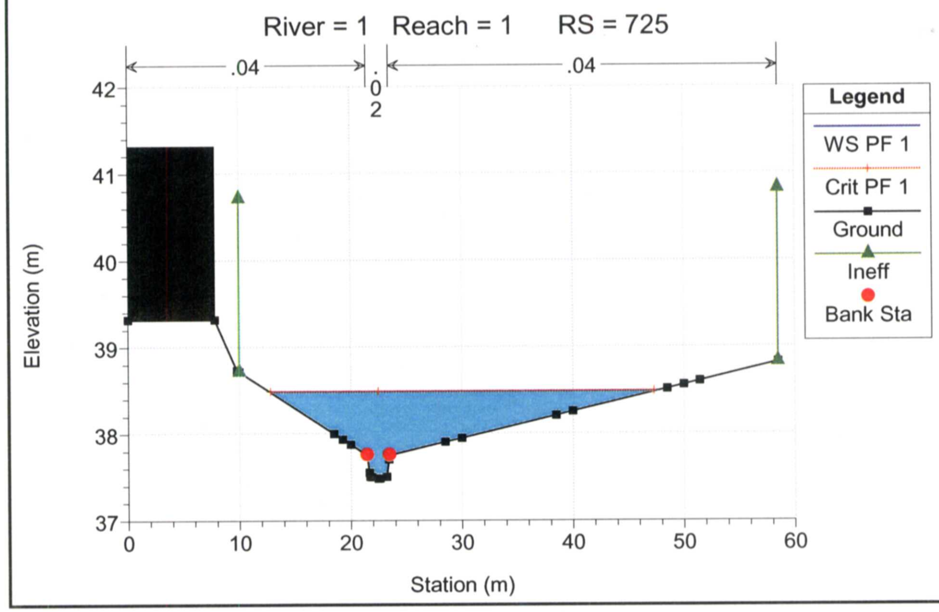

River = 1 Reach = 1 RS = 794.5 Culv
.04
.02
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Levee
Ineff
Bank Sta

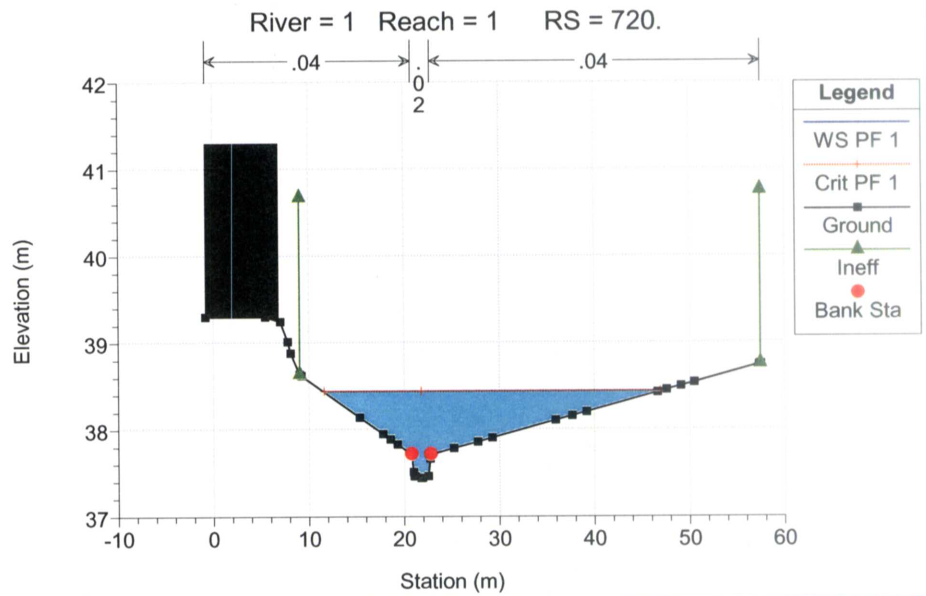

River = 1 Reach = 1 RS = 794.5 Culv
.04
.02
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta

PROPOSED

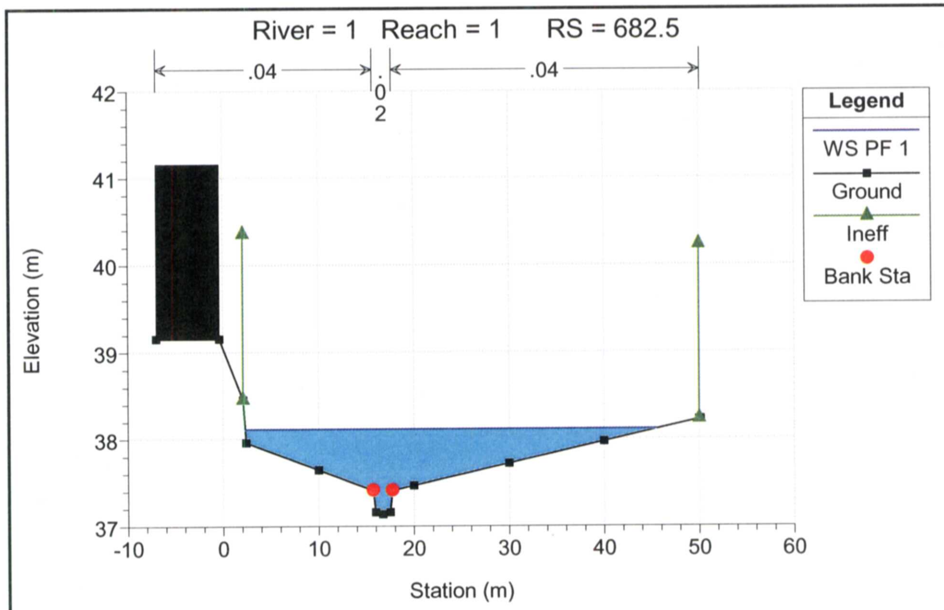

River = 1 Reach = 1 RS = 767
.04
.02
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
50% BLOCKAGE

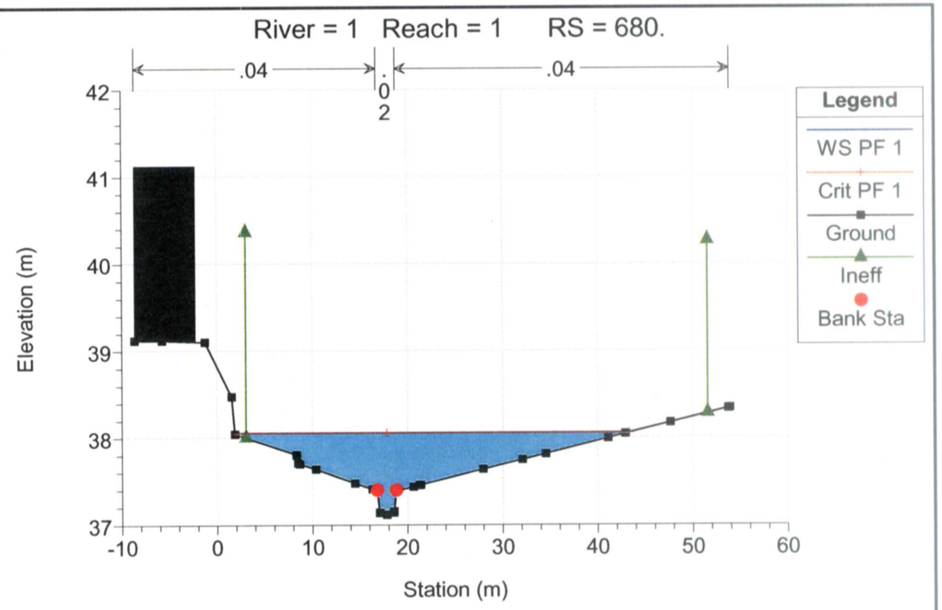

River = 1 Reach = 1 RS = 760.
.04
.02
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Bank Sta

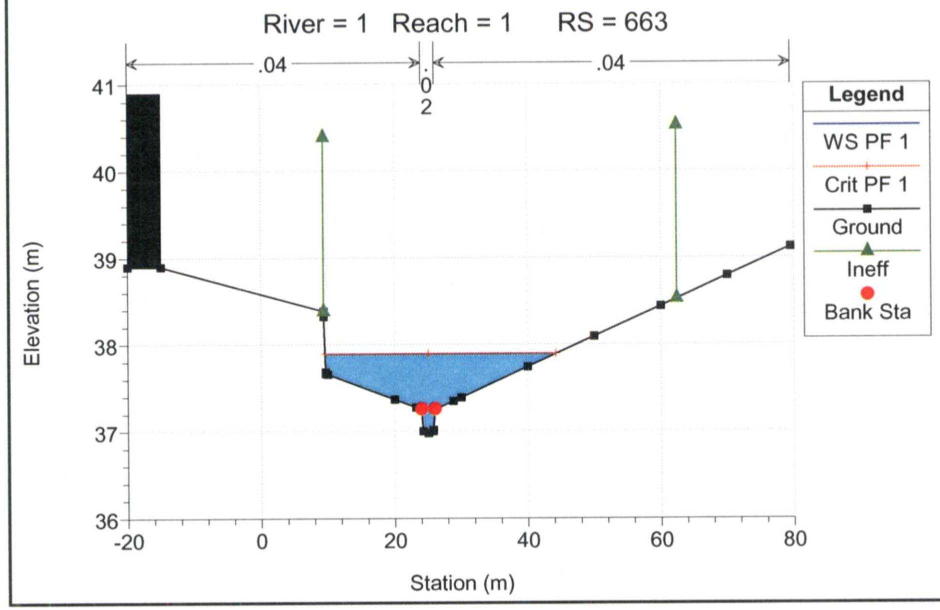

River = 1 Reach = 1 RS = 725
.04
.02
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta

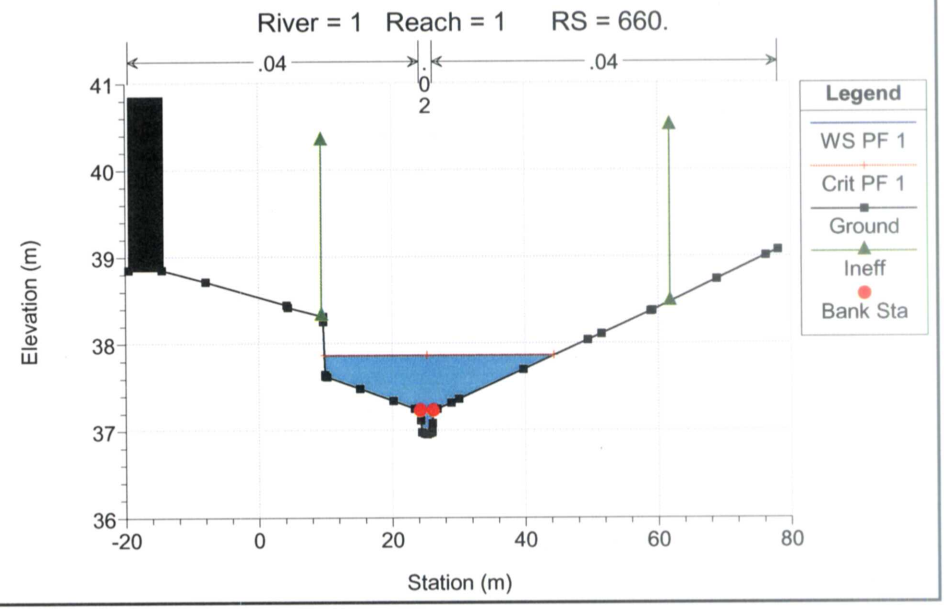

River = 1 Reach = 1 RS = 720.
.04
.02
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta

PROPOSED

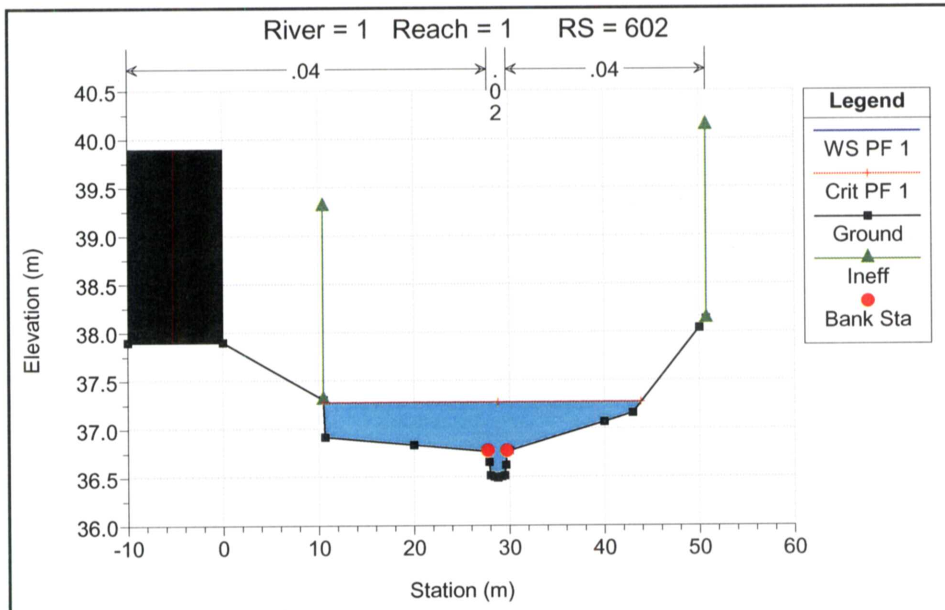

River = 1 Reach = 1 RS = 682.5
.04
.02
.04
Legend
WS PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)
42
41
40
39
38
37
-10
0
10
20
30
40
50
60

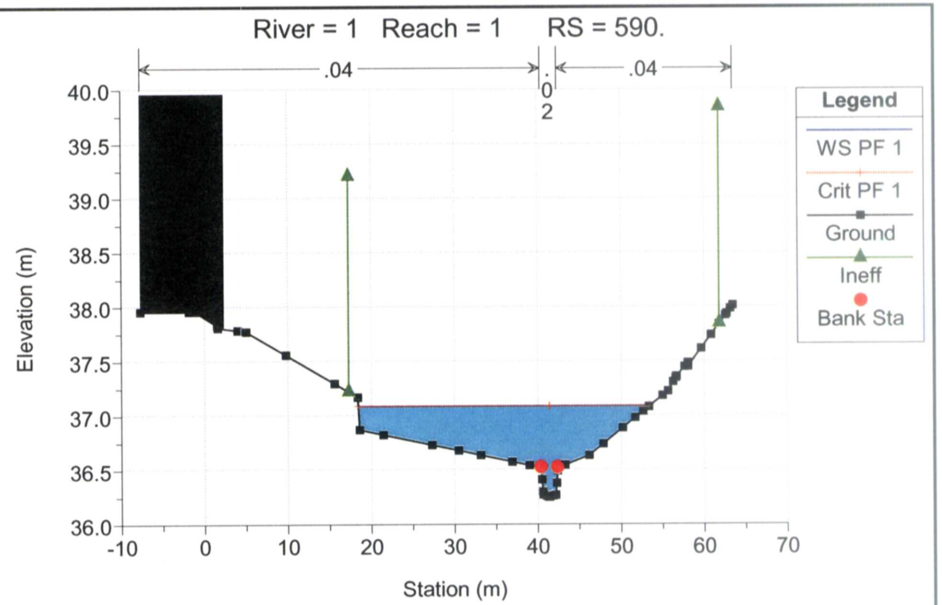

River = 1 Reach = 1 RS = 680.
.04
.02
.04
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)
42
41
40
39
38
37
-10
0
10
20
30
40
50
60

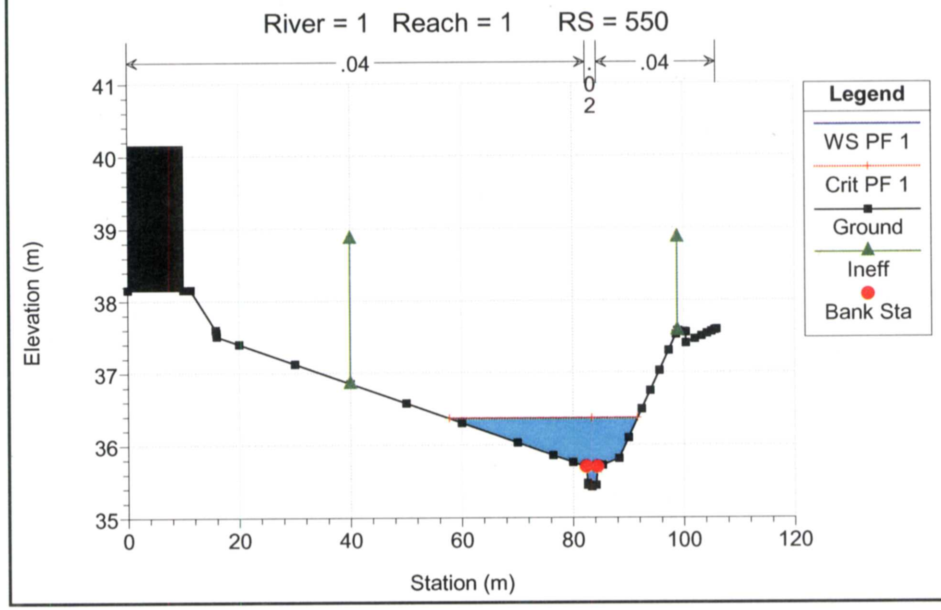

River = 1 Reach = 1 RS = 663
.04
.02
.04
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)
41
40
39
38
37
36
-20
0
20
40
60
80

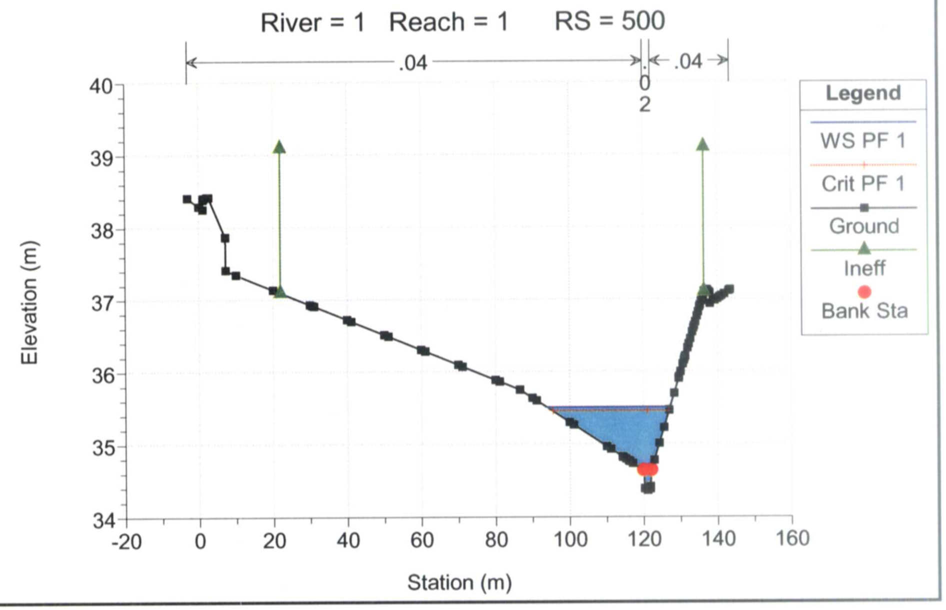

River = 1 Reach = 1 RS = 660.
.04
.02
.04
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)
41
40
39
38
37
36
-20
0
20
40
60
80

PROPOSED

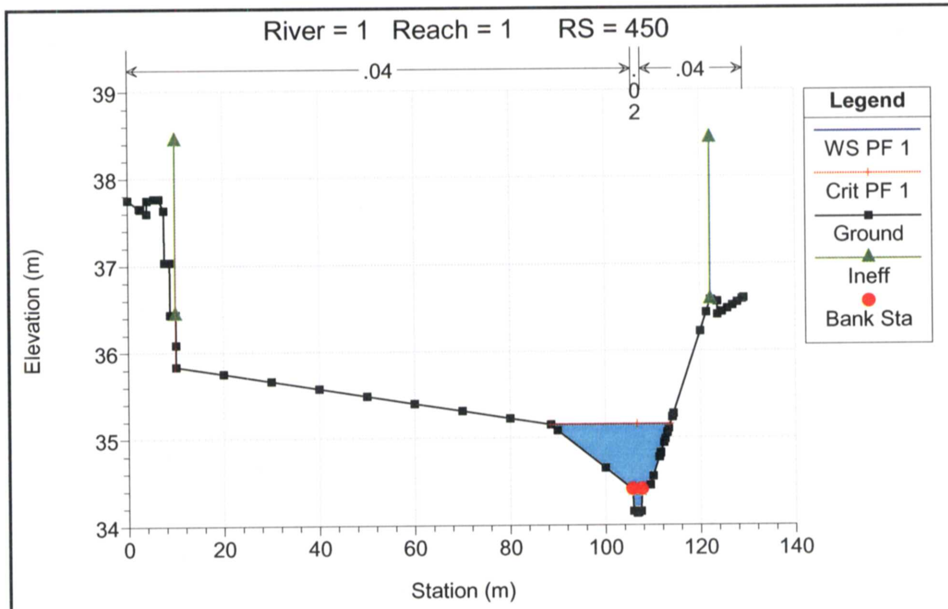

River = 1 Reach = 1 RS = 602
.04
.02
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta

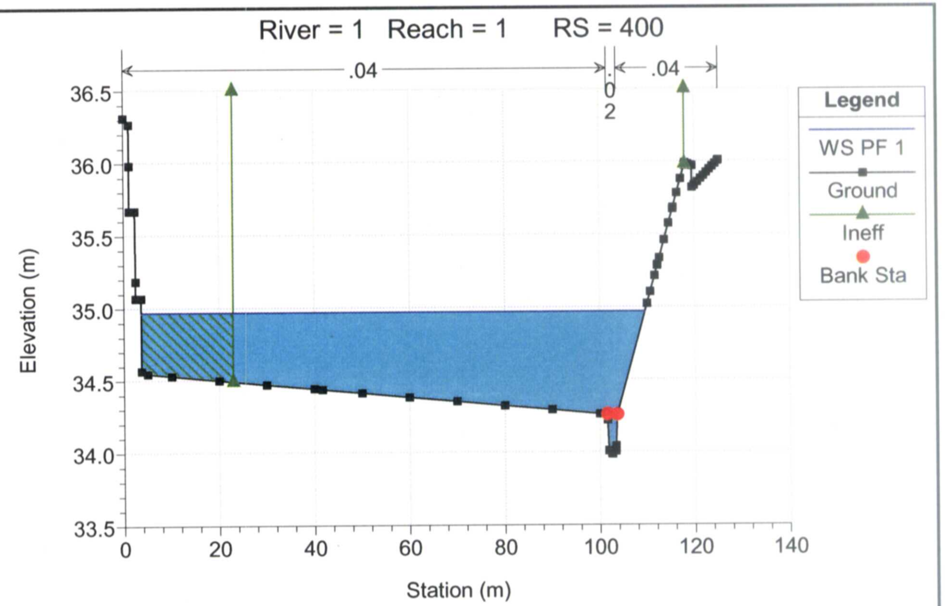

River = 1 Reach = 1 RS = 590.
.04
.02
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta

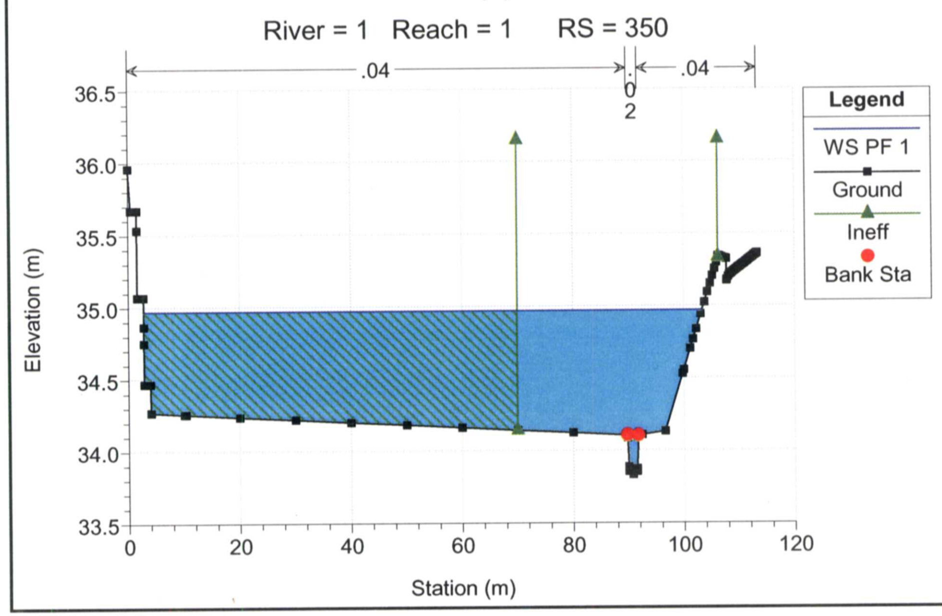

River = 1 Reach = 1 RS = 550
.04
.02
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta

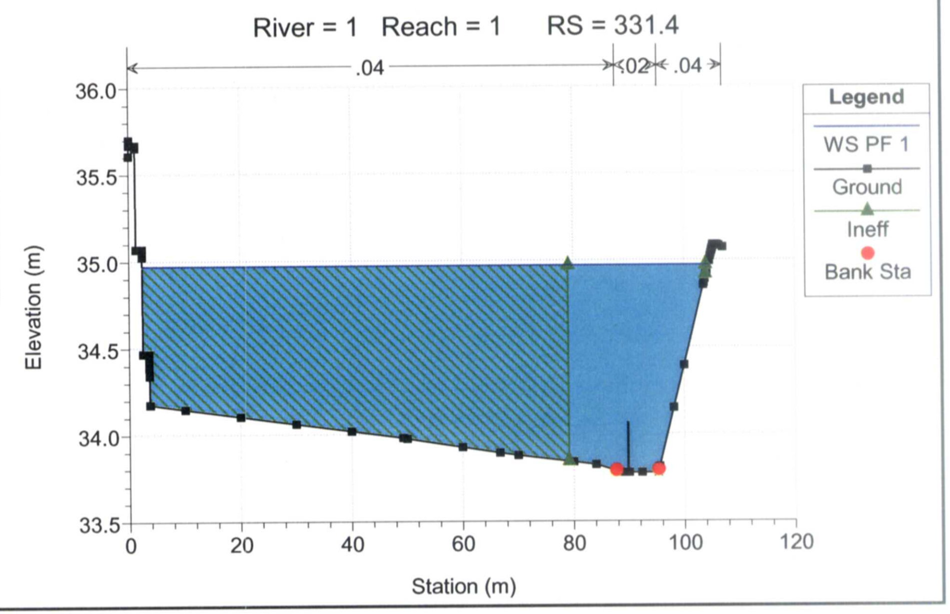

River = 1 Reach = 1 RS = 500
.04
.02
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta

PROPOSED

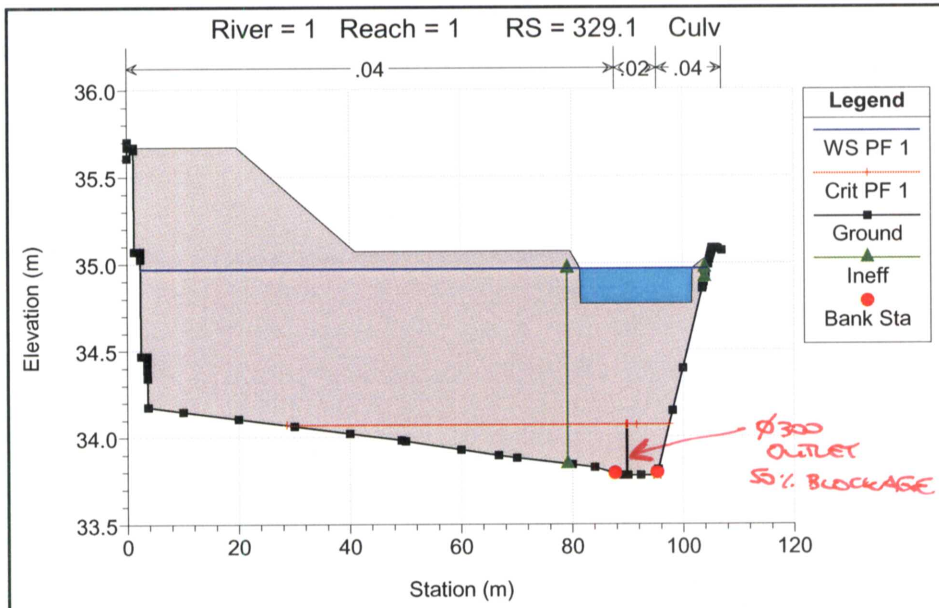

River = 1 Reach = 1 RS = 450
.04
0
2
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta

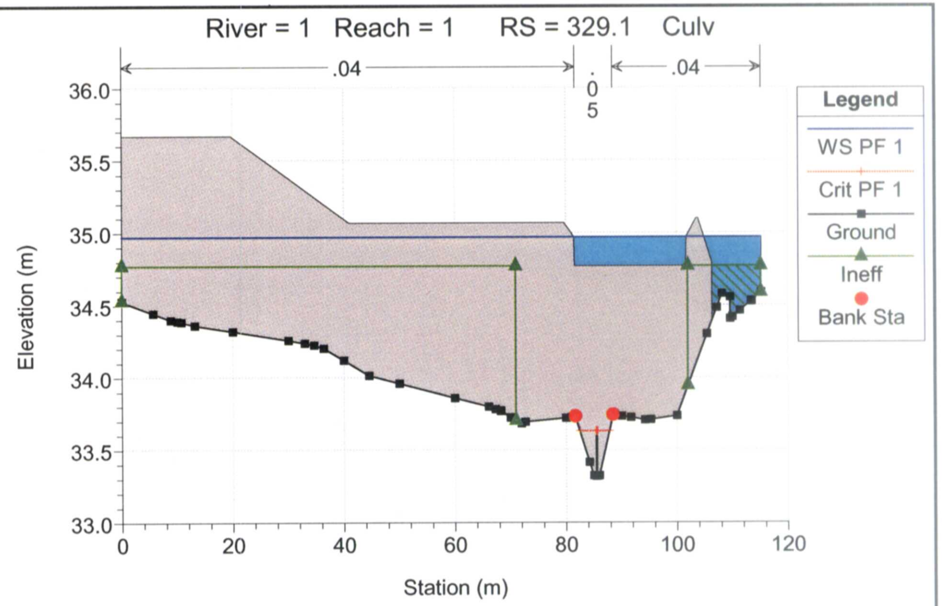

River = 1 Reach = 1 RS = 400
.04
0
2
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Ground
Ineff
Bank Sta

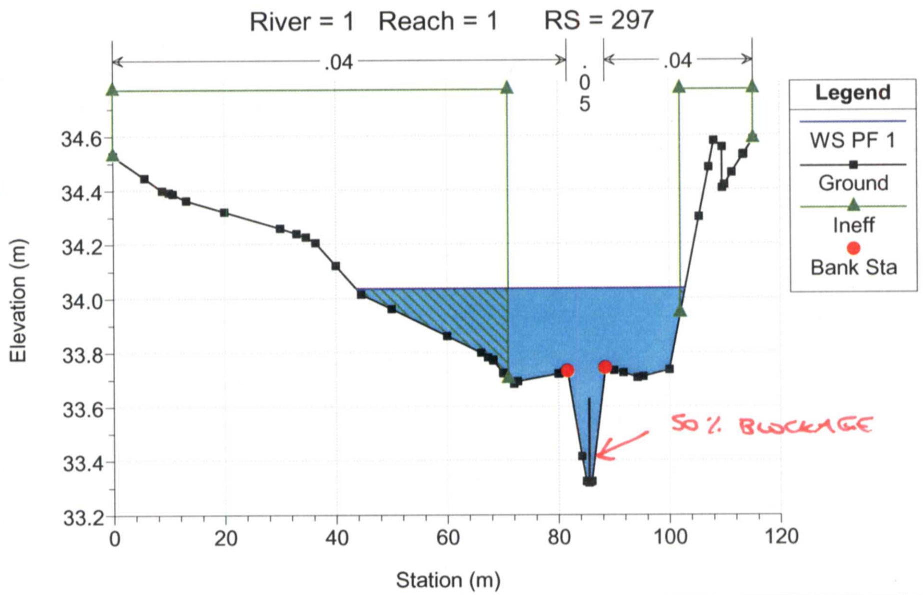

River = 1 Reach = 1 RS = 350
.04
0
2
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Ground
Ineff
Bank Sta

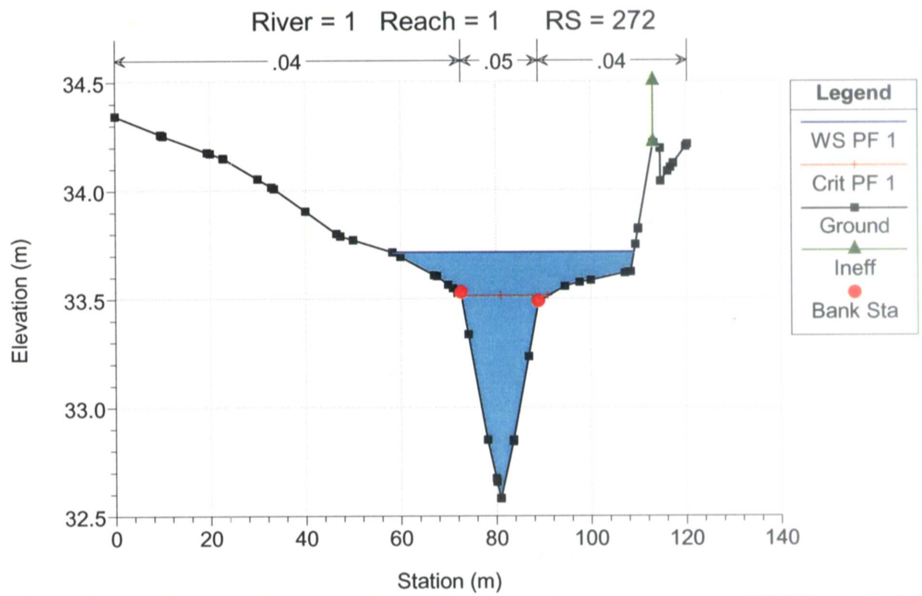

River = 1 Reach = 1 RS = 331.4
.04
.02
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Ground
Ineff
Bank Sta

PROPOSED

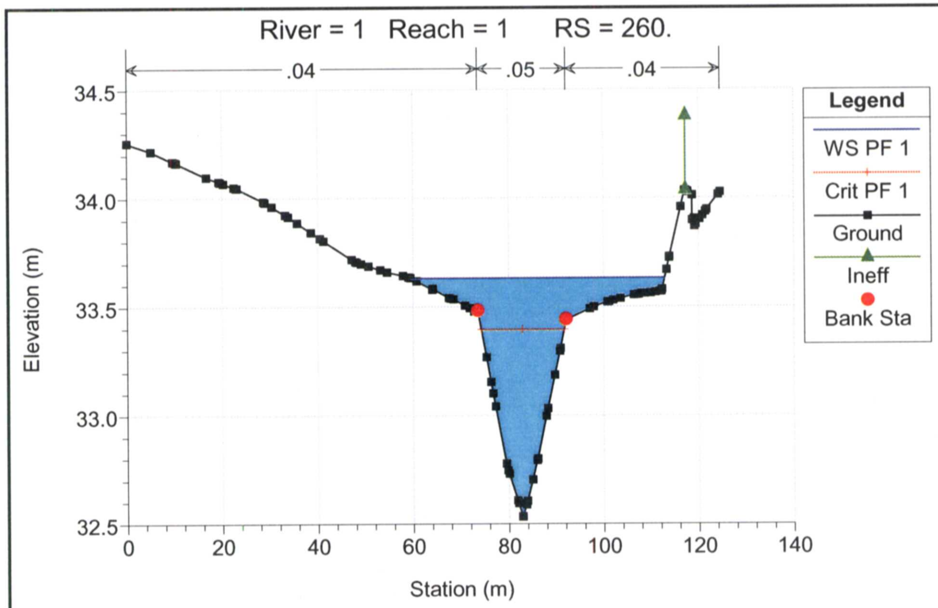

River = 1 Reach = 1 RS = 329.1 Culv
.04
.02
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Ø300 OUTLET 50% BLOCKAGE

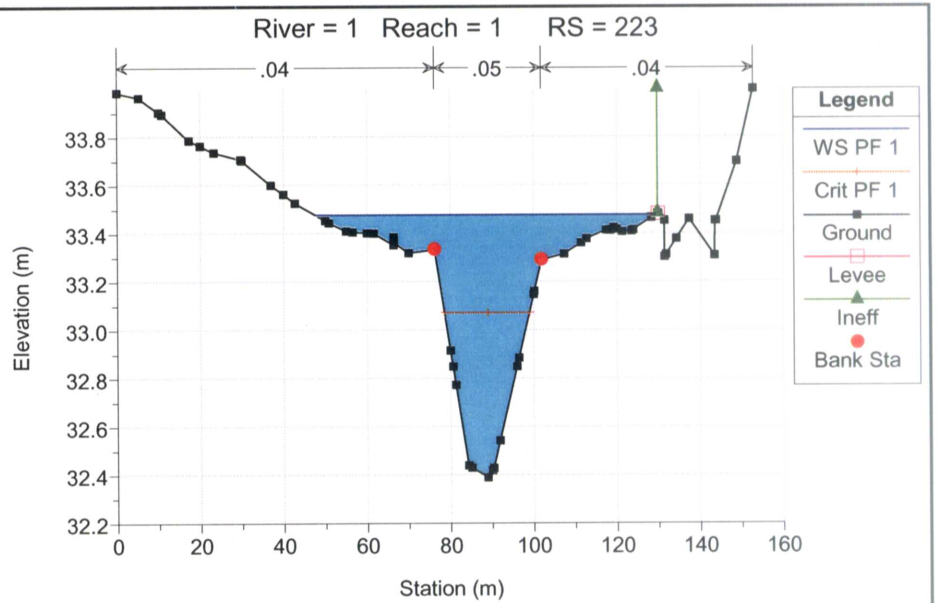

River = 1 Reach = 1 RS = 329.1 Culv
.04
0
5
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta

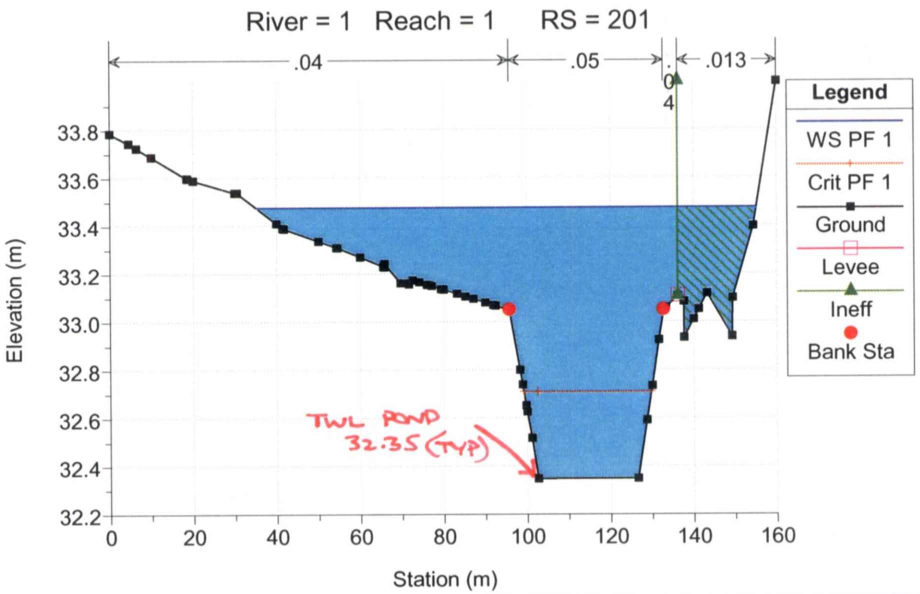

River = 1 Reach = 1 RS = 297
.04
0
5
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Ground
Ineff
Bank Sta
50% BLOCKAGE

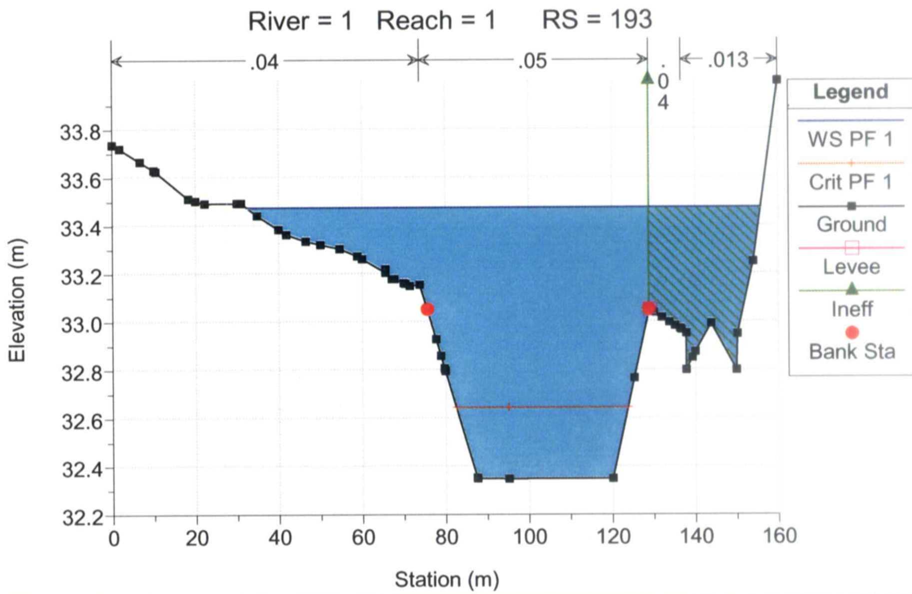

River = 1 Reach = 1 RS = 272
.04
.05
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta

PROPOSED

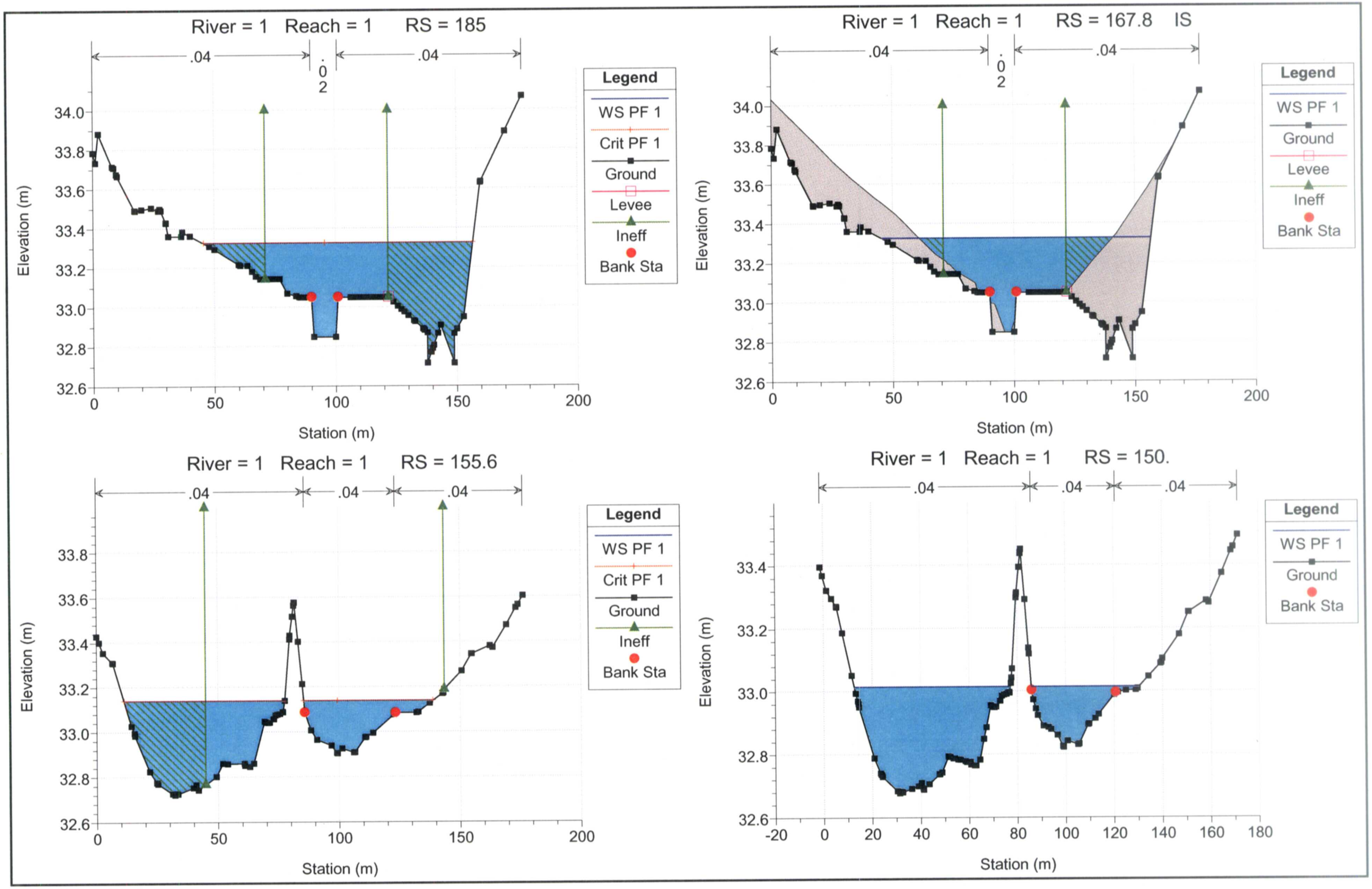

River = 1 Reach = 1 RS = 260.
.04
.05
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta


River = 1 Reach = 1 RS = 223
.04
.05
.04
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Levee
Ineff
Bank Sta

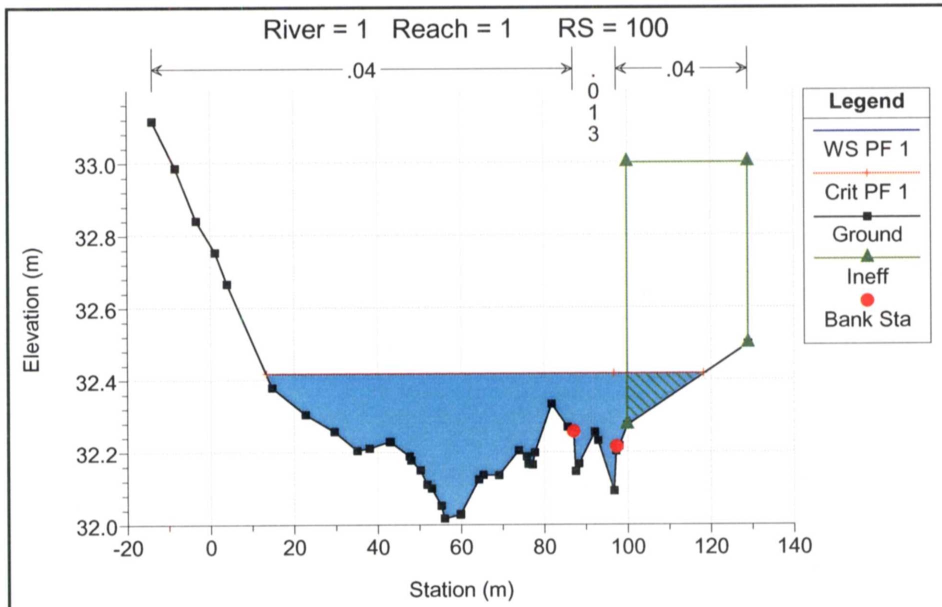

River = 1 Reach = 1 RS = 201
.04
.05
.013
Elevation (m)
Station (m)
TWL POND
32.35 (TYP)
Legend
WS PF 1
Crit PF 1
Ground
Levee
Ineff
Bank Sta

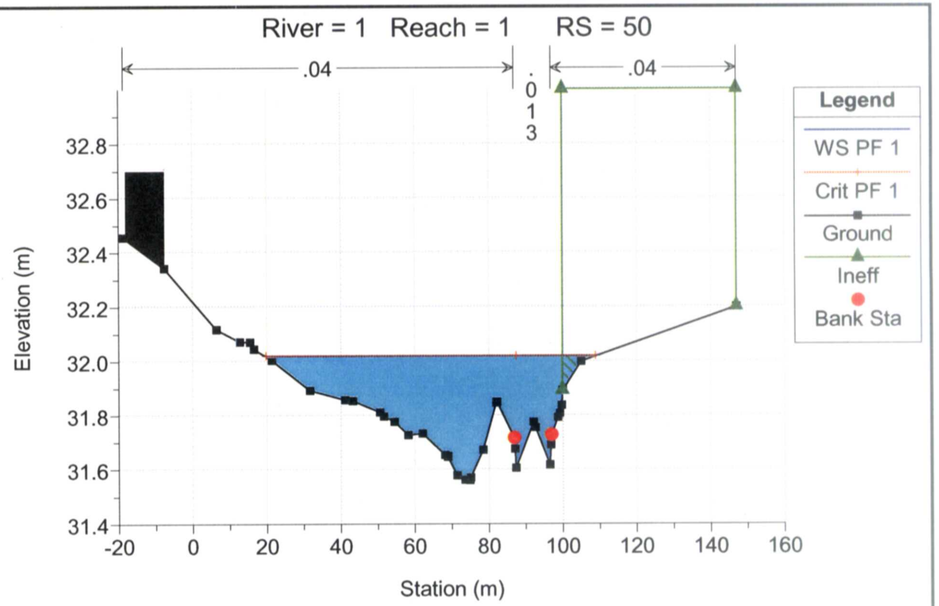

River = 1 Reach = 1 RS = 193
.04
.05
.013
Elevation (m)
Station (m)
Legend
WS PF 1
Crit PF 1
Ground
Levee
Ineff
Bank Sta

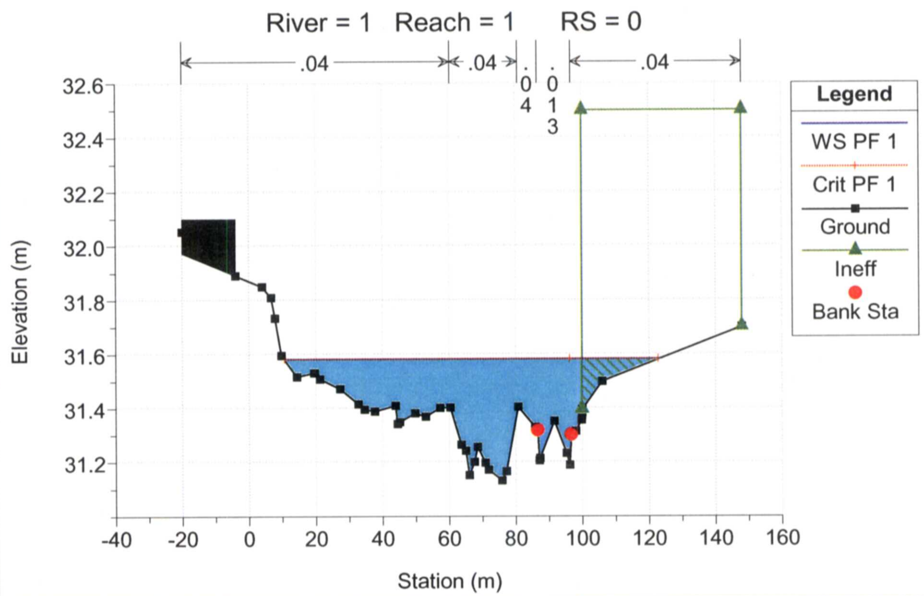
PROPOSED


River = 1 Reach = 1 RS = 185
.04
.02
.04
Legend
WS PF 1
Crit PF 1
Ground
Levee
Ineff
Bank Sta
Elevation (m)
Station (m)
River = 1 Reach = 1 RS = 167.8 IS
.04
.02
.04
Legend
WS PF 1
Ground
Levee
Ineff
Bank Sta
Elevation (m)
Station (m)
River = 1 Reach = 1 RS = 155.6
.04
.04
.04
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)
River = 1 Reach = 1 RS = 150.
.04
.04
.04
Legend
WS PF 1
Ground
Bank Sta
Elevation (m)
Station (m)

PROPOSED


River = 1 Reach = 1 RS = 100
.04
.04
.013
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)


River = 1 Reach = 1 RS = 50
.04
.04
.013
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)


River = 1 Reach = 1 RS = 0
.04
.04
.04
.04
.013
Legend
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)

PROPOSED