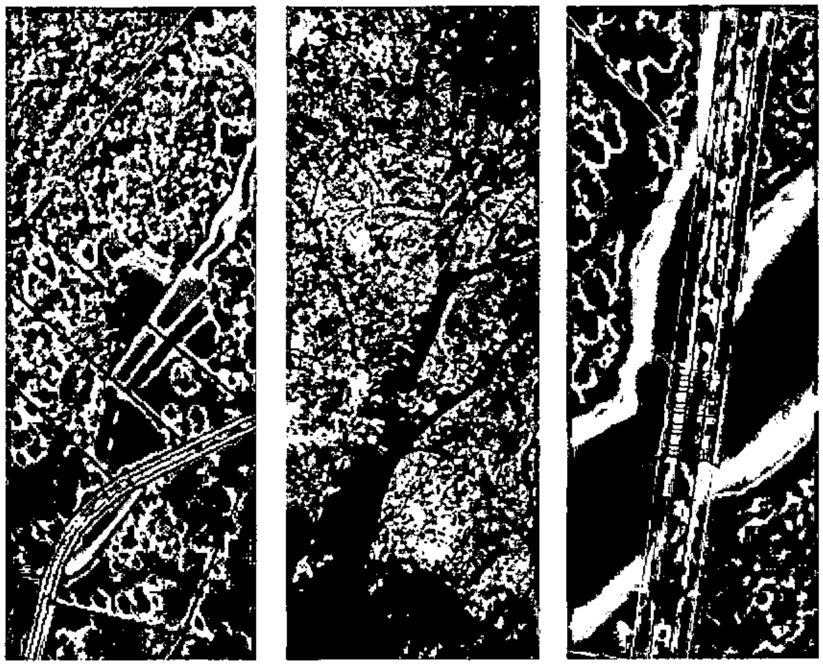


Fernhill Estate, Mulgoa Eastern Precinct

Stormwater Management Report

October 2013

Cubelic Holdings Pty Ltd

Mott MacDonald

Fernhill Estate, Mulgoa
Eastern Precinct

Stormwater Management Report

October 2013

Cubelic Holdings Pty Ltd

20 Bonnefin Road
Hunters Hill NSW 2110

Mott MacDonald, 90 Phillip Street, Parramatta NSW 2150, Australia
PO Box 163, Parramatta NSW 2124, Australia
T +61 (0)2 9891 5044 **F** +61 (0)2 9891 5386 **W** www.mottmac.com

Mott MacDonald

Issue and revision record

Revision	Date	Originator	Checker	Approver	Description
A	25.10.2013	J. Taylor	G. Lee	C. Avis	Development Application

Standard

Mott MacDonald

Contents

Appendices 29

Tables

Figures

1. Introduction

Mott MacDonald has undertaken this Stormwater Management Report in support of the Development Application for the proposed residential redevelopment located within the Eastern Precinct of the Fernhill Estate, Mulgoa. This report details the procedures used and results obtained from analysis of both stormwater management and flood study recommendations to support the application.

The purpose of the investigation is to:

- Outline the hydrology pertaining to the subject development site and its vicinity;
- Describe the catchment and identify appropriate Flood Management Strategies required to accommodate the proposed development including flood and stormwater modelling;.
- Water Quality control and Flood Risk Management;
- Preparation of Catchment Plan for the proposed development. The Catchment Plan will examine;
  - Existing site conditions, and
  - Post-development conditions;
- Provision of a Concept Stormwater / Drainage Plan;
- Recommend appropriate stormwater attenuation measures (and demonstrate the ability to achieve; Penrith City Council's (PCC) technical requirements for performance and maintenance where relevant);
- Discussion on possible innovative solutions to reduce on-going maintenance costs which will include a discussion of the proposed management schemes including community title; and
- The preparation of indicative footprints and locations for detention/retention requirements within the development footprint areas.

2. Methodology

The following methodology was incorporated for the report:

- A computer based hydrologic model of the existing catchment was constructed using *XP-RAFTS*. Design storms were applied to this model to give estimates of the 100 year ARI discharges at various critical points within the stream network.
- A second *XP-RAFTS* model was then created to reflect the proposed scenario. Design storms were again applied to the model to give estimates of the proposed 100 year ARI discharges at various critical points within the stream network.
- Comparisons of pre-post hydrographs were then made to identify areas where attenuation devices (detention storage) may be required. Iterations were performed within *XP-RAFTS* in order to determine suitable detention sizes in order to achieve pre-post requirements for the minor and major ARI events.
- A computer based one-dimensional, steady flow hydraulic model was constructed to represent the post-development scenario using *HEC-RAS*. The 100 year ARI discharges obtained from the proposed *XP-RAFTS* model were then input into the model to determine the 100 year ARI flood levels and extent. Analysis was made to confirm 100 year flow rates are clear of proposed development areas.
- To demonstrate compliance with water quality objectives, treatment removal loads were analysed for the proposed development scenario using MUSIC (Model for Urban Stormwater Improvement Conceptualisation) software.
- The site was analysed in the traditional way by comparing the proposed scenario with and without treatment devices. Iterations were undertaken to determine the most effective treatment train to meet Penrith City Councils pollutant reduction requirements.

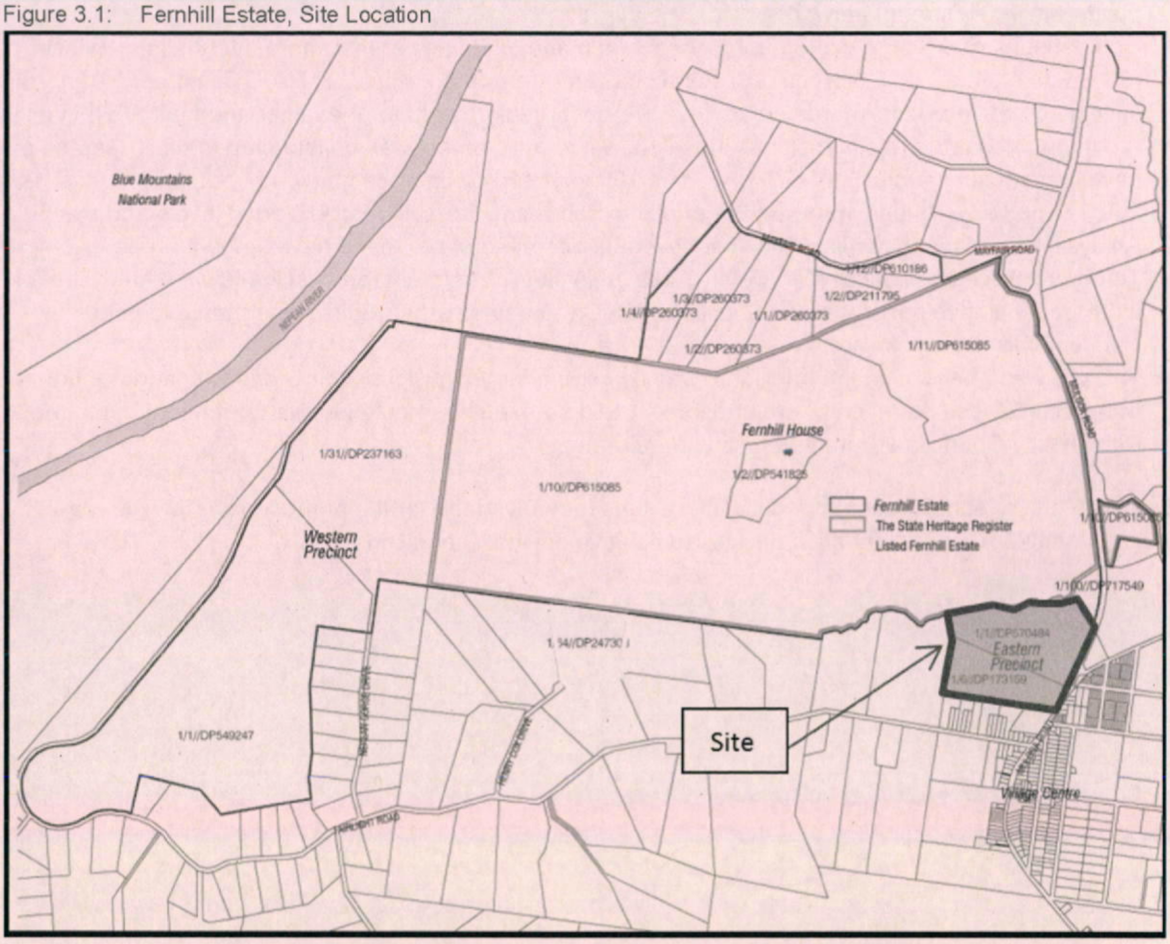
Based on these results, recommendations are subsequently made for the proposed stormwater management including attenuation devices to achieve pre-post conditions.

3. Site Description and Proposed Works

3.1 Catchment Description

The subject site encompasses an area, referred to as the Eastern Precinct:

Figure 3.1: Fernhill Estate, Site Location



The site is an approximately 25.9 hectare parcel of land with frontage to both Mulgoa Rd to the East; and Littlefields Creek to the North. Of the area, 15.9 hectares is within the proposed indicative development footprint. The site is proposed to accommodate 54 residential lots (including 1 existing lot to be retained) ranging in size from 950-1,500m^2. The site is bisected by an existing creek which runs S-N and functions as a tributary for large upstream catchments. Within the subject site, the creek widens to become a lake before discharging overflows to Littlefields Creek.

The proposed development footprint has been prepared to include:

- Retention of the existing lake;

- Proposed lot areas on the eastern side of the lake; and
- The implementation of a 10m wide riparian corridor measured from the top of the existing water level in the lake.

The existing catchment for the site predominately consists of undeveloped rural paddocks and rural / residential properties. The catchment is highest to the west and typically falls to the north at undulating grades ranging between 1% and 20%.

The site contains existing ridges which direct surface flows to:

- The Central lake;
- Littefields Creek; and
- Mulgoa Road Council drainage system.

Refer to Figure 01 in Appendix A for sub-catchment division.

The proposed residential development will increase the total impervious areas of the site compared to the existing scenario; however, this will be managed to ensure that post-developed flows do not exceed pre-development levels.

3.2 Condition and Function of Existing Basins

Under a previous but similar scheme, Mott MacDonald met with the then DECCW representative (Greg Brady) on site to discuss both the existing dam structures and watercourses in order to determine which areas will need to be retained, upgraded or removed as part of the proposed development of the site. For the purposes of this study, a reference number has been assigned to each of the existing basins as shown in Figure 01. The following comments are provided for each of these locations:

- The overflow weir on the existing lake wall (earth embankment) for East Basin 1 is damaged with evidence of high flows heavily eroding the bank. There is an existing concrete slab which appears to have been installed in an attempt to improve the weir.
- The existing wall height above the permanent top water level is approximately 0.5m high, while the lake wall has a steep embankment on the downstream side which runs to Littlefields Creek (approximately eight meters below).
- It is understood that since this initial meeting modifications are proposed to stabilise the existing lake wall and outlet.
- East Basin 1 is regarded as a lake whereby its primary function is for storage rather than detention purposes. Notwithstanding this, the lake wall / embankment provides some detention.
- Eco Logical Australia has undertaken some preliminary investigation work on East Basin 1. Subsequently we understand that the basin is man-made (approximately 40-50 years old) and has its own established habitat which is viewed as being beneficial for future development within the site.

4. Water Management Options

A proposed Stormwater Concept Plan has been prepared the development site. Refer to Mott MacDonald Civil Development Application drawings as well as the drawings in Appendix A for details of stormwater management measures.

4.1 Management Strategies Available

4.1.1 Major/Minor Drainage System

The major/minor approach to street drainage is the recognised drainage concept for rural/ residential catchments within the Penrith 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 residential areas are protected against floodwaters.

4.1.2 Detention Basins

Detention basins temporarily detain stormwater runoff 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 particular development. The storage volume may be above or below ground, while discharges are accurately controlled via an orifice or throttled outlet pipe.

4.2 Management Strategies incorporated within Future Development

The WSUD Strategy proposed as part of this submission incorporates the following stormwater management principles for the proposed development:

- The (minor) piped drainage system will be designed to control nuisance flooding and enable effective stormwater management for the site. In accordance with council standards, the minor system will be designed for a minimum 5 year ARI. The minor system will incorporate a pit and pipe network to collect surface flows from the internal roads and convey to the nearest detention basin;
- Stormwater quality devices shall be incorporated with the future development. Water quality treatment measures have been proposed and a treatment train consisting of Gross Pollutant Traps and bio-retention treatment within detention basins. Detailed assessment will be undertaken as part of detailed design. Provisional details have been indicated on the Mott MacDonald Civil DA plans.
- Water quality treatment devices shall be suitably positioned to avoid aesthetic impacts on riparian corridors. GPT's will be positioned alongside roadways just upstream of detention basins to maximise flows and allow easy access for maintenance.

[1] Australian Rainfall and Runoff 2001

- The major system (overland flow routes in and around structures, roadways, etc) will be designed to cater for 100 year ARI flows with overland flow paths directed to proposed detention basins shown on plan. The OSD philosophy is ensure that the proposed development does not have any net increase in flows to the existing lake or to the existing culverts beneath Mulgoa Road therefore ensuring that there is no flood affectation. Assessment will be completed to ensure that general safety and flooding issues will be addressed;
- If the major system cannot meet the safety and flooding criteria, the capacity of the minor system will be increased.
- Discharge from detention basins shall be made to the nearest riparian corridor as noted on the concept plans. Outlets shall be suitably designed in accordance with the relevant authorities and shall include suitable scour protection and aesthetic appearance.
- Riparian corridors shall be provided for Creek 1 (10 metre offset from top basin level)
- A number of detention basins shall be provided to achieve pre-post requirements. Each shall include a staged storage outlet with low flow box culvert arrangement and high level spillway. Refer Section 3.6.

5. Hydrology

5.1 Model Development

Hydrologic modelling was carried out using the *XP-RAFTS* software package (XP Solutions 2013, Mar 12 2013). *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 storage basins such as dams or detention basins.

5.1.1 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, 2001) and are broken up as follows:

5.1.1.1 Slopes

In accordance with AR&R (I.E Aust, 2001), the slopes of the site, pre and post developed sites were generated using "equal area".

5.1.1.2 Impervious and Catchment Areas

The extent of impervious area upon the pre-developed catchment was measured from aerial imagery and therefore no assumed percentage impervious value was adopted. The following table summarises the range of fraction impervious used within the post-developed model. This range of values was adopted in accordance with standard engineering practice, the RAFTS handbook and Penrith City Councils *Guidelines for Engineering Works for Subdivisions and Developments*.

Table 5.1: Typical Values of Fraction Impervious

Catchment Type	Impervious Fraction (%)
Road Reserve	95
Residential Lots	60*

*It is noted that values adopted above for the residential lots are lower than those specified by Penrith City Council. The minimum residential lot size is approximately 950m^2, with a maximum dwelling footprint of 450m^2 (a dwelling of this size is unlikely but does include provision for peripheral paving). This equates to 47% impervious area, 60% was adopted to allow additional impervious areas such as paths, driveways, sheds, etc. within the property.

The pre-developed catchment areas were derived from detailed site survey, while the proposed catchment areas were developed by also incorporating the proposed indicative development footprint. Impervious and pervious catchment areas for the pre and post developed site is included in Appendix B

5.1.1.3 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 per discussions with Penrith City Council, the incorporated initial and continuing loss parameters used were listed as follows:

Table 5.2: Initial and Continuing Loss Parameters

Losses	Rural	Developed (Pervious portion)	Developed (Impervious portion)
Initial Loss (mm)	5.0	5.0	1.0
Continuing Loss (mm/hr)	1.0	1.0	0.0

5.1.1.4 Land use

The land use within the pre-developed catchment is predominantly rural. This type of land use / vegetation does have some effect on the runoff by providing some "resistance" to 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 5.3: Adopted PERN 'n' values

Catchment Type	PERN 'n'
Developed (Impervious Portion)	0.015
Developed (Pervious Portion)	0.035
Undeveloped (Rural Pastures)	0.05
Developed (In riparian corridors)	0.04

5.1.1.5 Hydraulic Roughness Parameters

Hydraulic roughness parameters for the creek network were estimated based upon site visits and were applied in accordance with those recommended in AR&R. The following are typical values which were incorporated in the models.

Table 5.4: Channel Mannings Roughness Parameter 'n'

Channel Type	n
Fairly regular section, Some weeds, light brush on bank	0.035-0.05
Fairly regular section, Some weeds, heavy brush on bank	0.05-0.07
Presence of trees in channel, add to figures	0.01-0.02

Manning's values of 0.05 were typically used for the centre of the creek bed while 0.06 was used for the overbanks within the riparian corridor. Where it was observed through site inspections that some catchments had dense brush/ woodland, the Mannings value was increased to as high as 0.1

5.1.1.6 B-Multiplier

The *b*-multiplier (*b*) used in *RAFTS* is usually determined by calibration against recorded floods. The value for *b* is then used in the standard equation $S=bQ^n$. In the absence of previous flood studies we have kept a *b*-multiplier in the order of 1.0.

5.1.2 RAFTS Catchments

5.1.2.1 Pre-Developed Catchment

The pre-developed catchments were defined from detailed site survey and divided into sub-catchments. Each of these sub-catchments naturally adjoins the system at various points and exits the subject site at the Northern catchment boundary of the site.

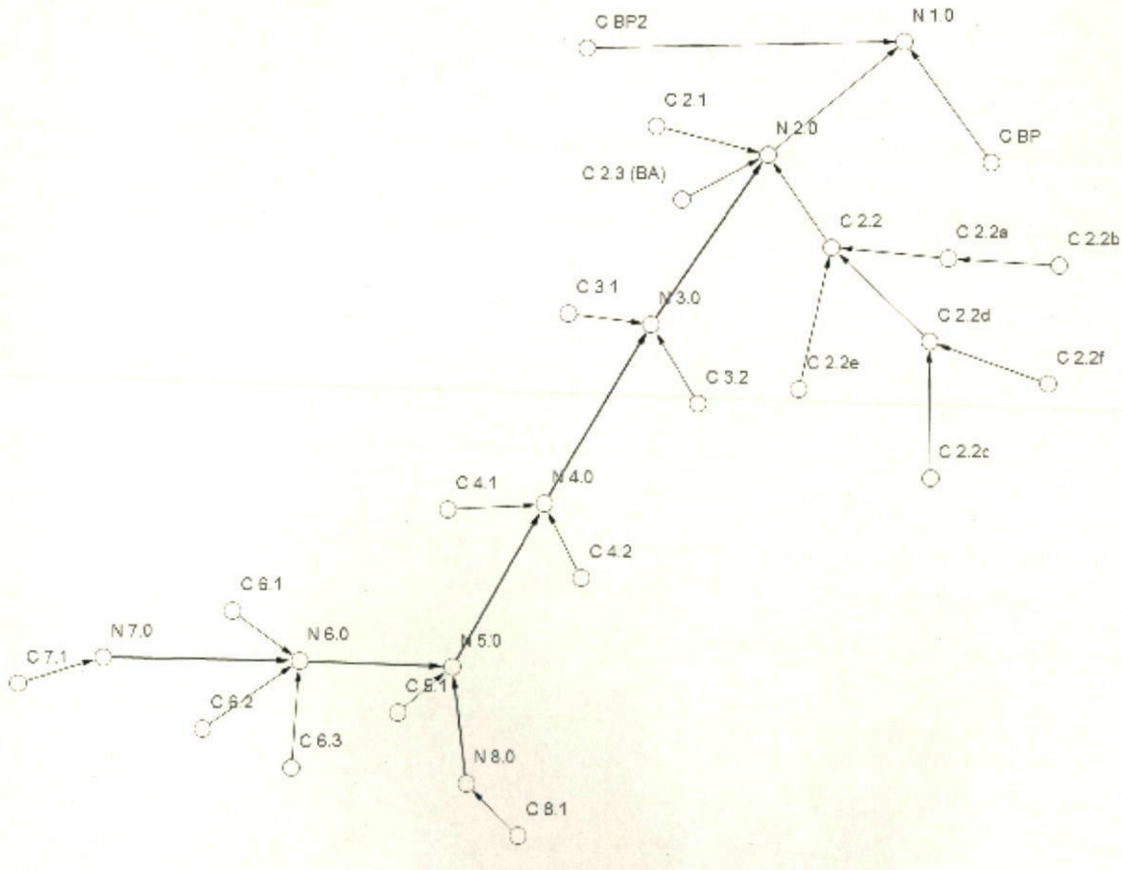
Figure 01 in Appendix A shows the pre-developed catchment division, while Figure 5.1 represents the existing network within *RAFTS*. The division of catchments was based upon natural stream patterns and showed some consideration of proposed catchments.

Links between nodes were generally modelled as "channel routing links" and are representative of the existing creek profiles. Sections were input from 12d as "HEC-2", while Manning's 'n' values were estimated from site visits.

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

See the Figures below for the *XP-RAFTS* layout.

Figure 5.1: Existing XP-RAFTS Model Layout



5.1.2.2 Post Developed Catchment (Including U/S catchments)

Sub-catchments for the post developed situation were generated using a combination of detailed site survey as well as the proposed site plan with preliminary concept grading. Critical points were considered for analysis and kept consistent so that comparison could then be made in order to achieve pre-post development requirements.

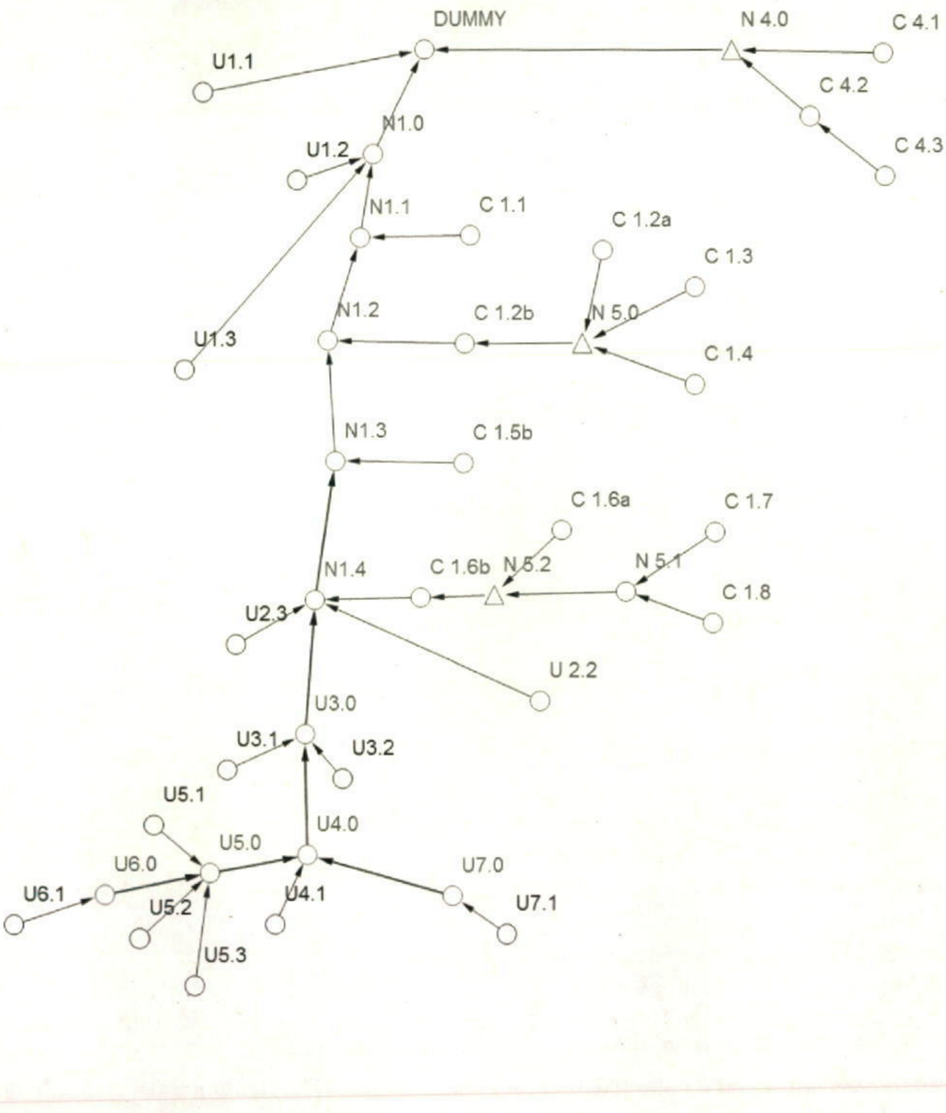
The existing upstream sub-catchments naturally adjoin the system at the same locations as in the pre-development model. While the proposed development will mean that sub-catchment areas on the subject site will enter the creek system at slightly different locations, the outlet remains the same.

Figure 02 and Figure 11 in Appendix A show the post-developed catchment division, while Figure 5.2 represent the proposed network within *RAFTS*.

Nodes defined as "U0.0" represent upstream sub-catchments which remain unchanged from the pre-developed models. Nodes with "C1.00" are indicative of post-development sub-catchments within the proposed development area. "N1.0" nodes act as dummy nodes to allow for both inflow and outflow hydrographs to be assessed at critical points.

The objective used in developing the Stormwater Concept Plan for the site is to drain as much of the development footprint towards a proposed basin via flow paths either within channels or along proposed roadways as well as via a piped network. Detention could then be provided at each of these positions in order to achieve pre-post requirements both at particular locations and for the overall development. Those areas which are not directed into a detention basin are treated as bypass and are also considered within the detention calculations.

Figure 5.2: Proposed XP-RAFTS Model Layout



5.2 Results

Table 5.5: Comparison of 100yr Results

Pre-Development				Post-Development			
Node	Duration (mins)	Peak Flow (m3/s)	Location	Peak Flow (m3/s) (Without Detention)	Peak Flow (m3/s) (With Detention)	Node	Duration (mins)
C BP	120	1.30	Outlet of Eastern Creek Bypass	1.54	1.30	N4.0	90
C BP2	120	0.38	Outlet of Western Creek Bypass	0.38	0.38	U1.1	120
N4.0	120	9.41	Confluence of Upstream Catchments	9.41	9.41	U3.0	120
N3.0	120	10.91	Existing Basin 1 Inlet	11.12	11.25	N1.4	120
N 2.0	120	**14.05**	Northern Outlet Bridge Weir	13.69	**13.90**	N1.0	120
N 1.0	120	**15.44**	Confluence Bypass and Main Creek	15.51	**15.29**	DUMMY	120

Figures marked in orange and green are the total discharge comparisons on site.

On-site Detention or attenuation measures are proposed to be implemented within the development site in order to ensure that pre-post requirements are met in accordance with Penrith City Council's technical standards. Recommendations for the size and location of these detention basins were based on the following methodology:

- Both the existing and proposed catchments were assessed to determine the most appropriate critical points which shall be used for comparison during analysis;
- Appropriate locations were selected using preliminary grading to ensure that overland flows are achievable for the conveyance of major flows;
- Existing and proposed hydrographs were generated and determined at critical points including detention basin locations and outlet positions;
- Iterations were performed within *RAFTS* using outlet pipe, area, overflow weir and depths as variables.

Lots within catchments 1.2 and 1.6 were too close to the existing lake to drain into the proposed basins at Nodes 5.0 and 5.2 respectively. As such, each catchment was split in *RAFTS* to model the proposed runoff generated by impervious areas separately to the pervious areas. The reason for this being that the majority of increased flows will be as a result of the proposed dwellings. Runoff from the roofs in these catchments can be picked up in a piped network and discharged to the basins via inter-allotment drainage lines, enabling them to be attenuated by the basins.

Refer to Table 5.5 for Post developed scenario "Without Detention". The results indicate that the flow rates are typically raised by 20% if development flows were not to be detained.

By incorporating the detention sizes recommended in Table 5.6, pre-post requirements shall be achieved at both the overall outlet positions and critical positions on the subject site. Flows from the proposed detention basins are to be controlled for all standard storm recurrence intervals and durations from the 2-100yr events. This is proposed with a system of staged outlets within a discharge control pit and overflows systems for major storms. Please refer to the Mott MacDonald Civil DA plans for typical/bio-retention details and outlet configurations.

5.2.1.1 Basin Recommendations

Based on the above assessment the following OSD basin sizes are proposed.

Table 5.6: Summary of Detention Basins

Basin	Contributing Catchment Area (Ha)	Volume Required (m3)
N5.0	3.01	515
N5.2	2.49	495
N4.0	3.78	565

Refer to Figure 02 in Appendix A for proposed basin positions.

The location of the detention basins has taken into consideration the following:

- Existing terrain in order to minimise unnecessary earthworks
- Position of Riparian Corridors.
- Preliminary grading of overland flow paths and internal road configuration;
- Overflow and piped discharge from the basin to the nearby system (i.e. Creek or Council drainage system); and
- Maximum depth of 1.2m with batters at 1:6 to minimise need for safety fencing in accordance with the Australian Rainfall and Runoff.

In order to minimise the aesthetic impact on the riparian corridor:

- Basins are shown to incorporate both 1V:6H and 1V:4H batter slopes in order to provide a natural appearance similar to the existing terrain.
- Planting within the basin and surrounding areas shall be selected by a suitably qualified ecologist to ensure minimal impact on riparian corridors.
- Piped discharges shall have scour protection and rock headwalls to DECCW standards.

It is anticipated at this stage that the basins will be dedicated to Council.

6. Hydraulics

6.1 Hydraulic Modelling - *HEC-RAS* Software Package

A one dimensional, steady flow hydraulic model was created to analyse the effect of flood flows on the proposed development lot layout using HEC-RAS. The *HEC-RAS* Version 4 hydraulic analysis program is used to analyse the effect of flood flows on both flood levels and the extent of inundation 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 interruptions in the floodplain are also considered in the computations.

6.2 Model Formulation

The *HEC-RAS* model for the post-developed site was developed based on the following methodology:

6.2.1 River Geometry

The *HEC-RAS* model for the site contains only one branch; "Creek 1". Here Creek 1 is a tributary to upstream catchment areas and flows S-N, widens to form a lake within the subject site before discharging to Littlefields Creek.

Surveyed cross-sections were developed within 12d to represent the existing lake extent and 10m wide riparian corridor width, with transitions to the proposed development area on the eastern bank. Cross-sections were positioned at critical points, with other sections placed between at 50 metre intervals. Figure 05 in Appendix A shows the locations and chainages of the cross-sections used in the proposed *HEC-RAS* model.

Inline Structures were also incorporated into the model to represent the existing lake overflow weirs at CH403 and CH28 respectively, with the overflow levels modelled based on detail survey data.

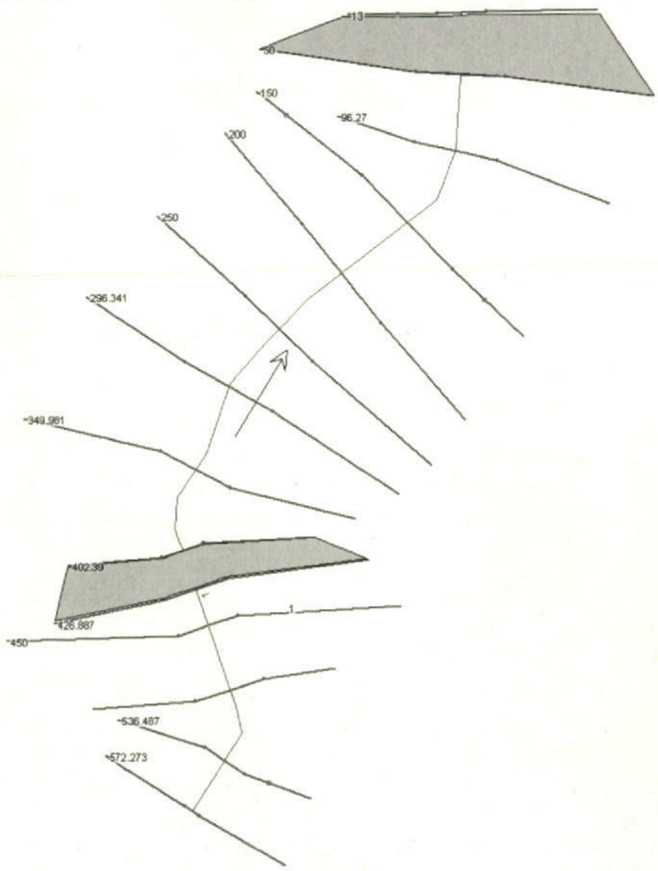
6.2.2 Manning's 'n' Values

Resistance to flow is a function of the surface roughness in the channel and overbank areas, and is affected by vegetation and development. 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 (2001) and *HEC-RAS* Hydraulic Reference Manual (2003). Values of Manning's 'n' were chosen on the basis of field inspection and are summarised in the table below:

Table 6.1: Manning's 'n' Values

Description	Manning's 'n'
Existing stored water within lake	0.02
Grassed areas within residential properties / overbanks	0.04
10m wide riparian corridor from lake extent	0.06

Figure 6.1: HEC-RAS Model



6.2.3 Boundary Conditions

Discharges calculated from hydrologic modelling in Section 5 were incorporated into the model. These were inserted at upstream locations as well as additional inflows along the branch at cross-sections corresponding to the hydrologic model nodes which were considered critical. Normal depth was used as the upstream boundary conditions where required.

Table 6.2: Steady Flow Discharges and Boundary Conditions

Chainage	Discharge (m^3/s)	Boundary Conditions
572.273	9.136	0.01
349.981	10.967	-
200	11.749	-
13	-	0.1

6.2.4 Results

100yr ARI flow rates from the post-developed hydrological model were run through the *HEC-RAS* model to produce design flood levels and the extent of inundation.

Probable Maximum Flood flow rates were also run through the *HEC-RAS* models in order to estimate the design flood levels and extent of inundation for the corresponding event. Here the detention areas were assumed to be full with 100% blockages on piped outlets. Subsequently ineffective flow areas were applied to each cross-section within the lake.

Results of the *HEC-RAS* analysis are summarised in the following table:

Table 6.3: HEC-RAS Results

Chainage	100yr ARI TWL	PMF TWL
CH572.273	61.73	62.45
CH536.487	61.59	62.78
CH490.366	61.59	62.82
CH450	61.58	62.78
CH426.887	61.58	62.78
CH402.39	61.20	61.90
CH349.981	61.20	91.98
CH296.341	61.04	61.94
CH250	61.04	61.90
CH200	61.04	61.90
CH150	61.04	61.89
CH96.27	61.04	61.73
CH50	61.04	61.74
CH13	55.08	56.07

Flood inundation results are shown in Figure 05 in Appendix A. The following comments are also provided:

- 100yr ARI flows are contained within the limits of the riparian corridor on the central creek and lake;
- Flood inundation during the 100yr ARI event is clear of the indicative development footprint;
- As peak flow rates are reduced within the proposed development and no works are proposed within the flood storage areas than 100yr flood levels are expected to be less than in the existing scenario therefore no flood affection is expected for the development.
- PMF extent does encroach slightly into properties adjacent to the western boundary of the indicative development footprint. Flood risk management principles shall be applied as discussed in Section 7.

7. Flood Management Strategy

In accordance with the NSW Floodplain Development Manual (2005), flood risk management has been considered on the subject site. Here flow rates from the 100year ARI event were estimated in Section 5 and assessed through the subject site based on preliminary design levels in Section 6. Similarly, the Probable Maximum Flood (PMF) was also determined from *Bureau of Meteorology: Estimation of PMP in Australia* and assessed across the development site.

The strategy imposed by the Stormwater Concept Plans includes the introduction of well-defined overland flow paths throughout the indicative development footprint, whilst achieving attenuation measures to minimize impact on both future properties and those existing properties downstream from the study area.

HEC-RAS results in Section 6 have indicated that the 1 in 100yr ARI flows will be predominantly clear of the proposed properties and most major roadways, with proposed flow paths primarily being situated beyond the rear of the indicative development footprints. Refer to Figure 05 in Appendix A for extent of flood inundation across the site.

Velocity depth ratios will be reviewed in further detail at the design stages. Results and appropriate flood risk management strategies are discussed below:

Access to the site is gained at two locations along Mulgoa Road. Flood extents do not impede on any accesses through the site, therefore it is not anticipated that there will be a high risk of injury in a major storm event. However, suitable flood management measures should still be incorporated in order to minimize potential risks and comply with regulatory requirements. These include, but are not limited to the following:

- Appropriate safety signage and warning systems;
- Flood evacuation plans and strategy to be prepared for tenants for use during extreme events (coordinated with SES). We note that it is likely that residents will be advised to stay in their houses as they are located outside the PMF footprint, however refuge to higher ground may be sought via Mulgoa Road.

8. Water Quality Modelling

The stormwater management systems for the site shall comply with Penrith City Council's Development Control Plan. Council's policy requires improved water quality of the stormwater flow from the developed site prior to discharge into the authorities' drainage system.

To demonstrate compliance with these objectives, treatment removal loads were analysed from pre to post development scenarios using MUSIC (Model for Urban Stormwater Improvement Conceptualisation) software, for each of the development site. Model development and results are discussed below.

8.1 Model Parameters

The soil properties for the pervious areas of the catchment were taken from the Draft Sydney Catchment Authority Music Modelling Guidelines (Rev 0). Soil Landscapes of Penrith indicate the site as being Luddenham with soil type primarily silty, clay loam.

Table 8.1: MUSIC Soil Parameters

Soil Properties:	Silty Clay Loam
Impervious threshold (mm)	1.0
Soil storage capacity (mm)	125
Initial storage (% of capacity)	25
Field capacity (mm)	30
Infiltration coefficient 'a'	180
Infiltration coefficient 'b'	3.0
Initial groundwater depth (mm)	10
Daily recharge rate (%)	25
Daily base flow rate (%)	30
Daily deep seepage rate (%)	0.0

8.2 MUSIC Methodology

MUSIC software allows the modeller to assess the effectiveness of the water quality devices by measuring against a "base" model (which assumes that no water quality treatment measures are installed). The proposed developed site was compared with and without water quality treatment measures and subsequent pollutant reduction percentages calculated, based on the compared results.

These were then compared with pollutant removal objectives set out by Penrith City Council (Table C3.2, DCP 2010) which are summarised in the table below.

Table 8.2: MUSIC Pollutant Reduction Targets

Pollutant	Minimum Removal Rates
Gross Pollutants (GP)	70%
Suspended Solids (TSS)	80%
Nitrogen (TN)	45%
Phosphorous (TP)	45%

8.2.1 Base Catchment

The RAFTS model developed for detailed analysis and design of the proposed water management system divided the site into 26 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 12 sub-catchment areas for the site, based on the proposed drainage system layout (refer Figure 8.1).

It should be noted that catchments M9 and M10 on the western side of the existing dam were excluded from the model. As no works are proposed in these areas there will be no increase in pollutant loading. Any future development that may take place here would need to consider water quality independent of the currently proposed development.

Figure 8.1: MUSIC Catchment Plan

8.2.2 Catchment Models

The proposed catchment model for the site was compared with and without treatment devices in accordance with PCC requirements. Table 8.3 identifies the catchment breakdown for the model.

Table 8.3: Area Breakdown per MUSIC Sub-Catchment

Sub-Catchment	Impervious Area (Ha)	Pervious Area (Ha)	Total Area (Ha)
M1	0.11	0.01	0.11
M2-A	0.35	2.28	2.63
M2-B	0.70	0.29	0.99
M3-A	1.87	0.88	2.75
M3-B	0.00	0.23	0.23
M4	0.00	0.53	0.53
M5	0.22	0.36	0.58
M6	1.90	1.11	3.01
M7	0.00	0.62	0.62
M8	0.24	0.37	0.61
M9	2.42	8.16	10.58
M10	0.00	4.72	4.72
Total	**7.80**	**19.55**	**27.35**

8.3 Management Strategies

Storm runoff generated on the proposed development site is proposed to be picked up in a piped street network and directed to one of three basins.

The proposed treatment train is as follows:

- Gross pollutant traps positioned upstream of each detention basin to capture larger pollutants and sediments before discharge into the downstream watercourse; and
- Bio-retention systems to be incorporated within the base of the proposed detention basins.

8.3.1 Gross Pollutant Traps

"Gross Pollutant Trap" is a term applied to either in-situ or proprietary units that remove litter, vegetative matter and sediment. In developing the MUSIC model for the proposed works, it is proposed to provide Gross Pollutant Traps (GPTs) upstream of each discharge point into the detention basins.

The location of the GPT has been arranged to maximise flow and allow easy access for maintenance vehicles. Proposed positions of these Gross Pollutant Traps are shown in Fig03 and the Civil DA drawings.

MUSIC requires that transfer functions for the reduction in pollutants be entered. The pollutant reductions vary for different types of GPTs. For the purposes of this assessment a Humegard GPT by Humes has been adopted with pollutant reduction parameters based on manufacturers' specifications as outlined in the table below:

Table 8.4: MUSIC Input – GPT Pollutant Reductions

Pollutant	Input	Output
Total Suspended Solids (mg/L)	500.2	250.7
Total Nitrogen (mg/L)	5.0	4.0
Total Phosphorus (mg/L)	4.978	4.006
Gross Pollutants (kg/ML)	15.0	2.2

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. Sizing of the GPTs to meet this requirement should be undertaken at the Detailed Design stage.

8.3.2 Bio-retention

Bio-retention basins have been incorporated as an end-of-line treatment to target nutrients and other soluble pollutants prior to discharge.

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

In developing the MUSIC model for the proposed development, bio-retention basins are proposed to treat runoff from sub-catchments M2, M3 and M7. After pre-treatment by GPT's, the runoff will be directed to the basins for treatment by the bio-retention system. The 3 month flows will be conveyed via the pipe network to the treatment facilities, with larger flows bypassing the GPTs, though still directed to the basins.

The following parameters were input into the MUSIC model:

Table 8.5: Bioretention Basin MUSIC Parameters

Catchment	Basin Surface Area (m^2)	Extended Detention Depth (m)	Filter Area (m^2)	Depth of Infiltration (m)
M2	273	0.30	460	0.60
M3	239	0.30	1635	0.60
M7	284	0.30	920	0.60

8.4 Results

The results of the model as summarised in Table 8.6 below, show that by including treatment trains as described above, the water quality improvement objectives set out in Penrith Councils DCP 2010 and the

Draft Sydney Catchment Authority Music Modelling Guidelines (Rev 0) are achieved. Figure 8.2 show the MUSIC model layout.

Table 8.6: Comparison of MUSIC Results

Pollutant	Post-Development with no WSUD Measures (kg/yr)	Post-Development with WSUD Measures (kg/yr)	Removal Rate (%)	Target Removal Rate (%)
Total Suspended Solids (TSS)	16000	3740	77	80
Total Phosphorus (TP)	30.3	17.1	44	45
Total Nitrogen (TN)	228	121	47	45
Gross Pollutants (GP)	2270	262	89	70

While the results tabulated above for TSS and TP do not strictly meet the requirements outlined in PCC guidelines, we believe the following should be taking in consideration when assessing the proposed development against pollutant removal targets:

- Councils guidelines for reduction of suspended solids, is broken up into two categories as listed below.
  - Coarse Sediment – Coarse sand (≥0.5mm) – 80% retention of particles ≤0.5mm diameter; and
  - Fine Particles – Fine sand (≥0.5mm) – 50% retention of particles ≤0.1mm diameter.

  MUSIC assesses total suspended solids without differentiating between particle sizes. Conservatively, it has been attempted to reduce TSS by the higher 80% removal rate for coarse sediments.
- Although the lots are residential, the typical lot size of between $950m^2$ and $1,500m^2$ is considerably larger than a standard urban residential lot, leaving room for a greater pervious area to be unchanged from the existing scenario.

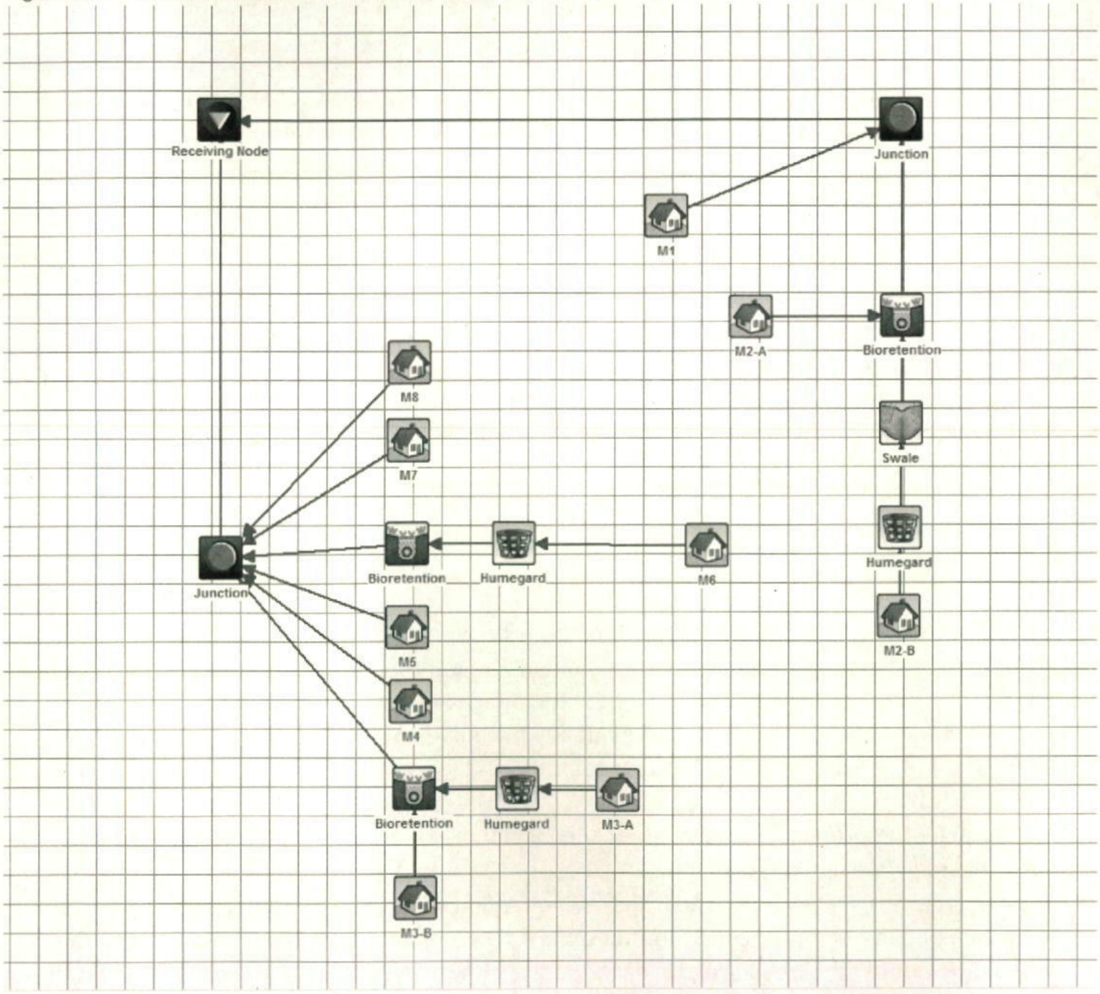
Although the results indicate the proposed development does not exactingly adhere to Council's requirements, we believe that the items listed above allow for some tolerance in the target removal rates outlined by Council.

We respectfully request Council's consideration in approving the proposed development with regard to the water quality requirements.

This overall WSUD Strategy has demonstrated that the future development on the site can proceed without an increase in stormwater impacts on either the Hawkesbury-Nepean Catchment or the surrounding areas. This strategy has considered a range of hydraulic situations and constraints and provides a framework for how future development may proceed across the site. Further refinement will need to be undertaken during detailed design.

Appendices

Figure 8.2: MUSIC Model



9. Conclusion and Recommendations

The report has detailed both flood and stormwater modelling investigations which have been undertaken in support of the proposed rezoning of the Eastern Precinct (Residential) located within the Fernhill Estate, Mulgoa.

In particular, flood modelling undertaken in *HEC-RAS* has demonstrated that 100yr flows are typically contained within the proposed channel realignments and associated riparian corridors. Further hydrological modelling undertaken in *RAFTS* has been carried out to help formulate a series of recommendations on the location and size of proposed detention basins, to achieve pre-post statutory requirements.

The Water Sensitive Urban Design Strategy (WSUD), as assessed and discussed in this Report, has identified that through the implementation of appropriate mitigation and management measures Stormwater across the subject site can be environmentally managed on site.

The proposed 54 residential lots to be located across the subject site will pose minimal impact to surrounding catchment areas adjacent to the investigation area. Further, the implementation of the below mechanisms and recommendations pertaining to the development site are to be appropriately integrated within the detailed design process so as to help ensure that surrounding catchment areas are not adversely affected by such a proposal.

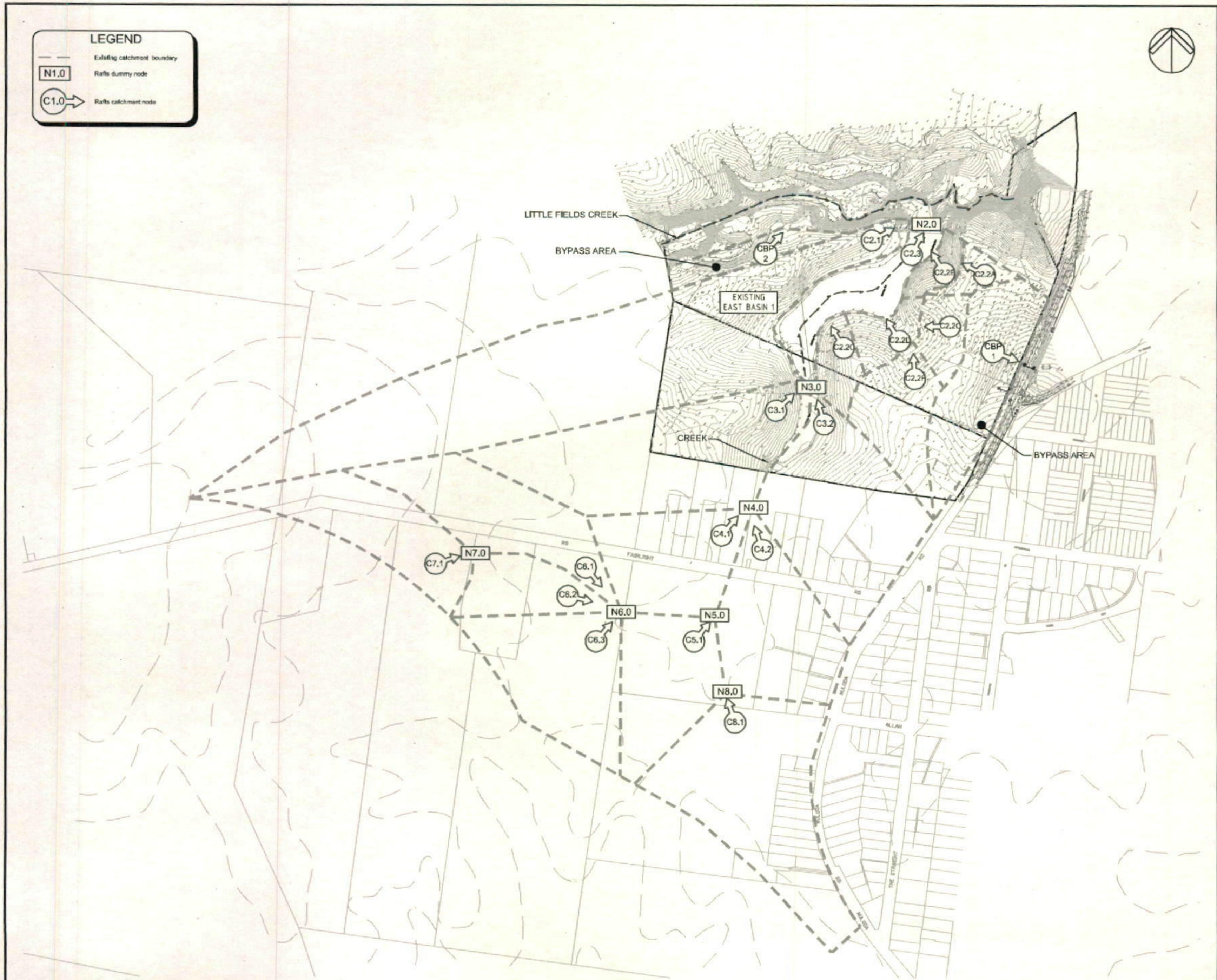
Importantly, a flood risk management assessment for the proposed development has indicated that site responsive treatment and management mechanisms should be appropriately implemented, through such means as well defined overland flow paths throughout the indicative development footprint area. By achieving such attenuation measures, these will evidently minimise potential flooding impacts on both future properties and those existing properties downstream.

The WSUD strategy for the proposed development site includes:

- Minor / major piped/swale drainage systems
- Quality devices including Gross Pollutant Traps, Bio-retention within proposed detention basins and grass lined swales have been proposed. Further details can be found on the Mott MacDonald Civil DA plans. It should be noted that these are preliminary only, with the type, size and locations of the devices to be confirmed during the detailed design stages.
- Detention basins shall be provided to achieve pre-post requirements. Each shall include a staged storage outlet with low flow discharge control pit arrangement and high level spillway.
- Riparian corridors shall be provided for Creek 1 (10 meter offset from top basin level).
- Crossings (for access) are proposed across riparian corridors. Each crossing will be designed to ensure safe evacuation during major rainfall events.

Suitable flood management measures will also need to be incorporated in order to minimize potential risks and comply with regulatory requirements. These include, but are not limited to the following:

- Appropriate safety signage
- Flood evacuation plans and strategy to be prepared for tenants for use during extreme events (coordinated with SES).



20 0 50 100 200
PLAN SCALE 1:3000 @ A1

Preliminary - Not For Construction

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	27.06.13	AMP	Issued for DA Approval	GL	DB

Mott MacDonald

Level 3, 60 Phillip Street
Parramatta NSW 2150
Australia
PO Box 163, Parramatta
NSW 2124, Australia
T +61 (0)2 9891 8344
F +61 (0)2 9891 8386
W www.mottmac.com.au

Client
Cubelic Holding Pty Ltd

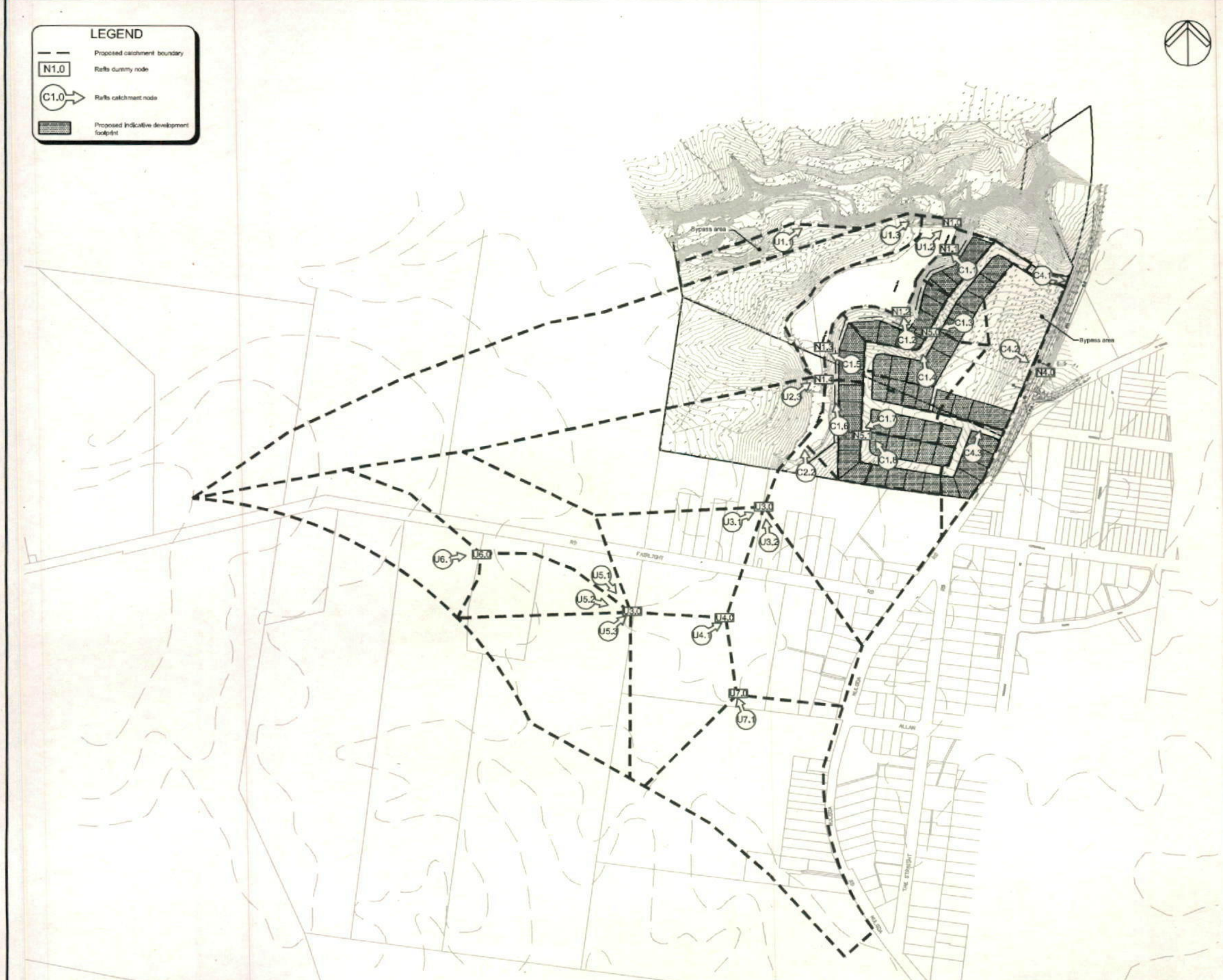
Title
Fernhill Estate
Existing Eastern Catchment Plan

Designed	GL	.	Eng check	GL	.
Drawn	ADS	.	Coordination	CJA	.
Dwg check	GC	.	Approved	CJA	.

Scale at A1	Status	Rev
1:3000	PRE	P1

Drawing Number
MMD-322876-C-DR-00-XX-FIG01

Appendix A. Plans



Preliminary - Not For Construction

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	27.06.13	AMP	Issued for DA Approval	GL	DB

Mott MacDonald

Level 3, 90 Phillip Street
Parramatta, NSW 2150
Australia
PO Box 163, Parramatta
NSW 2124, Australia

Client: Cubelic Holding Pty Ltd

Title: Fernhill Estate
Proposed Eastern Catchment Plan

Designed	GL	.	Eng check	GL	.
Drawn	ADS	.	Coordination	CJA	.
Dwg check	GC	.	Approved	CJA	.

Scale at A1	Status	Rev
1:3000	PRE	P1

Drawing Number: MMD-322876-C-DR-00-XX-FIG02

Chainage	100yr ARI TWL	PMF TWL
572.273	61.73	62.45
536.487	61.59	62.78
490.366	61.59	62.82
450	61.58	62.76
426.887	61.58	62.78
403	Lateral weir	Lateral weir
402.39	61.20	61.90
349.981	61.04	61.98
296.341	61.04	61.94
250	61.04	61.90
200	61.04	61.90
150	61.04	61.89
96.27	61.04	61.73
50	61.04	61.74
28	Lateral weir	Lateral weir
13	55.08	56.07

Preliminary - Not For Construction

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	27.06.13	AMP	Issued for DA Approval	GL	DB

Mott MacDonald
Level 3, 90 Phillip Street
Parramatta, NSW 2150
Australia
PO Box 163, Parramatta
NSW 2124, Australia
T +61 (0)2 9891 8044
F +61 (0)2 9891 8386
W www.mottmac.com.au

Client
Cubelic Holding Pty Ltd

Title
Fernhill Estate
Proposed Eastern HEC-RAS

Designed	GL	-	Eng check	GL	-
Drawn	ADS	-	Coordination	CJA	-
Dwg check	GC	-	Approved	CJA	-

Scale at A1	Status	Rev
1:1000	PRE	P1

Drawing Number
MMD-322876-C-DR-00-XX-FIG05

P:\Parramatta\Projects\32xxxx\322876\06 CAD\RL_s Working drawings\Fernhill\Autumn\Sketches\Stormwater Report\MMD-322876-C-SK-00-XX-FIG05.dwg Jun 27, 2013 - 5:34PM

Appendix B. *XPRAFTS* Catchment Data and Results

Fernhill Subdivision, Mulgoa

RAFTS Catchment Parameters

Eastern Precinct - Existing Scenario

Mott MacDonald

Catchment	Total Area (Ha)	Impervious Area (Ha)	Pervious Area (Ha)
C 2.1	15.79	0.87	14.92
2.2a	0.59	0	0.59
2.2b	0.66	0	0.66
2.2c	0.99	0	0.99
2.2d	0.94	0	0.94
2.2e	0.95	0	0.95
2.2f	2.39	0.33	2.06
C 2.3	2.42	2.42	0.00
C 3.1	7.71	0.09	7.62
C 3.2	6.68	1.98	4.70
C 4.1	3.76	0.94	2.82
C 4.2	4.52	1.71	2.81
C 5.1	3.68	0.05	3.63
C 6.1	4.23	0.38	3.85
C 6.2	1.99	0.02	1.97
C 6.3	4.65	0.04	4.61
C 7.1	3.90	0.79	3.11
C 8.1	7.30	1.66	5.64
C BP	3.84	0.00	3.84
C BP2	1.05	0.00	1.05
Total	**78.01**	**11.28**	**66.73**

Fernhill Subdivision, Mulgoa

RAFTS Catchment Parameters
Eastern Precinct - Proposed Scenario

Mott MacDonald

Catchment	Total Area (Ha)	Impervious Area (Ha)	Pervious Area (Ha)
C 4.1	0.11	0.11	0.01
C 4.2	2.65	0.35	2.30
C 4.3	1.14	0.70	0.44
C 1.1	0.61	0.24	0.37
C 1.2a	0.37	0.37	0.00
C 1.2b	0.62	0.00	0.62
C 1.3	1.10	0.70	0.40
C 1.4	1.54	0.83	0.71
C 1.5	0.58	0.22	0.36
C 1.6a	0.42	0.42	0.00
C 1.6b	0.75	0.00	0.75
C 1.7	0.92	0.67	0.25
C 1.8	1.15	0.78	0.37
U 1.1	1.05	0.00	1.05
U 1.2	2.42	2.42	0.00
U 1.3	15.79	0.87	14.92
U 2.2	5.11	0.26	4.86
U 2.3	7.71	0.09	7.62
U 3.1	3.76	0.94	2.82
U 3.2	4.52	1.71	2.81
U 4.1	3.68	0.05	3.63
U 5.1	4.23	0.38	3.85
U 5.2	1.99	0.02	1.97
U 5.3	4.65	0.04	4.61
U 6.1	3.90	0.79	3.11
U 7.1	7.30	1.66	5.64
Total	**78.04**	**14.61**	**63.43**

Fernhill Subdivision, Mulgoa

Peak Discharges (m^3/s) for 100yr ARI Standard Storm Durations
Eastern Precinct - Existing Scenario

Mott MacDonald

	100yr ARI Storm Duration										
Node/ Catchment	**10**	**15**	**20**	**25**	**30**	**45**	**60**	**90**	**120**	**180**	**Peak Discharge (m^3/s)**
C 2.1	0.692	0.794	0.904	0.98	1.017	1.28	1.474	1.684	1.822	1.758	**1.822**
C 2.2	1.74	1.917	2.24	2.327	2.187	2.007	2.264	2.443	2.341	1.735	**2.443**
C 2.2a	0.357	0.398	0.415	0.443	0.421	0.371	0.439	0.469	0.447	0.331	**0.469**
C 2.2b	0.116	0.148	0.173	0.179	0.173	0.174	0.198	0.208	0.215	0.168	**0.215**
C 2.2c	0.268	0.322	0.368	0.378	0.356	0.336	0.362	0.369	0.371	0.268	**0.378**
C 2.2d	1.021	1.185	1.409	1.431	1.339	1.275	1.452	1.572	1.522	1.142	**1.572**
C 2.2e	0.362	0.41	0.419	0.453	0.428	0.367	0.384	0.403	0.386	0.262	**0.453**
C 2.2f	0.431	0.542	0.636	0.636	0.596	0.614	0.723	0.818	0.78	0.616	**0.818**
C 2.3 (BA)	1.215	1.335	1.318	1.287	1.203	1.119	1.178	1.264	1.218	0.675	**1.335**
C 3.1	0.254	0.348	0.459	0.556	0.631	0.818	0.92	1.009	1.052	0.996	**1.052**
C 3.2	1.074	1.282	1.229	1.329	1.244	1.07	1.32	1.536	1.367	1.06	**1.536**
C 4.1	0.812	0.901	1.026	1.136	1.072	0.961	1.201	1.363	1.244	0.974	**1.363**
C 4.2	1.059	1.274	1.265	1.445	1.354	1.147	1.496	1.696	1.524	1.154	**1.696**
C 5.1	0.593	0.82	0.949	0.974	0.952	0.97	1.095	1.171	1.179	0.934	**1.179**
C 6.1	0.336	0.391	0.441	0.478	0.556	0.652	0.699	0.703	0.728	0.631	**0.728**
C 6.2	0.517	0.622	0.715	0.724	0.69	0.656	0.724	0.738	0.73	0.538	**0.738**
C 6.3	0.772	1.093	1.269	1.305	1.251	1.249	1.422	1.521	1.532	1.198	**1.532**
C 7.1	0.735	0.796	0.955	1.042	0.984	0.978	1.116	1.308	1.235	0.98	**1.308**
C 8.1	1.467	1.646	1.885	2.042	1.931	1.838	2.209	2.544	2.342	1.858	**2.544**
C BP	0.708	0.977	1.122	1.147	1.094	1.079	1.221	1.301	1.302	1.008	**1.302**
C BP2	0.256	0.321	0.367	0.369	0.348	0.34	0.372	0.381	0.383	0.281	**0.383**
N 1.0	7.19	9.042	10.942	12.281	12.453	13.247	14.685	14.759	15.444	12.677	**15.444**
N 2.0	6.293	7.745	9.622	11.072	11.402	12.197	13.402	13.549	14.051	11.389	**14.051**
N 3.0	4.583	6.392	7.822	8.522	8.872	9.341	10.315	10.597	10.91	8.811	**10.91**
N 4.0	4.336	6.006	7.333	7.686	7.629	7.917	8.804	9.169	9.411	7.631	**9.411**
N 5.0	3.95	5.014	5.786	6.03	5.767	5.972	6.804	7.493	7.488	5.941	**7.493**
N 6.0	2.128	2.733	3.256	3.397	3.229	3.229	3.733	4.027	4.06	3.246	**4.06**
N 7.0	0.735	0.796	0.955	1.042	0.984	0.978	1.116	1.308	1.235	0.98	**1.308**
N 8.0	1.467	1.646	1.885	2.042	1.931	1.838	2.209	2.544	2.342	1.858	**2.544**

Fernhill Subdivision, Mulgoa

Peak Discharges (m^3/s) for 100yr ARI Standard Storm Durations
Eastern Precinct - Proposed Scenario

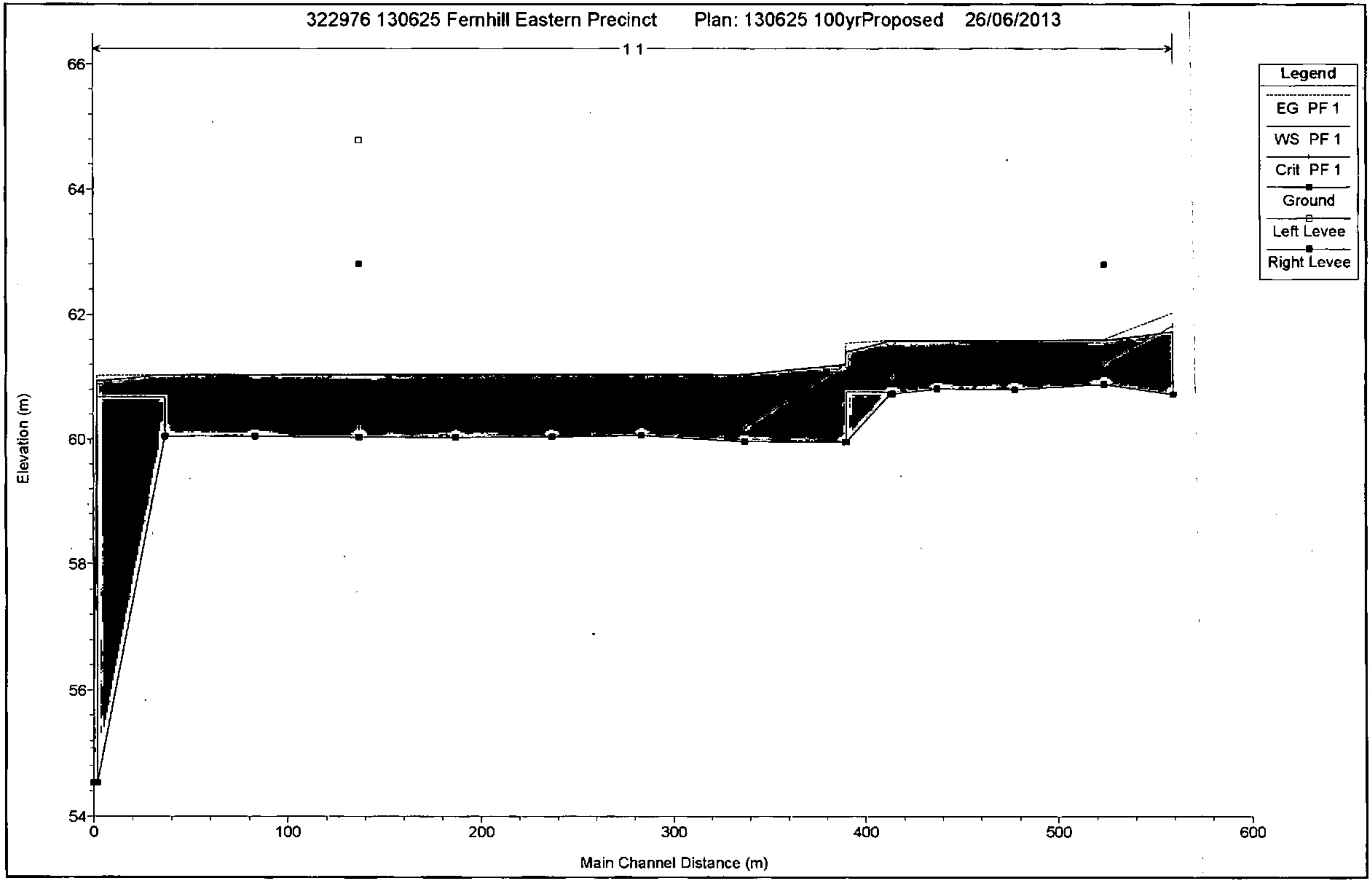
Mott MacDonald

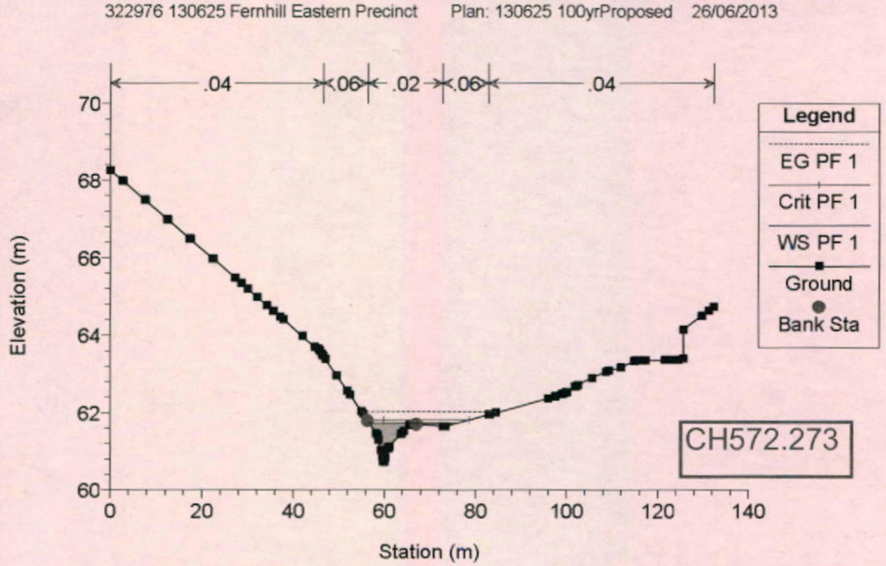
Node/ Catchment	100yr ARI Storm Duration										Peak Discharge (m^3/s)
	10	15	20	25	30	45	60	90	120	180	
C 1.1	0.262	0.313	0.288	0.312	0.293	0.259	0.276	0.294	0.273	0.168	**0.313**
C 1.2a	0.204	0.213	0.217	0.204	0.189	0.179	0.19	0.206	0.202	0.107	**0.217**
C 1.2b	0.966	1.152	1.377	1.528	1.424	1.228	1.509	1.605	1.486	0.996	**1.605**
C 1.3	0.401	0.482	0.443	0.514	0.481	0.397	0.489	0.518	0.487	0.304	**0.518**
C 1.4	0.573	0.668	0.63	0.732	0.691	0.57	0.67	0.704	0.654	0.426	**0.732**
C 1.5b	0.247	0.29	0.266	0.294	0.277	0.239	0.26	0.276	0.254	0.16	**0.294**
C 1.6a	0.227	0.242	0.244	0.233	0.216	0.206	0.217	0.233	0.229	0.119	**0.244**
C 1.6b	0.921	1.097	1.244	1.394	1.301	1.104	1.343	1.422	1.332	0.891	**1.422**
C 1.7	0.407	0.468	0.46	0.473	0.443	0.394	0.444	0.474	0.461	0.253	**0.474**
C 1.8	0.457	0.553	0.51	0.572	0.539	0.458	0.528	0.561	0.539	0.32	**0.572**
C 4.1	0.056	0.063	0.064	0.061	0.057	0.054	0.058	0.062	0.061	0.032	**0.064**
C 4.2	0.939	1.049	1.195	1.316	1.238	1.101	1.354	1.479	1.317	1.008	**1.479**
C 4.3	0.416	0.503	0.454	0.529	0.498	0.408	0.501	0.53	0.5	0.313	**0.53**
DUMMY	7.075	8.967	10.8	12.161	12.359	13.236	14.622	14.965	15.289	12.933	**15.289**
N 1.0	6.465	8.126	9.595	11.014	11.321	12.146	13.319	13.381	13.901	11.661	**13.901**
N 1.1	4.984	6.876	8.547	9.748	9.983	10.594	11.678	11.773	12.237	9.932	**12.237**
N 1.2	4.966	6.848	8.473	9.65	9.893	10.49	11.569	11.679	12.14	9.808	**12.14**
N 1.3	4.727	6.545	7.997	8.964	9.282	9.802	10.771	11.012	11.331	9.144	**11.331**
N 1.4	4.711	6.517	7.966	8.883	9.196	9.705	10.676	10.919	11.249	9.069	**11.249**
N 4.0*	0.988	1.111	1.24	1.375	1.294	1.14	1.409	1.537	1.373	1.04	**1.537**
N 5.0*	1.132	1.351	1.261	1.44	1.353	1.136	1.338	1.413	1.326	0.833	**1.44**
N 5.1	0.844	1.021	0.961	1.045	0.982	0.852	0.972	1.035	1	0.573	**1.045**
N 5.2*	1.028	1.213	1.168	1.244	1.164	1.013	1.168	1.245	1.202	0.689	**1.245**
U 1.1	0.256	0.321	0.367	0.369	0.348	0.34	0.372	0.381	0.383	0.281	**0.383**
U 1.2	1.277	1.343	1.366	1.291	1.198	1.136	1.228	1.295	1.292	0.682	**1.366**
U 1.3	0.692	0.794	0.904	0.98	1.016	1.28	1.474	1.684	1.822	1.758	**1.822**
U 2.2	1.041	1.207	1.166	1.234	1.155	1.013	1.187	1.32	1.238	0.855	**1.32**
U 2.3	0.254	0.348	0.459	0.556	0.631	0.818	0.92	1.009	1.052	0.996	**1.052**
U 3.0	4.336	6.006	7.333	7.686	7.629	7.917	8.804	9.169	9.411	7.631	**9.411**
U 3.1	0.812	0.901	1.026	1.136	1.072	0.961	1.201	1.363	1.244	0.974	**1.363**
U 3.2	1.059	1.274	1.265	1.445	1.354	1.147	1.496	1.696	1.524	1.154	**1.696**
U 4.0	3.95	5.014	5.786	6.03	5.767	5.972	6.804	7.493	7.488	5.941	**7.493**
U 4.1	0.593	0.82	0.949	0.974	0.952	0.97	1.095	1.171	1.179	0.934	**1.179**
U 5.0	2.128	2.733	3.256	3.397	3.229	3.229	3.733	4.027	4.06	3.246	**4.06**
U 5.1	0.336	0.391	0.441	0.478	0.556	0.652	0.699	0.703	0.728	0.631	**0.728**
U 5.2	0.517	0.622	0.715	0.724	0.69	0.656	0.724	0.738	0.73	0.538	**0.738**
U 5.3	0.772	1.093	1.269	1.305	1.251	1.249	1.422	1.521	1.532	1.198	**1.532**
U 6.0	0.735	0.796	0.955	1.042	0.984	0.978	1.116	1.308	1.235	0.98	**1.308**
U 6.1	0.735	0.796	0.955	1.042	0.984	0.978	1.116	1.308	1.235	0.98	**1.308**
U 7.0	1.467	1.646	1.885	2.042	1.931	1.838	2.209	2.544	2.342	1.858	**2.544**
U 7.1	1.467	1.646	1.885	2.042	1.931	1.838	2.209	2.544	2.342	1.858	**2.544**

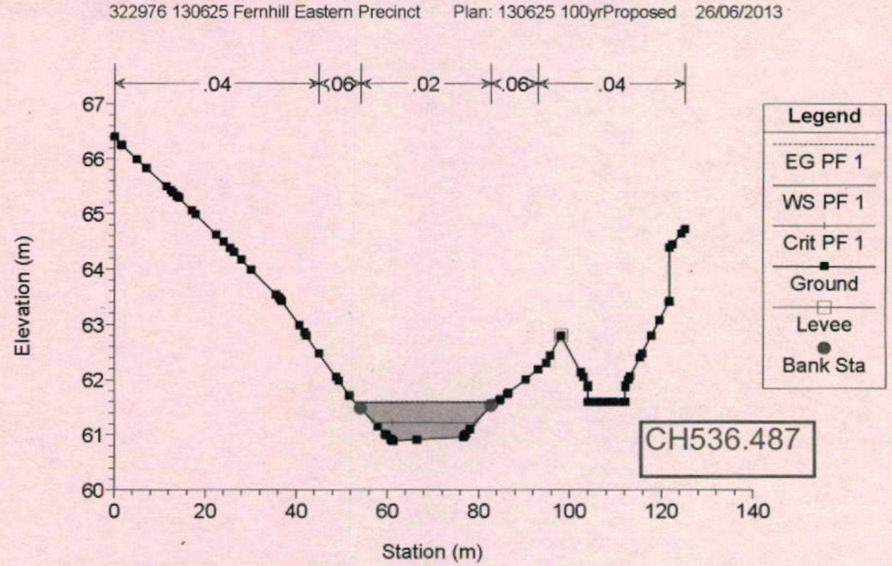
*Proposed basin locations. Flows shown are those entering the basin and do not include attenuation.

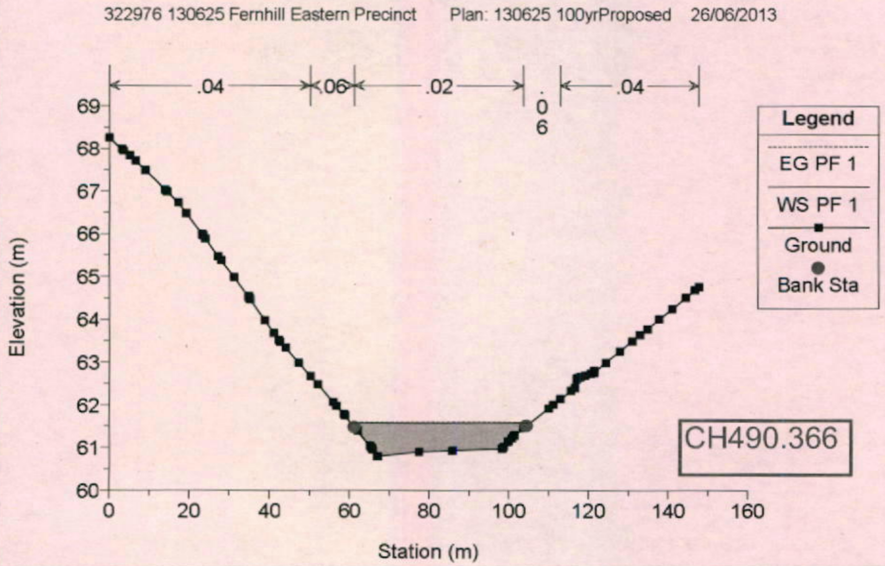
Appendix C. *HEC-RAS* Results

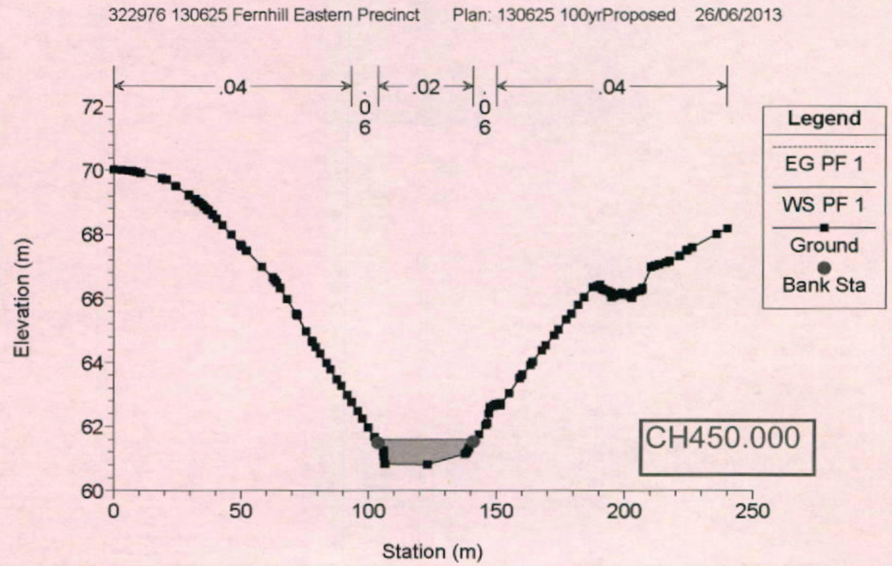
EASTERN PRECINCT - 100yr
ARI FLOOD EXTENTS

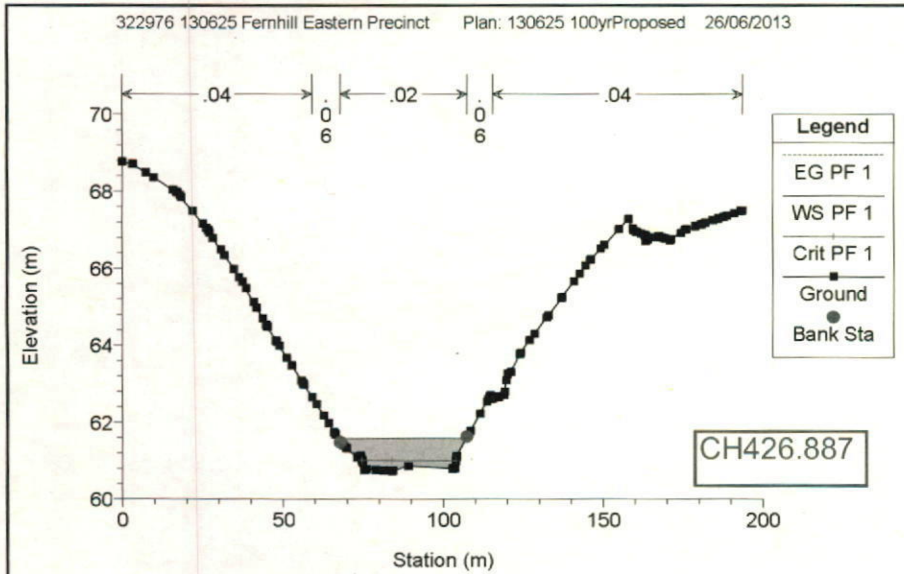


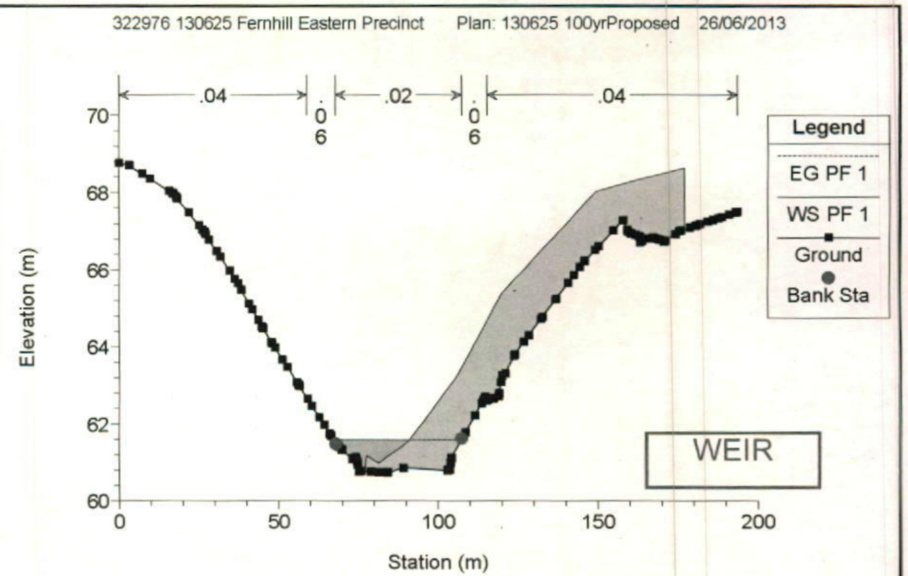

322976 130625 Fernhill Eastern Precinct Plan: 130625 100yrProposed 26/06/2013
.04 .06 .02 .06 .04
Legend
EG PF 1
Crit PF 1
WS PF 1
Ground
Bank Sta
CH572.273
Elevation (m)
Station (m)
70
68
66
64
62
60
0
20
40
60
80
100
120
140

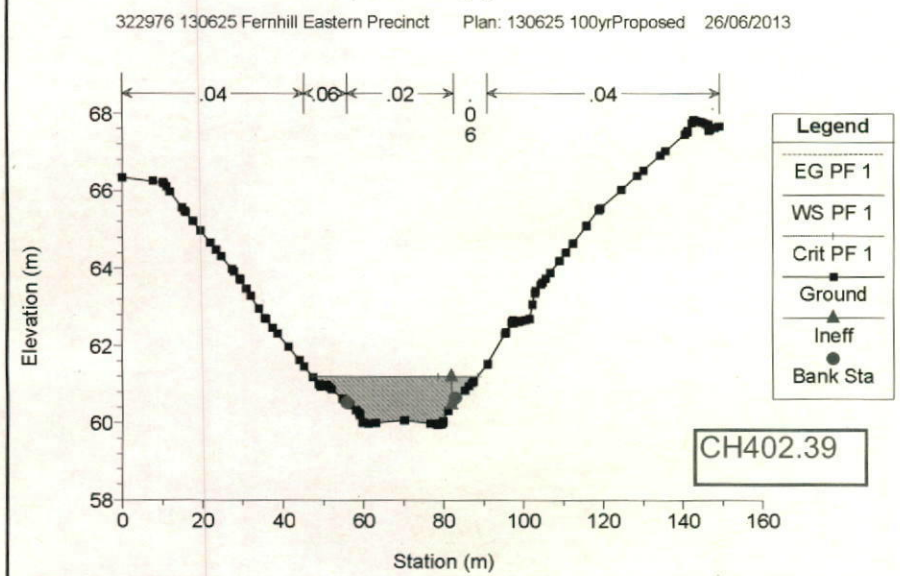

322976 130625 Fernhill Eastern Precinct Plan: 130625 100yrProposed 26/06/2013
.04 .06 .02 .06 .04
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Levee
Bank Sta
CH536.487
Elevation (m)
Station (m)
67
66
65
64
63
62
61
60
0
20
40
60
80
100
120
140

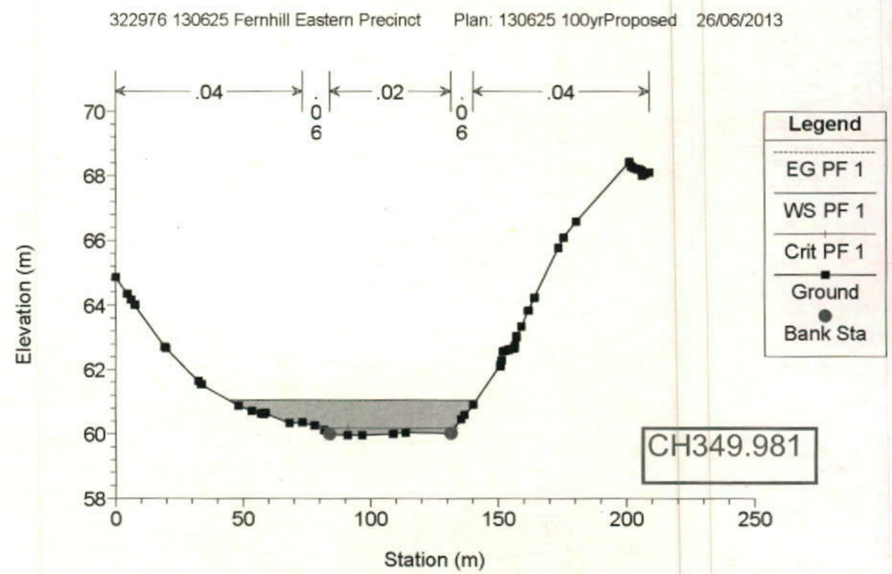

322976 130625 Fernhill Eastern Precinct Plan: 130625 100yrProposed 26/06/2013
.04 .06 .02 .06 .04
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
CH490.366
Elevation (m)
Station (m)
69
68
67
66
65
64
63
62
61
60
0
20
40
60
80
100
120
140
160

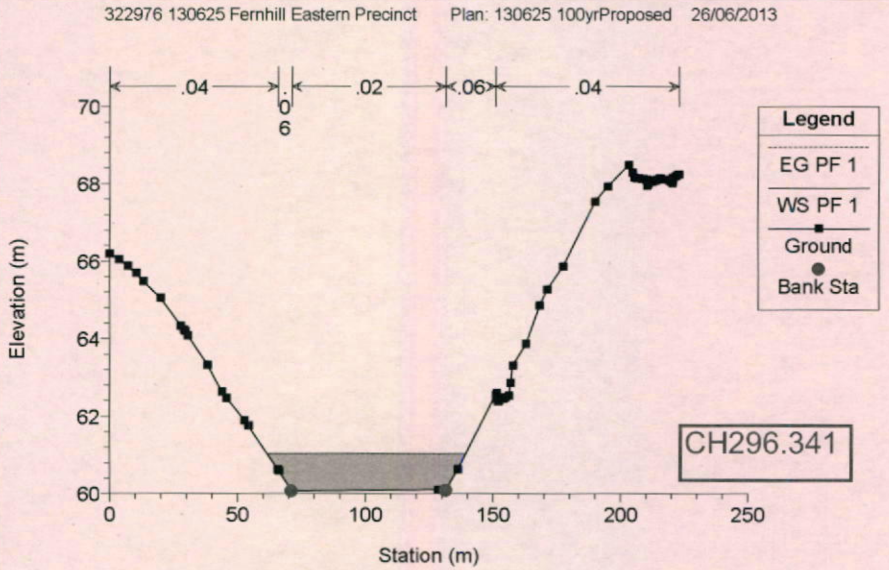

322976 130625 Fernhill Eastern Precinct Plan: 130625 100yrProposed 26/06/2013
.04 .06 .02 .06 .04
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
CH450.000
Elevation (m)
Station (m)
72
70
68
66
64
62
60
0
50
100
150
200
250


322976 130625 Fernhill Eastern Precinct
Plan: 130625 100yrProposed
26/06/2013
.04
.06
.02
.06
.04
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Bank Sta
CH426.887
Elevation (m)
Station (m)

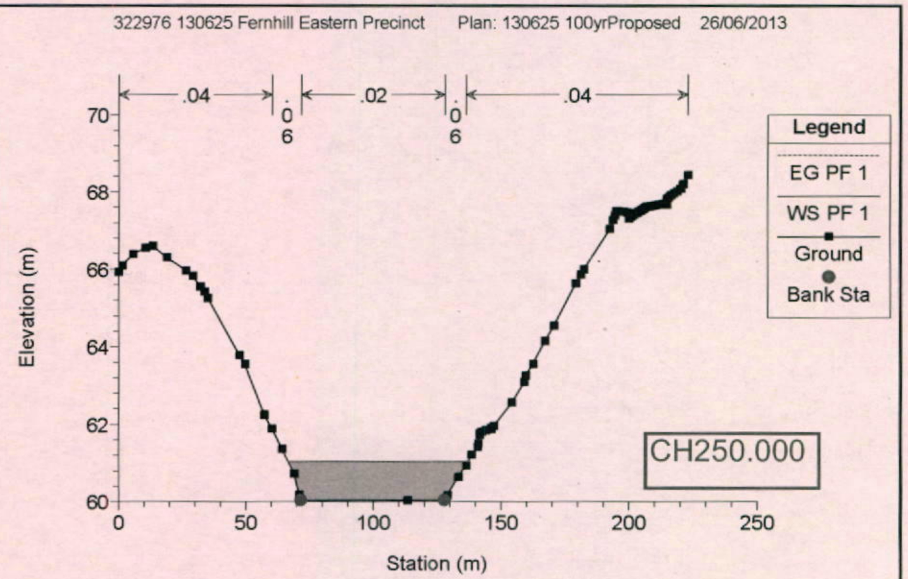

322976 130625 Fernhill Eastern Precinct
Plan: 130625 100yrProposed
26/06/2013
.04
.06
.02
.06
.04
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
WEIR
Elevation (m)
Station (m)


322976 130625 Fernhill Eastern Precinct
Plan: 130625 100yrProposed
26/06/2013
.04
.06
.02
.06
.04
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
CH402.39
Elevation (m)
Station (m)

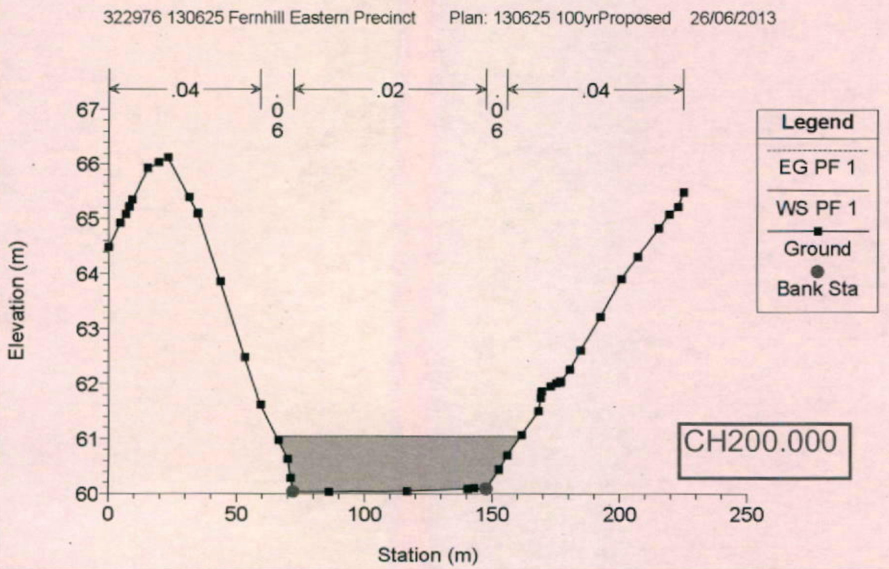

322976 130625 Fernhill Eastern Precinct
Plan: 130625 100yrProposed
26/06/2013
.04
.06
.02
.06
.04
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Bank Sta
CH349.981
Elevation (m)
Station (m)



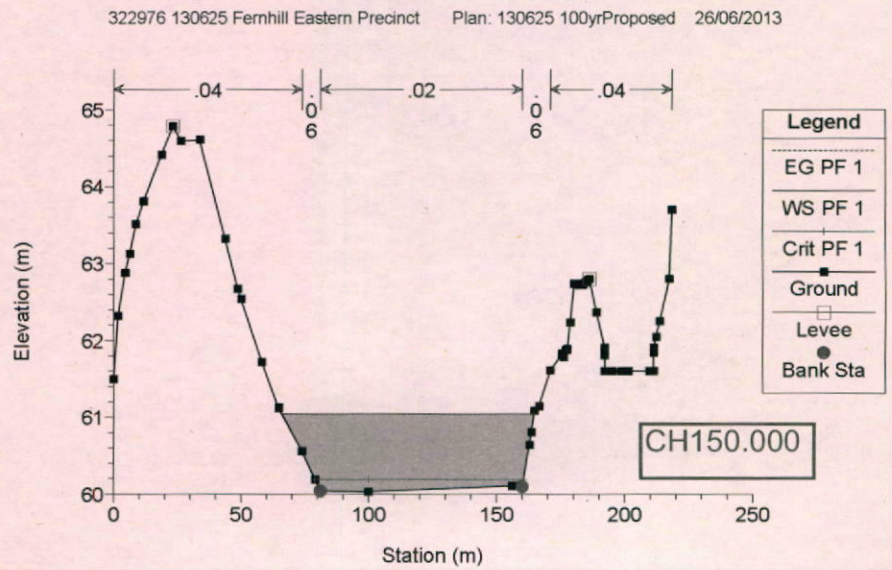
322976 130625 Fernhill Eastern Precinct Plan: 130625 100yrProposed 26/06/2013
.04
0
6
.02
.06
.04
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
CH296.341
Elevation (m)
Station (m)



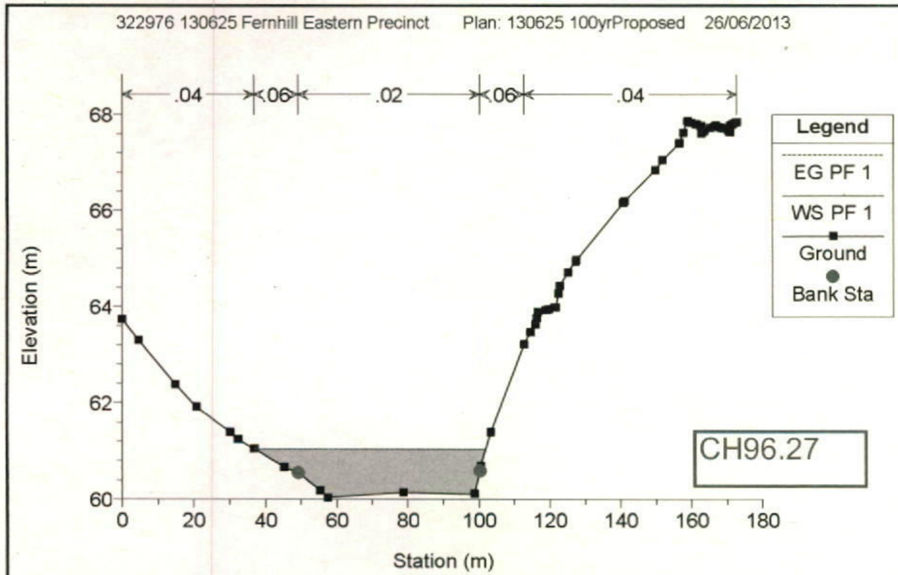
322976 130625 Fernhill Eastern Precinct Plan: 130625 100yrProposed 26/06/2013
.04
0
6
.02
0
6
.04
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
CH250.000
Elevation (m)
Station (m)

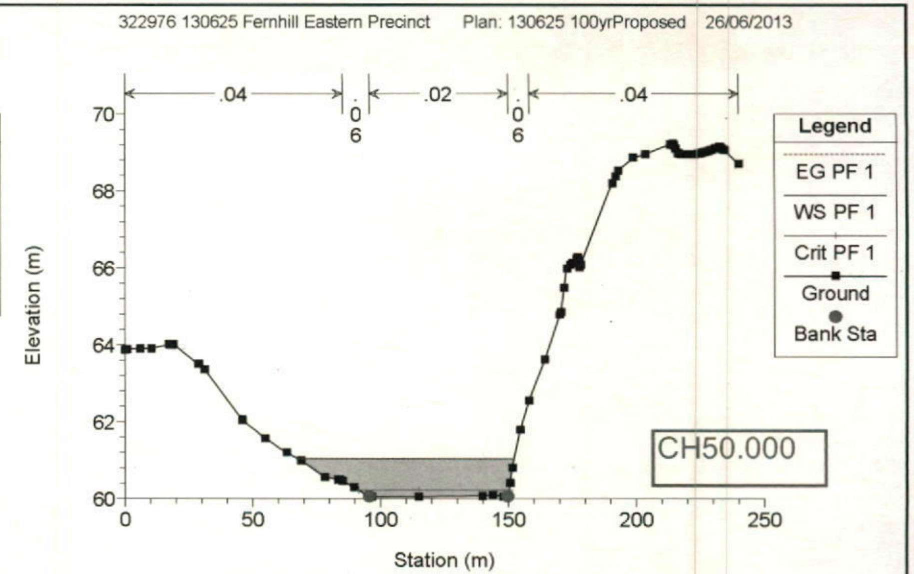


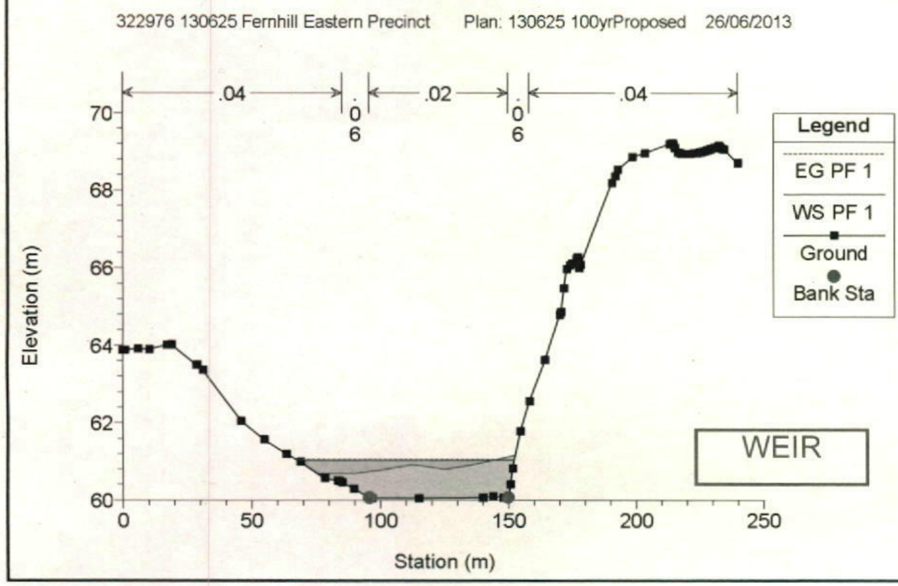
322976 130625 Fernhill Eastern Precinct Plan: 130625 100yrProposed 26/06/2013
.04
0
6
.02
0
6
.04
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
CH200.000
Elevation (m)
Station (m)

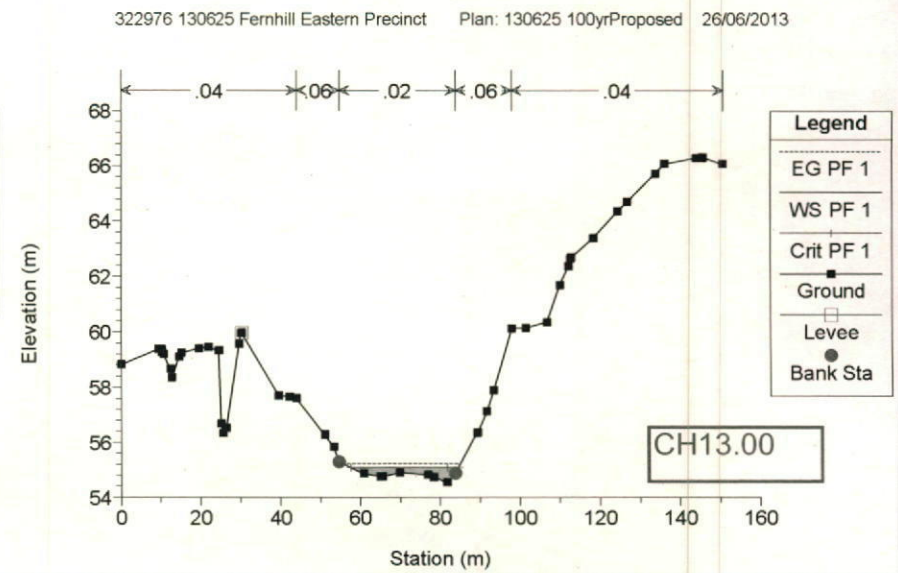


322976 130625 Fernhill Eastern Precinct Plan: 130625 100yrProposed 26/06/2013
.04
0
6
.02
0
6
.04
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Levee
Bank Sta
CH150.000
Elevation (m)
Station (m)


322976 130625 Fernhill Eastern Precinct Plan: 130625 100yrProposed 26/06/2013
.04 .06 .02 .06 .04
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
CH96.27
Elevation (m)
Station (m)


322976 130625 Fernhill Eastern Precinct Plan: 130625 100yrProposed 26/06/2013
.04 .06 .02 .06 .04
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Bank Sta
CH50.000
Elevation (m)
Station (m)


322976 130625 Fernhill Eastern Precinct Plan: 130625 100yrProposed 26/06/2013
.04 .06 .02 .06 .04
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
WEIR
Elevation (m)
Station (m)


322976 130625 Fernhill Eastern Precinct Plan: 130625 100yrProposed 26/06/2013
.04 .06 .02 .06 .04
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Levee
Bank Sta
CH13.00
Elevation (m)
Station (m)