Stormwater Detention Strategy

Central Precinct

89914020

Prepared for
Lend Lease

23 January 2017

Cardno
Shaping the Future

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1.0	10-05-16	Internal Draft	S. Gribble	S. Porter
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Executive Summary

Under pre-development conditions, the Central Precinct was predominately pervious in nature. The urbanisation of the Central Precinct that is planned to occur under the Central Precinct Plan will result in the landform being altered and an increased proportion of the site becoming impervious. The change in land use would have the potential to impact on stormwater runoff volumes downstream of the development.

The impact of altering the existing landform has been subject to numerous hydrologic and hydraulic studies. Ultimately, it was proposed to Penrith City Council that the proposed alteration of the pre-development Central Precinct landform would not result in adverse impacts on downstream waterbodies or downstream properties for rainfall events up to and including the 1% Annual Exceedance Probability (AEP).

An assessment was submitted to Penrith City Council in the form of a merit based assessment. The merit based assessment sought to remove the requirement of on-site detention (OSD) from the Central Precinct development. The merit based assessment is included at Appendix C of this report.

No written correspondence was provided by Penrith City Council regarding the outcomes of their assessment of the merit based assessment. However, it is understood that the merit based assessment was rejected for reasons associated with the cumulative impacts of development within the South Creek catchment.

In order to remain consistent with the 2009 Precinct Plan and to off-set the potential impacts of the change of land form within the Central Precinct a position of compromise was established between Penrith City Council personnel and Lendlease. The position of compromise is summarised as the following:

The potential downstream impacts of the Central Precinct development are to be off-set by the provision of a suitable stormwater detention volume within Basin I (located within the Regional Park).

This report summarises the hydrologic and hydraulic investigations undertaken by Cardno to determine a preliminary estimate of detention volume to be provided within Basin I to offset the impacts of the Central Precinct development on downstream watercourses. The investigations established that the required volume of storage within Basin I is highly sensitive to assumptions regarding lag times between Basin I and the existing watercourse that will link Basin I to South Creek.

Based on conservative assumptions, it is estimated that approximately 50,000 m^3 of active detention storage is required at Basin I to off-set the potential impacts of the development at Central Precinct. However, the final volume of storage required is particularly sensitive to assumptions regarding in-stream velocities for the existing watercourse linking Basin I to South Creek. It is recommended that additional investigations be completed in consultation with Penrith City Council personnel to agree upon appropriate lag time assumptions prior to a development application submission for Basin I.

Preliminary design of Basin I has been undertaken and this report demonstrates that the approximate volume of 50,000 m^3 of active storage can be reasonably accommodated within the nominated Basin I footprint with no adverse impact on its proposed water quality improvement function.

The delivery of Basin I will be protracted and will require a number of standalone environmental approvals prior to construction activities commencing. Accordingly, a series of interim strategies have been assessed to demonstrate that the potential impacts of the Central Precinct development can be off-set by utilising temporary storage basins within the Central Precinct development footprint, until Basin I is constructed..

Basin I would not need to be operational until such a time as the riparian corridor within the Central Precinct is converted from a temporary sediment basin to a riparian corridor. Based on previous Conditions of Consent issued by Council, it is reasonably assumed that the temporary sediment basin will not be converted to a riparian corridor until such a time where 80% of the contributing catchment is occupied. Based on the current project programme, it is estimated that this will not occur until the first quarter of 2019 (calendar year).

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1 Introduction

This report has been prepared to address Consent Condition No. 69 associated with DA 15/0299. Condition No. 69 states that:

> *"Prior to the issue of a Construction Certificate, a detailed report is to be prepared and submitted to Penrith City Council for approval that demonstrates stormwater flows for all events up to and including the 1% ARI from the development site will have no adverse impact upon the downstream properties and existing waterbodies."*

It is important to note, that a position of compromise was negotiated between Penrith City Council and Lendlease representatives such that Construction Certificates could be issued prior to the finalisation of this report. However, Subdivision Certificates would be retained until such a time as a detailed report outlining a detention strategy to off-set the potential impacts of the Central Precinct development was submitted and endorsed by Council.

Penrith Council has advised that On-Site Detention will need to be provided in accordance with Penrith City Council's Development Control Plan (2014). Section C3 of Penrith DCP includes the following controls:

> "a) Adequate stormwater systems shall be designed and constructed to ensure that, for all rainwater events up to and including the 1:100 Average Recurrence Interval (ARI) event, new developments and redevelopments do not increase stormwater peak flows in any downstream areas…
>
> d) On-site detention systems are to be designed using a catchment wide approach."

The provision of detention does not necessarily result in less adverse impact on downstream properties and existing waterbodies. There are 2 reasons for this as follows:

- Peak flows in South Creek downstream of the Central Precinct are impacted by the timing of peak flows from Central Precinct and other nearby sub catchment relative to the timing of peak flows in South Creek. Detention may decrease the relative differences in timing.
- More critical flood levels (i.e. tailwater) in South Creek downstream of Central Precinct in the 5% AEP and larger events are due to backwater from the Hawkesbury River. The provision of detention within the Central Precinct will have no impact on the Hawkesbury River backwater flood levels.

As part of the Development Applications for the bulk earthworks and Stage 1 civil works, a merit based assessment (Jacobs 2014) of on-site detention was prepared and submitted to Council for consideration. The merit based assessment demonstrated that detention within the Central Precinct increased peak flows in South Creek due to decreasing the time difference between the Central Precinct runoff hydrograph and the South Creek hydrograph. As such, it was argued that the removal of OSD from the Central Precinct footprint could result in a positive outcome for peak flows and water surface levels downstream of the development.

Notwithstanding, Council cited the cumulative impacts of the proposed approach being considered across the full extent of the South Creek catchment and nominated that suitable measures should be incorporated to limit downstream peak flow increases resulting from the development of the Central Precinct.

In preparing this assessment, a control point approximately 300 m north of the Central Precinct has been adopted. The nominated control point is immediately downstream of the junction between South Creek and a tributary which traverses the future Regional Park. This tributary captures stormwater runoff from existing urban development to the south of the St Marys Development site, a portion of the Central Precinct catchment, the Jordan Springs catchment and the Regional Park.

The control point is nominated in Figures 4-1 and 4-2.

It should be noted that this is a strategy report only. More comprehensive modelling and analysis is required to refine infrastructure requirements and is to be undertaken as part of future development application and construction certificate stages.

2 Pre-Development Catchment Characteristics

2.1 Pre-Development Drainage Overview

The Central Precinct forms part of the St Marys development site and covers an area of approximately 135 hectares. The Central Precinct will be bound by a future Regional Open Space to the east, Regional Park to the north and west and existing urban development to the south.

Under pre-development conditions the Central Precinct is largely pervious with a number of natural and constructed watercourses that drain the site towards South Creek which is located to the east of the Central Precinct. These watercourses also convey stormwater runoff from two urban catchments that are located to the south of the Central Precinct.

Under pre-development conditions the Central Precinct site is noticeably flat. Elevations vary between approximately 18 – 25 mAHD (excluding stockpiles). There is locally high ground in the south-western corner of the Central Precinct that has a maximum elevation of 40 mAHD. The existing natural and constructed watercourses on the site are largely inefficient in manoeuvring stormwater towards South Creek, an assertion that was supported by areas that remained “boggy” for extended periods after a rainfall event.

2.2 Pre-development Watercourses

The major watercourses external to Central Precinct are South Creek to east and an unnamed tributary of South Creek, referred to in this report as the ‘Western Tributary’. The latter joins South Creek to the north east of the Central Precinct

The Central Precinct drains towards South Creek via a network of open channels and road side table drains. The most significant water courses within the Central Precinct are illustrated in Figure 2-1 and described in Table 2-1.

Figure 2-1 Significant Pre-Development Water Courses within Central Precinct

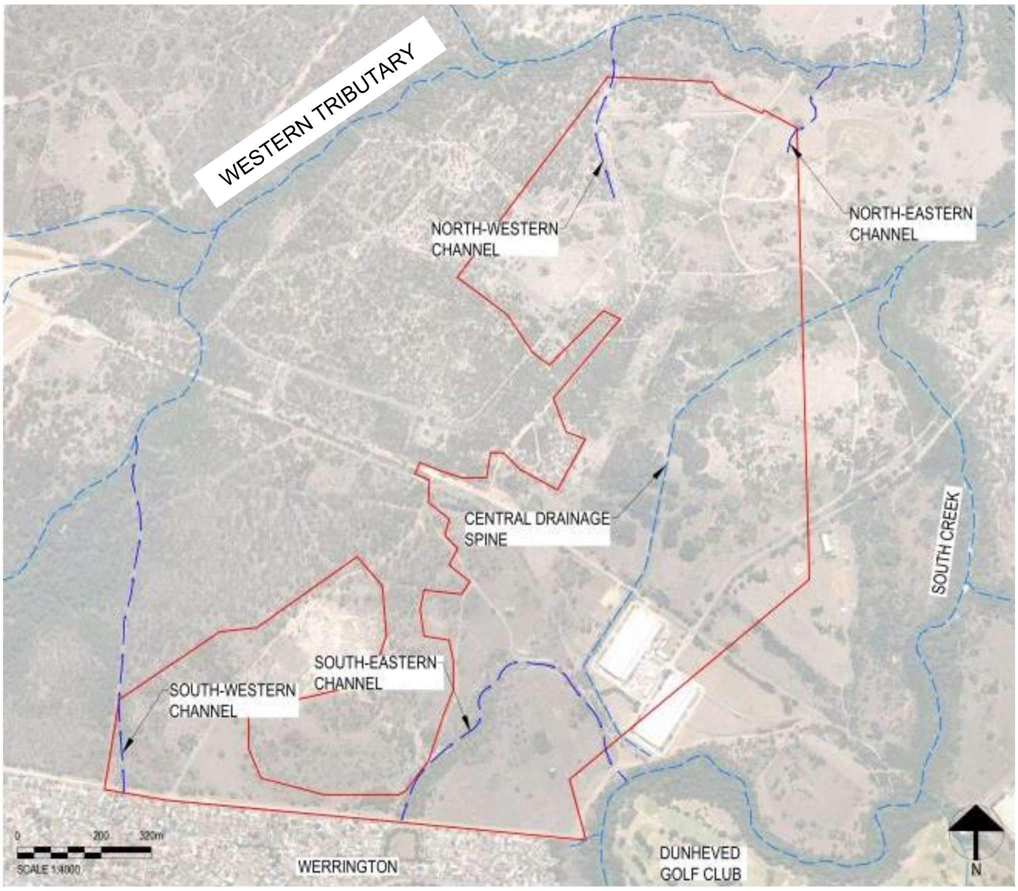

Table 2-1 Significant Water Courses within Central Precinct

Water Course Identification	Attributes
North-western channel	The north-western channel drains in a northerly direction towards the Western Tributary of South Creek.
North-eastern channel	The north-eastern channel drains in a northerly direction towards the Western Tributary. The channel appears to be natural and contains no drainage assets or structures.
Central drainage spine	The central drainage spine is an identified water course on the 1:25,000 topographic maps. The channel is manmade, primarily earth-lined and commences immediately to the south of the existing warehouses before draining in a north-easterly direction towards South Creek. The channel crosses two existing roads via concrete box culverts and passes under a series of timber bridges in the vicinity of the existing warehouses.
South-eastern channel	The south-eastern channel commences at the southern boundary of the site where an external catchment discharges into it via Council's existing drainage network. The channel then drains north a short distance before turning south east and discharging into South Creek.
South-western channel	The south-western channel commences at the southern boundary of the site where an external catchment discharges from Council's existing drainage network. The watercourse generally drains in a north-westerly direction towards the Western Tributary within the Regional Park. The channel transitions from a man-made earth channel to a very shallow watercourse with very little capacity.

2.3 Pre-development catchments

Pre-development catchments, both internal and external catchments included in the RAFTS model are shown on Figure 4-1.

2.3.1 External

There are two residential catchments draining into Central Precinct from the southern suburb of Werrington County. Other residential catchments from Werrington Downs and Cambridge Gardens are included in the Western Tributary catchment. Table 2-2 summarises these catchments.

Table 2-2 Southern External Catchments

RAFTS Node	Area (ha)	Drains to	Detention Basin
1.00	24	South Creek via Central Precinct south eastern channel	Leichardt Avenue
2.20	21	Western Tributary via Central Precinct south western channel.	None
2.00	84	Western Tributary.	Jim Anderson Park
2.10	163	Western Tributary	None
2.30	9	Western Tributary	None

In addition to the catchments to the southern external catchments, Jordan Springs and the southern portion of Llandilo drain to the western Tributary.

Some areas of the regional park to the west of the Central precinct also drain into the Central Precinct. However in the pre-development scenario these later catchments were not split from the internal catchments described below as due to the flat topography it was not possible to define subcatchment boundaries.

2.3.2 Internal

The internal catchments are associated with the significant pre-development watercourses listed below in Table 2-3.

Table 2-3 Pre-Development Internal Catchments

RAFTS Nodes	Area (ha)	Water Course Identification	Description
X5.0	12	North-western channel & North-eastern channel	Include large stockpiles. The catchment boundary between the channels is not clear, primarily due to stockpiles.
X3.0, X3.1	32	Central drainage spine	The developed areas of the Central Precinct including the Warehouses drain to this man-made channel
X4.0	82	Multiple minor channels	This large catchment of 82ha consists of sloping ground to the west and very flat boggy ground to the east. There appears to multiple channels rather than one distinct drainage path.
1.01	38	South-eastern channel	Relatively well defined catchment to south of the 'developed area'
2.21	10	South-western channel	Mostly cleared in pre-development scenario. No existing structures. Mostly sloping.

3 Proposed Catchment Characteristics

3.1 Central Precinct Grading Strategy

The Grading Strategy for Central Precinct has been based on the following objectives:

> To ensure all roads and lots are above the 1% AEP flood level. This objective has required the importation of significant volumes of fill;

> Inclusion of a central Riparian Corridor. The riparian corridor replaces both the south eastern channel and the central drainage spine;

> Minimum road grading of 0.7%.

3.2 Proposed Drainage Features

The key drainage features within the Central Precinct that will be permanent include a riparian corridor, a drainage reserve and a number of dry bio-filtration basins located strategically throughout the development. The riparian corridor is the main trunk drainage line. Conventional pit and pipe drainage networks convey runoff to the trunk drainage features.

3.3 Proposed Catchments

Proposed catchments included in the Hydrologic modelling are shown on Figure 4-2.

3.3.1 <u>External</u>

External catchments will remain mostly unchanged as the result of the proposed development.

The exception is the Werrington County catchment draining to the Leichardt Avenue detention basin (Node 1.0). The detention basin will need to be modified in order to make way for a bus link. Also this catchment now drains to the new central riparian corridor with the south eastern channel no longer remaining.

The Jordan Springs and Llandilo catchments have not been included in the Pre-Development or Post-Development hydrologic models as the objective of this strategy report was to consider the impact of the Central Precinct on peak flows separately from other precincts as per the 2009 Precinct Plan This is considered acceptable for a strategic level assessment to check whether the strategy is feasible, especially as the Jordan Springs development has detention basin to ensure there is no increase in peak flows. A complete holistic catchment analysis including the Jordan Springs, Llandilo and Cranebrook catchments is to be carried out as part of future development application and construction certificate stages.

3.3.2 <u>Internal</u>

There are 17 internal catchments consisting of pit and pipe networks that have been included in the Post Development RAFTS models. The stormwater pipe networks discharge to one of the following locations:

> The riparian corridor (45ha). There is also 50ha of regional park that drains to the riparian corridor;

> Directly to South Creek (31ha);

> The south western channel (12ha); and

> The Western Tributary at the northern end of the development (26ha). In additional 5ha of regional park discharges at this location.

4 Hydrologic Modelling

4.1 Hydrologic Model

Design flows were calculated using the XP-RAFTS software package. XP-RAFTS is rainfall runoff model that uses the Laurenson storage routing method to generate hydrographs from rainfall. It can model both urban and rural catchments as well as detention basins. Thus it is an appropriate software package for comparing pre-development and post-development flows for a sub-division such as Central Precinct.

4.2 Model Setup

4.2.1 Model Schematisation

RAFTS models were set up for both the pre-development and fully developed scenarios for Central Precinct. They include both the western (i.e. those sub-catchments draining to the western tributary) and eastern (i.e. subcatchments draining to the riparian corridor and South Creek) catchments. The extent of each catchment included in the model was only as far as the extent of the Central Precinct works. The Western Tributary was only modelled to just downstream of the Jordan Springs Connector Road.

The Jordan Springs and Llandilo catchments were not included as part of this assessment as peak discharges from these catchments are currently being finalised through a separate approval pathway. However it is acknowledged that the peak flow discharges from the Jordan Springs and Llandilo catchments will need to be calculated and incorporated into detailed design documentation for Basin I.

Lag links were included to route the modelled hydrograph to the downstream reference point — the confluence of the western tributary and South Creek.

The catchment subdivision for the pre-development scenario was based on flow patterns and topography. Survey contours were used for sub-catchments within the development area whilst 2m GIS contours were used to define external sub-catchments. For the post development model, the sub-catchments were based on the design site grading and stormwater network. Figures 4-1 and 4-2 show the sub-catchments for the pre-development and post development scenarios respectively.

Sub-catchments were assigned a fraction impervious based on different types of land use. Table 4-1 lists impervious fractions were used for different types of land use.

Table 4-1 Catchment Impervious Fractions

Land Use	% Impervious
Existing residential:	60%
Urban Open space	5%
Central Precinct Residential	80%
Central Precinct Employment Zone	90%

4.2.2 Links

The majority of Links in the model in the model were lag links. The velocities used to calculate the lag times were based on the following methods or sources:

> Table A.2 of the Worley Parsons (2014) *Updated South Creek Flood Study*. It is noted that the Manning's 'n' used to calculate the velocity for the Western Tributary seems low for a creek with heavily vegetated banks.

> HECRAS models set-up by Cardno for design purposes.

> A default value of 1m/s was adopted where a more accurate velocity estimate was not available.

Appendix A contains details of the lag time calculations for the links.

Field inspection and survey indicates that the watercourses upstream of the Jordan Springs Connector Road are quite shallow with flat wide overbank areas. So the routing link option was used to model these links. Cross-sections were derived from Lidar survey data. Manning's 'n' values of 0.06 for the channels and 0.09 for the overbank areas were adopted.

4.2.3 Basins

A number of formal and informal detention basins were included in the RAFTS model. These included the following.

- The Leichardt Avenue Detention Basin was included in the pre-development model. As this basin needs to be modified in order to accommodate the proposed bus route it was excluded from the post development model. The stage storage table was calculated from the survey DTM;
- The area upstream of the Jordan Springs Connector Road is relativity flat. Thus there is the possibility of significant volume of ponding behind the road embankment. So this road crossing was included in the RAFTS model as a basin. The stage storage table was derived from Lidar data. The stage-discharge relationship was determined by HECRAS modelling of the existing and proposed culverts.
- The Central Precinct bio-retention basins were included in the fully developed model. As these basins have not been designed as detention basins, they were found to have negligible value in attenuating peak flows.

The existing detention basin in Jim Anderson Park was not included from the in the model as no information was available about the basin outlet. The inclusion of this basin would make no difference when comparing pre-development flows with post development flows.

4.2.4 Hydrologic parameters

Hydrologic parameters including rainfall intensities, loss rates, and catchment roughness values were consistent with those adopted in the *St Marys (Byrnes Creek) Catchment Detailed Overland Flow Flood Study* (Cardno 2015). Rainfall intensities from Penrith Council (2013) were used. The adopted loss rates are as shown in Table 4-2. The exception to these loss rates was when modelling the 36 hour duration storm the same pervious area initial loss adopted by Worley Parsons (2015) was used.

Table 4-2 Loss Rates

Rainfall Loss Rate	Impervious Area	Pervious Area
Initial Loss (mm)	1.5	10
Continuing Loss (mm/hr)	0	1.5

The Manning's 'n' or PERN parameter was used to distinguish between different types of surface roughness in the different sub catchments. Table 4-3 summaries the adopted surface roughness values.

Table 4-3 Adopted PERN Values

Catchment Type	Adopted Value	RAFTS Manual Recommendation
National park	0.08	0.1 (1)
Pre-Development Central Precinct	0.03	
Impervious	0.015	0.015 (2)
Developed pervious	0.04	0.04 (2)

(1) Version 5 (1996) RAFTS-XP Manual; (2) 2009 RAFTS-XP Manual

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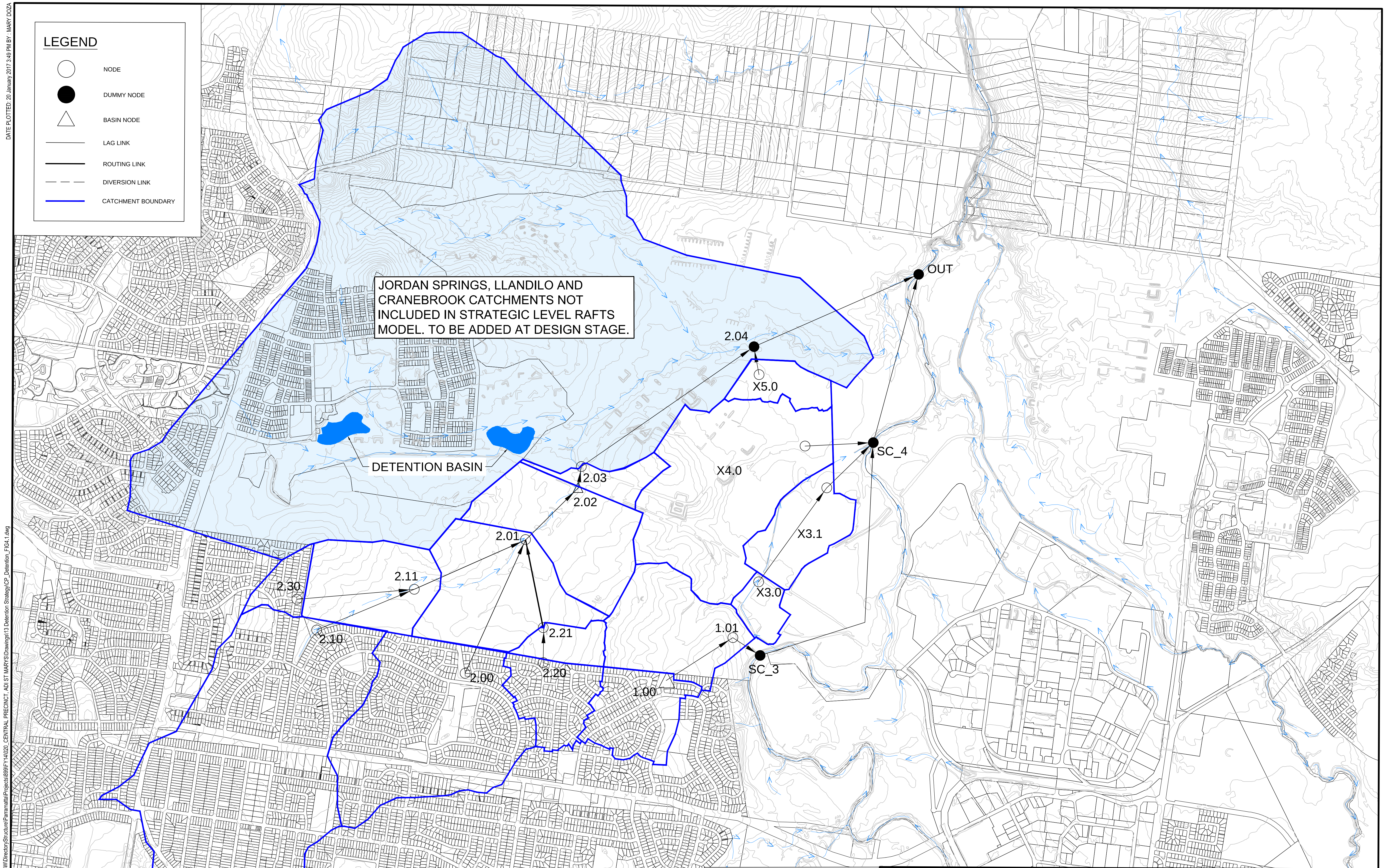

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CENTRAL PRECINCT
FIGURE 4.1
PRE DEVELOPMENT RAFTS NETWORK & CATCHMENT PLAN

Date	Scale	Size
20/01/2017	1:20000	A3

Drawing Number	Revision
FIGURE 4-1	01

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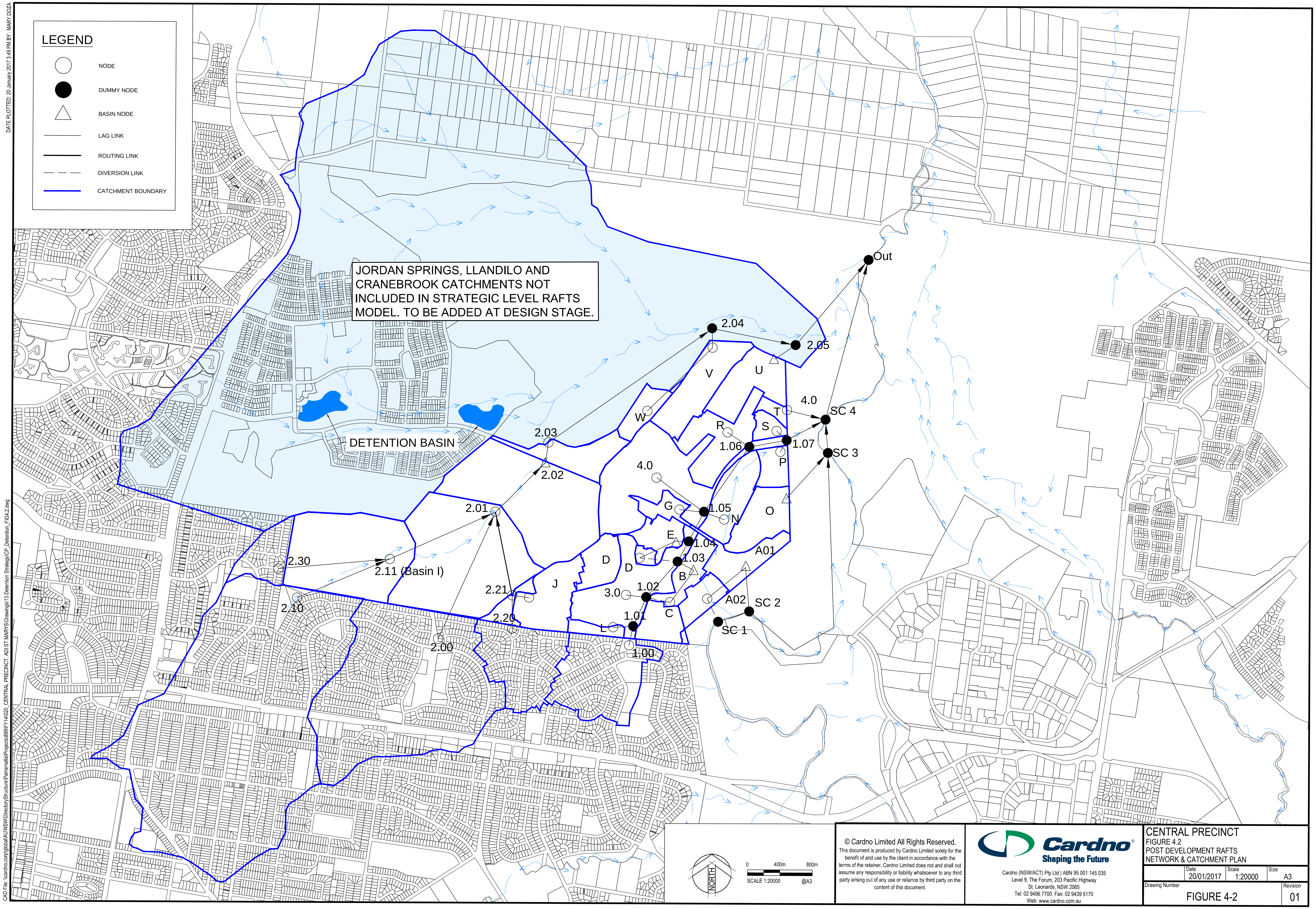

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CENTRAL PRECINCT
FIGURE 4.2
POST DEVELOPMENT RAFTS
NETWORK & CATCHMENT PLAN

Date	Scale	Size
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Drawing Number	Revision
FIGURE 4-2	01

5 Results

5.1 General

Design storms ranging in duration in 25 minutes to 3 hours from Australian Rainfall and Runoff (1987) were applied to the RAFTS-XP model to generate design flow hydrographs. Annual Exceedance Probabilities (AEP) ranged from 1:2 to 1:100. Additional durations of 9 hours and 36 hours were also modelled for the 1% AEP.

It was found that the 2 hour storm duration rainfall pattern resulted in the maximum peak flow. Table 5-1 compares the maximum pre-developed and post developed flows. Peak flows for each storm of 44 storms analysed are at Appendix B along with detailed RAFTS output for the 1:100 AEP 2 hour storm.

Table 5-1 Maximum Pre-Development and Post Development Peak Flows

AEP	Outlet Node		Eastern Catchment		Western Tributary	
	Pre Development	Fully Developed	Pre Development	Fully Developed	Pre Development	Fully Developed
50%	28.7	50	4.8	11.7	24.0	29.7
20%	37.2	50.2	7.2	16.1	30.4	41.1
10%	45.4	59.9	8.7	18.7	36.8	48.4
5%	54.7	65.1	11.7	22.2	43.5	53.1
2%	67.8	76.4	14.1	25.6	53.8	62.2
1%	80.2	88.1	16.9	29.1	63.4	71.5

The peak flows on the western tributary are about 80% of the total peak flows at the confluence. Peak flows on the eastern catchment increase from about 20% of the total peak flows in the pre-development scenario to about a 33% in the post development scenario.

5.2 Jordan Springs Connector Road

On the eastern catchment the flow increase is due the increased impervious area. However on the western catchment, the increased flows are primarily due to the increase in culvert capacity under the Jordan Springs Connector Road resulting in a loss of detention storage behind the road embankment. Table 5-2 shows the impact of the increased culvert capacity.

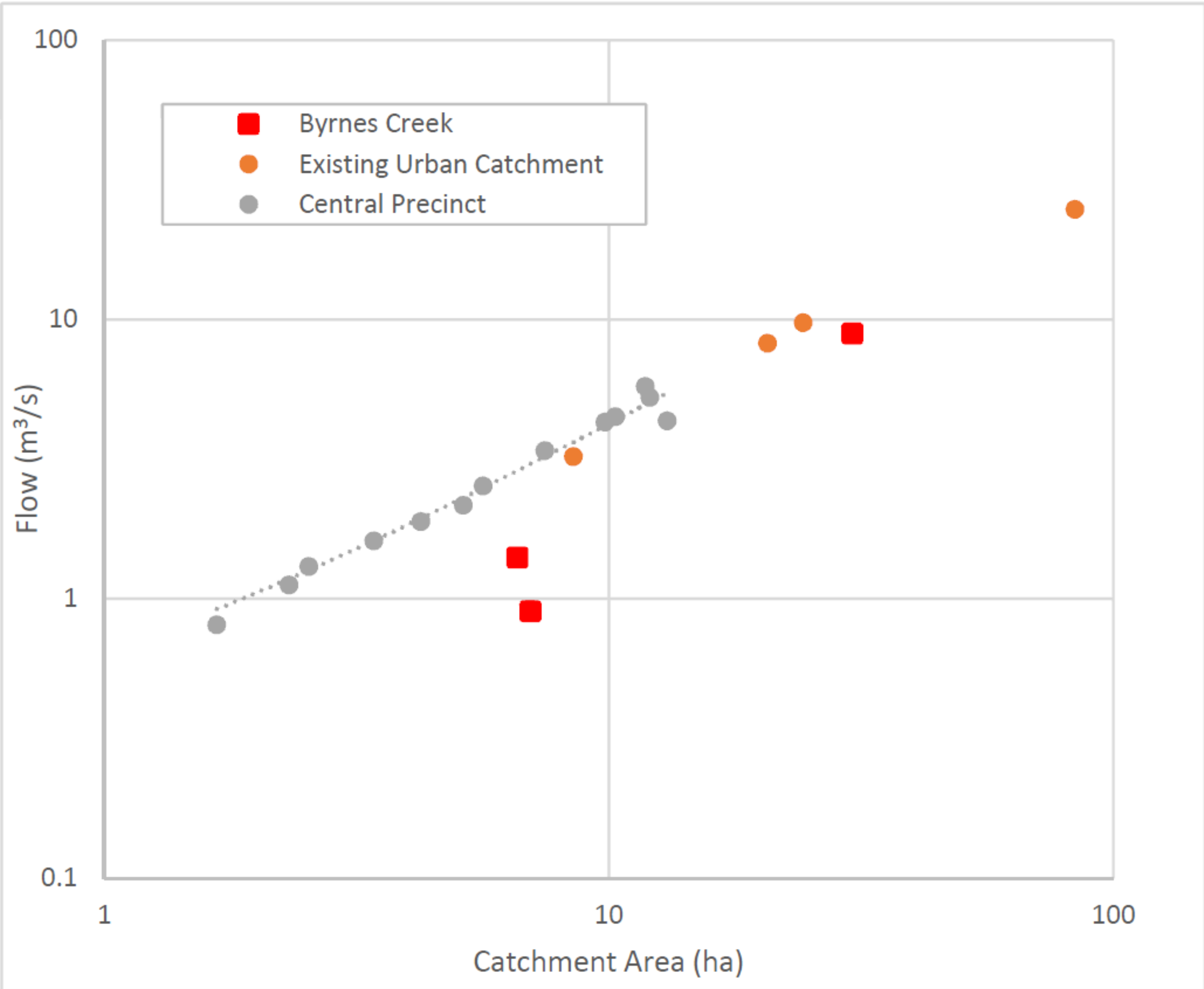
Table 5-2 Impact of Jordan Springs Connector Road

AEP	Pre Development Flows (m^3/s)		Post Development Flows (m^3/s)	
	Upstream of Road	Downstream of Road	Upstream of Road	Downstream of Road
50%	27.3	23.3	28.7	28.6
20%	38.2	29.2	39.8	39.5
10%	44.9	35.3	46.6	46.5
5%	50.4	41.8	51.1	51.0
2%	58.7	51.7	59.9	59.6
1%	67.9	60.9	69.0	68.6

5.3 Validation of Results

The 100 year ARI peak flows produced by the RAFTS model were plotted alongside peak flows from the *St Marys (Byrnes Creek) Catchment Detailed Overland Flow Flood Study* (Cardno 2015). This flood study was used for comparison purposes because of its geographical proximity. The plot of peak flows against catchment area is at Figure 3-4. A consistent relationship between peak flow and catchment area is not expected as different sub-catchments have differing slopes and impervious percentages. Figure 5-3 shows that the peak flows from the Central Precinct sub catchments are higher than those as from Byrnes Creek as would be expected due to the higher fraction impervious. However the flows are in the same order of magnitude. This shows that the flow estimates are in the expected range.

Figure 5-3 Catchment Area vs Peak Flow



6 South Creek Tailwater

6.1 Hydrograph Comparison

Hydrographs from the RAFTS model were compared with the South Creek flood hydrograph from the Worley Parsons (2009) *Updated South Creek Flood Study*. Only the 36 hours 100 year ARI hydrograph at the Ropes Creek Confluence was compared as the Worley Parsons Flood Study provides hydrographs for this event only. The primary objective of this comparison was to select an appropriate South Creek tail water AEP to be adopted for design of detention basins.

Figure 6-1 shows the hydrograph comparison. It can be seen that there is approximately 9 hours of lag time between runoff hydrographs from Central Precinct and the hydrograph for the entire South Creek catchment. Table 6-1 provides a summary of the lag time and peak flow differences.

Figure 6-1 South Creek and Central Precinct 36 hour 100 year ARI Hydrographs

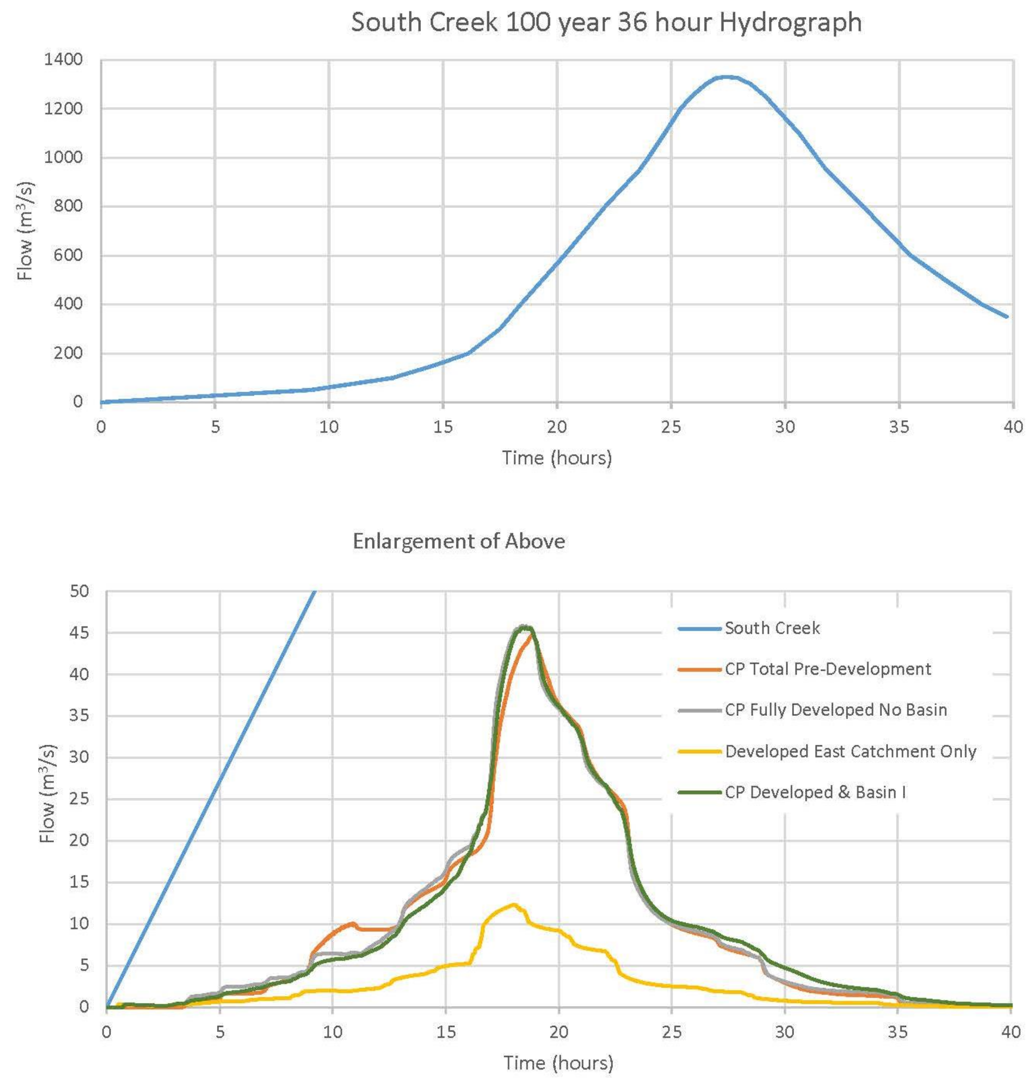


Table 6-1 Comparison of Central Precinct Runoff Hydrograph with South Creek Hydrograph.

	Peak Flow (m3/s)	Time to Peak (hours)	South Creek Flow at time of Local Peak
South Creek Flows	1331	27.4	
Total Pre-Development	41	19	460
Total Post Development	45.8	18.4	400
Total Post Development with Basin I	34.0	18.9	350

The hydrographs comparison shows:

> Runoff from the Central Precinct is not coincidence with the peak flow in South Creek. Therefore it is not appropriate to adopt peak South Creek flood levels as a tail water for the design of drainage infrastructure within the Central Precinct.

> The South Creek hydrograph is rapidly rising when the runoff from Central Precinct occurs. Therefore it would not be appropriate to disregard tailwater from South Creek when designing drainage infrastructure in the Central Precinct.

6.2 Tailwater Levels for Design

The process of determining South Creek tailwater level for the design of stormwater water infrastructure within the Central Precinct involved 2 steps as follows:

1. The first step was to select an appropriate tailwater AEP. The US Federal Highway Administration (2009) recommends that when the ratio of a tributary catchment to a mainstream catchment is 1:100, tailwater AEPs of 1:20 and 1:5 be adopted for the tributary 1:100 and 1:10 AEP flows respectively. At the Central Precinct, South Creek has a catchment area 200 times the size of the Central Precinct eastern catchment. The FHWA recommendations seem reasonable but slightly conservative when compared to the hydrograph plots in Figure 4-2. Tailwater AEP for the 2% and 5% Central Precinct storm events were determined by interpolation.
2. The second step was to determine flood levels for the AEPs selected in Step 1. Worley Parsons have only provided flood levels for the 5% AEP and rarer events. Jacobs (2016) has recently made an assessment of flows and flood levels in South Creek adjacent to Central Precinct for the more frequent events not included in the *Updated South Creek Flood Study*.

The tailwater levels adopted for the design of detention basins and other stormwater infrastructure in the Central Precinct are listed in Table 6-2. The levels are at the confluence of the Central Precinct Riparian Corridor and South Creek.

Table 6-2 South Creek Tailwater Level for Central Precinct Drainage Design

Central Precinct Local AEP	Adopted South Creek tail-water AEP	South Creek Flood Level
1%	5%	18.9
2%	7%	18.7
5%	10%	18.5
10%	20%	17.2

6.3 Impact on South Creek Flood Flows

The hydrograph plots in Figure 6-1 also show that:

> The attenuation provided by the detention basins in Central Precinct is very small compared to the peak flow in South Creek.

> At the time of the South Creek peak, the outflow from Central Precinct is higher for the case when detention is provided compared to when detention is not provided. Providing detention will result in higher flow at the peak of South Creek compared to without detention. This is consistent with the findings of Jacobs (2015).

7 Final Detention Strategy

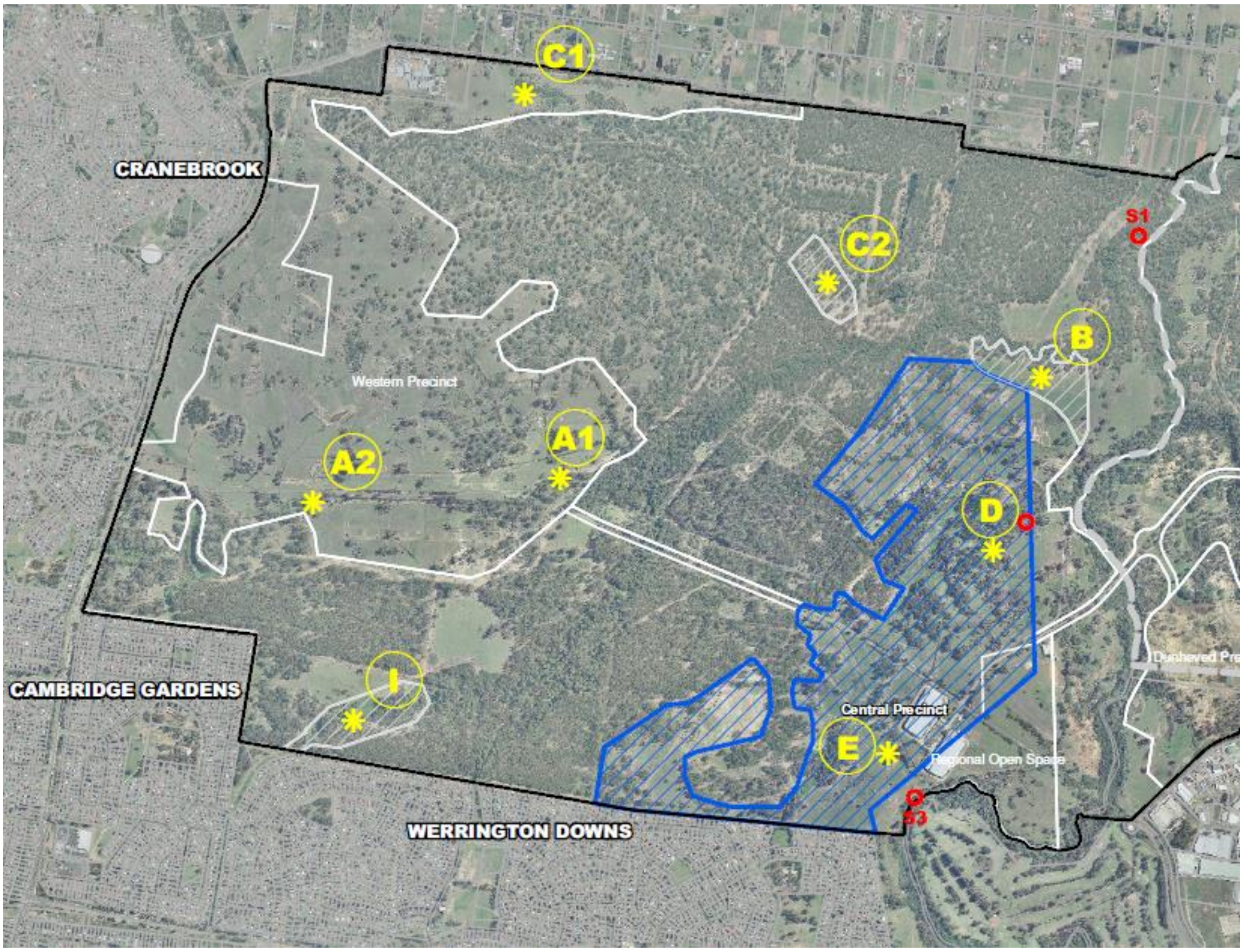
7.1 Proposed Basin Location

The development of the Central Precinct requires approximately 2,000,000 m^3 of imported fill material to elevate the site above the regional 1% AEP peak water surface level. To provide effective OSD within the Central Precinct would require the additional import of fill material to elevate basin inverts and the surrounding road networks.

To mitigate the environmental impacts associated with the additional fill volume, an alternative strategy has been proposed. An area in the south west corner of the Regional Park, near Cobbity Lane Werrington Downs, has been zoned as drainage under SREP 30. This basin site has been identified as “Basin I” within Figure 4.1 of *St Marys Project Central Precinct Plan Water, Soils and Infrastructure Report*, SKM, May 2009. An extract of this Figure is shown at Figure 7-1.

It is intended that this basin would be a water quality wetland with provision for active stormwater detention during high flows.

Figure 7-1 Location of Basin I (from SKM 2009)



7.2 Concept Design

The plan area required for Basin I will be determined by water quality objectives. Basin I has an upstream catchment of 206 hectares. Based on the preliminary sizing chart in Landcom (2009) Water Sensitive Design Guidelines a wetland would require a macrophyte zone area equivalent to 3% of the upstream catchment in order to meet Penrith Council’s stormwater pollution reduction targets. This gives a required area of 6.2ha. (Note: under a proposed land transfer to National Parks the footprint of Basin I may be increased to approximately 10ha.)

Detailed ground survey has not yet been undertaken at this location. A concept design has been prepared based on GIS contour information. The concept basin has a base area of 6.5 ha to allow for bunds and open water areas.1 A detention depth of 1m was adopted. The outlet consists of a 900mm x 1800mm grated pit for low flows and an 80m wide weir for higher flows. The concept basin is shown on Figure 7-1.

Further refinement of the design will be undertaken after detailed ground survey is completed.

7.3 Hydrologic Modelling

The Basin was modelled in the Post Development RAFTS model. The basin corresponds with RAFTS node 2.11 and a basin was added at this node. The results are shown in Table 7.1. It can be seen that the proposed basin is a feasible solution to reduce peak flows downstream of Central Precinct to pre-development values or less. However the final flows values for entire catchment draining to South Creek needs to be recalculated at the design stage.

Table 7-1 RAFTS results for Basin I

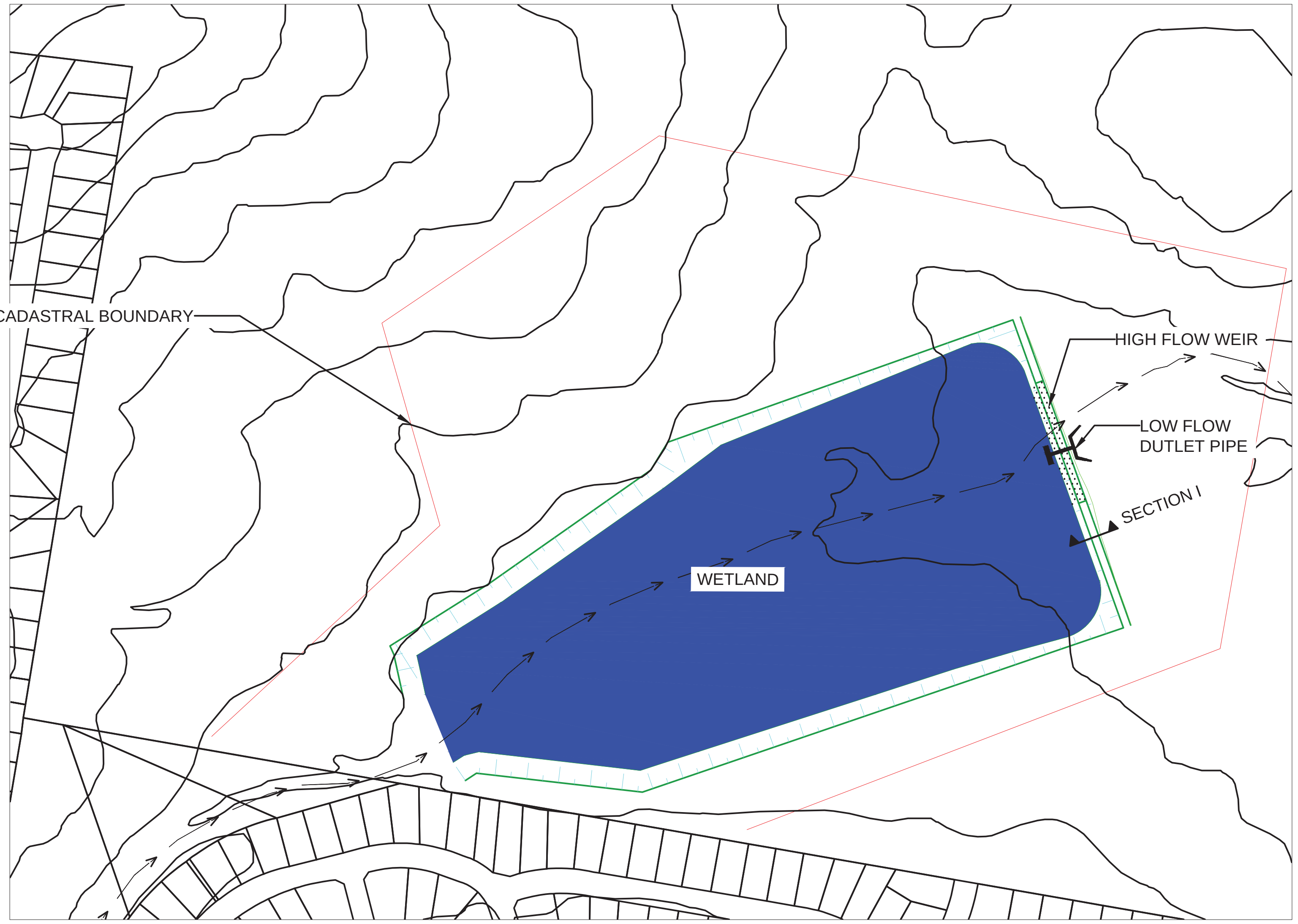
AEP	Basin I Results			Flow at Outlet Node (m^3/s)	
	Inflow (m^3/s)	Ouflow (m^3/s)	Storage (m^3)	Pre-Development	Developed with Basin I
50%	24.6	4.1	38,700	28.7	19.2
20%	33.2	9.1	43,700	37.2	28.4
10%	38.3	12.3	46,000	45.4	34.1
5%	45.4	17.1	49,000	54.7	41.2
2%	51.1	22.0	51,700	67.8	52.2
1%	58.3	25.9	53,700	80.2	63.2

7.4 Water Quality Impact

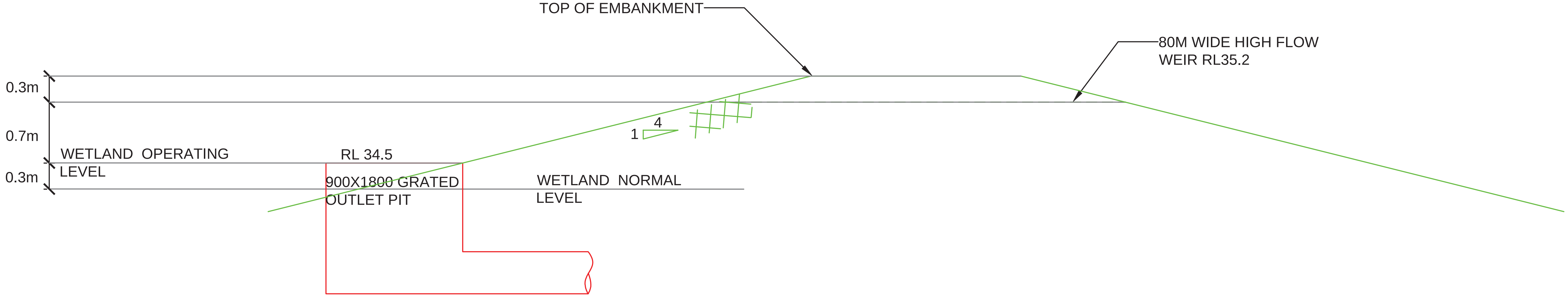
The site of the proposed wetland and detention basin contains an existing wetland. However the existing wetland is in a degraded condition, presumably as it cannot cope with the pollutant load from the upstream urban catchment. Figure 7-3 below shows that the existing wetland collects litter and is covered in an algal bloom.

A larger wetland, pre-treatment measures and a detention basin would enable the site to better cope with the stormwater pollutant loads from Werrington Downs. This will provide an improved local environment for fauna using the wetland as well as improved water quality downstream through the regional park.

[1] Note: under a proposed land transfer to National Parks the footprint of Basin I may be increased to approximately 10ha.



BASIN I PLAN



BASIN I OUTLET SECTION

NORTH

0 50m
SCALE 1:2000 @A3

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FIGURE 7-1
Basin I Plan and Section

DATE PLOTTED: 9 May 2016 3:49 PM BY : ROBIN ZUO
CAD File: \\cardno.corp\global\AU\NSW\Directory\Structure\Projects\899\FY14\020_CENTRAL PRECINCT_ADI ST MARYS\Drawings\13 Detention Strategy\CP_Detention_FIG5.1 NEW.dwg
XREF's: X-GIS Base

Figure 7-3 Existing Wetland at Basin I Site

(Date of Photo: 29 April 2016)

8 Interim Detention Strategy

8.1 Proposed Basin Location and Concept Design

Until such time as Basin I is constructed, development applications for Central Precinct are to confirm attenuation on a stage by stage basis. This is to be achieved by a temporary online basin within the central drainage corridor.

It is proposed to provide a detention zone above the settling zone of the most downstream sediment basin. Construction sediment control measures usually remain in place until development of a catchment is 80% complete. This sediment basin is identified as basin C on the Central Precinct bulk earthworks drawings (Cardno Drawing No.89914020-BE03-1311). This will be achieved by raising the weir by 1.2m and providing twin 600mm diameter pipes above the settling zone of the detention basin. Approval will be sought as part of the next subdivision DA for the Central Precinct. Figure 8-1 shows the concept basin.

The outlet weir was modelled in HEC-RAS to determine a stage discharge relationship. The tail water levels from Table 6-2 were used for the as the downstream boundary conditions for the HECRAS model. It was assumed that the temporary basin and sediment basin would only remain in place until the housing in the Central Precinct is 80% complete. Thus the impervious fraction in the interim scenario RAFTS model is 80% of the fully developed case. It was also assumed that the portion of the employment zone draining to the western tributary remained pervious in this scenario.

The design of the temporary basin needs to ensure that proposed residential properties have 0.5m freeboard above the 100 year ARI top water level. Therefore detailed design of the basin needs to be carried out in conjunction with the design of the adjoining roads and lots.

8.2 Hydrologic Modelling of Interim Basin

The Interim Basin was modelled in the Post Development RAFTS model. The basin corresponds with RAFTS node 1.06 and a basin was added at this node.

The results are shown in Table 8.1.

Table 8-1 RAFTS results for Interim Basin

AR	Interim Basins Results			Flow at Outlet Node (m3/s)		Eastern Catchment Flows (m3/s)	
	Inflow (m3/s)	Outflow (m3/s)	Storage (m3)	Pre-Development	Developed with Interim Basin	Pre-Development	Developed with Interim Basin
50%	7.0	0.7	17000	28.7	31.1	4.8	4.3
20%	9.2	1.1	27300	37.2	43.1	7.2	4.6
10%	10.6	1.4	33900	45.4	50.8	8.7	5.3
5%	12.5	1.9	42800	54.7	56.0	11.2	6.5
2%	14.3	5.0	47900	67.8	66.0	14.1	9.8
1%	16.4	7.0	49600	80.2	75.8	16.9	16.9

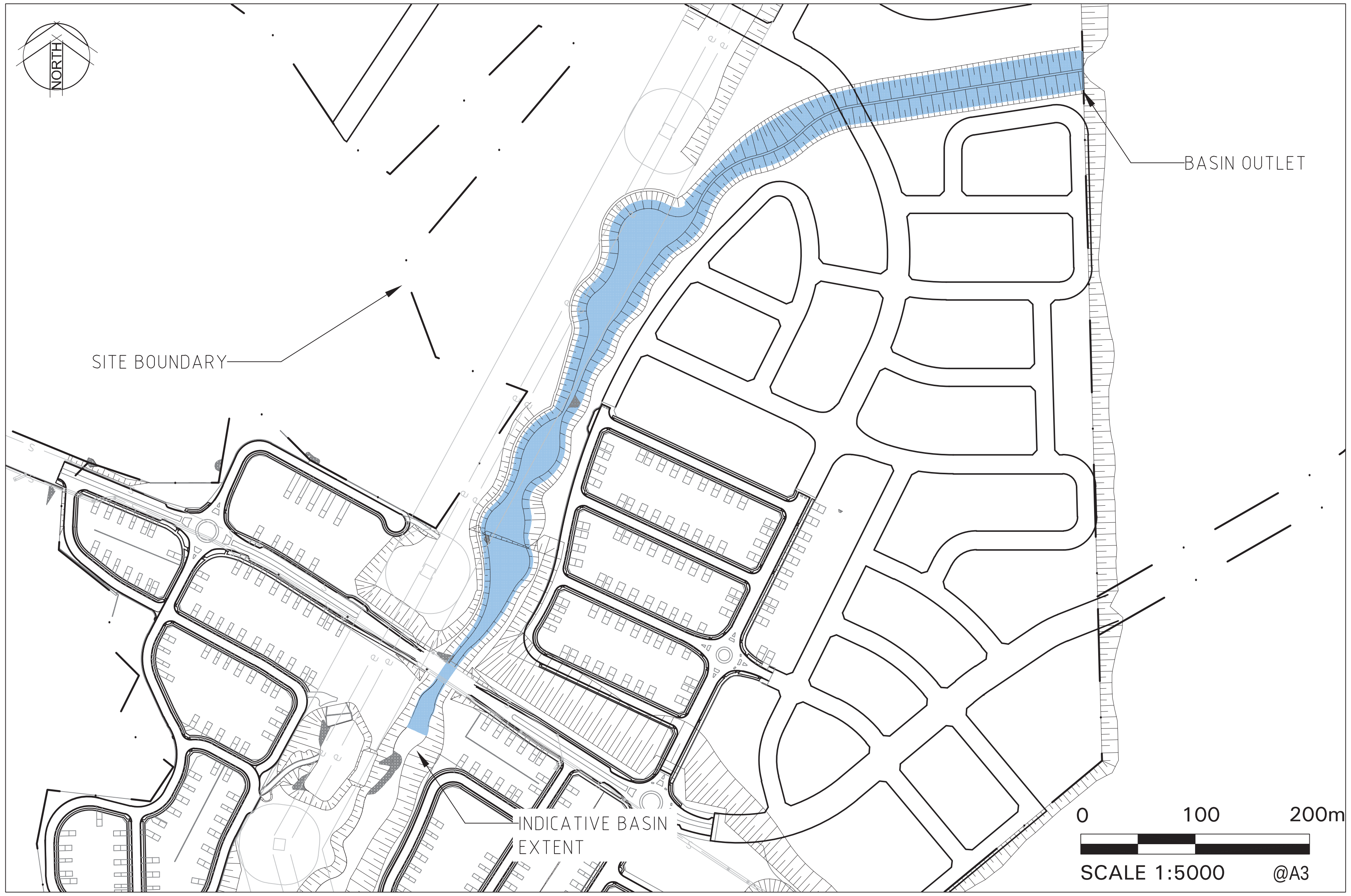
The proposed interim basin reduces flows at the confluence to pre-development measures for the 2% and 1% AEP events only. In the more frequent events, although peak flows at the confluence are reduced they are not reduced to pre-development values. When the eastern catchment is considered in isolation from the western tributary, peak flows are reduced for all AEPs.

The reason for this is that peaks from the western tributary are much larger than peak flows from the eastern catchment because of the western tributary has a much larger catchment area. Also the upgrading of the Jordans Connector culvert further increases peak flows. Therefore the western tributary has a more significant impact on peak flows at the confluence. The interim basin cannot attenuate peak flows on the western tributary and has limited value in offsetting western tributary flows.

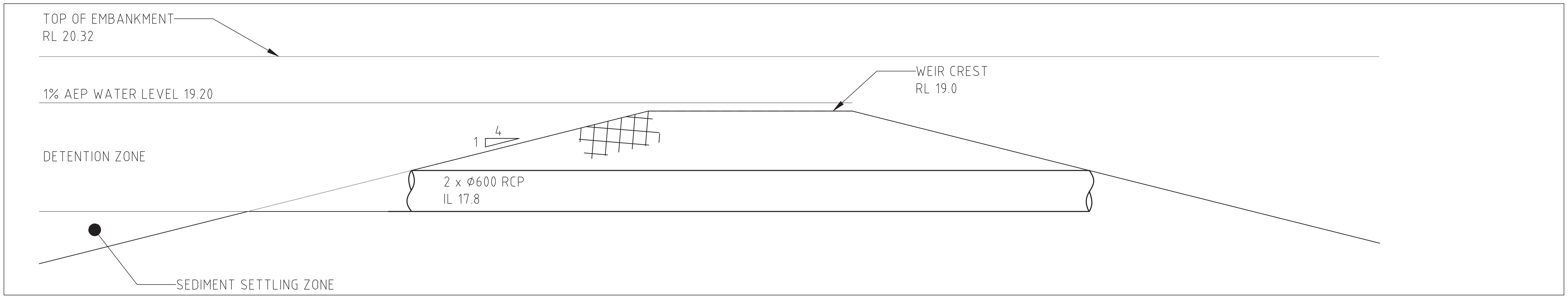
This is considered acceptable as an interim measure for the following reasons:

> it is only a temporary measure;
> the intention and wording of Condition 69 is “no adverse impact”. It is the 2% and 1% AEP events that would have an adverse impact in terms of flooding and peak flows for these events have been reduced to predevelopment values by the interim basin; and
> there is no increase in peak flows from the eastern catchment.

It also needs to be remembered that this report does not model the flow regime on the western tributary downstream of the Jordan Spring Connector Road. A more detailed assessment of this reach of the western tributary and the inclusion of the Jordan Springs and Llandilo catchments may alter the results at the confluence of the western tributary and South Creek.



INDICATIVE INTERIM BASIN EXTENTS



INTERIM BASIN OUTLET SECTION
N.T.S

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FIGURE 8-1
Interim Detention Basin

9 Conclusion

Condition No. 69 of the Central Precinct Stage 1 Development Consent requires that “a detailed report is to be prepared and submitted to Penrith Council for approval that demonstrates stormwater flows for all events up to and including the 1% ARI from the development site will have no adverse impact upon the downstream properties and existing waterbodies”

A hydrologic model has been setup to evaluate the stormwater flow from the development of the Central Precinct. It is considered that the increase in stormwater flows from the Central Precinct will not have an adverse impact downstream of the Central Precinct. Nevertheless this report proposes both temporary and permanent solutions to ensure that stormwater peak flows from the Central Precinct do not exceed pre-development flows.

The first stage of the strategy is an interim detention storage created by using additional storage above one of the construction sediment basins within the site. Hydrologic modelling demonstrates that this basin is able to attenuate peak flows to pre-development values in the 50 and 100 ARI events. This interim detention storage would remain in place until such time as Central Precinct is 80% developed or Basin I is constructed.

The permanent combined water quality and detention is proposed in the south western corner of the regional park within the drainage zone of SREP30. Hydrologic modelling demonstrates that this basin is able to ensure that stormwater peak flows from the stormwater do not exceed pre-development flows.

Further modelling and analysis is required to progress the strategy to detailed design as part of the future Development Application and Construction Certificate Stages. This includes the following steps.

1. Further hydrologic modelling of the Western Tributary with the Jordan Springs, Cranebrook and Llandilo catchments included.
2. Modelling, design and documentation of the interim basin to be included in the Development Application documentation for Stage 4 of the Central Precinct by mid-2017;
3. Detailed survey of Basin I site;
4. Development Application submission for Basin I by December 2017.
5. Construction completed for Basin I by September 2018.

10 References

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JBA (2009), *Central Precinct Precinct Plan*

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APPENDIX

A

APPENDIX A: RAFTS MODEL DATA

Table A-1 Catchment Data

PRE DEVELOPMENT CATCHMENT			
Node	Area (ha)	% Impervious	Slope
1.00	24.29	57%	5.2%
2.00	84.02	53%	1.2%
2.01	48.86	0%	0.8%
2.02	43.28	0%	1.4%
2.03	9.52	5%	2.5%
2.04	621.79	10%	0.7%
2.10	163.19	56%	3.6%
2.11	33.97	5%	1.4%
2.20	20.65	62%	3.1%
2.21	9.71	0%	3.8%
2.30	8.51	54%	2.3%
X1.01	38.35	5%	1.6%
X3.0	8.13	3%	0.3%
X3.1	23.57	5%	0.3%
X4.0	82.18	5%	0.5%
X5.0	11.80	5%	1.3%

POST DEVELOPMENT CATCHMENTS			
Node	Area (ha)	% Impervious	Slope
1.00	24.29	57%	5.2%
2.00	84.02	56%	1.2%
2.01	48.86	0%	0.8%
2.02	43.28	0%	1.4%
2.03	9.52	5%	2.5%
2.04	621.79	10%	0.7%
2.10	163.19	57%	3.6%
2.11	33.97	5%	1.4%
2.20	20.65	62%	3.1%
2.21	2.90	0%	2.5%
2.30	8.51	54%	2.3%
3.00	19.66	0%	1.7%
4.00	29.90	0%	1.8%
A.01	8.03	81%	0.7%
A.02	5.15	81%	0.6%
B	7.56	81%	1.0%
C	5.63	81%	1.2%
D	7.47	81%	0.0%
E	5.15	81%	3.4%
G	3.42	81%	2.5%
J	12.06	81%	0.0%
L	2.32	81%	3.9%
N	10.31	81%	0.8%
O	9.82	81%	1.0%
P	4.24	81%	0.8%
R	3.05	242%	0.8%
S	2.54	91%	3.2%
T	1.67	91%	0.5%
U	11.80	91%	1.4%
V	13.71	91%	0.6%
W	4.76	0%	3.5%

Table A-2 Link Lag Times

Link	Length (m)	Velocity (m/s)	Velocity Method	Lag Time
PRE-DEVELOPMENT MODEL				
1.00	900	1	Default =1m/s	15
2.02	124	0.8	HEC-RAS	3
2.03	1909	1.71	Worsley Parsons	19
2.04	500	1.71	Worsley Parsons	10
2.10	670	1	Default =1m/s	11
2.11	650	1	Default =1m/s	11
2.20	220	0.9	HEC-RAS	4
2.30	620	1	Default =1m/s	10
SC_1	2407	1.4	Worsley Parsons	27
SC_4	1228	1.4	Worsley Parsons	16
X3.0	802.00	1	Default =1m/s	13
X3.1	257	1	Default =1m/s	4
X4.0	257	1	Default =1m/s	4
X5.0				0
POST DEVELOPMENT MODEL				
1.00			HEC-RAS	1
1.01			HEC-RAS	2
1.02			HEC-RAS	5
1.03			HEC-RAS	0
1.04			HEC-RAS	12
1.05			HEC-RAS	8
1.06			HEC-RAS	3
1.07	257	1	Default =1m/s	4
2.04	500	1.71	Worsley Parsons	5
2.05	500	1.71	Worsley Parsons	5
A01	229	1	Default =1m/s	4
A02	141	1	Default =1m/s	2
O	340	1	Default =1m/s	6
T	242	1	Default =1m/s	4
U	132	1	Default =1m/s	2
V	51	1	Default =1m/s	1
SC_1	201	1.42	Worsley Parsons	2
SC_2	1962	1.42	Worsley Parsons	23
SC_3	245	1.42	Worsley Parsons	3
SC_4	1228	1.19	Worsley Parsons	17

Table B-3 Routing Links

Link	Length (m)	Slope %	Link	Length (m)	Slope %
2.00	750	0.80%	2.11	650	1.0%
2.01	470	1.1%	2.21	601	0.5%

APPENDIX

B

APPENDIX B: RAFTS MODEL OUTPUT

Pre-Development 100 year ARI 2 hour RAFTS Output

##

Results for period from 0: 0.0 1/ 1/1990
to 12: 0.0 1/ 1/1990

##

ROUTING INCREMENT (MINS) = 1.00
STORM DURATION (MINS) = 120.
RETURN PERIOD (YRS) = 100.
BX = 1.0000
TOTAL OF FIRST SUB-AREAS (ha) = 462.08
TOTAL OF SECOND SUB-AREAS (ha) = 144.35
TOTAL OF ALL SUB-AREAS (ha) = 606.43

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link Label	Catch. Area #1 (ha)	Catch. Area #2 (ha)	Slope #1 (%)	Slope #2 (%)	% Impervious #1 (%)	% Impervious #2 (%)	Pern #1	Pern #2	B #1	B #2	Link No.
2.10	87.600	75.600	3.600	3.600	100.0	5.000	.015	.040	.0080	.1465	1.000
2.30	4.360	4.150	2.500	2.500	100.0	5.000	.015	.040	.0020	.0388	2.000
2.11	33.970	0.000	1.400	0.000	0.000	0.000	.080	0.00	.3390	0.000	1.001
2.20	12.390	8.260	3.100	3.100	100.0	5.000	.015	.040	.0031	.0499	3.000
2.21	9.710	0.000	3.800	0.000	0.000	0.000	.050	0.00	.0726	0.000	3.001
2.00	42.750	41.270	1.200	1.200	100.0	5.000	.015	.040	.0096	.1850	4.000
2.01	52.120	0.000	.8000	0.000	0.000	0.000	.080	0.00	.5600	0.000	1.002
2.02	36.390	0.000	1.400	0.000	5.000	0.000	.070	0.00	.2521	0.000	1.003
2.03	9.520	0.000	2.500	0.000	5.000	0.000	.080	0.00	.1054	0.000	1.004
X5.0	11.800	0.000	1.250	0.000	0.000	0.000	.050	0.00	.1399	0.000	5.000
2.04	.00001	0.000	.6500	0.000	75.00	0.000	.040	0.00	0.000	0.000	1.005
X3.0	4.070	4.070	.2700	.2700	1.570	5.000	.015	.040	.0483	.1167	6.000
X3.1	23.577	0.000	.3200	0.000	5.000	0.000	.050	0.00	.3183	0.000	6.001
1.00	13.290	11.000	1.570	5.200	100.0	5.000	.015	.040	.0046	.0447	7.000
1.01	38.350	0.000	1.570	0.000	5.000	0.000	.050	0.00	.1853	0.000	7.001
SC_1	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	7.002
X4.0	82.180	0.000	.4700	0.000	5.000	0.000	.050	0.00	.5029	0.000	8.000
SC_4	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	6.002
Out	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	1.006

Link Label	Average Intensity (mm/h)	Init. Loss #1 (mm)	Init. Loss #2 (mm)	Cont. Loss #1 (mm/h)	Cont. Loss #2 (mm/h)	Excess Rain #1 (mm)	Excess Rain #2 (mm)	Peak Inflow (m^3/s)	Time to Peak	Link Lag mins
2.10	44.237	1.500	10.00	0.000	2.500	86.974	74.099	49.784	34.00	11.00
2.30	44.237	1.500	10.00	0.000	2.500	86.974	74.099	2.910	35.00	10.00
2.11	44.237	10.00	0.000	2.500	0.000	74.099	0.000	53.978	45.00	0.000
2.20	44.237	1.500	10.00	0.000	2.500	86.974	74.099	7.462	35.00	4.000
2.21	44.237	10.00	0.000	2.500	0.000	74.099	0.000	8.975	39.00	0.000
2.00	44.237	1.500	10.00	0.000	2.500	86.974	74.099	23.405	35.00	0.000
2.01	44.237	10.00	0.000	2.500	0.000	74.099	0.000	62.154	59.00	0.000
2.02	44.237	10.00	0.000	2.500	0.000	74.099	0.000	61.940	69.00	3.000
2.03	44.237	10.00	0.000	2.500	0.000	74.099	0.000	58.905	77.00	19.00
X5.0	44.237	10.00	0.000	2.500	0.000	74.099	0.000	1.419	80.00	0.000
2.04	44.237	1.500	0.000	0.000	0.000	86.974	0.000	60.107	96.00	10.00
X3.0	44.237	1.500	10.00	0.000	2.500	86.974	74.099	1.321	45.00	13.00
X3.1	44.237	10.00	0.000	2.500	0.000	74.099	0.000	2.394	61.00	4.000
1.00	44.237	1.500	10.00	0.000	2.500	86.974	74.099	8.860	35.00	15.00
1.01	44.237	10.00	0.000	2.500	0.000	74.099	0.000	10.341	58.00	0.000

SC_1	44.237	10.00	0.000	2.500	0.000	74.099	0.000	10.341	58.00	27.00
X4.0	44.237	10.00	0.000	2.500	0.000	74.099	0.000	4.958	120.0	4.000
SC_4	44.237	10.00	0.000	2.500	0.000	74.099	0.000	16.911	85.00	16.00
Out	44.237	10.00	0.000	2.500	0.000	74.099	0.000	76.840	106.0	0.000

SUMMARY OF BASIN RESULTS

Link Label	Time to Peak	Peak Inflow (m^3/s)	Time to Peak	Peak Outflow (m^3/s)	Total Inflow (m^3)	--------- Basin --------- Vol. Avail	Vol. Used	Stage Used
2.02	69.00	61.94	74.00	57.65	319464.	0.0000	22712.6	26.726
1.00	35.00	8.860	42.00	6.084	19716.8	0.0000	3498.1	29.701

SUMMARY OF BASIN OUTLET RESULTS

Link Label	No. of	S/D Factor (m)	Dia (m)	Width (m)	Pipe Length (m)	Pipe Slope (%)
2.02	1.0	1.000		0.000	27.800	0.6000
1.00	1.0		.6000	1.200	12.300	0.2000

SUMMARY OF CHANNEL/FLOODWAY DATA AND RESULT

Link Label	Ave. Vel. (m/s)	Ave. Rough. (n)	Flow Depth (m)	Max. Flow (m^3/s)	No. of Pipes	Pipe Dia. (m)	Pipe Slope (%)	Pipe Flow (m3^/s)
2.11	0.772	.0854	1.394	44.943	1.0	0.000	0.000	0.000
2.21	0.272	.0887	0.5664	7.600	1.0	0.000	0.000	0.000
2.00	1.09	.0852	0.7938	23.282	1.0	0.000	0.000	0.000
2.01	0.698	.0857	1.347	58.841	1.0	0.000	0.000	0.000

Post-Development 100 year ARI 2 hour RAFTS Output

```
############################################################################

Results for period from  0: 0.0  1/ 1/1990
                     to 10: 0.0  1/ 1/1990
############################################################################

                              ROUTING INCREMENT (MINS) =       1.00
                              STORM DURATION (MINS)    =       120.
                              RETURN PERIOD (YRS)      =       100.
                              BX                       =     1.0000
                              TOTAL OF FIRST SUB-AREAS  (ha) =     446.76
                              TOTAL OF SECOND SUB-AREAS (ha) =     161.44
                              TOTAL OF ALL SUB-AREAS (ha)    =     608.20
```

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link Label	Catch. Area #1 (ha)	#2	Slope #1 (%)	#2	% Impervious #1 (%)	#2	Pern #1	#2	B #1	#2	Link No.
2.10	87.600	75.600	3.600	3.600	100.0	5.000	.015	.040	.0080	.1465	1.000
2.30	4.360	4.150	2.500	2.500	100.0	5.000	.015	.040	.0020	.0388	2.000
2.11	33.970	0.000	1.400	0.000	0.000	0.000	.080	0.00	.3390	0.000	1.001
2.20	12.390	8.260	3.100	3.100	100.0	5.000	.015	.040	.0031	.0499	3.000

J	9.650	2.410	1.000	1.000	100.0	0.000	.015	.040	.0048	.0575	4.000
2.21	2.903	0.000	2.500	0.000	0.000	0.000	.060	0.00	.0554	0.000	3.001
2.00	42.750	41.270	1.200	1.200	100.0	5.000	.015	.040	.0096	.1850	5.000
2.01	45.800	0.000	.8000	0.000	0.000	0.000	.080	0.00	.5236	0.000	1.002
2.02	40.100	0.000	1.400	0.000	5.000	0.000	.070	0.00	.2651	0.000	1.003
2.03	9.520	0.000	2.500	0.000	5.000	0.000	.080	0.00	.1054	0.000	1.004
W	4.760	0.000	3.500	0.000	0.000	0.000	.080	0.00	.0772	0.000	6.000
V	12.340	1.370	.6000	.6000	100.0	0.000	.015	.040	.0071	.0553	6.001
2.04	.00001	0.000	.6500	0.000	75.00	0.000	.040	0.00	0.000	0.000	1.005
U	10.620	1.180	1.400	1.800	100.0	0.000	.015	.040	.0043	.0296	7.000
2.05	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	1.006
N	8.250	2.060	.8000	.8000	100.0	0.000	.015	.040	.0050	.0592	8.000
G	2.740	0.6800	2.500	2.500	100.0	0.000	.015	.040	.0016	.0188	9.000
D	5.970	1.490	1.900	1.900	100.0	0.000	.015	.040	.0027	.0325	10.00
E	4.120	1.030	.6000	3.400	100.0	0.000	.015	.040	.0040	.0201	10.00
C	4.500	1.130	1.200	1.200	100.0	5.000	.015	.040	.0030	.0285	11.00
B	6.040	1.510	1.000	1.000	100.0	0.000	.015	.040	.0038	.0451	11.00
1.00	13.290	11.000	1.570	5.200	100.0	5.000	.015	.040	.0046	.0447	12.00
L	1.860	0.4600	3.900	3.900	100.0	0.000	.040	.040	.0029	.0123	13.00
1.01	.00001	0.000	1.570	0.000	0.000	0.000	.050	0.00	0.000	0.000	12.00
3.0	19.660	0.000	1.700	0.000	0.000	0.000	.080	0.00	.2315	0.000	14.00
1.02	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	12.00
1.03	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	11.00
1.04	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	10.00
4.0	29.900	0.000	1.800	0.000	0.000	0.000	.080	0.00	.2798	0.000	15.00
1.05	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	8.001
R	8.100	1.970	.8000	.2000	100.0	5.000	.016	.050	.0054	.1107	16.00
1.06	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	8.002
S	2.280	0.2500	3.200	3.200	100.0	0.000	.015	.040	.0013	.0099	17.00
P	3.390	0.8500	.8000	1.000	100.0	0.000	.015	.040	.0031	.0334	18.00
1.07	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	8.003
T	1.500	0.1700	.5000	.5000	100.0	0.000	.015	.040	.0026	.0205	19.00
A.02	4.120	1.030	.6000	1.030	100.0	0.000	.015	.040	.0040	.0364	20.00
A.01	6.420	1.610	.7000	.6000	100.0	0.000	.015	.040	.0047	.0601	20.00
SC_1	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	21.00
SC_2.0	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	20.00
O	7.860	1.960	1.000	1.000	100.0	0.000	.015	.040	.0044	.0516	22.00
SC_3	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	20.00
SC_4	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	8.004
Out	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	1.007

Link Label	Average Intensity (mm/h)	Init. Loss #1 (mm)	Init. Loss #2	Cont. Loss #1 (mm/h)	Cont. Loss #2	Excess Rain #1 (mm)	Excess Rain #2	Peak Inflow (m^3/s)	Time to Peak	Link Lag mins
2.10	44.200	1.500	10.00	0.000	2.500	86.900	74.025	49.733	34.00	11.00
2.30	44.200	1.500	10.00	0.000	2.500	86.900	74.025	2.907	35.00	10.00
2.11	44.200	10.00	0.000	2.500	0.000	74.025	0.000	53.920	45.00	0.000
2.20	44.200	1.500	10.00	0.000	2.500	86.900	74.025	7.455	35.00	4.000
J	44.200	1.500	10.00	0.000	2.500	86.900	74.025	5.004	34.00	0.000
2.21	44.200	10.00	0.000	2.500	0.000	74.025	0.000	11.717	36.00	0.000
2.00	44.200	1.500	10.00	0.000	2.500	86.900	74.025	23.383	35.00	0.000
2.01	44.200	10.00	0.000	2.500	0.000	74.025	0.000	69.638	57.00	0.000
2.02	44.200	10.00	0.000	2.500	0.000	74.025	0.000	69.044	67.00	3.000
2.03	44.200	10.00	0.000	2.500	0.000	74.025	0.000	69.913	71.00	19.00
W	44.200	10.00	0.000	2.500	0.000	74.025	0.000	0.7379	62.00	0.000
V	44.200	1.500	10.00	0.000	2.500	86.900	74.025	6.541	35.00	1.000
2.04	44.200	10.00	0.000	2.500	0.000	74.025	0.000	71.050	90.00	5.000
U	44.200	1.500	10.00	0.000	2.500	86.900	74.025	5.526	33.00	2.000
2.05	44.200	10.00	0.000	2.500	0.000	74.025	0.000	71.500	95.00	5.000
N	44.200	1.500	10.00	0.000	2.500	86.900	74.025	4.261	34.00	0.000
G	44.200	1.500	10.00	0.000	2.500	86.900	74.025	1.514	35.00	0.000
D	44.200	1.500	10.00	0.000	2.500	86.900	74.025	3.228	33.00	0.000

E	44.200	1.500	10.00	0.000	2.500	86.900	74.025	2.939	35.00	0.000
C	44.200	1.500	10.00	0.000	2.500	86.900	74.025	2.430	33.00	0.000
B	44.200	1.500	10.00	0.000	2.500	86.900	74.025	3.493	34.00	0.000
1.00	44.200	1.500	10.00	0.000	2.500	86.900	74.025	8.851	35.00	1.000
L	44.200	1.500	10.00	0.000	2.500	86.900	74.025	1.054	34.00	0.000
1.01	44.200	10.00	0.000	2.500	0.000	74.025	0.000	9.831	36.00	2.300
3.0	44.200	10.00	0.000	2.500	0.000	74.025	0.000	1.718	86.00	0.000
1.02	44.200	10.00	0.000	2.500	0.000	74.025	0.000	12.019	38.00	5.000
1.03	44.200	10.00	0.000	2.500	0.000	74.025	0.000	16.085	41.00	0.000
1.04	44.200	10.00	0.000	2.500	0.000	74.025	0.000	18.394	41.00	12.00
4.0	44.200	10.00	0.000	2.500	0.000	74.025	0.000	2.471	101.0	0.000
1.05	44.200	10.00	0.000	2.500	0.000	74.025	0.000	21.518	53.00	9.000
R	44.200	1.500	10.00	0.000	2.500	86.900	74.025	4.084	34.00	0.000
1.06	44.200	10.00	0.000	2.500	0.000	74.025	0.000	22.692	62.00	3.000
S	44.200	1.500	10.00	0.000	2.500	86.900	74.025	1.253	32.00	0.000
P	44.200	1.500	10.00	0.000	2.500	86.900	74.025	1.772	33.00	0.000
1.07	44.200	10.00	0.000	2.500	0.000	74.025	0.000	23.568	65.00	4.000
T	44.200	1.500	10.00	0.000	2.500	86.900	74.025	0.7658	33.00	4.000
A.02	44.200	1.500	10.00	0.000	2.500	86.900	74.025	2.162	34.00	0.000
A.01	44.200	1.500	10.00	0.000	2.500	86.900	74.025	4.043	34.00	4.000
SC_1	44.200	10.00	0.000	2.500	0.000	74.025	0.000	1.425	34.00	2.000
SC_2.0	44.200	10.00	0.000	2.500	0.000	74.025	0.000	4.810	39.00	23.00
O	44.200	1.500	10.00	0.000	2.500	86.900	74.025	4.073	34.00	6.000
SC_3	44.200	10.00	0.000	2.500	0.000	74.025	0.000	6.005	63.00	3.000
SC_4	44.200	10.00	0.000	2.500	0.000	74.025	0.000	29.093	69.00	17.00
Out	44.200	10.00	0.000	2.500	0.000	74.025	0.000	88.082	99.00	0.000

SUMMARY OF BASIN RESULTS

Link Label	Time to Peak	Peak Inflow (m^3/s)	Time to Peak	Peak Outflow (m^3/s)	Total Inflow (m^3)	--------- Basin --------- Vol. Avail	Vol. Used	Stage Used
2.02	67.00	69.04	68.00	68.58	321409.	0.0000	2981.9	25.629
E	35.00	2.939	36.00	2.744	7126.6	0.0000	1220.2	21.718
B	34.00	3.492	36.00	3.027	8525.6	0.0000	1841.3	22.505
A.01	34.00	4.043	36.00	3.837	10193.7	0.0000	1183.3	18.970

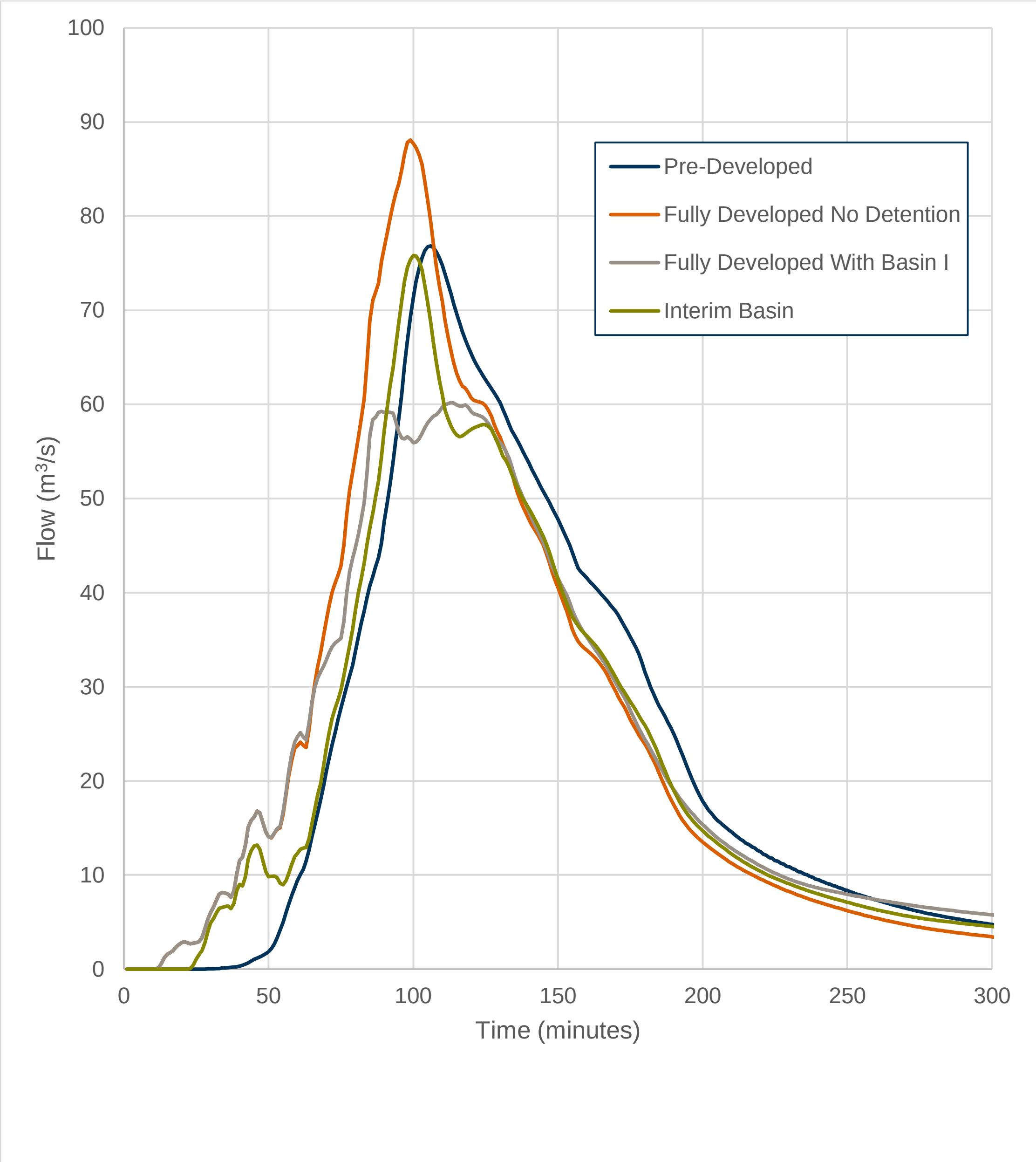
SUMMARY OF BASIN OUTLET RESULTS

Link Label	No. of	S/D Factor (m)	Dia (m)	Width (m)	Pipe Length (m)	Pipe Slope (%)
2.02	1.0	1.000		0.000	27.800	0.6000
E	1.0	1.000		0.000	20.000	0.2000
B	1.0	1.000		0.000	20.000	0.2000
A.01	1.0	1.000		0.000	20.000	0.2000

SUMMARY OF CHANNEL/FLOODWAY DATA AND RESULT

Link Label	Ave. Vel. (m/s)	Ave. Rough. (n)	Flow Depth (m)	Max. Flow (m^3/s)	No. of Pipes	Pipe Dia. (m)	Pipe Slope (%)	Pipe Flow (m3^/s)
2.11	0.779	.0854	1.388	44.922	1.0	0.000	0.000	0.000
2.21	0.291	.0888	0.6031	9.786	1.0	0.000	0.000	0.000
2.00	0.395	.0871	0.9844	17.763	1.0	0.000	0.000	0.000
2.01	0.700	.0860	1.400	65.801	1.0	0.000	0.000	0.000

Figure B-1 100 year 2 hour Hydrographs at Control Point (Confluence of Western Tributary & South Creek)



Central Precinct

APPENDIX

C

JACOBS HYDROLOGIC ASSESSMENT

Internal Memo

To	Glyn Richards (Lend Lease)	**Date**	12 November 2014
From	Shane Ruscheinsky	**Project No**	EN04189
Copy	John Constandopoulos		
Subject	**Hydrologic assessment of St Mary's Central Precinct**		

1. Introduction

A hydrologic assessment of the proposed St Mary's Central Precinct was undertaken to evaluate the proposed development's impact on flood discharges in South Creek. The objective of the assessment is to demonstrate the Central Precinct development has a negligible impact on flooding in South Creek and that stormwater detention is not necessary to mitigate against an increase in downstream peak flows and flood levels. The development has negligible impact on flooding in South Creek due to its location immediately adjacent the creek and its very small area relative to the total upstream catchment of South Creek.

The assessment was undertaken by developing a hydrologic model (XP-RAFTS) of the Central Precinct area for existing and developed conditions, and comparing the model results against discharges in South Creek obtained from the Draft South Creek Flood Study (Worley Parsons, 2014). The modelling of the Central Precinct for developed conditions has considered both with and without stormwater detention for peak flow mitigation.

2. South Creek flooding

A Flood Study of South Creek is currently being prepared by Worley Parsons for Penrith City Council. Flood modelling of South Creek was undertaken for the Flood Study and design flow hydrographs at a location immediately upstream of the Central Precinct site were provided to Jacobs for the 20 year ARI, 100 year ARI and PMF events.

The 20 and 100 year ARI flow hydrographs in South Creek are shown in Figure 2.1. The Flood Study identifies the 36 hour storm duration as critical and it is assumed the hydrographs provided relate to this critical duration. The hydrographs show the peak flow in South Creek is 825m³/s and 1140m³/s for the 20 and 100 year ARI events respectively, and both events peak at 27 hours following the start of the event.