North Penrith

Drainage, Stormwater & Groundwater Management Report

Summary

This report outlines the stormwater management strategies for the North Penrith development and Stage 1. The term stormwater management is used to describe a series of stormwater related matters including:

- stormwater drainage;
- stormwater quantity;
- stormwater quality;
- flooding; and
- surface runoff / groundwater interaction.

Objectives

The report describes the proposed strategies for managing stormwater within the North Penrith development and Stage 1. The objectives of the stormwater management strategies are common between the North Penrith development and Stage1. The objectives are:

- to replicate the existing drainage regimes present at upstream and downstream boundaries of the site;
- to provide a stormwater drainage network that has the capacity to convey stormwater runoff generated for events up to and including the 5 year Average Recurrence Interval (*ARI*) storm;
- to provide a stormwater drainage network that directs stormwater runoff towards stormwater quantity and quality management infrastructure;
- to match post-development peak flow rates with pre-development peak flow rates for events up to the 100 year ARI storm;
- to reduce post-development average annual pollutant loads in accordance with Landcom's baseline targets through the incorporation of Water Sensitive Urban Design (*WSUD*) measures within the development;
- to identify dedicated overland flow paths for major rainfall events (*i.e., beyond the capacity of the drainage network*);

- to estimate peak water surface levels within dedicated overland flow paths; and
- to mitigate the impacts of the surface water management strategy on groundwater behaviour and characteristics.

The North Penrith development has received Director General's Requirements (*DGRs*) for the Concept Plan (*MP 10-0075*) and Project Application (*MP 10-0078*). The Concept Plan relates to the entire North Penrith development whilst the Project Application relates specifically to works being undertaken in Stage 1. The North Penrith Concept Plan layout and Stage 1 boundaries are shown on **Diagram 1** and **Diagram 2** respectively.

DGRs addressed as part of this report are nominated in **Table 1**.

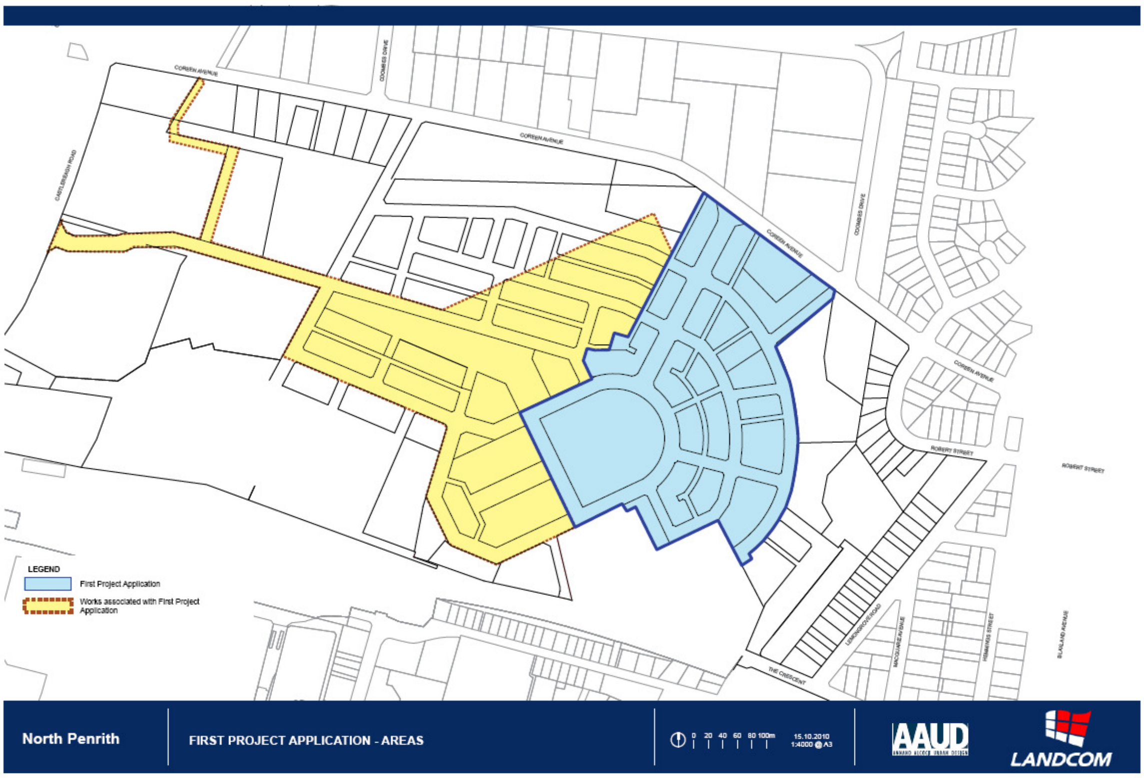
Table 1 DGRs addressed in this report

Director General's Requirements	Key Assessment Requirements Addressed	Description
Concept Plan (*MP 10-0075*)	6 (1)	The EA should provide details of and an assessment of impacts on any watercourses, wetlands and riparian land located on, and/or adjacent to the site. Details are to be provided as per the requirements of the NSW Office of Water's advice dated 28 June 2010.
	6 (2)	The EA should assess impacts on surface water. It should identify drainage, and stormwater management issues, including topography, on-site stormwater detention, water sensitive urban design measures, drainage infrastructure and water quality control measures.
	6 (3)	The EA shall address any impacts on groundwater resources including any potential degradation to the groundwater resource and any impacts on ground water dependant ecosystems. Where impacts are identified, provide contingency measures to remediate reduce or manage potential impacts. The EA needs to demonstrate that ground water is not connected to surface water.
	6 (4)	Provide details on existing water and groundwater licences under the Water Act 1912 and any proposed surface water and groundwater extraction.

Director General's Requirements	Key Assessment Requirements Addressed	Description
	6 (5)	Prepare a Concept Stormwater Management Plan that outlines general measures for stormwater and effluent management in relation to climate, topography, soil types and local geology and identify potential risk issues. Measures to be incorporated on site, include (but not limited to) on site stormwater detention, water sensitive urban design measures, the impact on the quality of surface water and groundwater. A notional schedule of costs and recurrent maintenance costs should be included.
	6 (6)	Proposed static water bodies on site should be designed to be of minimum cost to Council and the community once operational.
Project Application (*MP 10-0078*)	7 (1)	With reference to the Stormwater Management Plan submitted as part of the Concept Plan application, provide detail of measures to be implemented to manage and address impacts on drainage, stormwater and groundwater.

Diagram 1 North Penrith Concept Plan layout

Diagram 2 Stage 1 Project Application boundaries



Methods and findings

Methodology

The stormwater management strategies for the North Penrith development and Stage 1 were developed in parallel with the bulk earthworks strategy and to function within the constraints of the development layout.

Concept stormwater drainage networks were prepared for the North Penrith development and Stage 1. These networks were prepared to confirm the potential routing of stormwater runoff through the development and to assist in the preliminary design of the stormwater quantity and stormwater quality management infrastructure.

The industry standard modelling software package XP-RAFTS was used to model the hydrology of the site and to determine the required volume of storage to attenuate post-development flow rates back to pre-development flow rates.

The industry standard modelling software package MUSIC was used to estimate the concentrations of pollutants generated in the post-development scenario and the effectiveness of the proposed WSUD measures in reducing these loads.

Flooding assessments have been undertaken to consider the impacts of the regional and localised flooding on the proposed development. The '*North Penrith Regional Flooding Assessment*', WorleyParsons, October 2010 addresses regional flooding issues associated with the Nepean River. Localised flooding has been addressed within the North Penrith development and Stage 1 through the identification of major overland flow paths and the estimation of peak water surface levels for the 100 year ARI storm event.

To evaluate the potential for the North Penrith development and Stage 1 stormwater management strategies to impact upon the groundwater resources the '*Geotechnical & Groundwater North Penrith Assessment Report*', Geotechnique, October 2010 was reviewed.

Findings

Concept stormwater drainage networks

Concept stormwater drainage networks for the North Penrith development and Stage 1 are provided on **Figure 2** and **Figure 3** respectively.

Stormwater quantity

The North Penrith development requires the provision of approximately 11,000 m^3 of detention volume to attenuate post-development peak flow rates back to pre-development levels prior to discharging into existing drainage infrastructure. The volume of storage is provided above the constructed wetland and within the central canal.

Stage 1 requires approximately 4,000 m^3 of detention volume to attenuate post-development peak flow rates back to pre-development levels prior to discharging into existing drainage infrastructure. The volume of storage is provided within a temporary basin.

Stormwater quality

The North Penrith development incorporates a suite of WSUD measures to reduce the average annual pollutant loads for Total Suspended Solids (*TSS*), Total Phosphorus (*TP*) and Total Nitrogen (*TN*). Measures include rainwater tanks, bio-retention swales, gross pollutant traps, sedimentation basins and constructed wetlands. These WSUD measures are strategically located within the development to provide a treatment train approach to stormwater quality management. MUSIC modelling predicts the effectiveness of the treatment train in minimising the annual average reduction rates as:

- 88% for TSS;
- 68% for TP; and
- 46% for TN.

Stage 1 incorporates WSUD measures to reduce the average annual pollutant loads for TSS, TP, and TN. Measures include rainwater tanks, bio-retention swales, gross pollutant traps and a temporary sediment basin. These WSUD measures have been arranged into a treatment train and MUSIC estimates the following average annual reduction rates:

- 91% for TSS;
- 69% for TP; and
- 52% for TN.

The average annual reduction rates for the North Penrith development and Stage 1 both exceed the baseline targets nominated in '*Draft Water Sensitive Urban Design Book 1 Policy*', Landcom, May 2009.

Comparison of the proposed annual pollutant loads (*including treatment*) against the existing annual pollutant loads shows that the North Penrith development and Stage 1 reduce the volume of TSS (*by approximately 35%*), matches TP volumes and increases the volume of TN (*approximately 30%*) being discharged downstream of the site.

Flooding

The '*North Penrith Regional Flooding Assessment*', WorleyParsons, October 2010 nominates minimum road (*25.40 mAHD*) and minimum habitable floor levels (*25.90 mAHD*) for the North Penrith development.

Localised flooding has been addressed within the North Penrith development and Stage 1 to determine peak water surface levels for the 100 year ARI event within the constructed wetland, the central canal and the temporary basin. These water levels have been estimated based on the modelling work undertaken in XP-RAFTS and have been incorporated into the design of open spaces surrounding the water bodies.

Groundwater

Based on the '*Geotechnical & Groundwater North Penrith Assessment Report*', Geotechnique, October 2010 the existing groundwater table is found at depths exceeding 5.0 m. Based on preliminary design of the constructed wetland and the central canal there will be no direct interaction between the stormwater management infrastructure and the existing groundwater resource.

Under proposed conditions infiltration will occur within pervious areas, bio-retention swales and the constructed wetland. Qualitative assessment indicates that extent of infiltration would be relatively consistent between the post-development and pre-development scenarios. Thus, no adverse impacts upon the existing groundwater resource are anticipated.

Consultation
During the development of the stormwater management strategies for the North Penrith development and Stage 1 Penrith City Council (*Council*) was consulted. Preliminary concepts were presented and comments received have been incorporated into this report.

Conclusions

The stormwater management strategies for the North Penrith development and Stage 1 will maintain the existing drainage regimes present at upstream and downstream boundaries of the site for events up to the 100 year ARI.

Concept stormwater drainage networks have been prepared for the North Penrith development and Stage 1 that route stormwater runoff via a pipe network and overland flow paths towards stormwater management infrastructure. Through the provision of detention volume the North Penrith development and Stage 1 can demonstrate that peak flow rates are matched for events up to and including the 100 year ARI event and that average annual pollutant loads are reduced to levels consistent with Landcom's baseline requirements.

Flooding within the site has been considered through the estimation of peak water surface levels in the central canal and constructed wetland. Regional flooding has been assessed in a separate report.

The proposed stormwater management strategies will have no adverse impacts on the existing groundwater resource.

ESD principles demonstrated in the project
Rainwater tanks will be provided on each residential lot to assist in meeting BASIX requirements. Rainwater tanks will retain stormwater runoff for re-use in toilet flushing and for outdoor irrigation. Preliminary water balance modelling indicates that a 3 kL tank would represent an optimal cost-benefit scenario.

Recommendations

The stormwater management strategies for the North Penrith development and Stage 1 have been developed based on preliminary assumptions. As detailed design progresses for the development and Stage 1 assumptions will need to validated and refined to ensure the objectives of the stormwater management strategy are met. Accordingly, the following will need to be undertaken during the detailed design phases of the North Penrith development and Stage 1:

1. validation of the concept drainage network based on the final proposed surface;
2. validation of proposed land uses (*i.e., roof areas, road areas, etc*);
3. detailed design of the drainage network and stormwater detention infrastructure using DRAINS software;
4. detailed design of hydraulic controls within the temporary basin, central canal and constructed wetland;
5. refinement of the Sediment and Erosion control plans to reflect the phased construction proposed by Landcom and the contractor;
6. detailed design of all overland flow paths;
7. detailed design of WSUD measures;
8. validation of the depth to groundwater along the alignment of the central canal and within the vicinity of the constructed wetland and temporary basin;
9. additional water balance modelling of the central canal and constructed wetland;
10. detailed 1-Dimensional modelling of major overland flow paths within the development to determine localised flood hazard;
11. detailed design of temporary diversion drains required during Stage 1; and
12. liaison with Commuter Car Park designers to enable the stormwater management strategy for the Commuter Car Park to be integrated into the North Penrith development stormwater management strategy.

Contents

1. Objectives of assessment

At a glance

This report has been prepared to outline the stormwater management strategies for the North Penrith development and Stage 1. This report specifically addresses:

- the existing drainage regime at the site;
- stormwater drainage strategies for the North Penrith development and Stage 1;
- stormwater quantity management;
- stormwater quality management;
- localised flooding; and
- the interaction of surface water / groundwater.

2. Site analysis

At a glance

This chapter describes the catchment characteristics for the existing site and proposed development scenarios. Characteristics nominated include catchment area, catchment slope and percentage impervious. These catchment characteristics were used to develop hydrologic, hydraulic and water quality models.

Existing site description

The North Penrith development site is bound by Coreen Avenue to the north, existing residential development to the east, the Great Western Railway to the south and the Museum of Fire and Castlereagh Road to the west. In total the North Penrith development site covers approximately 41 hectares.

The existing topography of the North Penrith site is predominately flat. Minor grade exists from the north-western corner of the site towards the south-eastern corner of the site (*less than 1%*). There is a small region of the site towards the eastern property boundary that contains moderate grade (*more than 1% but less than 7%*).

Under existing conditions the site contains a series of earth lined open channels that generally drain stormwater runoff in a north-westerly direction towards existing stormwater infrastructure located within Coreen Avenue. Ultimately drainage channels within the site drain into Boundary Creek via stormwater infrastructure.

The site is predominately pervious. However, the site also contains a network of asphalt roads and concrete hardstand areas that combine to account for approximately 18% of the site area.

Existing catchments

The existing drainage channels within the North Penrith development site service stormwater runoff generated within the site boundary as well as some external catchments.

The existing catchments have been delineated based upon watershed boundaries and the location of existing drainage channels. An existing catchment plan has been included as **Figure 1** and catchment properties are summarised in **Table 2**.

Table 2 Existing catchment properties

Catchment Name	Catchment Area (ha)	Percentage Impervious	Catchment Slope
A	4.8	0%	0.9%
B	10.3	25%	3.4%
C	8.2	15%	0.8%

Catchment Name	Catchment Area (ha)	Percentage Impervious	Catchment Slope
D	8.7	34%	0.5%
E	4.0	0%	1.1%
F	0.4	50%	0.4%
G	2.1	0%	1.0%
H	0.3	63%	0.6%
I	1.3	0%	1.2%
J	0.5	74%	0.8$
TOTAL	40.7	18%	n/a

North Penrith proposed development

The North Penrith development consists of a variety of residential, commercial and employment zones. It is anticipated that approximately 1,000 residential dwellings will be provided as part of the proposed development. The North Penrith Concept Plan layout is included as **Diagram 1**.

The development will require approximately 120,000 m^3 of fill material to be imported to provide a surface that is conducive to urban development. The fill activities are described within the '*North Penrith Civils Report*', WorleyParsons, October 2010. Fill activities on the site will provide sufficient grade to drain the majority of the site back towards a central canal and constructed wetland.

Proposed catchments

Under proposed conditions drainage infrastructure within the development will need to convey stormwater runoff generated within the site as well as some external catchments within a drainage network (*i.e., pits and pipes*) as well as via designated overland flow paths (*i.e., roads, channels, etc*).

The proposed catchments for the North Penrith development are included as **Figure 2** and catchment properties are summarised in **Table 3**.

Table 3 North Penrith proposed catchment properties

Catchment Name	Catchment Area (ha)	Percentage Impervious	Catchment Slope
1	1.2	96%	1%
2	2.3	59%	1%
3	0.8	80%	1%
4	2.1	83%	1%
4a	0.2	93%	1%
5	1.2	86%	1%
6	3.1	88%	1%
6a	0.4	90%	1%
7	7.3	87%	1%
8	0.4	97%	1%
9	0.4	83%	1%
10	1.5	71%	1%
11	0.3	96%	1%
12	1.0	82%	1%
13	3.8	79%	1%
14	4.4	84%	1%
15	2.9	95%	1%
16	1.7	82%	1%
17	1.9	83%	1%
18	1.8	24%	1%
19	2.1	20%	1%
Total	**40.7**	**72%**	**n/a**

Stage 1 proposed development

Stage 1 of the North Penrith development covers approximately 12 hectares.

Proposed catchments
Under proposed conditions drainage infrastructure within Stage 1 will need to convey stormwater runoff generated within the Stage 1 boundary as well as runoff generated externally.

Modelling of the Stage 1 existing scenario adopted the average percentage imperviousness of the North Penrith development site (*i.e., 18%*) and an average catchment slope of 0.8%.

The proposed catchments for Stage 1 are included as **Figure 3** and are summarised in **Table 4**.

Table 4 Stage 1 proposed catchment properties

Catchment Name	Catchment Area (ha)	Percentage Impervious	Catchment Slope
A	1.8	89%	1%
B	0.5	85%	1%
C	1.5	88%	1%
D	1.7	75%	1%
E	1.4	87%	1%
F	2.1	29%	1%
G	0.3	93%	1%
H	3.0	86%	1%
Total	12.2	76%	n/a

3. Design guidelines

At a glance

A series of guidelines and professional standards of the industry were adhered to in the preparation of the stormwater management strategies for the North Penrith development and Stage 1, namely:

- *'Guidelines For Engineering Works For Subdivisions and Developments*', Penrith City Council, April 1997;
- '*Australian Rainfall and Runoff*', Institute of Engineers, 1987;
- *'A Guide to Water Sensitive Urban Design*', Australian Runoff Quality, Engineers Australia, 2005;
- '*Stormwater Flow and Quality, and the effectiveness of non-proprietary and stormwater treatment measures – a review and gap analysis*', Cooperative Research Centre for Catchment Hydrology, 2004;
- '*Managing Urban Stormwater – Soils and Construction 4th edition'*, Landcom, 2004;
- '*Climate Atlas of Australia, Evapotranspiration*', Bureau of Meteorology, 2001;
- '*Urban Stormwater Quality: A Statistical Overview*', H Duncan et al (CRCCH), 1999;
- '*Removal of Suspended Solids and Associated Pollutants by a Gross Pollutant Trap*', CRCCH, 1999;
- '*The Constructed Wetlands Manual*', NSW Department of Land and Water Conservation, 1998;
- '*Managing Urban Stormwater: Treatment Techniques*', New South Wales Environment Protection Agency, 1997; and
- '*New South Wales Floodplain Development Manual*', Department of Natural Resources, 2005.

4. Stormwater drainage

At a glance

Under existing conditions the North Penrith site discharges into Boundary Creek via existing drainage infrastructure located in close proximity to the existing access road to the Commuter Car Park and towards the north-western extent of the North Penrith site. Existing outlets are shown on **Figure 1**.

The proposed drainage network seeks to replicate the existing drainage regime present at the site. Thus, under proposed conditions the North Penrith site will ultimately drain into a constructed wetland located near the north-western extent of the site. The constructed wetland will have detention volume and outlets designed to control outflows from the proposed development towards the two existing drainage outlets that link the site with Boundary Creek.

The North Penrith drainage network will be designed to accommodate the 5 year ARI event and will have sufficient provision to accommodate the Commuter Car Park and the Penrith Training Depot. The North Penrith drainage network is shown on **Figure 2**.

The Stage 1 drainage network will be consistent with the drainage network proposed for the North Penrith development with the incorporation of some temporary works. The Stage1 drainage network is shown on **Figure 3**.

Existing drainage

Under existing conditions the site is drained via a network of earth lined open drainage channels. These open channels generally discharge stormwater in a north-westerly direction towards existing drainage infrastructure.

Existing drainage infrastructure links the North Penrith development to Boundary Creek. Existing drainage infrastructure is located in close proximity to the existing access road to the Commuter Car Park and near the extreme north-western corner of the property boundary (*refer* ***Figure 1***).

Infrastructure located in close proximity to the existing access road to the Commuter Car Park consists of two 1,200 mm diameter concrete pipes. Whilst the existing infrastructure located near the north-western property boundary discharges stormwater runoff under the Coombewood property access road and Coreen Avenue via twin 600 mm pipes and quadruple 900 mm pipes respectively.

North Penrith development drainage strategy

The proposed stormwater drainage network for the North Penrith development is shown on **Figure 2**.

The proposed stormwater network has been developed to provide an integrated stormwater management solution that:

- conveys stormwater runoff within a pit and pipe network for events up to the 5 year ARI;
- conveys stormwater runoff safely via a series of designated overland flow paths for events up to the 100 year ARI;
- directs stormwater runoff to key stormwater quality and quantity infrastructure such that quantity and quality targets can be met;
- manages existing external flow regimes through the proposed development; and
- can provide aesthetic benefits.

Drainage features

The North Penrith development contains two key drainage features (*refer* ***Figure 2***):

1. the central canal; and
2. the constructed wetland.

The purpose and some commentary on the key drainage features is provided below under the relevant sub-headings.

Central canal

The bulk earthworks strategy for the North Penrith development has been prepared such that the majority of the site will drain towards the central canal.

The canal will form part of the stormwater quality treatment train and will provide some flow attenuation during frequent storm events.

As well as contributing to stormwater quality and quantity, the central canal will also act as an aesthetic feature within the development. The central canal has been incorporated into the open space design and will contain a series of pathways, viewing platforms, bridges and stairs that will integrate the canal into the community. In order to provide a suitable aesthetic feature the canal will contain a permanent water depth of 0.9 m.

To provide a permanent water depth of 0.9 m the following is required:

- lining of the central canal to prevent infiltration;
- drawing down the permanent pool volume of the constructed wetland to top up the central canal; and
- a pumping system to circulate water through the canal to prevent water from stagnating.

A water balance for the central canal is described in **Chapter 8**.

Constructed wetland

The North Penrith development will drain towards a constructed wetland.

In order to satisfy stormwater quantity objectives approximately 7,000m^3 of detention storage will be provided within the constructed wetland. The constructed wetland will be located in close proximity to the two existing 1,200 mm concrete pipes that currently drain the majority of the site into Boundary Creek. The constructed wetland will contain a series of hydraulic controls that will restrict flow rates discharged from the site back to pre-development values for events up to the 100 year ARI.

The constructed wetland will also form part of the treatment train approach to stormwater quality improvement (*i.e., WSUD*). Through conceptual modelling the required surface area, planting zone and deep water zone for the wetland to promote nutrient update and settlement of suspended solids has been estimated.

Treatment of external catchments
The North Penrith development has three external catchments. These catchments are shown on **Figure 2**.

The Commuter Car Park is not part of this scope of works. However, the North Penrith development has incorporated a series of measures to ensure that the impacts of the Commuter Car Park are mitigated. That is, the impacts of the Commuter Car Park have been incorporated into the stormwater quality and quantity strategies for the North Penrith development.

A small catchment exists to the south-east of the North Penrith development site. This catchment drains in a south-westerly direction towards The Crescent where it would then flow into the Penrith Training Depot.

Under existing conditions the Penrith Training Depot discharges into Council drainage infrastructure via the North Penrith site. The existing flow regime for the Penrith Training Depot will be maintained through the North Penrith development.

Notwithstanding, no allowance has been made for the Penrith Training Depot in the development of the stormwater quality and stormwater quantity management strategies. However, peak flow estimates from the Penrith Training Depot have been included when estimating localised flood levels for events up to the 100 year ARI.

Stage 1 drainage strategy

The proposed stormwater drainage network for Stage 1 is shown on **Figure 3**.

The Stage 1 stormwater network has been developed to provide a temporary integrated stormwater management solution that:

- achieves stormwater quality objectives consistent with those for the whole development;
- conveys stormwater runoff within a pit and pipe network for events up to the 5 year ARI;

- conveys stormwater runoff safely via a series of designated overland flow paths for events up to the 100 year ARI;
- directs stormwater runoff to key stormwater quality and quantity infrastructure such that quantity and quality targets can be met;
- manages existing external flow regimes through the proposed development; and
- does not impact upon later construction stages of the development.

Drainage features

The Stage 1 drainage strategy incorporates a temporary basin that will serve as a sedimentation basin during construction and as a sedimentation basin / detention basin during the post-construction phase.

A series of hydraulic controls will be incorporated at the downstream end of the temporary basin to ensure that Stage 1 of the development does not result in any increase in peak flow rates downstream of the site for events up to the 100 year ARI event.

Due to the bulk earthworks that will be completed during Stage 1 a new channel will need to be constructed from the two existing 1,200 mm pipes to the temporary basin. Additionally, two existing drainage channels will need to be extended towards the Stage 1 boundary to capture stormwater runoff discharging into the site from the Penrith Training Depot and Catchments A and B as well as the runoff collected in the diversion drain. All extensions/modifications to the existing drainage channel are nominated on **Figure 3**.

Treatment of external catchments

Stage 1 needs to address stormwater runoff entering Stage 1 via the Penrith Training Depot as well as the area located to the east of the Stage 1 boundary.

The function of the Stage 1 basin would be compromised by routing the flows from the Penrith Training Depot through the temporary basin. As such, stormwater runoff from the Penrith Training Depot will be diverted in a westerly direction towards an existing drainage line (*refer **Figure 3***).

The catchment located to the east of the Stage 1 boundary will be captured within a diversion drain. The diversion drain will grade in a north-westerly direction and will ultimately be piped through Stage 1 and into an existing drainage line (*refer **Figure 3***).

5. Stormwater quality methods and results (construction)

At a glance

Construction activities can result in large amounts of sediment and other pollutants migrating downstream during storm events.

It is proposed to treat surface runoff during the construction phase in accordance with the NSW Department of Housing publication, '*Managing Urban Stormwater – Soils and Construction*' (*i.e., the "Blue Book"*). As such, runoff during construction phases will be managed through the design of a sediment and erosion control plan prior to construction commencing. It is likely that the sediment and erosion control plan will incorporate the following measures:

- temporary settling basins;
- silt fencing;
- straw bales;
- flow diversion channels; and
- management of construction entry and exit locations.

Sediment and Erosion control plans have been prepared for the North Penrith development and Stage 1 and are included in the '*North Penrith Concept Plan Application Drawings*', WorleyParsons, October 2010 and the '*North Penrith Stage 1 Project Application Drawings*', WorleyParsons, October 2010.

6. Stormwater quality methods and results (post-construction)

At a glance

The stormwater quality management strategy mitigates the impact of urbanisation on the water quality of receiving waters. Through the provision of a suite of Water Sensitive Urban Design (*WSUD*) measures the mean annual pollutant concentrations can be minimised to an acceptable level.

The software package MUSIC (*Model for Urban Stormwater Improvement Conceptualisation*) was used to estimate pre-development and post-development mean annual pollutant concentrations for Total Suspended Solids, Total Phosphorus and Total Nitrogen.

The North Penrith development stormwater quality management strategy incorporates rainwater tanks, bio-retention swales, gross pollutant traps, sediment ponds and a constructed wetland to satisfy Landcom's baseline and performance target for pollution control as nominated in the '*Draft Water Sensitive Urban Design Book 1 Policy*', Landcom, 2009.

Stage 1 incorporates rainwater tanks, bio-retention swales, gross pollutant traps and a sediment basin to satisfy pollutant reduction targets.

Methodology – MUSIC modelling

MUSIC is a continual-run conceptual water quality assessment model developed by the CRCCH. MUSIC can be used to estimate the long-term annual average stormwater volume generated by a catchment as well as the expected pollutant loads. It is able to conceptually simulate the performance of a group of stormwater treatment measures (*i.e., treatment train*) to assess whether a proposed stormwater quality strategy is capable of satisfying stormwater quality objectives. MUSIC was chosen for this investigation because it has the following attributes:

- it can account for the temporal variation in storm rainfall throughout the year;
- modelling steps can be as low as 6 minutes to allow accurate modelling of treatment devices;
- it can model a range of treatment devices;
- it can be used to estimate pollutant loads at any location within the catchment; and
- it is based on logical and accepted algorithms.

MUSIC modelling requires a series of parameters to be nominated for climate data, soil characteristics, and Event Mean Concentration (*EMC*) values. The adopted parameters were consistent across all modelling scenarios and are nominated under the relevant sub-headings below.

Climate data

Rainfall

MUSIC has the capacity to model actual rainfall events on a 6-minute time step. To harness this capacity it is preferable to use 6-minute pluviograph data. Pluviograph data recorded at the Bureau of Meteorology station at Penrith Lakes (*Station Number 67113*) between years 1998 and 2005 inclusive has been used.

The long term average annual rainfall at the Penrith Lakes rainfall station is 692 mm/year (*based on data collected from 1996 to 2009*). The eight years of data used for the MUSIC modelling had a mean annual rainfall of 694 mm/year. Despite the close correlation between the long-term average and the average across the eight years of data used, an appropriate range of wet and dry years are present within the data set.

Evapotranspiration

Monthly aerial potential evapotranspiration values were obtained for the site from the '*Climate Atlas of Australia, Evapotranspiration*', Bureau of Meteorology, 2001. The adopted values are shown below in **Table 5**.

Table 5 Monthly Aerial Potential Evapotranspiration

Month	Aerial Potential Evapotranspiration (*mm*)	Month	Aerial Potential Evapotranspiration (*mm*)
January	180	July	43
February	140	August	58
March	128	September	88
April	85	October	127
May	58	November	152
June	43	December	180

Soil Data and model calibration

In the absence of the appropriate site specific geotechnical data required to calibrate soil parameters within MUSIC, the DECC's recommended soil parameters for MUSIC modelling in western Sydney have been adopted. The DECC's recommended soil parameters are included as **Table 6**.

Table 6 DECC's Recommended Soil Parameters

	Units	Urban	Non-Urban
Impervious area parameters			
Rainfall threshold	mm/day	1.4	1.4
Pervious area parameters			
Soil storage capacity	mm	170	210
Initial storage	% of capacity	30	30
Field capacity	mm	70	80
Infiltration capacity coefficient – a	n/a	210	175
Infiltration capacity coefficient – b	n/a	4.7	3.1
Groundwater properties			
Initial depth	mm	10	10
Daily recharge rate	%	50	35
Daily base flow rate	%	4	20
Daily deep seepage rate	%	0	0

The recommended soil parameters were evaluated for appropriateness through the consideration of the volumetric runoff coefficient. In order to establish the legitimacy of a set of soil parameters, the volumetric runoff coefficient has been evaluated for a 100% pervious non-urban scenario and a 60% impervious urban scenario. The adopted soil parameters were applied to 1.0 hectare urban and non-urban catchments. The rainfall volume, runoff volume, and runoff coefficient values for the urban and non-urban scenario are summarised below in **Table 7**.

Table 7 Volumetric Runoff Coefficients

	1.0ha 100% Pervious Non-Urban Catchment	1.0ha 60% Pervious Urban Catchment
Rainfall Volume	6.94 ML/year	6.94 ML/year
Runoff Volume	0.77 ML/year	3.94 ML/year
Runoff Coefficient (C_v)	0.11	0.57

Based on the former NSW Government Department for Environment and Conservation publication, '*Managing Urban Stormwater: Strategy Framework*', 1997, the runoff coefficients calculated in **Table 7** lie within an acceptable range. Thus, the DECC's recommended soil parameters can be considered as appropriate and relevant for use on the site.

Event Mean Concentrations

DECC has recommended that the Event Mean Concentration (*EMC*) values presented in **Table 8** be adopted for MUSIC models for catchments throughout New South Wales. The recommended EMC values were determined by the CRCCH following an extensive literature review, '*Urban Stormwater Quality: A Statistical Overview*', H Duncan et al (CRCCH), 1999, which drew on data collected throughout Australia, but focussed more specifically on studies within New South Wales.

Table 8 DECC Recommended Event Mean Concentration Values

Land use	Base Flow						Storm Flow					
	Total Suspended Solids		Total Phosphorus		Total Nitrogen		Total Suspended Solids		Total Phosphorus		Total Nitrogen	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	(all values expressed as log_{10} mg/l)											
General urban Residential Industrial Commercial	1.20	0.17	-0.85	0.19	0.11	0.12	2.15	0.32	-0.60	0.25	0.30	0.19
Rural	1.15	-	-1.22	-	-0.05	-	1.95	-	-0.66	-	0.30	-
Roads	-	-	-	-	-	-	2.43	0.32	-0.30	0.25	0.34	0.19
Roofs	-	-	-	-	-	-	1.30	0.32	-0.89	0.25	0.30	0.19
Forest/Natural	0.78	0.17	-1.52	0.19	0.52	0.12	1.60	0.32	-1.10	0.25	-0.05	0.19

Proposed Water Sensitive Urban Design measures

The North Penrith development and Stage 1 incorporate a series of water sensitive urban design measures to satisfy annual pollutant load reduction targets. Measures included are rainwater tanks, bio-retention swales, gross pollutant traps, sediment basins and constructed wetlands. A description of each water sensitive urban design measure is provided under the sub-headings below.

Rainwater tanks

Rainwater tanks help reduce pollutant export into downstream drainage system by collecting and storing rainwater for reuse. Furthermore, rainwater tanks will assist in the reduction of potable water demand.

It has been assumed that each residential lot will contain a 3 kilolitre rainwater tank. The 3 kilolitre rainwater tank will retain stormwater runoff for reuse. Reuse measures include toilet flushing and outdoor irrigation.

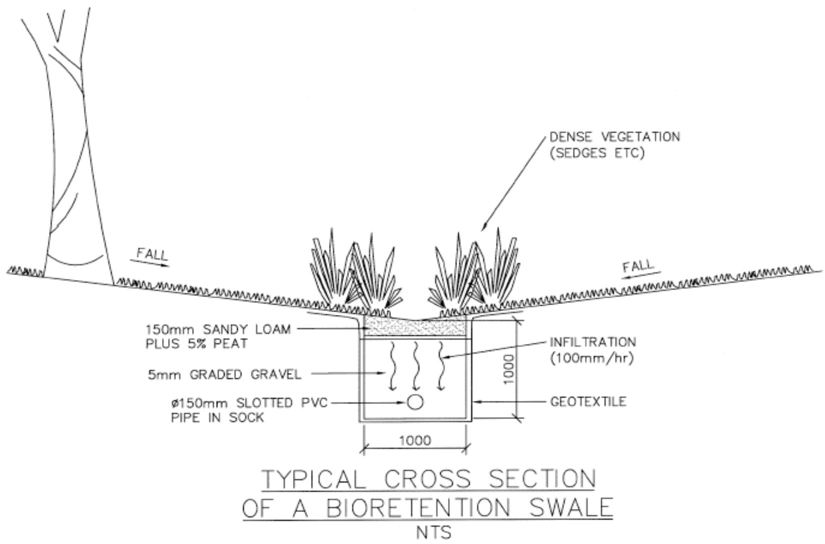
Works undertaken to date assume that one third of the total roof area from each residential lot would drain into a rainwater tank.

Conservatively, modelling undertaken to date assumes that employment, commercial and community title residential land uses will not contain rainwater tanks.

Bio-retention swales

Bio-retention swales consist of a planted region containing native grasses, shrubs and trees underlain by an infiltration area. Bio-retention swales are proposed to be gravel filled and approximately 700mm deep with 200mm of sandy loam topsoil and a perforated pipe at the base. A typical bio-retention swale cross-section, with indicative dimensions, is included below as **Diagram 3**.

Diagram 3 Typical Bio-retention Swale/Rain garden Cross Section



Bio-retention swales remove stormwater pollutants via detention and an extended filtration process. Further treatment would be achieved by filtering through the gravel trench and biological action due to growth on the gravel.

Bio-retention swales are typically designed to allow stormwater runoff to pond upon their surface (*the maximum depth of ponding for swales located within the proposed development is 0.3m*). Over time, the ponded water filters through vegetation and a layer of gravel. Flows maintained on the surface enable sunlight exposure and introduce small degrees of turbulence as flows travel along the vegetated base. Turbulence is beneficial to improving stormwater quality by enabling oxygen to enter flow volumes.

Gross pollutant traps

Proprietary GPT units will be incorporated into the North Penrith Concept Plan and Stage 1. In accordance with Council's requirements GPTs will contain dry sumps.

GPTs capture litter, debris, coarse sediment, oils, and greases. While the pollutant capture efficiency of GPTs may vary from manufacturer to manufacturer, the paper '*Removal of Suspended Solids and Associated Pollutants by a Gross Pollutant Trap*', CRCCH, 1999 suggests the following efficiencies for GPTs:

- Gross pollutants majority;
- Total suspended solids up to 70%;
- Total phosphorus up to 30%; and
- Total nitrogen up to 13%.

Sedimentation basins

The North Penrith development includes a central canal as a major architectural feature. The central canal will contain a series of weirs that will act as hydraulic controls and enable the canal to assist in achieving stormwater quality and quantity targets.

For the purposes of stormwater quality the central canal will act as a series of sedimentation basin. The principle treatment mechanism within a sedimentation basin is the physical settling of suspended solids and exposure to ultra violet light.

The sedimentation basins will consist of 1.05 m permanent pool depth and an additional 0.15 m extended detention depth. The sedimentation basins will be lined to prevent infiltration and to reduce the volume of top up water required within the central canal (*refer* ***Chapter 8***).

Sedimentation basins will be constructed during Stage 2 of the North Penrith development.

Temporary basin

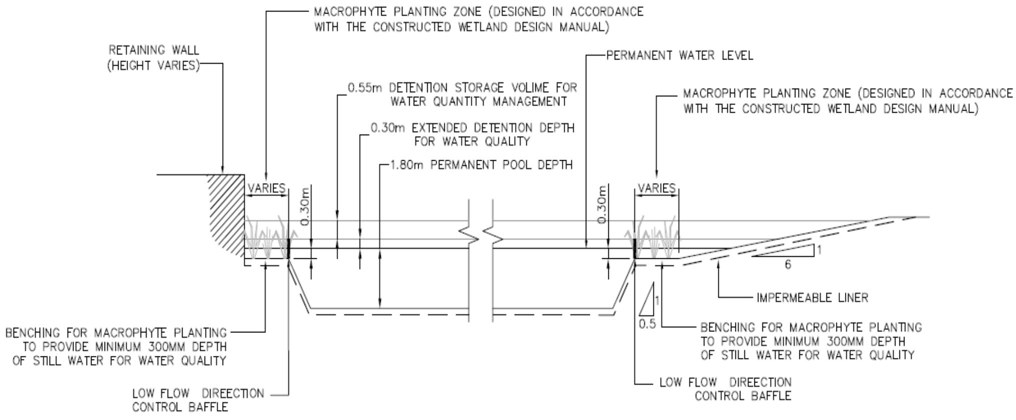
A temporary basin will be constructed during Stage 1 of the development to ensure that water quality and quantity objectives are met.

The temporary basin will act as a sedimentation basin and will cover an area of approximately 4,000m^2 and have a permanent pool depth of approximately 1.5m. 0.3 m of extended detention depth will be incorporated above the permanent pool depth.

Constructed wetlands

The proposed constructed wetland will be designed for a dual purpose encompassing stormwater quality improvement, and stormwater detention. A typical cross-section through a constructed wetland is included below as **Diagram 4**.

Diagram 4 Typical Constructed Wetland Cross Section



TYPICAL BASIN CROSS–SECTION
NTS

Constructed wetlands are typically installed as end-of-line stormwater quality improvement devices. Through a combination of sedimentation, filtration and other pollutant uptake processes, constructed wetlands reduce stormwater pollutant loadings. The constructed wetland is proposed to consist of a 1.5m permanent pool depth an additional 0.3m of extended detention depth. A macrophyte zone will be established around the perimeter of the basin and will be sized in accordance with '*The Constructed Wetlands Manual*', NSW Department of Land and Water Conservation, 1998.

In addition to the water quality improvement capability, the constructed wetland will also contain an allocated volume of detention storage to attenuate post-development peak flow rates back to pre-development levels.

The constructed wetland will be built during Stage 2 of the North Penrith development.

Existing conditions

Methodology

MUSIC modelling requires land uses to be defined. The definition of land uses enables appropriate EMC values to be applied to existing surfaces.

In order to estimate the existing annual pollutant loads the site was modelled as the General Urban land use and to be 18% impervious. The respective catchment areas for Stage 1 and the North Penrith development (*including the Commuter Car Park*) were modelled as 12.2 hectares and 43.7 hectares.

Results

The existing annual pollutant loads for the North Penrith development (*including the Commuter Car Park*) and Stage 1 are summarised in **Table 9**.and **Table 10**.

Table 9 North Penrith development site – existing annual pollutant load estimates

Pollutant	Average Annual Load (kg/yr)
Total Suspended Solids	9,010
Total Phosphorus	19
Total Nitrogen	159

Table 10 Stage 1 – existing annual pollutant load estimates

Pollutant	Average Annual Load (kg/yr)
Total Suspended Solids	2,510
Total Phosphorus	6
Total Nitrogen	44

North Penrith development

Methodology

MUSIC modelling requires land uses to be defined. The definition of land uses enables appropriate EMC values to be applied to surfaces.

Accordingly the proposed catchments of the North Penrith development were broken down into roof, road and general urban areas. The breakdown of the proposed catchment characteristics is included as **Table 11**.

Table 11 North Penrith proposed catchment characteristics

Catchment Name	Total Area (ha)	Roof Area (ha)	Road Area (ha)	General Urban Area (ha)	General Urban % Impervious
1	1.2	0.7	0	0.5	90
2	2.3	0	0	2.3	35
3	0.8	0	0.8	0	0
4	2.1	0.8	0.8	0.5	64
4a	0.3	0.2	0	0.1	64
5	1.2	0.5	0.4	0.3	74
6	3.1	1.1	1.3	0.7	83
6a	0.4	0.4	0	0.4	90

Catchment Name	Total Area (ha)	Roof Area (ha)	Road Area (ha)	General Urban Area (ha)	General Urban % Impervious
7	7.3	2.7	2.8	1.8	78
8	0.4	0.2	0	0.2	92
9	0.4	0.1	0.2	0.1	60
10	1.5	0	0	1.5	40
11	0.3	0.2	0	0.1	90
12	1.0	0.4	0.4	0.2	60
13	3.8	1.3	1.4	1.1	51
14	4.4	2.1	0.9	1.4	70
15	2.9	1.0	1.0	0.9	60
16	1.7	0.6	0.8	0.3	60
17	1.9	0.9	0.3	0.7	60
18	1.8	0.1	0.1	1.6	20
19	2.1	0	0	2.1	20
CCP	3.0	0	0	0	0
Total	**43.7**	**12.9**	**14.2**	**16.6**	**n/a**

Roof areas were modelled as being 100% impervious and roads were modelled as being 90% impervious. General urban areas were modelled with varying impervious percentages to account for the variation of the proposed composition of land uses (*i.e., residential, commercial, industrial*) and open spaces.

The Commuter Car Park was modelled as being 90% impervious.

The proposed catchments were then routed through the proposed drainage strategy for the North Penrith development. This enables the effectiveness of the stormwater quality "treatment train" in removing stormwater pollutants to be estimated. The proposed "treatment train" for the North Penrith development is shown on **Figure 2**.

Results

The objectives set out by Landcom for stormwater quality are driven by percentage reduction targets for four pollutants; Total Suspended Solids, Total Phosphorus and Total Nitrogen. Thus, the North Penrith MUSIC model is required to estimate two things:

1. the average annual pollutant loads generated by sources (*i.e., roofs, roads and general urban*); and

2. the effectiveness of the proposed stormwater quality "treatment train" in removing stormwater pollutants.

The effectiveness of the stormwater quality treatment train in minimising stormwater pollutants for the North Penrith development is summarised in **Table 12**.

Table 12 North Penrith development – effectiveness of stormwater quality treatment train

	Sources	Residual Load	Percentage Reduction	Landcom Target
Total Suspended Solids (kg/year)	27,100	3,360	88%	85%
Total Phosphorus (kg/year)	59	19	68%	65%
Total Nitrogen (kg/year)	408	220	46%	45%

Stage 1

Methodology

MUSIC modelling requires land uses to be defined. The definition of land uses enables appropriate EMC values to be applied to surfaces.

Accordingly the proposed catchments of Stage 1 were broken down into roof, road and general urban areas. The breakdown of the proposed catchment characteristics is included as **Table 13**.

Table 13 North Penrith proposed catchment characteristics

Catchment Name	Total Area (ha)	Roof Area (ha)	Road Area (ha)	General Urban Area (ha)	General Urban % Impervious
A	1.8	0.7	0.6	0.5	72%
B	0.5	0.2	0.2	0.1	59%
C	1.5	0.2	1.1	0.2	60%
D	1.7	0.6	0.5	0.6	41%
E	1.4	0.5	0.5	0.4	60%
F	2.1	0	0.3	1.8	20%
G	0.3	0	0.3	0	0
H	3.0	0.9	1.5	0.5	60%
Total	**12.2**	**3.1**	**5.0**	**4.1**	**n/a**

Roof areas were modelled as being 100% impervious and roads were modelled as being 90% impervious. General urban areas were modelled with varying impervious percentages to account for the variation of the proposed composition of land uses (*i.e., residential, commercial, industrial*) and open spaces.

The proposed catchments were then routed through the proposed drainage strategy for the Stage 1. This enables the effectiveness of the stormwater quality "treatment train" in removing stormwater pollutants to be estimated. The proposed "treatment train" for Stage 1 is shown on **Figure 3**.

Results

The objectives set out by Landcom for stormwater quality are driven by percentage reduction targets for four pollutants; Total Suspended Solids, Total Phosphorus, Total Nitrogen and Gross Pollutants. Thus, the Stage 1 MUSIC model is required to estimate two things:

1. the average annual pollutant loads generated by sources (*i.e., roofs, roads and general urban*); and

2. the effectiveness of the proposed stormwater quality "treatment train" in removing stormwater pollutants.

The effectiveness of the stormwater quality treatment train in minimising stormwater pollutants during Stage 1 is summarised in **Table 14**.

Table 14 Stage 1 – effectiveness of stormwater quality treatment train

	Sources	Residual Load	Percentage Reduction	Landcom Target
Total Suspended Solids (kg/year)	8,980	828	91%	85%
Total Phosphorus (kg/year)	19	6	69%	65%
Total Nitrogen (kg/year)	118	57	52%	45%

Maintenance program and costs

Maintenance program

The proposed maintenance program for the proposed WSUD features outlined below has been based upon '*Managing Urban Stormwater: Treatment Techniques*', New South Wales Environment Protection Agency, 1997 and would consist of the following:

- inspection of bio-retention swales should be undertaken quarterly and following large storm events. The following items should be inspected and if required remedial action should be taken:
  - channelisation and erosion;
  - vigour and density of vegetation;
  - weed inundation;
  - access and wear;
  - sediment build up; and
  - litter/debris.
- Gross Pollutant Traps should be inspected quarterly and following large storm events. Any trapped pollutants should be removed;

- the sedimentation basins should be inspected annually and following large storm events. Testing of the overlying water should be undertaken to determine the necessity of dewatering and removal of trapped sediments; and
- the constructed wetland should be inspected quarterly and following large storm events. The following should be inspected and if required remedial action taken:
  - performance of outlet structures;
  - integrity of embankments;
  - weed infestation;
  - mosquito breeding;
  - litter and sediment levels; and
  - health and diversity of macrophytes.

Maintenance costs

Maintenance costs have been estimated based the life cycle cost analysis function available within MUSIC modelling. Maintenance costs for the water sensitive urban design measures for Stage 1 and the North Penrith development are provided below in **Table 15** and **Table 16** respectively.

Table 15 Maintenance costs – Stage 1

Item	Frequency	Annual Maintenance Cost Estimate ($/item)	Total Annual Cost
Bio-retention swales	2	$1,900	$3,800
Gross pollutant traps	2	$2,000	$4,000
Sedimentation basin	1	$6,500	$6,500
		Total	$14,300

Table 16 Maintenance costs – North Penrith

Item	Frequency	Annual Maintenance Cost Estimate ($/item)	Total Annual Cost
Bio-retention swales	2	$1,900	$3,800
Gross pollutant traps	9	$2,000	$18,000
Sedimentation basin	5	$3,000	$15,000
Constructed wetland	1	$10,500	$10,500
		Total	$47,300

7. Stormwater quantity methods and results

At a glance

The stormwater quantity management strategy mitigates the increase in stormwater runoff arising from the proposed development. Through the provision of on-site detention, post-development discharge flow rates are reduced to match existing discharge peak flow rates.

The software package XP-RAFTS was used to estimate pre-development (*i.e., existing*) and post-development peak flow rates. XP-RAFTS was also used to estimate the volume of storage required to attenuate post-development peak flow rates back to pre-development levels.

Whilst various measures will provide detention storage throughout the North Penrith development, the bulk of the detention volume will be provided within the constructed wetland. The constructed wetland has been designed to provide 7,000m^3 of detention storage.

A temporary basin will be constructed during Stage 1 works. The temporary basin will provide approximately 4,000m^3 of detention volume to ensure peak discharge rates off the site are not increased for events up to the 100 year ARI.

XP-RAFTS

The XP-RAFTS software package was used to model the hydrology of the pre-development (*i.e., existing*) and post-development catchments. XP-RAFTS is a non-linear rainfall/runoff program used to estimate peak flow rates for catchments using actual storm events or design rainfall data derived from '*Australian Rainfall and Runoff*', Institute of Engineers Australia, 1987. The XP-RAFTS software package is used extensively by authorities and industry professionals throughout Australia on both rural and urban catchments.

XP-RAFTS requires a catchment to be broken down into a number of sub-catchments based on watershed boundaries and the following information to be nominated for each sub-catchment:

1. catchment area;
2. percentage of impervious surfaces;
3. catchment slope;
4. rainfall losses; and
5. surface roughness (*Manning's "n" values*).

North Penrith development

The North Penrith development will increase the impervious area at the site by approximately four times. This increase in area will result in an increased volume of stormwater runoff being generated during storm events. Thus, on-site detention will be required to attenuate post-development flow rates back to pre-development values.

Methodology

XP-RAFTS software was used to estimate pre-development and post-development peak flow rates. The XP-RAFTS model adopted the catchment properties for the pre-development and post-development scenarios as nominated in **Table 2** and **Table 3** respectively.

The stormwater drainage strategy for the North Penrith development will incorporate various infrastructure with a capacity to detain stormwater infrastructure. Proposed infrastructure includes:

- rainwater tanks on each residential lot;
- bio-retention swales along the entry boulevarde;
- a series of sedimentation ponds along the central canal; and
- a constructed wetland.

Modelling work undertaken to date only includes the volume of storage available within the central canal and constructed wetland. By ignoring the detention capabilities of rainwater tanks and bio-retention swales the detention of volume required is conservative.

Central Canal – detention capability

The central canal's primary function is aesthetic. However, the central canal does afford some benefits for stormwater quality (*refer **Chapter 6***) and quantity management for frequent storm events.

The central canal includes five weirs along its length. The width of the weir coincides with the width of the central canal. These weirs will be responsible for maintaining a permanent volume of water within the canal and for providing extended detention depth for stormwater quality improvement during frequent storm events (*refer **Chapter 6***). Additionally, the weirs will act as hydraulic controls.

Thus, the five weirs have been incorporated into the XP-RAFTS model to ensure accurate post-development flow rates and hydrographs are generated. To model the weirs within XP-RAFTS the stage – storage and stage – discharge relationships were defined for each weir. The stage – storage relationship was derived from a surface area and depth calculation whilst the stage – discharge relationship was derived from the weir equation. Summaries of the stage – storage and stage – discharge relationships for each of the five weirs are nominated in **Table 17**.

Table 17 Detention capabilities – central canal

Weir Number	Invert (mAHD)	Top of Weir (mAHD)	Weir Width (m)	Stage (mAHD)	Storage (m^3)	Discharge (m^3/s)
1	22.95	24.15	15	24.15	0	0
				24.48	145	4.8
				24.80	290	13.4
2	23.10	24.30	18	24.30	0	0
				24.59	157	4.8
				24.88	315	13.5
3	23.26	24.46	30	24.46	0	0
				24.67	510	4.9
				24.88	1,020	13.9
4	23.41	24.61	17	24.61	0	0
				24.93	985	5.2
				25.24	1,970	14.5
5	23.56	24.76	16	24.76	0	0
				25.11	675	5.6
				25.46	1,350	15.9

Constructed Wetland – detention capability

The constructed wetland acts as the primary source of stormwater detention within the North Penrith development. The constructed wetland has been designed to provide stormwater quality benefits (*refer* ***Chapter 6***) during minor storm events as well as providing an adequate storage volume to enable post-development flow rates to be attenuated back to pre-development flow rates prior to discharging into existing Council infrastructure.

The constructed wetland will contain two outlets. One outlet will discharge into existing stormwater infrastructure located underneath the existing access road to the commuter car park. Once the capacity of the existing Council infrastructure is met the constructed wetland will discharge stormwater to existing infrastructure located to its west. The discharge arrangements for the constructed wetland are nominated on **Figure 2**.

In order to determine the detention of volume that is required within the constructed wetland to attenuate post-development flow rates back to pre-development flow rates stage – storage and stage – discharge relationships were modelled in XP-RAFTS.

The stage – storage relationship was generated based on the footprint of the constructed wetland. Meanwhile, the stage – discharge relationship was a modelling output. The discharge values were fixed at the pre-development flow rates for a series of ARI storm events and the peak basin stage (*a modelling output*) for each storm event was used to calculate the required volume of storage (*i.e., peak basin stage multiplied by surface area*).

The stage – storage relationship for the constructed wetland was modelled based upon the assumption that the constructed wetland would cover a footprint of approximately 8,000m^2 and would rise with vertical walls. Whilst this does not accurately reflect the final arrangement of the constructed wetland the process reflects an appropriately conservative methodology for estimating the required volume of storage to attenuate post-development flow rates back to pre-development values.

Results

Pre-development peak flow estimates

The pre-development peak flow estimates for various ARI storm events are nominated in **Table 18**.

Table 18 Pre-development peak flow estimates

Average Recurrence Interval (years)	Pre-development peak flow estimate (m^3/s)
2	3.1
5	4.7
20	6.9
100	9.6

Post-development volume estimates

Post development flows without detention are summarised in **Table 19** for various ARI events.

Table 19 also indicates the volumes required within the constructed wetland to attenuate post-development flow rates back to pre-development levels.

Table 19 Post-development flow estimates and detention volumes

Average Recurrence Interval (years)	Post-development flow estimate – no detention (m^3/s)	Volume required within the constructed wetland (m^3)	Post-development flow estimate – with detention (m^3/s)
2	8.7	2,100	3.1
5	11.5	3,400	4.7
20	15.5	5,050	6.9
100	19.6	7,000	9.6

Stage 1

Stage 1 of the North Penrith development will result in an increased impervious area within the Stage 1 boundary. Thus, peak flow rates will increase as a result of Stage 1.

Methodology

The phased construction of the North Penrith development will see Stage 1 completed prior to the construction of the central canal and the constructed wetland. Thus, a temporary basin will need to be constructed to attenuate the Stage 1 post-development peak flow rates back to pre-development flow rates.

XP-RAFTS software was used to estimate pre-development and post-development peak flow rates. The XP-RAFTS model adopted the catchment properties associated with Stage 1 for the pre-development and post-development scenarios. These catchment properties are nominated in **Chapter 2**.

The stormwater drainage strategy for Stage 1 will incorporate various infrastructure within a capacity to detain stormwater runoff. Proposed infrastructure includes rainwater tanks, bio-retention swales and a temporary basin.

Modelling work undertaken to date only includes the volume of storage available within the temporary basin. By disregarding the detention capabilities of rainwater tanks and bio-retention swales the detention of volume requires is conservative.

Temporary basin – detention capability

The temporary basin will provide three functions:

1. act as a sedimentation basin during construction phases;
2. provide stormwater quality treatment; and
3. provide stormwater detention.

The temporary basin will discharge into existing drainage corridors and will provide a sufficient storage volume to enable post-development peak flow rates to be attenuated back to pre-development flow rates for events up to the 100 year ARI.

In order to determine the detention volume that is required within the temporary basin to attenuate post-development flow rates back to pre-development flow rates, stage – storage and stage – discharge relationships were modelled in XP-RAFTS.

The stage – storage relationship was generated based on the footprint of the temporary basin. For the purpose of modelling it was assumed that the temporary basin would have a footprint of 4,000 m^2 and an average depth of 1.5 m. Whilst this does not accurately reflect the final arrangement of the temporary basin the process reflects an appropriately conservative methodology for estimating the required volume of storage to attenuate post-development flow rates back to pre-development values.

Due to grading constraints, a small portion of the Stage 1 development will not drain back towards the temporary basin. This area by-passing the temporary basin was considered when determining the stage – discharge relationship. The discharge values were fixed to a level to ensure that the cumulative discharge from Stage 1 (*i.e., the combined volume of flow entering and by-passing the temporary basin*) under post-development conditions did exceed the pre-development peak flow rates. A series of ARI storm event were simulated in XP-RAFTS to determine the peak basin stage (*a modelling output*) for each ARI event. This peak basin stage was then used to calculate the required volume of storage (*i.e., peak basin stage multiplied by surface area*).

Results

Pre-development peak flow estimates

The pre-development peak flow estimates for various ARI storm events are nominated in **Table 20**.

Table 20 Pre-development peak flow estimates

Average Recurrence Interval (years)	Pre-development peak flow estimate (m^3/s)
2	0.7
20	1.6
100	2.2

Post-development volume estimates

Post development flows without detention are summarised in **Table 21** for various ARI events. **Table 21** also indicates the volumes required within the constructed wetland to attenuate post-development flow rates back to pre-development levels.

Table 21 Post-development flow estimates and detention volumes

Average Recurrence Interval (years)	Post-development flow estimate – no detention (m^3/s)	Volume required within the temporary basin (m^3)	Post-development flow estimate – with detention (m^3/s)
2	2.4	2,300	0.7
20	4.3	2,850	1.6
100	5.5	4,050	2.1

8. Central canal water balance

At a glance

Water will need to be re-circulated through the central canal to prevent stagnation and the build up of odour. Additionally, the continual circulation of water through the central canal will boost the aesthetic value to the community by providing an opportunity to maintain a semi-permanent water level within the central canal.

To maintain the aesthetic appeal of the central canal it is the intention to provide a minimum depth of water of 0.90 m even during more extended dry periods.

The preferred source for supply water for re-circulation and topping up of the central is the deep water zone of the constructed wetland. The constructed wetland contains a permanent pool volume of approximately 5,200m^3. MUSIC modelling outputs were used to establish a daily water balance calculation for the re-circulation of water and topping up of the canal. The daily water balance established that a water level of 0.90 m within the canal could be maintained approximately 80% of the time for the modelled period (*i.e., 1998 – 2005*).

It is recommended that additional water balance modelling be undertaken during detailed design. Further water balance modelling would be used to drive a cost-benefit analysis of re-circulation and topping options. Revised water balance modelling would need to consider:

- the impact of lowering the desire permanent water depth within the canal on the capacity of the constructed wetland to service demand;
- the potential increase in the deep water zone storage volume within the constructed wetland;
- the potential of including an underground storage volume to service the demands of the canal; and
- the potential to use alternate water supplies during dry times to top up the central canal.

Central canal water balance

Methodology

A daily water balance calculation has been established for the North Penrith development. The water balance calculation was based on MUSIC modelling work undertaken for the North Penrith development (*refer **Chapter 6***). MUSIC enables the inflow and outflow volumes to be exported for all treatment nodes (*i.e., the central canal and the constructed wetland*).

A water balance spreadsheet was prepared that included allowances for daily inflow volumes, outflow volumes, evapotranspiration, infiltration and topping up of the canal.

Results

The water balance calculation indicates that a permanent pool volume of 5,200m^3 has the capacity to service the re-circulation and top up (*to a depth of 0.9 m*) demands of the central canal can be achieved 80% of the time for the period modelled (*1998 – 2005*).

Sensitivity analysis

A sensitivity analysis was undertaken to determine the impact on varying conditions. The capacity of the deep water zone to top up the central canal is increased by expanding the permanent pool volume of the constructed wetland or reducing the desired permanent pool volume from depth from 0.9 m.

The expansion of the permanent pool volume of the constructed wetland from 5,200m^3 to 7,000m^3 would enable the central canal to maintain a permanent depth of 0.9 m for more than 90% of the time for the period modelled (*1998 – 2005*).

The reduction in the desired permanent pool volume from 0.9 m to 0.8m would enable the constructed wetland (*with a permanent pool volume of 5,200m^3*) to service the re-circulation and top up demands of the central canal approximately more than 90% of the time for the period modelled (*1998 – 2005*).

Recommendations

It is recommended that further cost-benefit analyses be undertaken on re-circulation and top up options associated with the central canal. The cost benefit analysis would be aided by additional sensitivity analyses being undertaken within the water balance model and evaluating the following options:

- lowering the permanent water level within the central canal;
- increasing the permanent pool volume of the constructed wetland;
- the possibility of including an underground storage facility; and
- the possibility of using alternate water supplies during dry times.

9. Flooding

At a glance

Flooding issues have been considered at the regional and local levels. The Nepean River flood behaviour governs the response to regional flooding issues whilst local flood behaviour considers overland flow paths that drain internal and external catchments through the site and into downstream water bodies.

Regional flooding

Regional flooding has been addressed in a separate report prepared by WorleyParsons, '*North Penrith Regional Flooding Assessment*', WorleyParsons, October 2010. This report addresses:

- habitable floor levels;
- flood emergency response plans for the flood events up to the Probable Maximum Flood;
- the development's impact on existing flood emergency responses; and
- risk to life.

Localised flooding

The adopted approach to localised flooding is to manage stormwater runoff in excess of the piped drainage network (*i.e., beyond the 5 year ARI storm event*) within dedicated overland flow paths.

Dedicated overland flow paths will include road reserves, dedicated open channels and some regions of open space. Overland flow paths will be designed to ensure that they are classified as "low-risk" under the '*New South Wales Floodplain Development Manual*'. To be nominated as "low-risk" overland flow paths typically have to demonstrate a velocity depth product no greater than 0.4 m^2/s.

Works undertaken to date have estimated the peak water surface levels within the central canal and the constructed wetland. Predicted peak water surface levels include external catchments draining through the site. The predicted peak water surface levels have been used to assist in the design of open spaces around the central canal and the constructed wetland.

10. Surface water / groundwater interaction

At a glance

Under existing conditions the North Penrith development site contains a significant portion of pervious areas. Pervious areas enable surface water runoff to infiltrate the ground surface and form part of the groundwater resource.

Review of the '*Geotechnical & Groundwater North Penrith Assessment Report*', Geotechnique, October 2010 establishes that the groundwater table is at depths greater than 5.0 m below existing surface levels. The report does not indicate the direction of flow associated with the ground water resource under existing conditions. However, given the proximity of the site to the Nepean River and Boundary Creek it is assumed that the groundwater resources generally drains in a north-westerly direction. This will need to be confirmed during further geotechnical investigations.

Based on the proposed stormwater management strategy no stormwater infrastructure will be located at depths greater than 5.0 m below existing surface levels. As such, surface water will not be directly connected to the groundwater resource.

The increase in impervious area on the site has the capacity to reduce the extent of infiltration. This impact will be off-set by including a constructed wetland with a permeable base within the development. The location of the constructed wetland is such that infiltration will be promoted towards the downstream extent of the site. Through this promotion of infiltration towards the north-western extent of the site the development's impact on the groundwater resource downstream of the site would be reduced.

The North Penrith development does not require the extraction of groundwater to service water demands.

11. Assessment

At a glance

Integrated stormwater management strategies have been prepared for the North Penrith development and Stage 1. The integrated stormwater management strategies demonstrate that the objectives for drainage, stormwater quality, stormwater quantity, flooding and groundwater can be satisfied. Further refinement of the stormwater management strategies will be required during detailed design.

North Penrith Development

Stormwater drainage

A concept stormwater drainage network has been prepared based on proposed catchment boundaries and the requirement to drain stormwater runoff towards water sensitive urban design infrastructure and stormwater detention volumes. The concept stormwater drainage network is shown on **Figure 2**.

The stormwater drainage network will be designed to accommodate the 5 year ARI peak storm event. Pit locations and pipe diameters will be established during the detailed design process.

Stormwater quality

The North Penrith development adopts a treatment train approach to stormwater quality. Modelling work undertaken demonstrates the proposed treatment train has the capacity to satisfy Landcom's stormwater quality pollution reduction targets.

The stormwater quality management strategy will need to evolve during detailed design and may need refinement to accommodate changes made to the concept stormwater drainage network.

A sediment and erosion control plan has been prepared for the North Penrith development construction phase. The sediment and erosion control plan is preliminary only and will need to be finalised in consultation with the contractor.

Stormwater quantity

Through the provision of stormwater detention volume in the central canal and constructed wetland the North Penrith development will attenuate post development peak flow rates back to pre-development levels.

Whilst the stormwater detention volumes have been subject to concept design the configuration of outlets will need to be confirmed during detailed design.

Flooding

Minimum road levels (*25.40 mAHD*) and Flood Planning Levels (*25.90 mAHD*) have been set for the North Penrith development based on the '*North Penrith Regional Flooding Assessment*', WorleyParsons, October 2010.

Localised flooding has been considered in the preparation of the stormwater drainage network. Dedicated overland flow paths will convey stormwater runoff for events exceeding the 5 year ARI (*i.e., the capacity of the drainage network*).

100 year ARI flood levels have been estimated for the central canal and constructed wetland based on XP-RAFTS modelling undertaken to date. These flood levels will need to be confirmed during detailed design. In addition to the central canal and constructed wetland road reserves will act as designated overland flow paths. Overland flow paths will need to manage flood risk for events up to the 100 year ARI flood. This will include the management of velocity and depth within road reserves. Flood risk will be established and appropriate mitigation strategies incorporated during the detailed design phase.

Surface water / ground water
Given the depth of the water table below the existing surface, surface water and ground water will not be directly linked.

The proposed development will reduce the amount of pervious area at the site. This has the potential to reduce the extent of surface runoff infiltrating the ground surface. This impact is considered to be off-set by the promotion of infiltration in the north-western corner of the site – the assumed downstream extent of the ground water resource.

Additional geotechnical investigation will need to be undertaken during detailed design to confirm the depths of the groundwater table in the vicinity of the constructed wetland and central canal. This geotechnical investigation should also establish the flow characteristics of the groundwater resource to confirm assumptions made to date.

Stage 1

Stormwater drainage
A concept stormwater drainage network has been prepared based on proposed catchment boundaries and the requirement to drain stormwater runoff towards water sensitive urban design infrastructure and stormwater detention volumes. The concept stormwater drainage network is shown on **Figure 3**.

The stormwater drainage network will be designed to accommodate the 5 year ARI peak storm event. Pit locations and pipe diameters will be established during the detailed design process.

Three existing drainage channels within the site will be amended (*refer **Figure 3***) such that they can be integrated into the Stage 1 stormwater drainage network.

Stormwater quality
Stage 1 adopts a treatment train approach to stormwater quality. Modelling work undertaken demonstrates the proposed treatment train has the capacity to satisfy Landcom's stormwater quality pollution reduction targets.

The stormwater quality management strategy will need to evolve during detailed design and may need refinement to accommodate changes made to the concept stormwater drainage network and the North Penrith development drainage network.

A sediment and erosion control plan has been prepared for the Stage 1 construction phase. The sediment and erosion control plan is preliminary only and will need to be finalised in consultation with the contractor.

Stormwater quantity

Through the provision of stormwater detention volume in the temporary basin Stage 1 post development peak flow rates will be attenuated back to pre-development levels.

Whilst the stormwater detention volumes have been subject to concept design the configuration of outlets will need to be confirmed during detailed design

Flooding

Stage 1 adopts the minimum road levels and Flood Planning Levels recommended in the '*North Penrith Regional Flooding Assessment*', WorleyParsons, October 2010.

Localised flooding has been considered in the preparation of the stormwater drainage network. Dedicated overland flow paths will convey stormwater runoff for events exceeding the 5 year ARI (*i.e., the capacity of the drainage network*).

Overland flow paths will need to manage flood risk for events up to the 100 year ARI flood. This will include the management of velocity and depth within road reserves. Flood risk will be established and appropriate mitigation strategies incorporated during the detailed design phase.

Surface water / ground water

The stormwater management strategy for Stage 1 will not intercept the groundwater table. Thus, the surface water and ground water will not be directly linked.

Additional geotechnical investigation is recommended within the vicinity of the temporary basin to confirm the depth of the groundwater table and to establish the existing flow regime of the groundwater resource.

12. References

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- '*The Constructed Wetlands Manual*', NSW Department of Land and Water Conservation, 1998
- '*Managing Urban Stormwater: Treatment Techniques*', New South Wales Environment Protection Agency, 1997
- 'New South Wales Floodplain Development Manual', Department of Natural Resources, 2005
- 'North Penrith Concept Plan Application Drawings', WorleyParsons, October 2010
- 'North Penrith Stage 1 Project Application Drawings', WorleyParsons, October 2010
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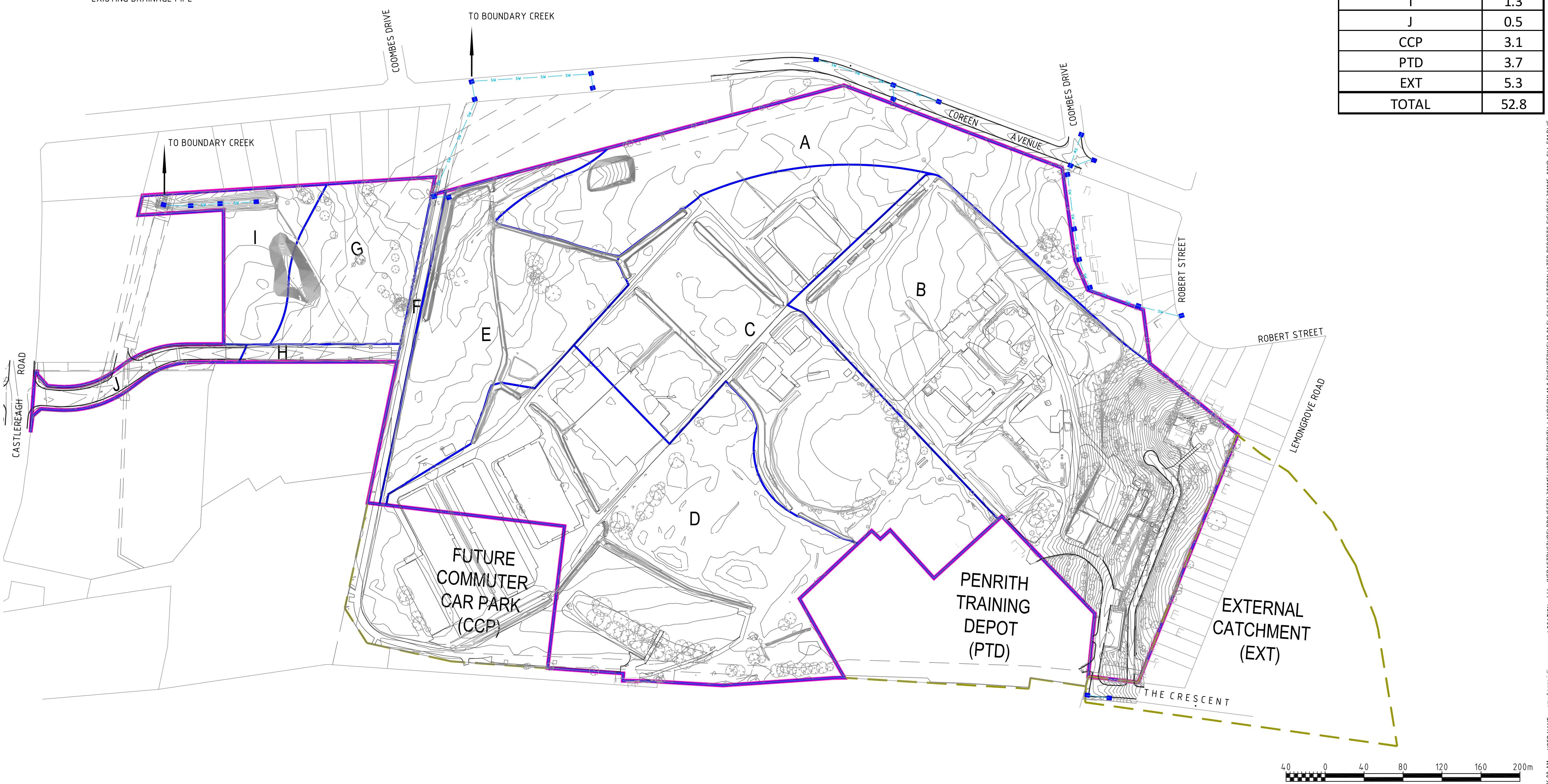
- 'Urban Stormwater Quality: A Statistical Overview', H Duncan et al (CRCCH), 1999

- ‘Removal of Suspended Solids and Associated Pollutants by a Gross Pollutant Trap’, CRCCH, 1999

13. Figures



LEGEND

- EXISTING SURFACE CONTOUR (0.25m INTERVAL)
- SITE BOUNDARY
- INTERNAL CATCHMENT BOUNDARY
- EXTERNAL CATCHMENT BOUNDARY
- B — CATCHMENT NAME
- EXISTING DRAINAGE PIT
- EXISTING DRAINAGE PIPE

NAMES	AREA(ha)
A	4.8
B	10.3
C	8.2
D	8.7
E	4.0
F	0.4
G	2.1
H	0.3
I	1.3
J	0.5
CCP	3.1
PTD	3.7
EXT	5.3
TOTAL	52.8

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B	26.10.10	FINAL
A	20.10.10	ISSUED FOR INFORMATION

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NORTH PENRITH
STORMWATER MANAGEMENT
EXISTING CATCHMENT PLAN

301015-00NP-SW-F01

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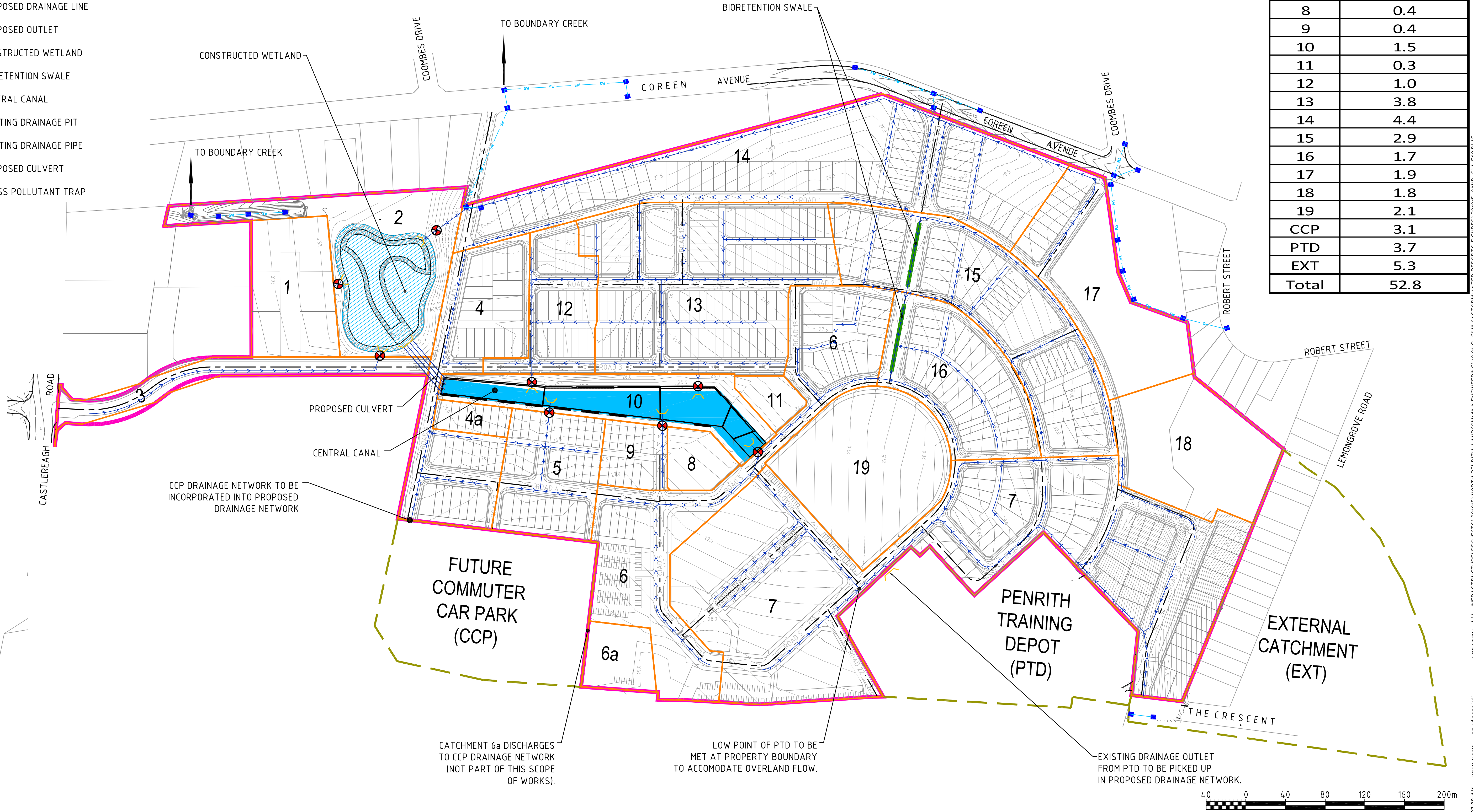
LEGEND

- PROPOSED SURFACE CONTOUR (0.25m INTERVAL)
- PROPOSED SURFACE CONTOUR (0.5m INTERVAL)
- SITE BOUNDARY
- INTERNAL CATCHMENT BOUNDARY
- EXTERNAL CATCHMENT BOUNDARY
- 3 CATCHMENT NAME
- PROPOSED DRAINAGE LINE
- PROPOSED OUTLET
- CONSTRUCTED WETLAND
- BIORETENTION SWALE
- CENTRAL CANAL
- EXISTING DRAINAGE PIT
- EXISTING DRAINAGE PIPE
- PROPOSED CULVERT
- GROSS POLLUTANT TRAP

NAMES	AREA(ha)
1	1.2
2	2.3
3	0.8
4	2.1
4a	0.2
5	1.2
6	3.0
6a	0.5
7	7.3
8	0.4
9	0.4
10	1.5
11	0.3
12	1.0
13	3.8
14	4.4
15	2.9
16	1.7
17	1.9
18	1.8
19	2.1
CCP	3.1
PTD	3.7
EXT	5.3
Total	52.8



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NORTH PENRITH
STORMWATER MANAGEMENT
PROPOSED DRAINAGE NETWORK

301015-00NP-SW-F02

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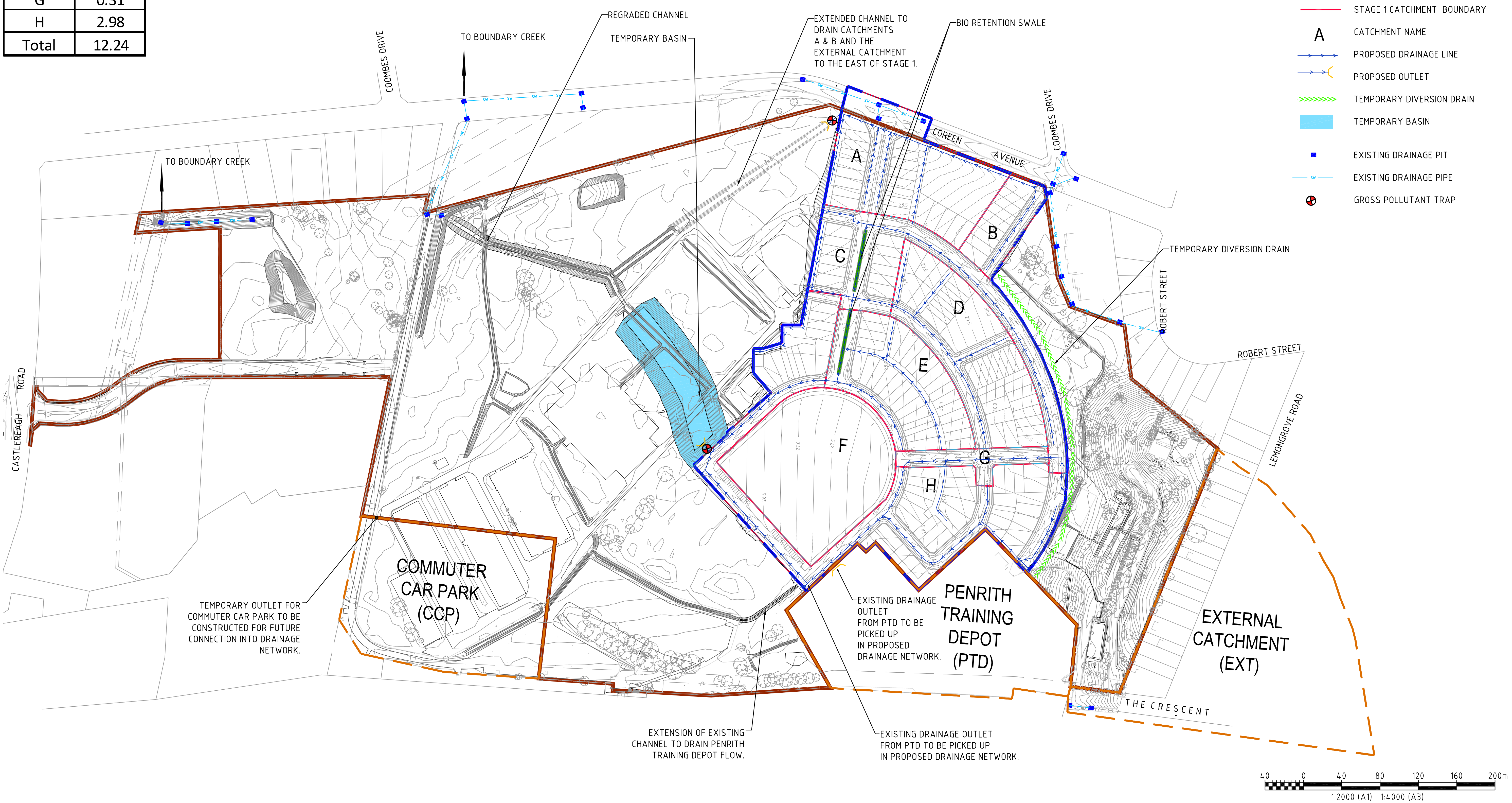
Total	12.24



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STORMWATER MANAGEMENT
STAGE 1 PROPOSED DRAINAGE NETWORK
301015-00NP-SW-F03