Member of the Surbana Jurong Group

Austral and Leppington North Design of Water Management Infrastructure

Draft Detailed Concept Design Report

Prepared for: Liverpool City Council
Reference No: ST2575
7/12/2018

Document/Report Control Form

File Location Name:	I:\projects\30011388 – Austral and Leppington North\
Project Name:	Austral and Leppington North – Design of Water Management Infrastructure
Project Number:	30011388
Revision Number:	01

Revision History

Revision #	Date	Prepared by	Reviewed by	Approved for Issue by
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Issue Register

Distribution List	Date Issued	Number of Copies
Liverpool City Council	07-12-2018	1
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Executive Summary

Abbreviations

Abbreviation	Description
AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
BCC	Blacktown City Council
BOM	Bureau of Meteorology
BoQ	Bill of Quantities
CAD	Computer Aided Design
Ch.	Chainage
CBD	Central Business District
CEH	Craven Elliston & Hayes, Dapto Pty Ltd
CL	Continuous Loss
CSS	Catchment Simulation Solutions
DBYD	Dial Before You Dig
DCP	Development Control Plan
DEM	Digital Elevation Model
DP&E	Department of Planning & Environment
DPI	Department of Primary Industries
DSC	Dam Safety Committee
EDD	Extended Detention Depth
EE	Endeavour Energy
EIA	Effective Impervious Area
EPA	Environment Protection Authority
GIS	Geographical Information Systems
GPs	Gross Pollutants
GPT	Gross Pollutant Trap
IFD	Intensity Frequency Duration
IL	Initial Loss
ILP	Indicative Layout Plan
LCC (Council)	Liverpool City Council
LiDAR	Light Detection and Ranging
ISEPP	State Environmental Planning Policy (Infrastructure)
LTC	Leppington Town Centre
OEH	Office of Environment & Heritage
OLFP	Overland Flow Path
RCBC	Reinforce Concrete Box Culvert

Abbreviation	Description
RCP	Reinforced Concrete Pipe
REF	Review of Environmental Factors
RFT	Request for Tender
RMS	Roads and Maritime Services
RTA	Roads and Traffic Authority NSW
RWT	Rainwater Tank
QUDM	Queensland Urban Drainage Manual
SiD	Safety in Design
SMEC	SMEC Australia Pty Ltd
SZ	Submerged Zone
TIA	Total Impervious Area
TN	Total nitrogen
TP	Total Phosphorous
TSC	Threatened Species Conservation
TSS	Total Suspended Solids
VMP	Vegetation Management Plan
WCM	Water Cycle Management
WSUD	Water Sensitive Urban Design

1. Introduction

1.1. Project Overview

The precincts of Austral and Leppington North are the latest release areas in the Liverpool and Camden Local Government Areas (LGA's) proposed for future residential development. The precincts, which cover a combined area of approximately 20 km^2, are currently characterised by rural residential land use with small-scale agricultural farming, market gardens and hobby farms. There are also a small number of light industrial and commercial developments in each of the precincts (LCC, 2016).

There are three major watercourses and tributary waterways that traverse the study area; namely Kemps Creek, Scalabrini Creek and Bonds Creek, as shown on Figure 1.1.

A Water Cycle Management (WCM) strategy for the study area was previously developed by Cardno for the Department of Planning & Environment (DP&E), as part of the precinct planning process (Cardno, 2011a; Cardno, 2011b; Cardno, 2012b). The objective of the Cardno studies was to address the adverse impacts on flooding and water quality caused by the proposed precinct development. The WCM strategy proposed a series of detention basins, overland flow paths and constructed channels to control stormwater runoff, while a series of bioretention systems and gross pollutant traps (GPTs) was proposed to achieve the water quality objectives.

SMEC Australia Pty Ltd (SMEC) was subsequently engaged by Liverpool City Council (Council) to prepare detailed concept designs for the water management infrastructure and water quality control structures proposed in the WCM strategy. This was specifically related to the development area within the Liverpool City Council LGA, north of Bringelly Road, as shown in Figure 1.1.

The refined project extent covers an area of approximately 15 km^2. The project area is bounded by the Sydney Water Upper Canal on the eastern end, Kemps Creek on the western end, Western Sydney Parkland on the northern end and Bringelly Road on the southern end.

The original project scope involved the investigation and concept design of 21 co-located flood detention and water quality control basins (bio-filters), 53 stand-alone bio-filters, 29 culvert crossings, 17 piped trunk drainage systems and 20 overland flow path systems. However, the final numbers were revised as the project progressed.

The project was carried out in two distinct phases. The first phase involved a data review, preliminary ecological and environmental assessment, hydrologic and hydraulic modelling and the optimisation of the detention basin layout. While the second phase involved the preliminary concept design and the final detailed concept design of the water management infrastructure. The second phase also included additional survey, geotechnical assessment and the preparation of a more detailed Review of Environmental Factors (REF).

It should be noted that the 2016 version of Australian Rainfall and Runoff (ARR) (Geoscience Australia, 2016) (referred to as ARR2016) was made publicly available concurrent to the commencement of the project, and Council requested that SMEC to use the ARR2016 guidelines for the project. However, the previous WCM studies were based on the previous version of ARR (Engineers Australia, 1987) (referred to as ARR1987). As such, the review of the previous WCM strategy was conducted as per the ARR1987 procedures, while the basin optimisation and the concept design were based on the ARR2016 procedures.

Figure 1.1: Project Area. Source: RFT ST2575 (LCC, 2016)

1.2. Environmental Planning Approvals

A desktop environmental assessment was undertaken during the first phase of the project to determine general constraints associated with the proposed water management infrastructure, across a range of environmental and planning considerations. The assessment outcomes were presented in the Data Assessment Report (SMEC, 2017a).

In summary, the provision of flood mitigation works and stormwater management systems are development without consent under the *State Environmental Planning Policy (Infrastructure) 2007* ISEPP) (NSW Government, 2007), provided the work is carried out by or on behalf of a public authority. The planning approval pathway requires an environmental assessment in the form of a Review of Environmental Factors (REF) in accordance with Division 5.1 of the *Environmental Planning and Assessment Act, 1979* (NSW Government, 1979)

The majority of land within the Growth Centre Precincts is certified under the Biodiversity Certification Order. As such development on this land may occur without the need for further assessment under the Threatened Species Conservation Act 1995 (TSC Act) (NSW Government, 1995). However, any proposed development on land designated as ‘non-certified’ would require further y assessment.

The areas of vegetation classified as non-certified land pose the highest level of constraint for the project. The majority of non-certified land, within the Austral and Leppington North Precincts, is associated with flood prone lands. Therefore, a biodiversity assessment will be conducted for development within non-certified land as part of the REF prepared for the proposed water management infrastructure. The clearing of any land in the non-certified area will require offsets and consultation with the DP&E and the Office of Environment and Heritage (OEH).

Aboriginal heritage impacts are likely to occur and an Aboriginal Heritage Impact Permit will be required for construction. A more detailed Aboriginal Heritage Assessment will be included in the final REF.

1.3. Purpose of the Report

This report documents the preliminary and detailed concept design stages of the project and outlines the methodology, assumptions and justification for the concept design of the proposed water management infrastructure, including the water quality controls. This includes the following:

- Outline of the data that was used to develop the concept designs;
- Summary of the previous (Phase one) studies;
- Design criteria and assumptions;
- Modelling details and methodology; and,
- Concept design drawings.

2. Scope of Work

This section of the report outlines the overall scope of the concept design of the water management infrastructure, including the water quality control structures, that are proposed for the project area.

2.1. Water Management Infrastructure (Flooding)

The main water management infrastructure proposed to manage flooding within the project area and to minimise downstream impacts includes detention basins, trunk drainage pipes, overland flow paths/constructed channel systems, culvert crossings and creek enhancement works.

It should be noted that it was necessary to adopt an integrated approach for design of the water management infrastructure. Therefore, each of the individual elements was included in an integrated drainage system for each drainage catchment, as the design of each element had an impact on the other elements. Therefore, although the design approach for each element is outlined individually below, they were designed as an integrated drainage system.

2.1.1. Detention Basins

The WCM strategy, that was adopted for the Precinct Masterplan, identified 21 flood detention basins within the two precincts (i.e. Austral and Leppington North). The basin capacities were determined based on the hydrologic/hydraulic model, to ensure post-development flows, downstream of development areas, did not exceed pre-development flows for the 50% and 1% Annual Exceedance Probability (AEP) flood events.

The number of basins and their performance criteria were subsequently optimised during Phase one of the project. This resulted in a reduced number of basins, and some basins only being designed to control the 50% AEP flows. For further details of the Basin Optimisation refer to the Basin Optimisation Report (SMEC, 2017b). Another two basins were (Basins B9 and B10) were subsequently removed based on the results of further modelling. Ultimately, eight basins were designed to control the 50% and 1% AEP flows, while eleven basins were designed to control only the 50% AEP flow.

In addition to mitigating the adverse impacts of development (i.e. reducing post-development flows to pre-development levels), the detention basins were also proposed to provide water quality improvement by incorporating biofilters in the basin floor. Although biofilters were proposed in the WCM strategy to be included in all of the detention basins it was not possible to operate a biofilter in some basins due to hydraulic constraints (refer to Section 2.2 for the scope of biofilter design).

The main tasks that were undertaken during concept design of the detention basins included:

- Hydraulic assessment to define the inlet, outlet and basin invert levels, based on the existing topography;
- Define the stage-storage and stage-discharge relationships for each of the basins using 12d earthwork modelling;
- Undertake hydrologic and hydraulic modelling, using XP-RAFTS and TUFLOW, to determine flows for both pre-development and post-development scenarios, based on the stage-storage and stage-discharge relationships;
- Refine the basin layout plan and basin locations based on:
  - More detailed topographic survey information; and,
  - Existing and proposed utility information.
- Design/sizing of embankments, outlets and spillways to suit the storage and flow mitigation requirements, based on:
  - Updated hydrologic and hydraulic models; and,

- Adopted design criteria.
- Prepare layout plans and concept design plans and drawings for each basin using 12D.

2.1.2. Trunk Drainage

The trunk drainage system was designed to convey runoff from major storm events (up to the 1% AEP event) through a combination of pipes and culverts, located within the road reserve, and overland flow on roadways.

Where a combination of pipe/culvert and bypass flows on the roadway are used, the assessment also considered pedestrian and vehicular safety criteria, as defined in Council guidelines. The proposed trunk drainage system will discharge into the existing creek system, proposed flood detention basins, overland flow paths and bioretention systems.

A requirement of the study brief (Addendum 2 of RFT number ST2575) states that "*The trunk drainage system shall be the major stormwater pipe systems along existing roads of the development, which discharge into the creeks, constructed channels/overland flow paths and basin system*". SMEC, in consultation with Council, proposed a deviation to the definition of trunk drainage in the Trunk Drainage Concept Design Basis Report (SMEC, 2017c) and in the progress review meeting held at Council premises on 01 November 2017. As such, the trunk drainage system for the current project is comprised of both piped and open channel sections. Further details of each trunk drainage system (i.e. piped and channels) are provided in the following sections.

2.1.2.1. *Piped*

Piped trunk drainage systems were proposed for all catchment areas greater that 15 ha, with the piped system commencing downstream of the 15 ha headwater catchment. The systems were designed to convey the 1% AEP flow through a combination of pipe flow and bypass flow in the roadway.

The piped drainage system includes both Reinforced Concrete Pipes (RCP) and Reinforced Concrete Box Culverts (RCBC). The Box Culverts were required in a number of locations due to the hydraulic constraints (i.e. the flat topography).

As per Council advice, the piped trunk drainage system follows the existing and proposed road networks, shown in the Indicative Layout Plan (ILP) for the development area. A total of 23 piped trunk drainage systems are included in the project area.

The main tasks that were undertaken during concept design of the trunk drainage pipes included:

- Undertake appropriate hydrologic and hydraulic modelling to determine flows for the post-development scenario, using DRAINS;
- Determine the type (i.e. RCP or RCBC), size, slope and invert levels of the trunk drainage system required to convey post-development flows (allowing for minor bypass flows to be conveyed within the roadway);
- Define any bypass flow within the roadway and carry out stability assessment to ensure vehicular and pedestrian safety;
- Prepare detailed plans and drawings of the stormwater trunk drainage network showing proposed junction pits, and long sections of the pipelines providing inverts, surface levels, flow, velocity, pipe details; and,
- Document/report the details of the hydrologic and hydraulic analysis, catchment plans, and model and catchment parameters.

2.1.2.2. *Channels*

There are 22 constructed channel systems within the project area that were designed as trunk channel systems. These are the overland flow paths (OLFP) that were identified in the previous WCM study to be formalised as constructed channel system to covey post-development flows. However, due to limited easement width allowed in ILP, five constructed channels were fully replaced by piped drainage, while five constructed channels were partially replaced by piped drainage. Additionally, two constructed channels associated with detention basins B9 and B10 were excluded from the design.

The main tasks that were undertaken during concept design of the trunk drainage channels included:

- Determine post-development flows for major (1% AEP) and minor (20% AEP and 3-month Average Recurrence Interval (ARI) (the equivalent of 98% AEP)) flow events;
- Selection of a suitable channel cross-section profile that complies with the adopted design guidelines, which is capable of conveying post-development flows;
- Update hydraulic model to incorporate constructed channel systems;
- Produce layout plans, cross sections and long sections of the trunk channel system; and,
- Report hydrologic and hydraulic modelling analysis outcomes.

2.1.3. Culverts

In total, there are 22 culverts to be designed for the proposed precinct development. Out of these, 12 culverts are along the major creeks while there 10 culverts are along the proposed drainage channels (i.e. where channels intersect with roads). A further break down of culverts are shown in Table 2.1.

Table 2.1: Culvert Design Scope

Culvert Location	Existing Culvert Redesign	Proposed/New Culvert Design
Along the major creeks	9	3
Along the proposed drainage channels	5	5

The objective of the design was to enable the safe passage of the design flows (1% AEP) through the culverts (including allowance for blockage of the creek culverts in accordance with ARR2016), minimise upstream flooding and protect the downstream waterway from scour.

The main tasks that were undertaken during concept design of the creek culverts included:

- Determine post-development flows for the 1% AEP flood event at the culvert locations, based on the TUFLOW model results (based on the updated TUFLOW model that included the other water management infrastructure);
- Carry out ARR2016 design blockage assessment to define the risk of culvert blockage and to determine the appropriate blockage factors;
- Collect additional survey information for the existing creek culverts;
- Carry out hydraulic modelling, using HY-8, to determine, capacity enhancement requirements for the culvert crossings;
- Prepare preliminary concept plans and drawings for the selected culverts; and,
- Document the outcomes of the assessment showing plans and culvert details.

For the culverts associated with the open channels, a similar methodology was followed. However, DRAINS was used to estimate flow and no allowance was made for the blockage.

2.1.4. Creek Enhancement Works

The WCM study has proposed filling of parts of the floodplain where the 1% AEP flood depth is less than the 300 mm to the maximise developable area within the precinct. The filling of flood fringe areas was assessed by incorporating the proposed filling in an updated version of the TUFLOW hydraulic model that was originally used to quantify existing flooding behaviour. However, no compensatory excavation was considered to offset the impact of filling as part of the modelling.

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2.1.5. Hydrologic and Hydraulic Modelling and Flood Mapping

The precinct-scale hydrologic (XP-RAFTS) and hydraulic (TUFLOW) models, which were initially developed for the Phase one - Basin Optimisation study, were updated with the preliminary concept design of the flood mitigation works, to confirm the following:

- No adverse flooding impact within the creek system, both upstream and downstream of the precinct boundaries, in terms of increased flows, flood velocities and levels (afflux < 20 mm) due to precinct development;
- The flood detention basin system effectively mitigated post-development flooding impacts of the precinct for the 1% and 50% AEP events;
- The flood detention basins did not have an adverse flooding impact on adjoining properties;
- The overland flow paths (trunk channels) effectively managed overland flows from sub-catchments, with flood water contained within the proposed channels for the 1% AEP event; and,
- No additional properties in the precinct are affected by flooding for up to the 1% AEP event, compared to the pre-development scenario.

The following flood maps covering the entire project area for the 50% and 1% AEP events, under existing and post-development scenarios, were produced:

- Flood extent and depth
- Flow velocity

A difference map for the 1% AEP event was also produced to assess the likely impacts of climate change.

The precinct-scale hydrologic and hydraulic modelling and flood mapping outcomes are presented in a separate report, *"Austral and Leppington North Design of Water Management Structures – Hydrologic and Hydraulic Modelling of Detailed Concept Detention Basin Designs"* (CSS, 2018a) and hence the reporting of this deliverable is excluded from the Concept Design Report.

2.2. Water Quality Control Structures

Biofilters and GPTs were the main water quality control structures proposed for the project area in the WCM strategy. The WCM strategy proposed 21 biofilters, which were to be co-located within the detention basins to treat stormwater runoff from catchments draining to each basin (hereinafter referred to as co-located biofilters). An additional 53 biofilters to treat stormwater runoff generated from the catchments that do not drain to any detention basin (hereinafter referred to as stand-alone biofilters) were proposed. Each catchment also included a GPT, located upstream of the biofilter, as an additional water quality control.

It should be noted that due to the latest catchment delineation adopted in the current project (based on more current LiDAR), the number of drainage systems that required stand-alone biofilters was reduced to 41. Furthermore, it was found that co-located biofilters and stand-alone biofilters were not feasible at several sites due to site-specific constraints (primarily inadequate hydraulic head) suggested and due to limited footprint area allocated in the ILP, some of the co-located biofilters were undersized. Therefore, additional streetscape controls were proposed to meet the required water quality targets. Also, due to the difficulties (hydraulics and spatial constraints) associated with implementing the stand-alone biofilters, they were replaced with raingardens distributed throughout the development area, for the non-basin catchments.

The tasks that were undertaken during the concept design of the water quality control structures included:

- Review the suitability of the selected water quality controls based on hydraulic and footprint area constraints;
- Develop drainage system-scale MUSIC models for the water quality controls;
- Prepare the layout plans and the concept design drawings;
- Document/report the outcomes of the MUSIC model assessment; and,
- Document the Development Control Plan (DCP) requirements to facilitate the interpretation of streetscape (raingarden) water quality controls by developers.

2.3. Vegetation Management Plan

A Vegetation Management Plan (VMP) was prepared on a precinct-scale to facilitate a coordinated approach to land management, particularly in riparian zones and within the co-located biofilters. The main scope of the VMP includes:

- Establish an overarching strategy for vegetation management across the precinct;
- Inform the management of impacts on vegetation during construction activities;
- Provide a guide to revegetation and rehabilitation of riparian zones following completion of works; and,
- Provide a guide to coordinate management of the riparian zones and associated passive recreation zones.

2.4. Dam Break Assessment

A dam break analysis for each detention basin was carried out in accordance with the guidelines and the requirements of the Dam Safety Committee (DSC). A separate report, *"Austral and Leppington North Design of Water Management Structures –Dam Break Assessment"* (CSS, 2018b) was prepared to document the outcome of the dam break assessment. Therefore, this deliverable is excluded from the Concept Design Report.

2.5. Geotechnical Investigation

A desktop geotechnical review was previously undertaken during the Phase 1 of the project to review available information and document the anticipated ground conditions and potential geotechnical risks associated with the design and construction of the proposed stormwater management system. The outcomes of this review were reported in the Data Assessment Report (SMEC, 2017a). An additional geotechnical investigation was carried out during the Concept Design stage to supplement the desktop review. A separate report, *"Austral and Leppington North Design of Water Management Structures –Geotechnical Interpretive Report"* (SMEC, 2018a) was prepared to document the outcome of this investigation. Therefore, this deliverable is excluded from the Concept Design Report.

Additionally, a contamination assessment (Phase 1) was conducted to identify potential contamination and associated risks and provide recommendations for investigations and/or management based on preliminary findings. A separate report, *"Austral and Leppington North Design of Water Management*

Structures –Draft Phase 1 Contamination Assessment" (SMEC, 2018b) was prepared to document the outcome of this investigation. Therefore, this deliverable is excluded from the Concept Design Report.

2.6. Review of Environmental Factors

A REF was conducted to determine the impact on the environment associated with the construction of proposed drainage infrastructure, co-located biofilters, creek culverts and creek enhancement works. The outcome of the REF was documented in a separate report, "*Austral and Leppington North Design of Water Management Structures –Review of Environmental Factors"* (SMEC, 2018d). Therefore, this deliverable is excluded from the Concept Design Report.

2.7. Preliminary Cost Estimates

Preliminary concept cost estimates have been developed for the proposed water management infrastructure, based on the detailed concept designs. The final costing will be subjected to completion following detailed design. The preliminary costing is provided for planning purposes only.

3. Study Data

This section outlines various types of data that form the basis of the design presented in this report.

3.1. Topographic Data

3.1.1. LiDAR

Light Detection and Ranging (LiDAR) data was collected across the Sydney metropolitan area by Land and Property Information in 2011. LiDAR data used for this project was provided to SMEC by Council. The raw LiDAR data provides a minimum point density of 1 point per square metre. The LiDAR also has an absolute horizontal accuracy of 0.8 m and an absolute vertical accuracy of 0.3 m, which is considered to be suitable for this study.

The LiDAR was considered to provide the most reliable description of contemporary topographic conditions across the study area. However, a comparison of LiDAR data along waterways with the topographic survey data reported in the previous WCM study (Cardno, 2012b) found that the LiDAR channel inverts were typically higher than the ground survey (the average difference in elevation was +0.8 metres) (SMEC, 2017a). This is associated with the LiDAR providing less reliable topographic information in the vicinity of dense vegetation, which frequently occurs along the creek lines.

Accordingly, the raw LiDAR information was adjusted along the creek lines based upon survey information, where available. This included survey information collected as part of the WCM study as well as survey/design elevation information extracted from design plans (e.g., Bringelly Road upgrade and South-West Rail Link). The modified creek elevation information was combined with the "raw" LiDAR data to derive a digital elevation model (DEM) for the project area. The adjusted DEM was utilised to develop precinct-scale hydrologic and hydraulic models, earthworks models as well as the layout of the flood mitigation structures. However, as the detailed ground survey data was only collected at selected locations, the suitability of this approximation across the vast majority of the study area is not known. Therefore, it was recommended that the LiDAR information be supplemented with additional detailed topographic survey, which is discussed below.

3.1.2. Detailed Topographic Ground Survey

Since the areas subject to high vegetation density or covered by water (e.g., creeks) are generally not well defined by the LiDAR, a detailed topographic ground survey was conducted to collect more detailed data. The detailed topographic ground survey was conducted by Craven Elliston & Hayes, Dapto Pty Ltd (CEH).

The survey locations included the available footprint area identified for 20 proposed detention basins, 20 cross-sections along existing receiving watercourses downstream of each proposed detention basin and on upstream drainage paths, and at 21 existing road culvert or bridge sites. The detailed topographic ground survey had an absolute horizontal accuracy of 0.02 m and an absolute vertical accuracy of 0.05 m, which is considered to be suitable for this study.

Detailed topographic ground survey data were used to refine hydraulic and earthworks models for the detention basins and related structures proposed for the project.

3.2. Data from Previous WCM Studies

Various forms of data derived from previous WCM studies (Cardno, 2011a; 2011b; 2012b) were provided to SMEC by Council. The data was used to determine drainage infrastructure locations, catchment characteristics for hydrologic, hydraulic and water quality modelling and to identify environmental planning constraints.

3.2.1. GIS Data

A range of GIS data including cadastre, aerial photography (2005, 2007 and 2016), Indicative Layout Plan (ILP), sub-catchment boundaries, drainage infrastructure and flood extents was provided by Council as a part of this study.

3.2.2. Hydrologic and Hydraulic Models

XP-RAFTS and TUFLOW models for existing conditions were provided to SMEC at the commencement of the project. However, the XP-RAFTS and TUFLOW models for the proposed conditions (including the proposed detention basins) were not provided to SMEC at the commencement of the project. Therefore, new post-development hydrologic and hydraulic models were developed during the first phase of the project, as part of the Basin Optimisation Study (SMEC, 2017b). It should be noted the post-development hydrologic and hydraulic models from the previous WCM studies (Cardno, 2011a; 2012b) were only received by SMEC in June 2017. Since the first phase of the project was already progressed by that time, these models were not used for this project.

The existing case models were verified against the Cardno “existing” conditions model, as part of the original ARR1987 assessment. However, the “post-development” models were not directly comparable as the basin arrangement was different and the models were updated to ARR2016.

3.2.3. Water Quality Models

The MUSIC model developed for the Austral and Leppington North Precincts – Water Cycle Management – WSUD Report (Cardno, 2011b) was received by SMEC. However, the additional MUSIC modelling reported in Austral and Leppington North Precincts – Water Cycle Management –Responses to Exhibition Submissions (Cardno, 2012b) was not available for SMEC review.

3.3. Utility Data

The approximate locations of underground utilities within the project area were collected using a Dial Before Your Dig (DBYD) search and GIS data provided by several service providers as wells as Council. Utility data was used to conduct a desktop investigation to identify potential service conflicts. This is discussed further in the Utility Services Investigation Report (SMEC, 2018c).

3.4. Site Visits

Two site visits were conducted by the project team in March 2017 and August 2017 as summarised below.

3.4.1. Site Visit 1

Two members of the SMEC project team participated in the first site visit on 08 March 2017. The purpose of this site visit was to collect existing culvert information (culvert type, geometry and blockage) at the following six sites. Data collected during the site visit was used to develop the TUFLOW model reported in the Basin Optimisation Study (SMEC, 2017b).

- The unnamed tributary crossing of Edmondson Avenue (~130 metres north of Seventh Avenue)
- The unnamed tributary crossing of Bellfield Avenue (~100 metres east of North Avenue)
- The unnamed tributary crossing of Gurner Avenue (~250 metres east of Fourth Avenue)
- The unnamed tributary crossing of Fourth Avenue (~30 metres south of Thirteenth Avenue)
- The unnamed tributary crossing of Fourth Avenue (~200 metres north of Thirteenth Avenue)
- The unnamed tributary crossing of Tenth Avenue (~550 metres west of Fourth Avenue)

3.4.2. Site Visit 2

Representatives from Council, SMEC and E2DesignLab, SMEC's sub-consultant for water quality management aspects of the project, participated in the second site visit on 04 August 2017. The purpose of this site visit was to familiarise the project team with study area terrain and to collect qualitative information relevant to the proposed water quality management strategy. The site visit covered the following locations:

- An existing detention basin and water quality treatment (wetland) facilities at Amalfi Park, Lurnea.
- The proposed location for detention basin 5 (50% AEP basin site).
- Proposed locations for basins 25, 27 and 29 (1% AEP basin sites).
- Corner Fourth Avenue and Tenth Avenue (sites where only water quality controls are proposed).

3.5. Rainfall, Losses and Climate Change Data

The following parameters were downloaded from the ARR2016 Data Hub (http://data.arr-software.org/) on 21 April 2017. These parameters were used to develop the hydrologic and hydraulic models, and a detailed description of the following can be found in Appendix A.

- Bureau of Meteorology (BOM) Intensity Frequency Duration (IFD) depths
- Temporal patterns
- Storm losses
- Median pre-burst depths and ratios
- Interim climate change factors

It should be noted that two sets of slightly different loss parameter were used for the precinct-scale modelling and system-scale modelling. The loss parameters used for the precinct-scale models were extracted from a location south of Bringelly road. This location was selected to apply the same loss parameters across Austral, Leppington North and East Leppington precincts. The location selected for the system-scale modelling was north of Bringelly road. The selected location was more suitable for drainage system-scale modelling as all the drainage systems were north of Bringelly Road. Nevertheless, the precinct-scale and system-scale model results were comparable.

4. Review of Related Studies

This section provides a brief of overview of the studies that form the basis of the concept design. A summary of the previous WCM studies conducted at the planning stage in 2011 and 2012 is followed by a summary of the Basin Optimisation Study conducted during the first phase of the current project.

4.1. Previous WCM Studies

4.1.1. Austral & Leppington North Precincts – Riparian Corridor and Flooding Assessment (Cardno, 2011a)

A detailed review of this study was previously provided in the 'Austral and Leppington North Design of Water Management Infrastructure – Data Assessment Report' (SMEC, 2017a). However, an outline of the previous review is presented below.

The previous study (Cardno, 2011a) presented a hydrologic and hydraulic assessment to define the potential extent of flood liable land, quantify the potential for the development of the precincts to impact on existing flood behaviour as well as the extent of the stormwater management infrastructure that would need to be implemented to mitigate any adverse flood impacts. The study included the development of an XP-RAFTS model to define catchment hydrology and a TUFLOW model to simulate flood hydraulics. These models were updated in the following year in response to post-exhibition submissions (Cardno, 2012b).

The previously developed models were provided by Council as the basis for the current study. However, before the models could be used, it was necessary to review the models to ensure they were fit-for-purpose. A detailed review of the XP-RAFTS and TUFLOW models was completed, and key outcomes from this review were summarised in the Data Assessment Report (SMEC, 2017a). Overall, both XP-RAFTS and TUFLOW models were considered to be generally suitable for use in the current study with some updates, which are noted in Section 6.1 of this report.

As noted previously (in Section 3.2.2) the post-development WCM models were not used in the current study.

4.1.2. Austral and Leppington North Precincts – Water Cycle Management – WSUD Report (Cardno, 2011b)

The 'Austral and Leppington North Precincts, Water Cycle Management - WSUD Report' (Cardno, 2011b) addresses the water quality control strategy proposed for the development precinct. A detailed review of this study was previously reported in Appendix 4 of the Data Assessment Report (SMEC, 2017a), therefore only an overview of the study is presented in this report.

The previous study (Cardno, 2011b) only addressed the water quality control strategy required for the catchments draining to the detention basins. A treatment train approach was adopted to achieve the treatment targets for Gross Pollutants (GPs), Total Suspended Solids (TSS), Total Phosphorus (TP) and Total Nitrogen (TN). Rainwater tanks were introduced at the upper-end of the treatment train to manage rainwater quality, while stormwater runoff quality was managed via GPTs and biofilters. The biofilters were co-located within the detention basins. The sizing of the water quality controls was carried out using MUSIC modelling, based on the best practice guidelines at the time of the study.

The Council WSUD technical guideline (Alluvium, 2016) had not been developed at the time of the two previous studies. Additionally, the Council guidelines were not included in MUSIC-*link*. Therefore, the MUSIC model developed during the previous WCM study needed to be updated. However, in order to be consistent with changes made to the hydrologic and hydraulic modelling of the current study, a new

MUSIC-*link* model was developed for the project area. The details of this modelling can be found in Sections 5.2.2 and 6.3 of this report.

Some practical limitations of the proposed WSUD treatment train strategy and opportunities to improve the treatment strategy were identified. These limitations and opportunities are further described in Section 5.2.2 of this report.

4.1.3. Austral and Leppington North Precincts – Water Cycle Management – Responses to Exhibition Submissions (Cardno, 2012b)

The Cardno 2012 Water Cycle Management report summarises additional assessments and revisions to the original WCM strategy that was proposed in the previous report (Cardno, 2011a). This was in response to submissions received during the exhibition of the draft Precinct Plan for the Austral and Leppington North Precincts.

The following water quality management initiatives, which were not part of the original WCM strategy, were assessed in the 2012 Cardno study:

- Further modelling of the Leppington Town Centre (LTC) to inform the requirements of the lot based On-Site Detention (OSD) strategy;
- The configuration of an on-line basin located on Scalabrini Creek and the location of bioretention basins; and
- Inclusion of rain garden footprints for sub-catchments that do not drain to a combined detention basin/biofilters.

Three main options were proposed to improve the water quality for sub-catchments that do not drain to a combined detention basin/biofilter.

- Residential land use - more centralised biofilter basins
- Commercial, retail, business and industrial land uses - lot scale WSUD options
- Public domain - biofiltration measures located in road reserves and other paved areas, e.g., street trees and rain gardens

An assessment of each sub-catchment was undertaken using MUSIC modelling. However, the MUSIC model was not provided to SMEC for use in the current project. Since the previous MUSIC model was not available, and the Council WSUD Technical Guideline (Alluvium, 2016) had not been developed at the time of the previous study, it was necessary to develop a new MUSIC model for the catchments that do not drain to detention basins.

4.2. Basin Optimisation Study (SMEC, 2017b)

A Basin Optimisation Study was conducted during the first phase of the current project, and the outcomes were presented in the Basin Optimisation Report (SMEC, 2017b). A brief summary of the study outcomes is presented below.

The Basin Optimisation Report documents the outcomes of hydrologic and hydraulic modelling that was completed to support the concept design of water management infrastructure across the Austral and Leppington North precincts. The assessment was completed using an XP-RAFTS hydrologic model and a TUFLOW hydraulic model. A sensitivity analysis was also conducted to test the impact of the development of the catchments upstream of Bringelly Road. The assessment was originally completed in accordance with ARR1987 guidelines, but following Councils request, the models were updated to be consistant with the requirements of the updated ARR2016 guidelines.

Findings from the Basin Optimisation Study show that only the basins along Tributaries 2 and 3 need the capacity to detain flood flows for events up to and including the 1% AEP event; while the detention basins along Kemps, Scalabrini and Bonds creeks will only be required to detain events up to and including the 50% AEP flood. This was a departure from the design requirements recommended in the original WCM strategy.

5. Design Criteria and Assumptions

This section of the report outlines the design criteria, assumptions, standards, parameters and computer software that was adopted for development of the concept designs.

5.1. Reference Documents

Council's drainage guidelines detail various aspects of the drainage works, including materials, construction, quality management and environmental management. The Council documents listed in Table 5.1 were referenced to develop design parameters for stormwater quantity and quality control infrastructure.

Table 5.1: List of Council Reference Documents

Title/Description	Version/Date
Hand Book for Drainage Design Criteria (LCC, 2003a)	January 2003
New South Wales Development Specification D5 Stormwater Drainage Design (NSW-D5- Drainage Design) (LCC, 2003b)	July 2003
New South Wales Specification 220 Stormwater Drainage General (NSW Specification No. 220) (LCC, 2004a)	April 2004
New South Wales Specification 221 Pipe Drainage (NSW Specification No. 221) (LCC, 2004b)	April 2004
Liverpool City Council WSUD Technical Guidelines (Alluvium, 2016)	January 2016

In addition to the Council reference documents, SMEC utilised several other design guideline documents, which are listed in Table 5.2. These standards/guidelines were used if the necessary design information was not included in the Council guidelines.

Table 5.2: List of Additional Reference Documents

Title/Description	Author/Publisher	Version/Date
Australian Rainfall and Runoff (ARR2016)	Geoscience Australia	2016
Queensland Urban Drainage Manual (referred to as QUDM2013) (DEWS, 2013)	Department of Energy and Water Supply, QLD	Third Edition-provisional/2013
Guide to Road Design Part 5: Drainage – General and Hydrology Considerations (Austroads, 2013a)	Austroads	2013
Guide to Road Design Part 5A: Drainage – Road Surface, Networks, Basins and Subsurface' (Austroads, 2013b)	Austroads	2013

Title/Description	Author/Publisher	Version/Date
Guide to Road Design Part 5B: Drainage – Open Channels, Culverts and Floodways (Austroads, 2013c)	Austroads	2013
Guide to Road Design Part 6: Roadside Design, Safety and Barriers (Austroads, 2010)	Austroads	2010
Roads and Maritime Services (RMS) Technical Guideline - Temporary stormwater drainage for road construction (RMS, 2011)	RMS	December 2011
RMS Standard Drawings – R0200 Stormwater Drainage Series (RMS, 2017a)	RMS	October 2017
RMS Roadworks Specifications – design and Construct – Drainage (RMS, 2017b)	RMS	Current
Culvert Inventory Collection Guideline (RTA, 2008)	Roads and Traffic Authority (RTA)	October 2008
Culvert Risk Assessment Guideline (RTA, 2010)	RTA	Version 3.02/December 2010
Design Guidelines for Engineering Works for Subdivisions and Developments (Penrith City Council, 2013)	Penrith City Council	2013
Engineering Guide for Development (BCC, 2005)	Blacktown City Council	2005
Developer Handbook for Water Sensitive Urban Design (BCC, 2013)	Blacktown City Council	Version 1.1/November 2013
Water Sensitive Urban Design (WSUD) Standard Drawings (BCC, 2017)	Blacktown City Council	February 2017
Bioretention Technical Design Guidelines (Water by Design, 2014)	Water by Design	Version 1.1/October 2014
Wetlands Technical Design Guidelines Draft (Water by Design, 2017)	Water by Design	May 2017
Use of rock in engineering (webpage) (Catchments and Creeks, 2011)	Catchments and Creeks Pty Ltd	2011
Fisheries NSW Policy and Guidelines for Fish Habitat Conservation and Management (2013 update) (DPI, 2013)	Department of Primary Industries (DPI)	2013

Title/Description	Author/Publisher	Version/Date
Policy and Guidelines for Fish Friendly Waterway Crossings (DPI, 2003)	DPI - Fisheries	2003
Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings (Fairfull & Witheridge, 2003)	Fairfull and Witheridge	2003

5.2. Design Criteria

Design criteria adopted for development of concept designs for the water management infrastructure and water quality control structures are presented in the following sections. This information was presented, discussed and agreed with Council during several progress review meetings and via design basis reports.

5.2.1. Water Management Infrastructure

5.2.1.1. *Trunk Drainage*

Piped Drainage

The trunk drainage system is designed to convey major storm events through pipes and culverts under roadways and overland flow on roadways. Where a combination of pipe and roadways are used, the assessment has also considered pedestrian and vehicular safety criteria, as defined in Council guidelines. Figure 5.1 illustrates the combined flows of the pipe system and overland flow along a local road for the 1% AEP event, in compliance with flow depth and hazard criteria.

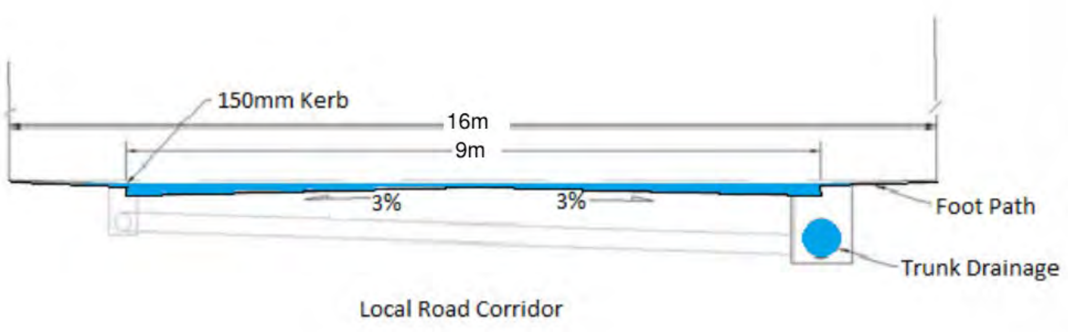


Figure 5.1: Flow Conveyance for Combined Pipe System and Overland Flow within Roadway

The Austral and Leppington North Precincts ILP road network was adopted as the basis for the future trunk drainage layout (i.e. trunk pipe drainage would follow the existing and future road network) with no allowance for additional easements through private property.

In the absence of the future road design (i.e. vertical alignment), it was assumed that the future roads would follow the slope of the existing terrain.

The design criteria adopted for design of the piped trunk drainage is provided in Table 5.3.

Table 5.3: Design Criteria Adopted for the Trunk Drainage Pipes

Item	Criteria	Reference
Design AEP	1% AEP	(LCC, 2003b)
Depth(D) × Velocity (V)	Maximum of 0.4 m^2/s	(LCC, 2003b)
The Depth of Flow Above the Gutter Invert	200 mm	(LCC, 2003b)
Average Factor of Impervious - Trunk drainage	Average - 85%	As per Council request, based on Edmondson Avenue, Leppington development
Headwater Catchment Area	15 ha	LCC drainage design guideline does not specify a headwater catchment for the trunk drainage system. The local councils in NSW (Camden Council, Wollongong City Council etc.) use minimum headwater catchments ranging from 15 ha to 20 ha for trunk stormwater network.
Pressure Loss Coefficient (Ku)	0.5	Based on engineering judgement
Minimum pipe size (mm)	Single pipe (1050 mm) Multiple pipes (900 mm)	Based on initial assessment and engineering judgement
Minimum Pipe Slope	Preferred 0.5% (to avoid ponding and siltation) Minimum 0.3% (the minimum practical slope for construction)	(Austroads, 2013c)
Blockage Factor	Sag pit – 50% Continuous Grade inlet – 20%	(LCC, 2003b)

It should be noted that RCBC was used instead of RCP for the trunk pipes in most cases to meet the minimum cover requirements in very flat terrains.

Open Channels

The location and easements nominated for the proposed open channels, located within the development area, were adopted from the ILP.

A DRAINS analysis was carried out to estimate design flows up to the 1% AEP event, for the main channel section, and 3-month ARI (60% of 1-year ARI) event for the proposed low flow channel.

In the absence of the locations where minor drainage will be connected to the channel, a conservative approach was used to size open channels. Each channel segment (i.e. between road crossings) was sized to be sufficient to carry the entire catchment flows draining to the channel at the most downstream end of the channel segment (i.e. either the connection to a proposed detention basin or an existing major creek).

The design also considered backwater analysis to check the hydraulic operation and performance of the combined trunk drainage and detention basin system. Open channel elements were designed using Manning's equation and incorporated into the individual DRAINS network models, that were developed for each of the drainage systems (refer to Section 6.1.2 of this report for more details regarding the DRAINS models). In addition, a sensitivity check was performed using HEC-RAS.

Table 5.4 summarises the design criteria adopted for the open channel design, which were developed in accordance with relevant Australian Standards and Guidelines. These were discussed and agreed with Council.

Scour protection (and possibly drop structures) may be required at locations where the flow velocities exceed guideline values. This will be subject to detail design.

Table 5.4: Design Criteria Adopted for the Trunk Drainage Channels

Item	Criteria	Reference
Manning's Coefficient "n"	n = 0.030 Grassed Floodway n = 0.050 Vegetated Main Channel n = 0.035 Rock Lined Low Flow Channel	ARR2016- Table 6.2.1
Maximum Channel Velocity	2.0 m/s [a] 1.5 m/s [b]	QUDM2013 - Table 9.5.2
Minimum Channel Velocity	0.5 m/s	(Austroads, 2013c) - Section 2.8.1
Channel Batter Slope	Typical and maximum 1 in 4 for floodway section and main channel section[c] Typical and maximum 1 in 2 for rock lined channel section	As per meeting with Council on 30 April 2018
Channel Bed Slope	0.5% minimum will be adopted for the proposed channel design	(Austroads, 2013c) - Section 2.13.1

Item	Criteria	Reference
	0.4% minimum to avoid ponding and siltation 0.3% minimum practical slope for construction	
Channel Freeboard	500 mm above maximum water level for 1% AEP flood event	(LCC, 2004a)
Access and Maintenance Berm	4.5 m minimum width, on at least one side of the main channel, if space within the nominated easement is sufficient	(DEWS, 2013) - Section9.7.2

Notes:

(a) Assumed 70% stable vegetation cover with erosion-resistant soils.

(b) Assumed 70% vegeation cover with easily erroded soils. Additional scour protection may be required when channels are constructed using exsiting easily erroded soils.

(c) Where there wasn't sufficient ILP footprint area to achieve the preferred maxium side slopes, the main channel and the floodway were combined. If the combined main channel and the floodway option could not achieve the preferred maxium side slopes, the channel was replaced with a pipe/culvert.

Three options for the proposed channel cross-sections were considered in terms of their hydraulic performance, constructability, long-term stability and ecological benefits.

Option 1 – Compound Channel with Overbank Maintenance Berms on Both Sides

The proposed channel cross-section for option 1, which is shown in Figure 5.2, includes the followings:

- Low flow channel designed for 3-month ARI;
- Main channel designed for 20% AEP;
- Floodway designed for 1% AEP, with overbank maintenance berms on both sides.

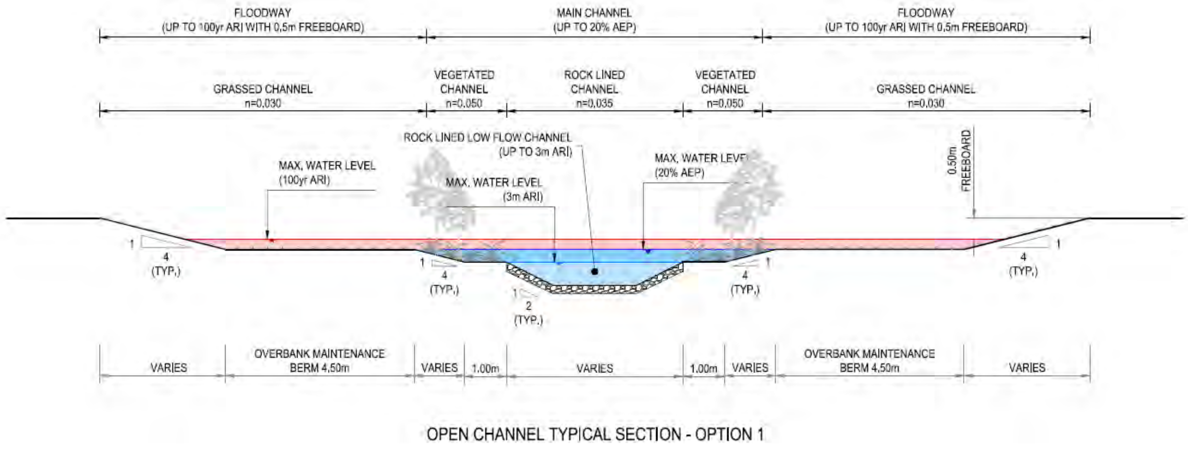


Figure 5.2: Proposed Typical Open Channel Cross-Section 1

The rock-lined low flow channel provides good stability and erosion control, as well as ecological benefits for habitat and low-flow water quality.

The main channel, which is designed to convey the 20% AEP flow, is a low maintenance, heavily vegetated and closed canopy system.

The floodway, which is a more open grassed area, will incorporate maintenance and construction access on both sides, as well as walking paths and/or cycleways. The floodway is designed to convey flows greater than the 20% AEP event, up to the 1% AEP event, with 500 mm of freeboard.

Where existing drainage channels are located within the stormwater easement, the existing channel cross-section may be incorporated on one side with this option. However, this is subject to detailed survey and design.

Option 2 - Compound Channel with Overbank Maintenance Berm on One Side Only

The proposed channel cross-section for option 2, which is shown in Figure 5.3, includes the followings:

- Low flow channel designed for 3-month ARI;
- Main channel designed for 20% AEP;
- Floodway designed for 1% AEP with overbank maintenance berm on one side.

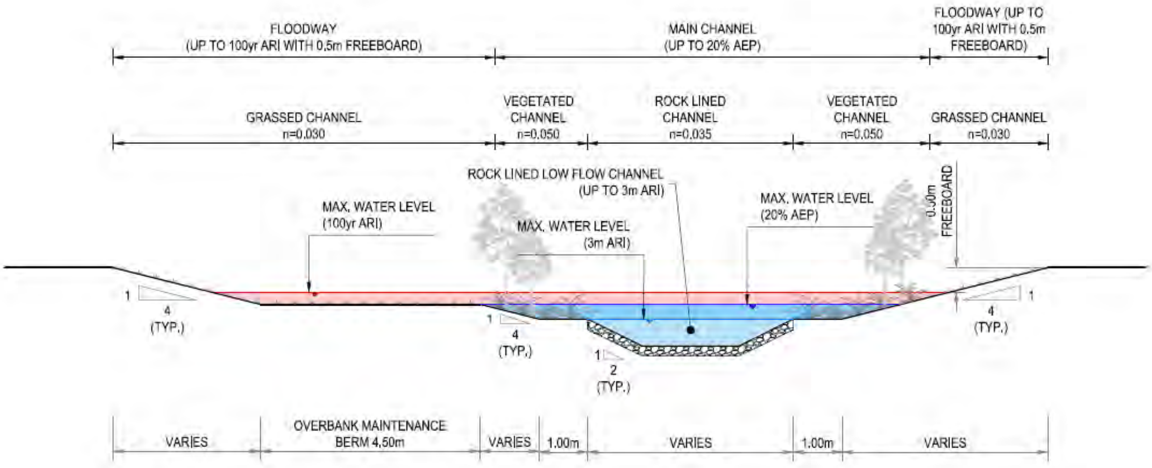


Figure 5.3: Proposed Typical Open Channel Cross-Section 2

This option is very similar to option 1 with a rock-lined low-flow channel and vegetated main channel to convey stormwater up to 20% AEP event.

However, the floodway will incorporate maintenance and construction access on only one side as per the minimum requirement, as well as walking paths and/or cycleways. The floodway is designed to convey flows greater than the 20% AEP event, up to the 1% AEP event, with 500 mm of freeboard

Where existing drainage channels are located within the stormwater easement, the existing channel cross-section may be incorporated on one side with this option. However, this is subject to detailed survey and design.

Option 3 – Combined Low-flow and High-Flow Channel

The proposed channel cross-section for option 3, which is shown in Figure 5.4, includes the followings:

- Low flow channel designed for 3-month ARI;
- High flow channel designed for 1% AEP (100-year ARI), with an overbank maintenance berm on one side only (which is located outside the floodway but within the drainage easement).

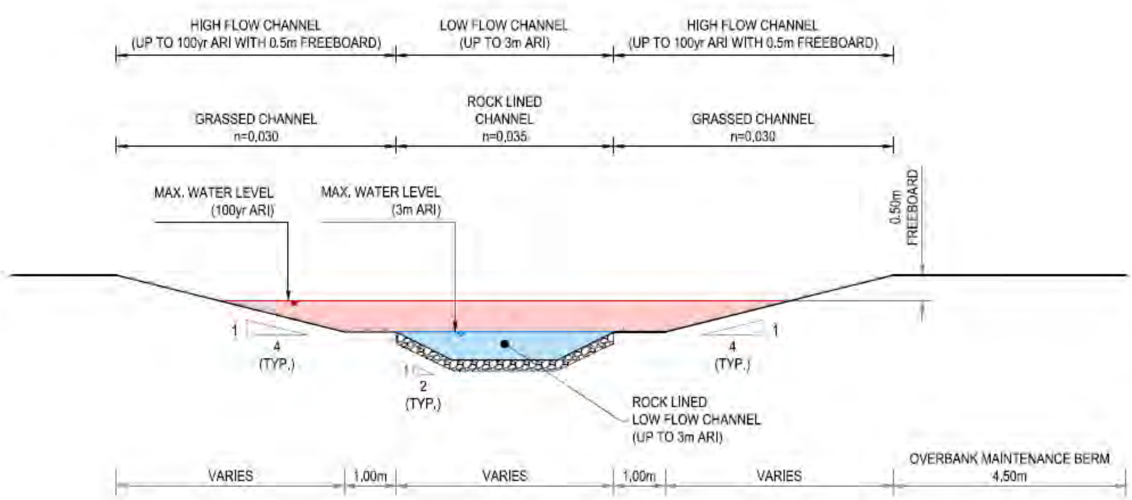


Figure 5.4: Proposed Typical Open Channel Cross-Section 3

Similar to the other two options, Option 3 includes a rock-lined low-flow channel, but the main channel and floodway sections are combined as a high-flow channel.

The high-flow channel is designed as a grassed channel to convey the 1% AEP event. The full bed width will be wet, and thus pedestrian access will generally be prohibited during flood events greater than the 3-month ARI event.

Maintenance and construction access, as well as walking paths and/or cycleways is included on one side of the channel, within the easement, but outside the main channel.

In addition, it will be very difficult to incorporate the existing channel section under this option, if required.

The Preferred Option

Option 2, which is a compound channel section, with a maintenance berm on one side only, was recommended as the preferred option. This was based on an assessment of hydraulic performance, maintenance access, constructability habitat/ecological benefits, excavation volumes, and ability to incorporate walking paths and/or cycleways within the drainage reserve.

Although Option 2 was chosen as the preferred channel cross-section, it was necessary to modify the profile in some locations based on site constraints (primarily the available easement width).

Although a generic channel cross-section is proposed (i.e. Option 2), it can also be modified to accommodate existing drainage channels, if required. However, this would be done at the detail design stage, based on more detailed survey information incorporating the final finished surface levels.

5.2.1.2. *Detentions Basins*

Design of the detention basins was carried out in accordance with Council's Handbook for Drainage Design Criteria (LCC, 2003a).

The original WCM strategy proposed that all basins be designed to control flows up to and including the 1% AEP event. However, this was modified based on the findings from the Basin Optimisation Study (SMEC, 2017b). The eight detention basins located along Tributaries 2 and 3 were designed with the capacity to detain flood flows for all events up to and including the 1% AEP event, while the remaining thirteen detention basins located along Kemps, Scalabrini and Bonds creeks were designed only to detain events up to and including the 50% AEP event. Subsequent modelling resulted in the removal of an additional two 50% AEP basins.

It should be noted that as biofilters are co-located with the detention basins, the biofilter/wetland extended detention volume is not included in the flood storage volume (Water by Design, 2014).

The key design parameters applicable to the co-located detention basins and biofilters, as summarised in Table 5.5, were based on design criteria outlined in Council's Handbook for Drainage Design Criteria (LCC, 2003a) and relevant WSUD guidelines (Water by Design, 2014).

Table 5.5: Design Criteria Adopted for the Co-Located Detention Basins and Biofilters

Item	Criteria	Reference
Design event AEP	Major event – 1% AEP Minor event – 50% AEP[a]	(LCC, 2016)
Embankment slide slopes	Preferred maximum of 1 in 4[b]	Meeting with Council held on 30 April 2018
Maximum active flood storage depths	Maximum of 1.2 m in 5% AEP [c]	(LCC, 2003b)
Freeboard	0.5 m above 1% AEP flood level to basin crest level for 1% AEP basins and 0.5 m above 50% AEP flood level for 50% AEP basins.	(LCC, 2003b)
Spillway width	50% AEP basin – sufficient to contain 10% AEP flow without overtopping 1% AEP basin – sufficient to contain 0.1% AEP flow without overtopping	Meeting with council held on 14 August 2018 and corresponding email from Council dated 31 August 2018
Access and Maintenance Berm	4.5 m minimum width on at least one side of the biofilter	(DEWS, 2013) (Water by Design, 2014)
Biofilter width	Preferred maximum width = 20 m [d]	(Water by Design, 2014)
Biofilter depth	Filter media depth = 400 mm Approximate total depth = 1 m	(Alluvium, 2016)

Item	Criteria	Reference
Extended Detention Depth (EDD)	100 - 300 mm	(Water by Design, 2014; Alluvium, 2016)
Biofilter Embankment Slope	Maximum of 1 in 2 up to 0.5 m height Maximum of 1 in 3 up to 1 m height Maximum of 1 in 4 greater than 1 m height	(Water by Design, 2014)

Notes

(a) This is the major design AEP event for the eleven basins located along Kemps, Scalabrini and Bonds creeks.

(b) In situations where the preferred maximum embankment side slopes could not be achieved due to limited footprint area, the earth embankment was replaced with a combined sandstone step wall (at the base) and a 1 in 4 grassed embankment (on top of sandstone step wall) as per Council advice received on 30 April 2018.

(c) As per Council's advice received during the meeting held on 30 April 2018, this criterion no longer applied to the detention basin design. Greater water depths were therefore permitted. This may require the provision of additional safety measures, such as signage and fencing, which is to be addressed at the detail design stage.

(d) The best practice guidelines suggest a maximum biofilter area of 800 m^2 mainly due to constraints associated with inflow distribution. A wetland channel was proposed as the biofilter inflow distribution to address the potential issues with even flow distribution on the biofilter surface. Therefore, it was not required to limit the proposed biofilter layout to a maximum biofilter cell area.

5.2.1.3. *Culverts*

Culverts were designed at a number of locations along the major creek lines and along the trunk drainage channels. The culverts were designed in accordance with NSW-D5- Drainage Design (LCC, 2003b) and Section 3 of AGRD - Part 5B (Austroads, 2013c).

The design of the creek culverts also took into account the potential for culvert blockage, in accordance with the ARR2016 guidelines.

In a number of locations, along the major waterways, it was necessary to modify the culvert design to allow for the passage of terrestrial fauna (i.e. larger culverts were required for fish passage than for hydraulic reasons). These culverts were designed in accordance with DPI fisheries guidelines, as noted in Table 5.2.

The design criteria adopted for the design of the culverts is provided in Table 5.6.

Table 5.6: Design Criteria Adopted for the Culverts

Item	Criteria	Reference
Design AEP Event	1% AEP	(LCC, 2003b)
Design Methodology	n/a	(Austroads, 2013c) - section 3
Minimum Velocity (6-month ARI or 86% AEP)	0.7 m/s	(Austroads, 2013c) - Section 3.7.4
Manning's Coefficient "n"	0.013 - Concrete pipe 0.030 - Grassed area 0.050 - Vegetated area 0.035 - Rock Lined area	ARR2016- Table 6.2.1
Maximum Outlet Velocity	Stable rock 4.5 m/s Stone 150mm diameter 3.5m/s Gravel 100mm diameter/Grass 2.5m/s Firm loam or Stiff clay 1.2 - 2.0 m/s Sandy or silty clay 1.0 - 1.5 m/s	(Austroads, 2013c) - Section 3.7.2
Culvert Material and Pipe Class	Reinforced Concrete - Class 4	(LCC, 2003b)
Minimum Cover	100 mm below subgrade level	(Austroads, 2013c) - Section 3.6.4
Siltation and Blockage	Comply with ARR2016	(Austroads, 2013c) - Section 3.7.4 ARR2016
Space between Culvert Barrels	Governed by type of compaction equipment	(Austroads, 2013c) - Section 3.6.3
Sizing Considerations	< 1.25 * the depth of the tailwater	(Austroads, 2013c) - Section 3.5.2
Minimum Culvert Size	750 mm diameter/rise (risk of blockage and allow access)	(Austroads, 2013c) - Section 3.5.1
Culvert Outlet Protection	Outlet velocity > scour velocity of the bed or bank material	(Austroads, 2013c) - Section 3.13 (Catchments and Creeks, 2011)
Minimum Water Depth for Fish Passage	0.2 m – 0.5 m	(Fairfull & Witheridge, 2003)

Scour Protection at outlets

The culvert outlet protection was carried out generally in accordance with AGRD Part 5B (Austroads, 2013c)-section 3.13. Additionally, as per Council requirements, scour protection was provided for each culvert outlet regardless of the velocity criteria mentioned in Table 5.6. A plan of a rock apron, the minimum rock size and length of apron for a single pipe outlet is shown in Figure 5.5 and Figure 5.6.

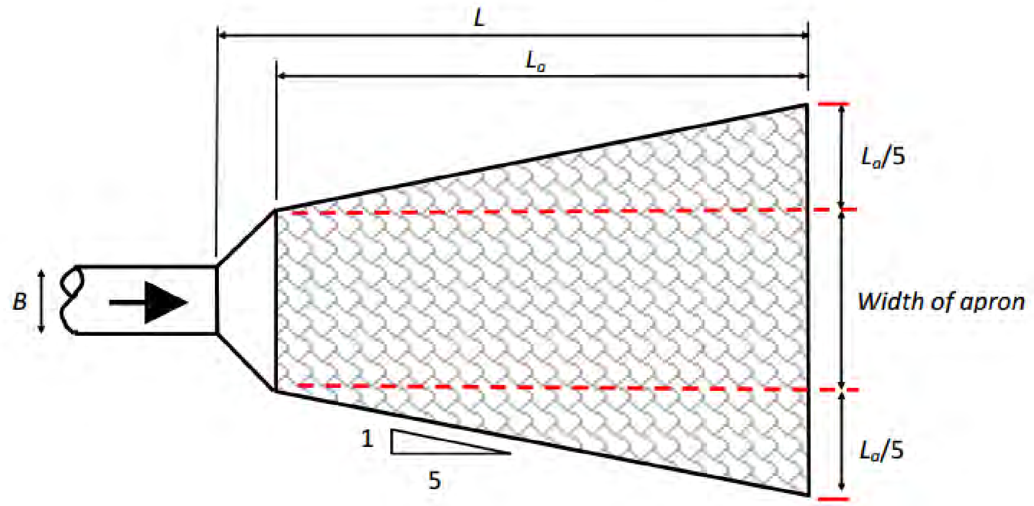


Figure 5.5:Rock apron detail for single pipe outlet (AGRD Part 5B - Figure 3.15)

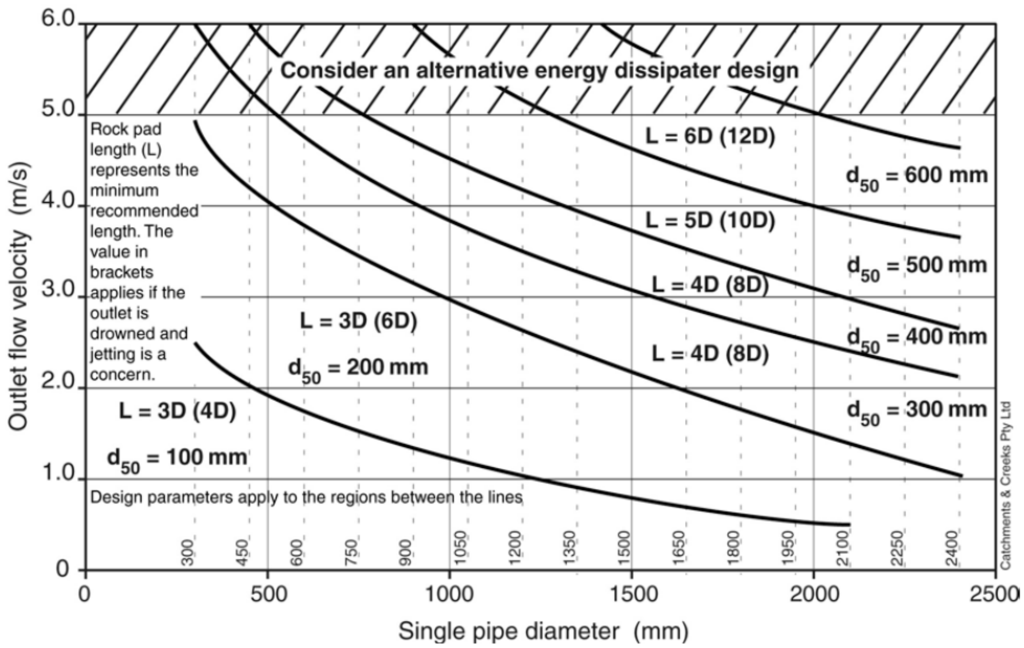


Figure 5.6: Single pipe outlet minimum rock size and length of the apron (Catchment and Creeks, 2011)

The pipe diameter in Figure 5.6 is for a single pipe. In a situation where a multi-pipe outlet is used, e.g., for an outlet of 2 x 1200 mm pipes, a pipe diameter of 1200 mm is used to determine the dimensions of the rock apron (Catchments and Creeks, 2011).

Outlet structures (i.e. precast headwalls) are required to prevent scour damage to the road embankment, the downstream channel and adjacent property as well as retaining the road fill and supporting the end of the culvert. Precast concrete culvert outlet structures should be used where possible to minimise the cost and construction time.

Culvert end treatments, which include wingwalls, cut-off walls and anchorages, and erosion control measures, were designed in accordance with AGRD Part 5B (Austroads, 2013c) - section 3.14.

As the size of the culvert increased, the required protection at the endwall was designed in accordance with AGRD Part 5 (Austroads, 2013a) - Section 3.7.6. The treatment of culverts to improve roadside safety should be designed in accordance with AGRD Part 6 (Austroads, 2010), which covers the provision of roadside barriers across culverts.

Additionally, culverts located within the areas classified as key fish habitat, based on the DPI Fisheries latest classification, were designed in accordance with the list of statutory requirements outlined by DPI Fisheries (refer section 5.4 for further details).

5.2.1.4. *Creek Enhancement Works*

The current study extended the modelling to further investigate the impact of filling of the 1% AEP flood depth is less than the 300 mm. The latest post-development condition TUFOW model results showed that the proposed filling caused localised increases in peak 1% AEP flood levels. Therefore, reasonable compensatory earthworks were proposed to mitigate the adverse flood impacts. However, most of the areas where compensatory earthworks are required were located in the non-certified land. Works within these areas was considered undesirable.

In recognition of these constraints, the following additional investigations were carried out as part of the current study;

- compensatory earthwork was only carried out across certified land (this was likely to provide small benefits)
- provide additional filling across habitable areas/roadways to compensate for flood level increases and still meet freeboard requirements (additional filling may increase potential for flood level increases)
- Provide additional detention capacity top offset predicted flood level increases
- Provide an offset plan for works in non-certified land

The outcomes of the above investigations were presented to Council with the goal of Council selecting the preferred strategy which considers the most environmentally friendly methodology for the creek enhancement work. Council selected the option involving the additional filling to compensate for the anticipated flood level increases. Based on the council preferred option, the TUFLOW model was further refined. This involved further elevating the terrain representation in areas where the flood level increases were predicted to ensure the proposed roads and urban areas stayed “dry” during the 1% AEP flood.

5.2.2. Water Quality Control Structures

Council's WSUD Technical Guidelines (Alluvium, 2016) set out the basis for the stormwater quality management in the proposed Austral and Leppington North development. The water quality management targets applicable to the project area are listed below:

- Reduce the post-development annual pollutant load for GP by 90%;
- Reduce the post-development annual pollutant load for TSS by 85%;
- Reduce the post-development annual pollutant load for TP by 65%; and
- Reduce the post-development annual pollutant load for TN by 45%.

The Austral and Leppington North Precincts Water Cycle Management Study (Cardno, 2011b) essentially recommended an end-of-pipe approach to managing stormwater quality, by either co-locating bioretention and detention basins or providing stand-alone end-of-pipe biofilters. Although a treatment train approach was advocated, most of the water quality improvement was to be achieved by the end-of-pipe bioretention basins.

Based on more detailed hydraulic modelling carried out for the concept design, it was found that, in a number of locations, it was not possible to incorporate the end-of-pipe bioretention system within the detention basin or as a stand-alone system. This was primarily associated with insufficient grade (i.e. the topography was too flat to achieve the necessary hydraulic grade across the biofilter).

Other challenges associated with the proposed end-of-pipe bioretention systems were also identified and discussed with Council. This included their scale, size of the contributing catchment, difficulty in achieving the required distribution of flows within the biofilters, and the potential for clogging.

Potential solutions for mitigating these challenges were discussed with Council during several progress review meetings, and a short interim report on the selection of biofilters and wetlands was submitted to Council (SMEC & E2DesignLab, 2018a). A summary of the main recommendations derived from the report and discussions with Council is presented below.

Bioretention basins may not be the ideal treatment technology to be used in the Austral and Leppington North Precincts, mainly because these systems are proposed to be designed as end-of-pipe basins treating flows from relatively large catchments. Therefore, these systems are exposed to relatively high sediment loads and prone to clogging. Furthermore, the larger footprint required with the end-of-pipe solution presents challenges to distribute stormwater flows evenly across the filter surface.

Alternatively, wetlands are more suitable as an end-of-pipe treatment technology since these systems are less prone to clogging and have the capacity to retain and treat larger stormwater volumes. Furthermore, wetlands can be easily incorporated into relatively flat terrain. Nevertheless, wetlands require a footprint three to six times larger than that of a biofilter to achieve the same pollution reduction.

In summary, it was agreed to proceed with the use of end-of-pipe bioretention basins for the Austral and Leppington North Precincts, primarily due to the space constraints, except in locations where the available head was not sufficient to operate the bioretention basin. However, it is noted that there is a risk of clogging co-located biofilters leading to failure and potential increased maintenance costs. Most catchments, which had detention basins and co-located biofilters, still required supplementary streetscape controls to achieve the water quality targets. For the no-basin catchments (i.e. no detention basins), it was decided to replace the end-of-pipe biofilters with raingardens/streetscape controls distributed throughout the catchment. These would be mandated via a DCP, rather than funded with Section 94 Contributions.

A treatment train approach, which is similar to the previous WSUD study (Cardno, 2011b), was proposed to meet the required water quality targets for the development precinct. The proposed treatment train comprised rainwater tanks (RWT), either Gross Pollutant Traps (GPTs) or sedimentation basins and either end-of-pipe biofilters and raingardens. The sizing of the water quality control structures was carried out using MUSIC modelling, as per Council's WSUD guidelines (Alluvium, 2016). A schematic of the typical treatment train adopted for MUSIC modelling is shown in Figure 5.7. Refer to Section 6.3 for further details of the different treatment technologies and MUSIC modelling.

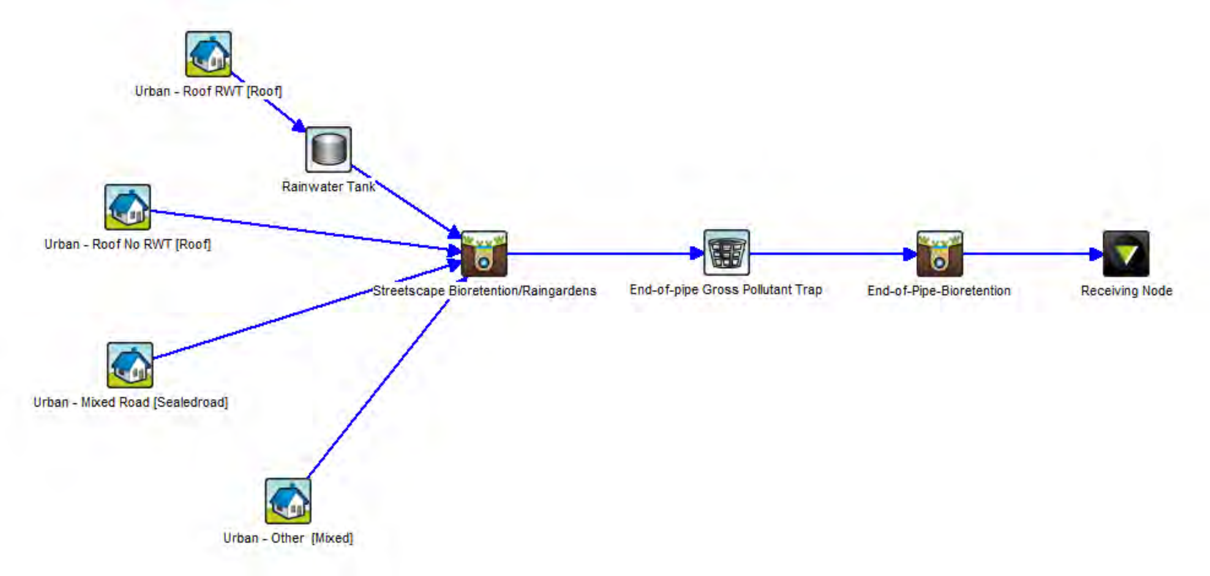


Figure 5.7: MUSIC Representation of a Typical Treatment Train Approach in Drainage Systems with Basins

The following section summarises the specific design constraints, and potential resolutions adopted for the design on co-located biofilters and raingardens.

5.2.2.1. *Co-located Biofilters*

Due to the placement of co-located biofilters, there were two main design constraints that needed to be addressed, namely;

- Risk of uneven flow distribution over very large biofilter surface areas; and
- Risk of clogging and damage to biofilter vegetation when exposed to high flows and associated sediment loads.

It was proposed to address the abovementioned constraints to some extent by using a novel wetland channel distribution system and an access path/backflow weir surrounding the biofilter. A typical layout of a detention basin including co-located biofilter components is shown in Figure 5.8.

The wetland distribution channel system was proposed to distribute flows evenly across the large biofilter surfaces. A typical cross section of the proposed wetland distribution channel is shown in Figure 5.9.

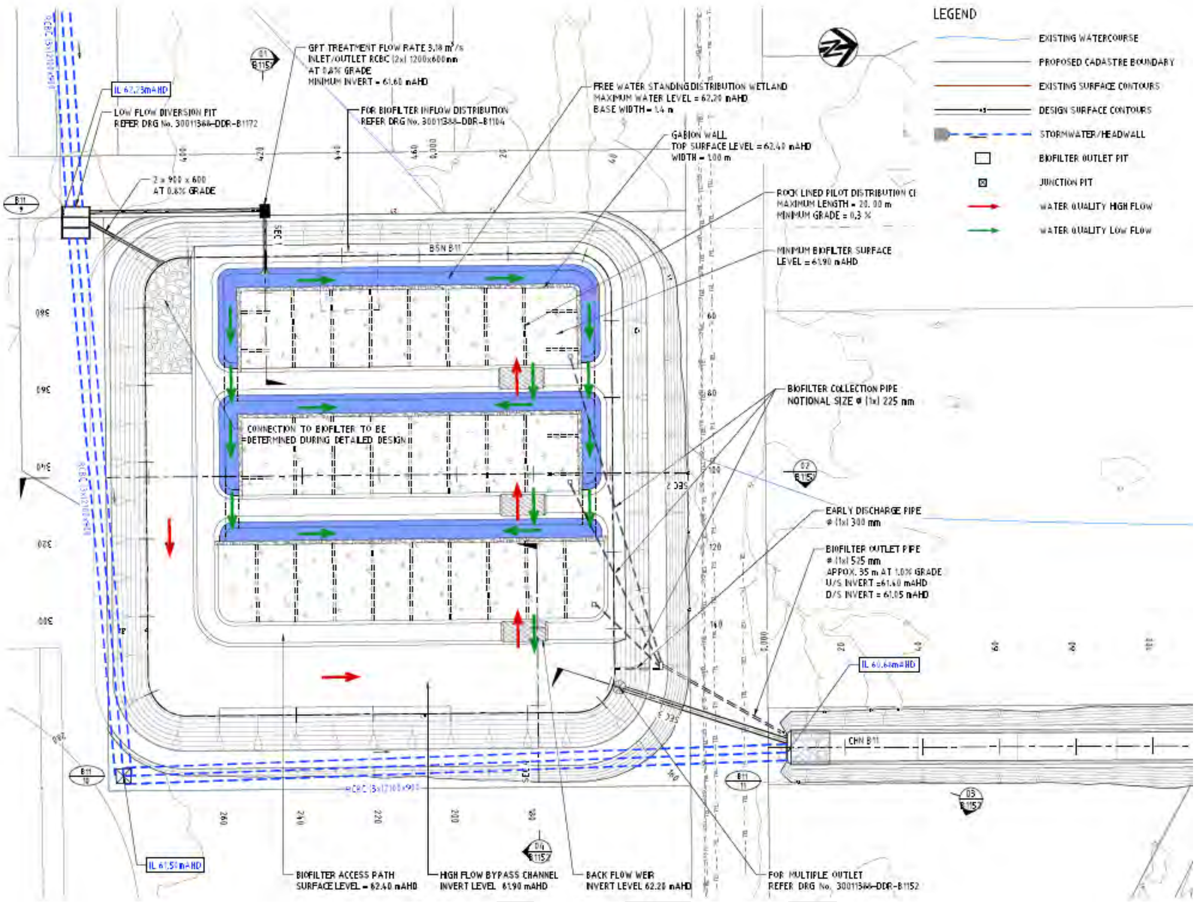


Figure 5.8: Typical detention basin layout including co-located biofilter components

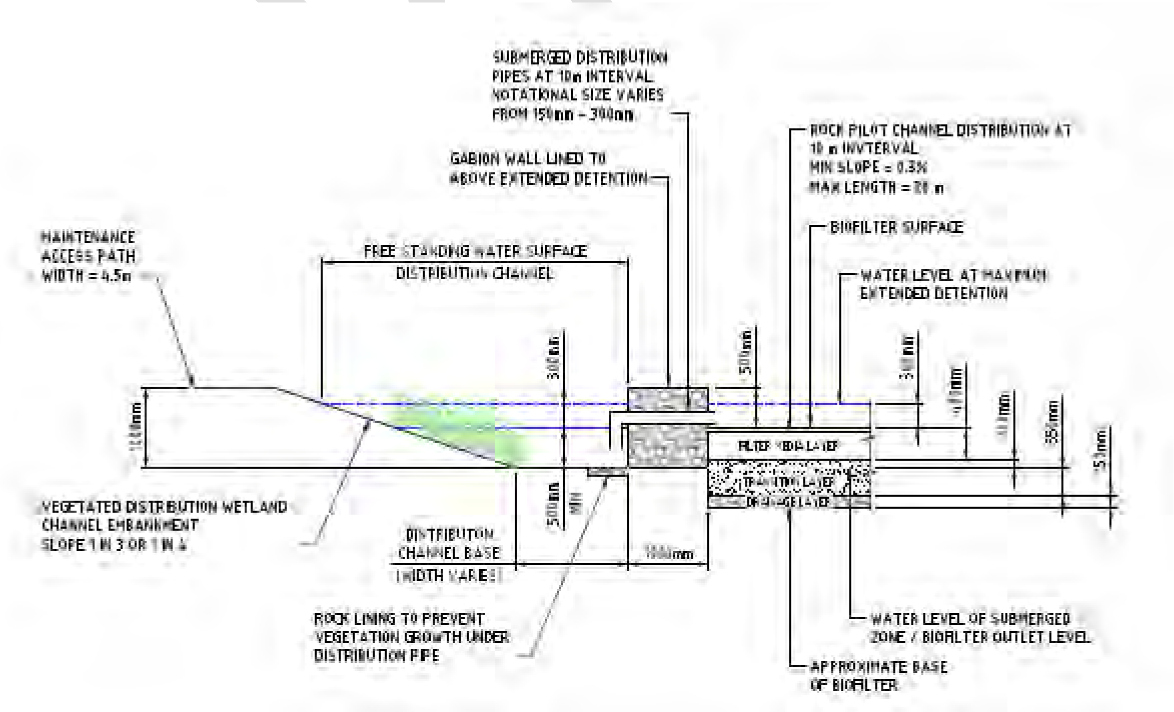


Figure 5.9: Typical wetland distribution channel cross section

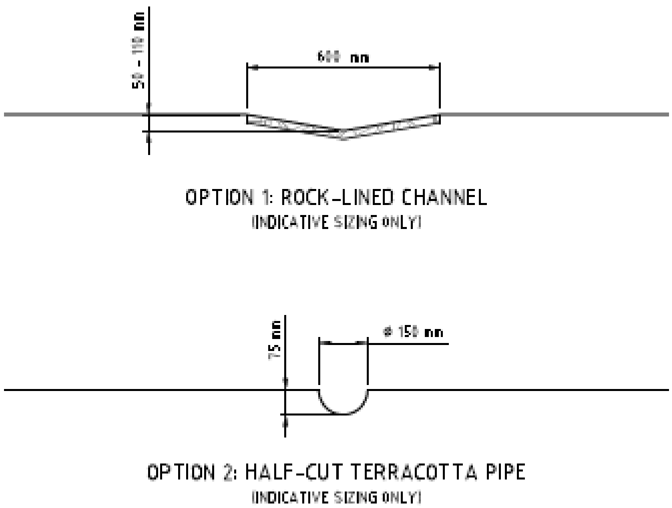


Figure 5.10: Typical rock-lined pilot distribution channel cross section

The main design considerations of the distribution channel are listed below while the main design parameters are listed in Table 5.7.

- The distribution wetland channel sizing was carried out using Manning's equation;
- The distribution wetland channel adopts a free-standing surface water wetland channel, to create an even hydraulic gradient along the length of the distribution (as opposed to piped system which will experience head losses proportional to length);
- The distribution channel was designed with a permanent pool depth of 0.5 m to ensure water is available within the channel during extended dry weather periods. It is important to ensure sufficient water is retained in the channel to provide habitat for mosquito predators;
- This channel has rock-lining under the outlet pipes to inhibit plant growth, apart from that the channel can be vegetated, which should provide a pleasant aesthetic;
- Small distribution pipes exit the wetland distribution channel through a lined gabion wall every 10 metres along the length (all at the same level). The distribution pipes distribute flows to the biofilter surface via small rock-lined pilot channels (typical cross section shown in Figure 5.10;
- These channels may have a nominal slope away from the pipe, however the biofilter surface does not have any grade;
- The distribution pipe system effectively provides a notional biofilter cell size well under the 800 m^2 limit. However, having physical separation between these notional cells is considered unnecessary, if not detrimental to achieving even flow distribution (taking into consideration the potential for pipe blockages etc); and
- Where more than one set of biofilter cells was placed in a detention basin, more than one wetland distribution channels was adopted. Each wetland distribution channel was connected via oversized trafficable culverts placed under the biofilter access path.

It was proposed to provide a berm (or access path) surrounding the biofilter to protect against high flows. Any high flows will be carried through a high flow bypass channel placed on the remaining detention basin floor (outside the berm). Additionally, an early discharge pipe is placed at the end of the high flow bypass channel to direct at least the first portion of the high flows away from the biofilter. A backflow weir was also placed on the berm, further away from the detention basin inlet. The backflow weir was designed as the first entry point of high flows onto the biofilter surface.

During a low-flow event (up to the 3-month ARI event), all flows are diverted from either a trunk pipe or channel to a GPT. The GPT outflow is discharged to the wetland distribution channel and subsequently onto the biofilter surface. Treated water is discharged via the biofilter outlet pipe. However, since most of the co-located biofilters are undersized (due to limited footprint available), a portion of the low flow may overflow via the backflow weir and be discharged via the early discharge pipe.

During a high-flow event, (greater than the 3-month ARI event), low flows are diverted and treated by the biofilter. The remaining inflows enter the detention basin via the high flow bypass channel. The early discharge pipe is engaged and the high flows will be discharged. If the flood waters continue to rise, the backflow weir is then engaged and high flows are directed towards the biofilter surface and the water level at the detention basin will continue to rise further. As the flood water level rises the detention basin main outlet is engaged and the flood waters will be discharged at controlled rates.

It should be noted that the flows through the early discharge pipe were not taken into consideration when sizing the detention basin outlet to control the 50% and 1% AEP events, as it was assumed that due to its size (300 mm diameter) the pipe will be blocked during any event greater than 50% AEP. This assumption is in accordance with ARR2016 blockage policy.

Table 5.7: Design Criteria Adopted for the Wetland Distribution Channel System

Item	Criteria	Reference/Notes
Design event AEP	3-month ARI	Set at the biofilter high flow bypass flow rate.
Embankment and gabion height	Maximum height = 1 m	
Embankment side slopes	Preferred maximum of 1 in 3	(Water by Design, 2014)
Bed slope	0.15%	This slope was used to size channel profile.
Manning's Coefficient "n"	n = 0.030 Grassed channel	ARR2016- Table 6.2.1
Permanent pool depth	500 mm	To avoid drying over extended dry weather periods to promote survival of mosquito predators. Depth needs to be confirmed using a detailed water balance modelling at the detailed design.
Extended detention depth	Maximum = 300 mm Minimum = 150 mm	Equivalent to biofilter extended detention depth.
Channel Freeboard	200 mm	The maximum embankment height is limited to 1 m to be aligned with the biofilter access path (set at 500 mm above detention basin floor).

Item	Criteria	Reference/Notes
		Therefore, the wetland distribution channel freeboard is limited to 200 mm.
Distribution Pipe Size	150 – 300 mm	
Distribution Channel and rock-lined pilot channel Interval	10 m	
Rock-lined pilot channel – maximum length	20 m	

Additional Water Quality Controls for Drainage Systems with Basins

Swales were proposed to be incorporated within the trunk drainage channels (i.e. the low-flow channel) to help achieve the required water quality targets, when the end-of-pipe biofilter surface area was not sufficient. However, in most instances, the treatment provided by the swale and biofilter combination did not meet the required water quality targets. Therefore, the only feasible way to achieve the water quality targets in these catchments will be to acquire additional land to provide enough space for a larger biofilter, or to incorporate additional treatment (bioretention street trees and rain gardens in road reserves) and other source control measures within the catchments (refer Section 5.2.2.2). It should be noted that the design of additional water quality controls is out of the current project scope.

Other Considerations

Council also requested to investigate the potential opportunities for stormwater harvesting at basin sites, especially those located next to passive open spaces. It was identified that nine basin sites (B5, B6, B8, B11, B13, B14, B16, B19, B20 and B25) have the potential for stormwater harvesting. However, it should be noted that additional storage will be required for stormwater harvesting, as the active flood storage volume cannot be utilised for this purpose. One possible option for the additional storage is to provide underground tanks along the detention basin embankment. A detailed assessment of water demand and yield is required to determine the storage requirements of the stormwater harvesting system. This is outside of the current scope of works. Moreover, it should be noted that further water treatment is likely to be necessary to meet stringent water quality requirements set for public health protection based on different stormwater reuse applications (NHMRC, 2009).

5.2.2.2. *Streetscape Controls*

There is approximately 8.8 km^2 of land that does not drain to the proposed detention basins and co-located biofilters. The previous WCM study (Cardno, 2012b) identified 46 end-of-pipe, stand-alone biofilter locations would be required within the project area to treat the runoff from sub-catchments that do not drain to a detention basin. It should be noted that no footprint was allocated in ILP for these end-of-pipe, stand-alone biofilters. SMEC conducted a preliminary investigation to review the suitability of proposed stand-alone biofilters as documented in the design memos dated 7 June 2018 and 20 July 2018. Due to limited data availability (final urban form and minor drainage network connecting to these biofilters) and site constraints (insufficient hydraulic grade for biofilter operation and non-certified land), it was recommended to replace end-of-pipe stand-alone biofilters with suitable streetscape controls. Additionally, streetscape controls are required to be included in catchments that drain into detention basins since the co-located biofilters are generally undersized.

Council was concerned about the available footprint within road corridors for the streetscape controls. Therefore, a further investigation was conducted to estimate the treatment performance of different streetscape WSUD options that can be implemented in the setback and road corridors across the catchment. Raingardens, tree pits, permeable pavements and proprietary media filtration were among the streetscape controls investigated. The treatment area required to manage stormwater quality in a single residential lot was documented in the design memo dated 5 October 2018. Council subsequently estimated that the 4-way intersections could accommodate a raingarden area of 252 m^2 and requested a further investigation to assess the impact of distributed raingardens on overall performance and to estimate the treatment area required to achieve the water quality targets in a single catchment. The details of this modelling exercise can be found in Section 6.3.

Eventually, considering the variability in the flow direction, distribution and raingarden footprint area, land use within each drainage catchment, the streetscape control footprint areas required per hectare of residential, commercial and industrial land uses were estimated.

5.2.2.3. *GPTs*

An additional assessment was also conducted to investigate appropriate treatment approaches for the removal of gross pollutants before stormwater enters the biofilters. The findings were presented in an interim report (SMEC & E2DesignLab, 2018b) and discussed with Council at progress review meetings. The incorporation of Gross Pollutant Traps (GPTs) was the preferred management option, based on space and hydraulic constraints, Council's prior experience and ease of maintenance.

It should be noted that GPTs that can operate with a minimum head loss (0.2 head loss coefficient) or the inlet and outlet are at the same level or with a minimal level difference are to be used in the project area due to the very flat terrain. Furthermore, ease of access to maintenance was considered when placing GPTs. Therefore, GPTs were provided in one of the following locations when possible;

- Overbank maintenance berm of trunk drainage channels
- Basin crest (within 4.5 m wide access/maintenance track)
- Within the road corridor adjacent to basin crest (when there is not sufficient space on basin crest)

GPTs are only proposed as a pre-treatment upstream of the co-located biofilters or within drainage systems with basins. Streetscape controls implemented throughout other catchments are expected to trap gross pollutants generated within their local drainage sub-catchments.

5.3. Design Assumptions

The following assumptions were made during the design of the stormwater management infrastructure:

5.3.1. General

- The survey data provided by Council was suitable for the detailed concept design;
- Since the digital elevation model for the post-development scenario was not available, it was assumed that the finished surface levels would follow the existing ground surface;
- Final road levels will be at or above the 1% AEP flood level (based on the TUFLOW model results with ARR2016 rainfall); and,
- Future roads follow the existing terrain.

5.3.2. Trunk Drainage and Culverts

- Pipe grades and the slope of the road gutter flow path (OLFP) are generally the same as the existing ground surface slope;
- Where possible, a cover of 1m was assumed for all trunk pipes (with a minimum of 700 mm otherwise); and,
- Minimum pipe Class 4 to allow for construction loading with minimum 700 mm cover.

5.3.3. Water Quality Control Structures

- Water quality control structures treat runoff generated from the catchments within the project boundary;
- Runoff generated outside the project boundary will be treated to the required quality before discharging to project area;
- The representation of distributed rainwater tanks and streetscape biofilters using single model nodes is adequate for the project scope;
- The GPT inlet and outlet pipes are at the same level, or else there is a minimal level difference between the two pipes (allowed for 0.2 head loss coefficient);
- No reduction in TSS, TN and TP are achieved via GPTs;
- The early discharge pipe is blocked during 50% AEP event and any larger event including 1% AEP; and,
- The biofilter outlet pipe is set at the submerged zone surface level due to level constraints.

5.4. Environmental Considerations

The REF, which was submitted as a separate deliverable (SMEC, 2018d), address the environmental considerations relevant for the proposed drainage infrastructure.

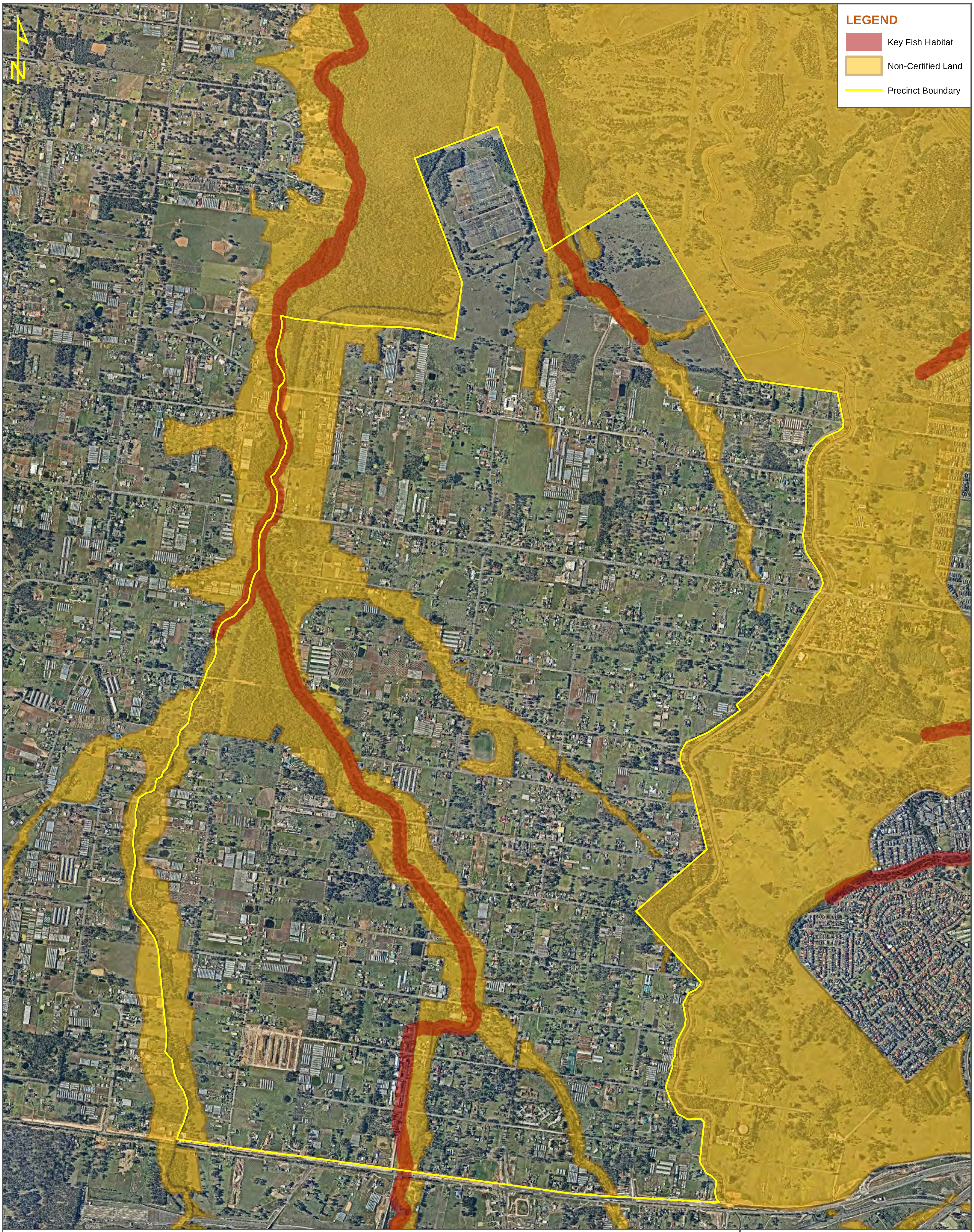
The non-certified land areas and key fish habitat areas were considered during the concept design. Figure 5.11 shows the non-certified land areas and key fish habitat areas within the project area.

DPI Fisheries require drainage infrastructure, within the key fish habitat areas, to be designed to comply with the following:

- avoid and minimise direct impact upon key fish habitat from dredging and reclamation activities and erosion from stormwater discharge points;
- the use of energy dissipation devices around stormwater outlet structures within waterways to minimise erosion; and,
- stormwater treatment systems and flood mitigation basins are constructed off-line and outside of riparian zones.

Based on the DPI Fisheries latest classification shown in Figure 5.11, the culverts and basin/channel outlet structures on the following creeks will be designed for fauna movement and fish migration:

- Bonds Creek downstream of Tributary 1 (Scalabrini Creek);
- Tributary 1 (Scalabrini Creek) downstream of Fifth Avenue;
- Kemps Creek downstream of Bonds Creek; and,
- Tributary 3 downstream of Eighteenth Avenue.



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SMEC Member of the Surbana Jurong Group

LIVERPOOL CITY COUNCIL

FIG NO. 5.10

FIGURE TITLE Non-Certified Land and Key Fish Habitat Areas within the Project Area

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilminin Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

Location: I:\projects\30011388 - Austral Leppington North Liverpool City Council\009 Deliverables\001 Stormwater Trunk Infrastucture\006 GIS\map\ArcMap for Report\SMEC_A3_LCC_MAP_CONSTRAINTS.mxd

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5.5. Climate Change

To allow for the potential impacts of climate change, the ARR data hub recommends that the 1% AEP rainfall intensity should be increased by 18.6% (2090 climate change scenario). This has the potential to increase design flow rates, flood volumes and resultant flood levels.

No allowance was made for the increase in rainfall intensity, due to climate change, in the concept design. However, the performance of the water management infrastructure was tested under the climate change scenario (as a sensitivity test).

Table 5.8 shows the potential adverse impacts on the water management infrastructure associated with increased flow rates, flood volumes and flood levels, which may result from potential climate change. Potential remedial measures are also shown.

The increase in rainfall intensity recommended in ARR was adopted to assess the potential impact of climate change. The sensitivity testing carried out when the precinct-scale hydrologic and hydraulic models were updated to assess the performance of the final concept design under a potential climate change scenario. The resultant impact on flood level is shown in the separate report (CSS, 2018a). In general, the potential increase in flood level was less than 500 mm.

Table 5.8: Potential adverse impacts of climate change on water management infrastructure

Infrastructure	Potential Adverse Impact(s)	Potential Remedial Action
Detention Basins	Water spills over the embankment (i.e. water levels greater than the 0.5 m freeboard)	Ensure water level remains within 0.5 m freeboard over the spillway. If not, increase basin area to keep water level within the available freeboard.
Culverts	Water depth over the road exceeds the maximum allowable depth (200 mm); V x D exceeds the maximum permitted for a 1% AEP event (0.4 m^2/s)	Roads are set at the 1% AEP flood level. If the water level on the road is above 200 mm, keep the water level below 200 mm by increasing the culvert capacity; and/or raising the road level.
Trunk Drainage Pipes	Water surcharges and impacts the safety of vehicles and/or pedestrians by exceeding: • the maximum allowable depth (200 mm); and, • the maximum permitted V x D for a 1% AEP (0.4 m^2/s).	Reduce extra water in road reserve by increasing pipe/pit capacity and/or relaxing the hazard criteria (criteria to be confirmed)
Trunk Drainage Channels	The increase in the depth of flow is greater than 0.5 m freeboard	Make sure water level remains within 0.5 m freeboard by increasing the flood conveyance (widening floodplain or deepening/widening the channel)
Water Quality Controls	These structures are designed for smaller events, hence not considered for climate change impacts	N/A
General Flood Planning Level	The increase in flood levels is greater than the 0.5 m freeboard	Widen the creek/channel to increase conveyance through creek/channel

5.6. Adopted Engineering Software

The engineering software listed in Table 5.9 was adopted for use in the project.

Table 5.9: List of Adopted Engineering Software

Software	Version	Purpose
12d	Version 11 C1p	Used to model bulk earthwork associated with the detention basins and open channel. The software was also used to develop the trunk pipe network, delineation of catchments and to draw overland flow paths for hydraulic calculations in DRAINS software.
CatchmentSIM	Version 3.54	To delineate catchments based on existing topography for developing XP-RAFTS models.
DRAINS	Version 2017.13	To undertake hydrology and hydraulic calculations of trunk drainage (pipe and channels) and detention basins.
HEC RAS	Version 4.0.0	To undertake hydraulic assessment and sizing of trunk channels.
HY-08	Version 7.3	To undertake hydraulic assessment and sizing of transverse culverts.
TUFLOW	2017-09-AC-iSP-w64	To assess the flooding behaviour for pre and post-development scenarios and determine flood levels.
XP-RAFTS	XPRAFTS2013	To estimate design flows for pre and post development scenarios.
MUSIC	Version6.2 Build 1	To size water quality controls (biofilters and raingardens).

6. Methodology

This section outlines the different modelling and iterative design process utilised for the integrated concept design of the stormwater management infrastructure. The first two sections outline the design process adopted for the flood-related controls, and the last section outlines the design methodology for the water quality control structures.

6.1. Hydrologic and Hydraulic Modelling

6.1.1. Precinct-Scale Models

Precinct-scale flood modelling was completed to assist in the design of the required water management infrastructure. The modelling was intended to provide a holistic understanding of flood behaviour across the Austral and Leppington North precincts, for both pre and post-development conditions. This was intended to:

- Determine design tailwater levels along the main watercourses to assist in defining boundary conditions in the system-scale design/modelling (discussed in more detail in Section 6.1.2);
- Confirm the individual detention basin designs developed as part of the system-scale modelling were suitably attenuating post-development discharges to existing levels; and,
- Confirm that, when considered together, the complete detention basin system would not generate any adverse flood impacts across adjoining or downstream properties.

The precinct-scale modelling was completed using two computer models:

- XP-RAFTS hydrologic model, which was used to describe the rainfall-runoff process and develop design discharge hydrographs at various locations across the precincts for existing and proposed conditions; and,
- TUFLOW hydraulic models, which were used to route the discharge hydrographs generated by the hydrologic model and generate information on design flood levels, depths, velocities and extents for existing and post-development conditions.

Detailed information on how each model was developed is included in the Basin Optimisation Report (SMEC, 2017b). The report also summarises the results of the initial hydrologic and hydraulic analysis that was completed based on ARR1987.

Subsequent to the original hydrologic and hydraulic analysis being completed, a revised analysis was completed based on ARR2016. The following sections provide a summary of the updates that were completed to the original hydrologic and hydraulic models as part of the more recent ARR2016 assessment.

It is noted that the precinct-scale model is intended to provide a broad-scale understanding of flood behaviour and potential flood impacts and is not intended to be used as the primary tool for the design of water management infrastructure. In this regard, the system-scale modelling discussed in Section 6.1.2 provides a more detailed design and analysis tool (particularly with regard to basin outlet hydraulics) and should be referred to when assessing the performance of individual components of the water management system.

6.1.1.1. *XP-RAFTS Model*

The layout and sub-catchment input parameters (e.g. areas, slopes, pervious "n") adopted in the XP-RAFTS models were generally retained as part of the most recent ARR2016 analysis. However, Section 3.4.2.2 of Book 5 of ARR2016 recommends the use of "Effective Impervious Area" (EIA) in preference to the "Total Impervious Area" (TIA), to better account for impervious areas that are not directly connected to the drainage system (referred to as indirectly connected impervious areas). ARR2016 outlines that EIA will typically be 50% to 70% of the TIA. That is, only 50% to 70% of the total impervious area is directly connected to the drainage system. The remaining 30% to 50% of the impervious area is, therefore, indirectly connected and has additional opportunities for infiltration.

ARR2016 notes that the above adjustment factors are based upon historic analysis of residential areas and goes on to say a higher EIA factor may be appropriate in highly urbanised areas. As the precincts are likely to include higher density residential areas in addition to commercial areas, which typically comprise higher levels of imperviousness, it was considered that a higher EIA adjustment factor should be adopted for the Austral and Leppington North precincts. For this study, the 80% adjustment factor was adopted when TIA > 80% and 60% adjustment factor was adopted when TIA <80%. That is, the total impervious areas that were originally calculated for each sub-catchment were multiplied by either 0.8 or 0.6 to develop a revised "EIA version" of the XP-RAFTS model.

Several other hydrologic inputs were modified in the existing and post-development models to comply with the requirements of ARR2016. This included:

- Pervious initial loss: Calculated as the storm loss – burst loss (the burst loss varying based upon information presented on the ARR2016 data hub). However, the rural storm loss was reduced by 40% based upon recommendations in Book 5 of ARR2016 to account for the fact that the existing and future catchments will comprise a significant non-rural proportion.
- Design Rainfall: The design rainfall depths for each storm were updated based upon 2016 IFD information downloaded from the BOM webpage.
- Temporal Patterns: One of the most significant differences between ARR2016 and ARR1987 is in the use of storm temporal patterns (i.e. the patterns describing the distribution of rainfall throughout the storm). ARR1987 used a single temporal pattern for each AEP/storm duration while ARR2016 uses 10 temporal patterns for each AEP/storm duration.
- Selection of Critical Discharge and Durations: The peak discharges from the full suite of temporal patterns for each design event were reviewed to determine the most representative temporal pattern for each storm. The temporal pattern that generated the peak discharge immediately above the median discharge was selected as the most representative temporal pattern for each sub-catchment. This process was completed for all AEPs and storm durations.

Refinement of the storage and discharge relationships for each detention basin, in the post-development XP-RAFTS model, was also completed in the post-development model based upon the outcomes of the more detailed system-scale DRAINS modelling discussed in Section 6.1.2.

Basin 23, which was removed as part of the original ARR1987 assessment, was also reinstated in the model.

6.1.1.2. *TUFLOW Model*

No modifications to the original TUFLOW model were completed as part of the ARR2016 analysis (as ARR2016 is focussed on hydrology). However, the upstream boundary conditions (i.e. inflows) to the TUFLOW model were updated to reflect the revised ARR2016 XP-RAFTS model results.

It was noted that ARR2016 includes revised approaches for defining blockage of hydraulic structures (i.e. bridges and culverts). However, as blockage has the potential to provide additional attenuation of flows and we cannot be completely confident which structures will be subject to blockage, it was considered more appropriate to apply no blockage to culverts/bridges contained within the precincts during the initial design of the water management system. That is, no blockage was assigned to hydraulic structures to confirm the proposed water management system could perform satisfactorily in its own right and not need to rely on any additional attenuation provided behind road embankments.

6.1.2. System-Scale - DRAINS Model

In addition to the above-mentioned precinct-scale models, system-scale DRAINS models were also set up. The rationale for setting up additional DRAINS models was that the precinct scale modelling was not sufficiently detailed for the design of local stormwater management systems in terms of the selection of an appropriate critical storm duration/loss parameters and basin outlet hydraulics.

In order to maintain the consistency between the precinct-scale and the system-scale modelling, the same losses and parameters used in the precinct-scale models described above were applied to the DRAINS modelling. The DRAINS models were set up using a hydraulic calculation starting from the basin outlet location (where applicable) at the waterway working towards the trunk drainage inlet maintaining either the minimum channel slope or the existing ground slope. The DRAINS models were set-up based on ARR2016 procedures and were refined several times until the hydraulic components complied with the design criteria described in Section 5.2, and there was a reasonable match in outlet flow rates and velocities between the DRAINS and XP-RAFTS models.

6.1.2.1. *Low flow diversion*

All flows up to the 3-month ARI event need to be diverted from the trunk drainage or minor drainage systems to a GPT, as a biofilter pre-treatment. Additionally, any flows up to the 50% AEP flow are required to be diverted to the detention basins that were designed to control the 50% AEP flow. A weir arrangement shown in Figure 6.1 was utilised to divert low flows. However, instabilities in the system-scale DRAINS model were observed when the diversion weirs were included. These instabilities were caused by the significant turbulence within the diversion pits. Therefore, the diversion weir was sized manually using the system-scale DRAINS model results (model setup excluding diversion weirs) and weir equations. It is recommended to confirm the weir sizing during the detailed design. A summary of calculation procedure for a pipe system is listed below.

- A suitable location to position the diversion pit was identified based on the preliminary Concept Design Drawings;
- The 3-month ARI flow rate and the hydraulic grade line at the downstream end of the incoming pipe (connecting to diversion pit) were extracted from the system-scale DRAINS model. It should be noted that the DRAINS model takes into account the additional storage provided in the high flow bypass channel within the basin and discharges through the early discharge pipe;
- The first weir to divert the low flows up to the 3-month ARI flow was set at the above mentioned hydraulic grade line level;
- The 50% AEP flow and the hydraulic grade line at the same location were extracted from the system-scale DRAINS model. It should be noted that the additional storage provided by the high flow bypass channel was excluded as the basin flood storage was set at the top of biofilter extended detention level as specified in Section 5.2.1.2. Furthermore, the early discharge pipe was also assumed fully blocked;
- If the pipe was pressurised during the 50% AEP flow, the second weir was set at the pipe obvert level. Otherwise, the second weir was set at the hydraulic grade line level at the downstream end of the pipe;
- The minimum length of the first weir was estimated by maintaining the flow height above the weir to be equal to the difference between the two weir levels for a flow rate equal to the difference between the 50% AEP flow and the 3-month ARI flow;
- The second weir length and the diversion pit width were the same length as the first weir; and,
- If the diversion pit width was not sufficient to accommodate incoming trunk pipes, then the minimum weir lengths and the pit width was increased accordingly.

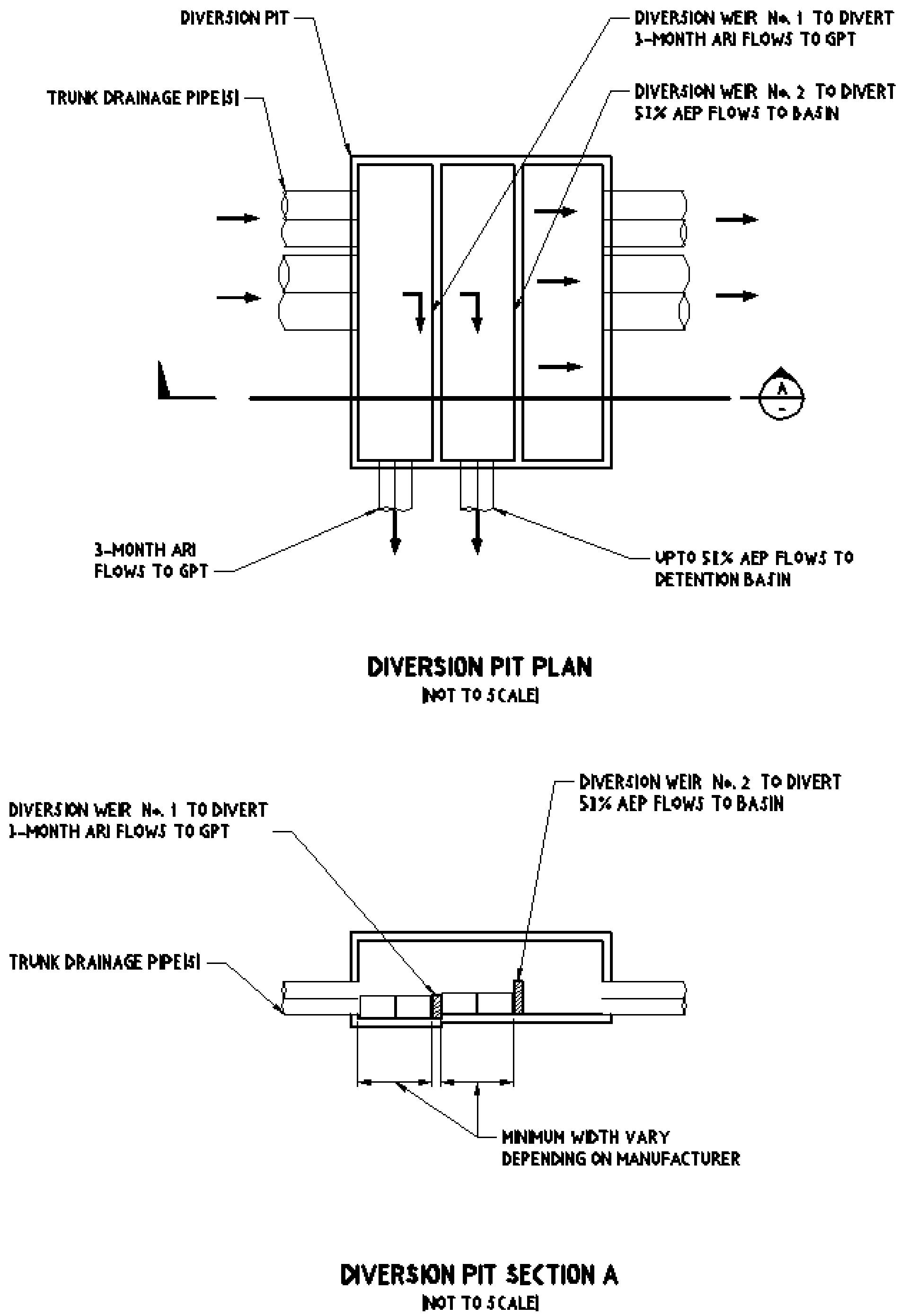


Figure 6.1: Typical Diversion Pit Arrangement

When the 3-month ARI flow is to be diverted from a trunk drainage channel (rather than a pipe), a diversion weir was placed across the low-flow section of the channel. The weir height was the same as the low-flow channel as the low-flow channel was designed with a capacity to carry the 3-month ARI event. The second weir, to divert the flows up to the 50% AEP, was not needed for any of the trunk channels, as none of the trunk channels was discharging into the 50% AEP basins.

6.1.3. HY-8 Model

HY-8 modelling was used to size the creek culvert crossings. The creek culverts were initially modelled using the additional survey information. The culverts were tested for the 1% AEP flows that were extracted from the TUFLOW model results. All of the existing culverts were found to be under capacity to carry the post-development 1% AEP flow. Therefore, the existing creek culverts were redesigned. Additionally, the blockage factors determined as per ARR2016 design blockage assessment was applied to each creek culvert to test culvert capacity to pass through the 1% AEP flow. It should be noted that due to relatively large culvert sizes and other factors, the culvert blockage factors derived as per ARR2016 procedure was generally found to be very close to zero.

6.2. Integrated Design of Water Management Infrastructure

An integrated approach was followed for the concept design of trunk drainage, culverts, detention basins and creek enhancement works, using the models described above. The design process was highly iterative, as summarised schematically in Figure 6.2 and described below.

The design process started with the catchment delineation. Catchment delineation for the pre-development scenario was presented in the Basin Optimisation Report (SMEC, 2017b). In summary, the pre-development catchments were delineated based on the alignment of major flow paths and the locations of key drainage features (existing and proposed culvert/bridge crossings and detention basins). These catchments were used to develop pre-development scenario XP-RAFTS and DRAINS models.

It was necessary to refine the pre-development scenario catchments in order to take into account the potential changes to flow paths in the post-development scenario (i.e. future stormwater pipe networks along the proposed road layout shown in the ILP). These refined catchments were used for the post-development scenario XP-RAFTS and DRAINS models.

The pre and post-development scenarios (with preliminary stage-storage relationships) were modelled using the precinct-scale XP-RAFTS hydrologic model.

It should be noted that the system-scale DRAINS models were set-up with outlets that are discharging freely to the atmosphere. This was mainly because the individual drainage systems have shorter critical durations than that of the main creek system and it was overly conservative to apply the tailwater levels from the main creeks to the drainage system outlets. The system-scale DRAINS models were refined until the post-development scenario flow rate, downstream from each basin outlet, was close to the pre-development scenario flow rate.

Thereafter, 12d earthworks models were set-up within the allocated ILP footprint of each detention basin. Using the 12d model, the earthworks for each basin was designed to comply with the design parameters described in Section 5.2.1.2, as far as possible. The 12d model was then used to obtain a stage-storage relationship for the proposed detention basin. The stage-storage relationship was then applied to the DRAINS model to obtain the associated stage-discharge relationship.

The precinct-scale XP-RAFTS model was updated with the stage-storage and stage-discharge relationships. The XP-RAFTS and DRAINS model parameters were further refined until a reasonable match in flow rates and velocities was obtained between the two models. At this stage, the precinct-scale TUFLOW model was updated with the flows extracted from the XP-RAFTS model and the concept design dimensions and level of trunk pipes, channels, culverts and detention basins to obtain the preliminary 50% and 1% AEP envelop flood surface. An additional check was performed at this stage to confirm that the detention basins have sufficient capacities when operating under the appropriate tailwater levels. The system-scale DRAINS models and precinct-scale XP-RAFTS model for the post-development scenario was updated with the new basin capacity/outlet configuration if needed.

Finally, the updated TUFLOW model was used to carry out the flood impact assessment modelling and produce flood mapping for the project area. The final concept design parameters of the individual stormwater management structures were extracted from the system-scale DRAINS models and associated 12d earthworks models.

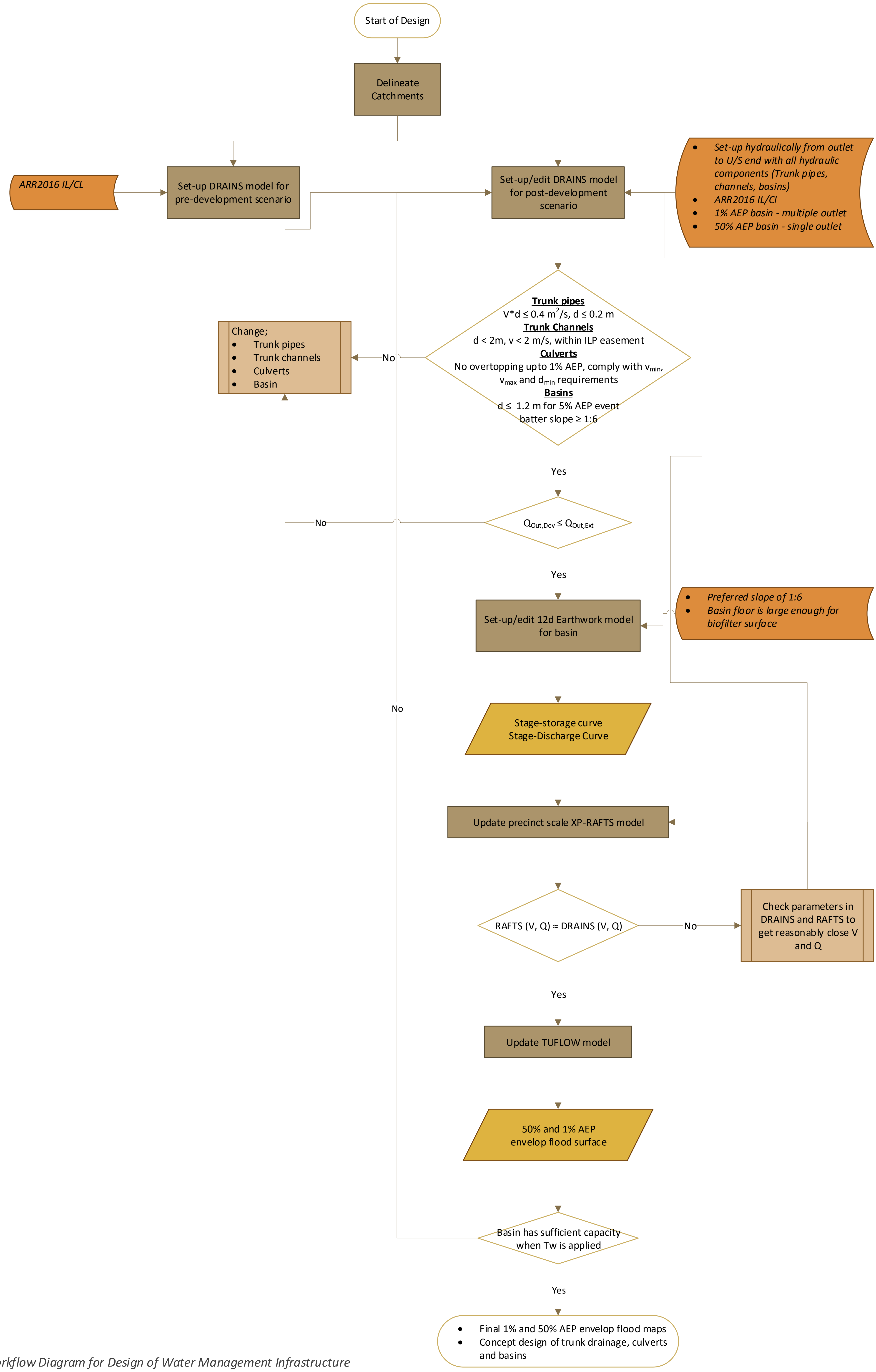


Figure 6.2: Workflow Diagram for Design of Water Management Infrastructure

6.3. Water Quality Modelling

MUSIC modelling was used to size each of the WSUD elements to meet the required water quality targets. The following two sections provide a summary of MUSIC model parameters and different MUSIC models developed for the Austral and Leppington North precincts.

6.3.1. MUSIC Model Parameters

Since Council's recommended model parameters are available in MUSIC-*link*, a new MUSIC-*link* model was developed. Out of the three soil groups available in MUSIC-*link*, "Liverpool Development – Clay.mlb" was selected as the model template to match with "Blacktown (bt)" soils, which is the predominant soil type present in the Austral and Leppington North development area (Council WSUD Technical Guidelines: Figure 1 and Table 6).

Since a new MUSIC-link model was developed, rainfall-runoff parameters were automatically generated according to LCC WSUD guidelines. As such, these parameters are not listed in this report. The following sections only provide assumptions and parameters related to catchment splitting and treatment nodes.

6.3.1.1. *Water Quality Catchment Splitting*

Council's MUSIC-*link* model provides six default Zoning/Surface Types ("Mixed", "Roof", "Sealed Road", "Residential", "Commercial" and "Industrial"). Furthermore, stormwater quality parameters are different for roofs, roads and general urban categories. As such, it was necessary to split roof areas and road areas from the rest of the catchment area. The overall catchment imperviousness fractions were also required to comply with LCC Hand Book for Drainage Design Criteria (LCC, 2003a). Table 6.1 summarises the adopted surface type percentages and the overall imperviousness for the different land-use categories in the MUSIC model.

Table 6.1: Distribution of Surface Types and Imperviousness in MUSIC Model

Land-use	Surface Type	Imperviousness	Area	Overall Imperviousness
Residential [(a)]	Roof	100%	55%	85%
	Road	100%	10%	
	Other-Residential	57%	35%	
Town Centre [(b)]	Roof	100%	50%	100%
	Road	100%	20%	
	Other-Commercial	10%	30%	
Industrial [(b)]	Roof	100%	60%	90%
	Road	100%	20%	
	Other-Industrial	50%	20%	

Notes:

(a) The surface area distribution was based on the indicative surface distribution for Growth Centres given in Blacktown City Council MUSIC modelling (BCC, 2013).

(b) The surface distribution was the same as the MUSIC model presented in the previous WCM study (Cardno, 2011b). These distributions were originally assumed to be based on the indicative layout plans.

In catchments where more than one land-use was shown in the final ILP, the roof, road and other surface areas, for each land-use, were estimated separately as per the surface distribution shown in Table 6.1. These were then summed to obtain the total of each surface type in the catchment. The imperviousness of "other" surface types in mixed land-use catchments was estimated as the area-weighted average imperviousness of "other" surfaces in each individual land-use type.

The proposed school areas were assumed to be equivalent to residential land use; while community centres, next to the retail/commercial centres, were assumed to be the same as the Town centre.

6.3.1.2. *GPTs*

A generic treatment node with 95% GP removal efficiency was assumed to model all of the GPTs. The model assumed no reduction of TSS, TP and TN, which is similar to Blacktown City Council's generic GPT treatment node (BCC, 2013).

Although GPTs have varying degrees of capacity to remove TSS, TN and TP this conservative approach was adopted as it is not known during the concept design which propriety/non-propriety devices will be used in the study area by the different developers.

The high flow by-pass for the GPTs was set to the 3-month ARI peak flow.

6.3.1.3. *Swales*

The low-flow section of the trunk drainage channels was modelled as a swale when the proposed treatment area of the wetland/biofilter at the end of the catchment could not meet the required water quality targets. The adopted properties for the swales are listed in Table 6.2.

Table 6.2: Swale Design Parameters used for MUSIC Modelling

Parameter	Value
Inlet Properties	
Low Flow Bypass	0 m^3/s
Storage Properties	
Length	~ Trunk channel length (an allowance was made for the length lost for culvert end treatments)
Bed Slope	Trunk channel bed slope
Base Width	Base width of the low-flow channel
Top Width	Top width of the low-flow channel
Depth	Depth of the low-flow channel

Vegetation Height	0.25 m
Exfiltration Rate	0 mm/hr [(a)]

Note:

(a) The exfiltration rate was set to 0 mm/hr since the predominant soil group found in the project area (Blacktown Soil) were specified as unlikely to be suitable for infiltration.

6.3.1.4. *Biofilters and Raingardens*

The bioretention system parameters adopted for the MUSIC modelling are listed in Table 6.3. It should be noted that all biofilters were modelled with a submerged zone (SZ), since the inclusion of a SZ is known to protect biofilter vegetation during long dry weather periods. However, it was observed that the addition of a SZ resulted in reduced TP removal performance in the MUSIC modelling. This is contradictory to the latest research work which suggests an improved TP removal after addition of a SZ (Payne, et al., 2015). The current best practice guidelines specify the carbon source in SZ to be of very low nutrient to avoid nutrient leaching. The plausible explanation for the observed discrepancy is that MUSIC modelling algorithm is based on an early dataset where the carbon source in SZ had a relatively high nutrient content (eWater, 2014).

After discussion with the specialist water quality consultants, E2DesignLab, the related biofilter parameter, Orthophosphate Content of Filter Media, was lowered below the value specified in Council WSUD Guidelines (Alluvium, 2016). The modification was needed since the current version of the MUSIC model does not take into account the relatively lower Orthophosphate content of the SZ compared to that of the filter media.

Table 6.3: Bioretention Design Parameters used for MUSIC Modelling

Parameter	End-of-pipe Biofilter Value	Raingarden Value
Inlet Properties		
Low Flow Bypass	0 m^3/s	0 m^3/s
High Flow Bypass	3-month ARI peak flow	3-month ARI peak flow
Storage Properties		
Extended Detention Depth	150 - 300 mm	100 – 300 mm
Filter Media Properties		
Unlined Filter Media Perimeter	100 mm	100 mm
Saturated Hydraulic Conductivity	120 mm/hr	120 mm/hr
Filter Depth	600 mm	600 mm
TN Content of Filter Media	800 mg/kg	800 mg/kg

Parameter	End-of-pipe Biofilter Value	Raingarden Value
Orthophosphate Content of Filter Media	20 mg/kg[a]	30 mg/kg
Infiltration Properties		
Exfiltration Properties	0 mm/hr	0 mm/hr
Lining Properties		
Is Base Lined?	Yes	Yes
Vegetation Properties		
Vegetated with Effective Nutrient Removal Plants	Yes	Yes
Outlet Properties		
Overflow Weir Width	As per Concept Design Drawings	Distributed raingarden = 2 m Lumped raingarden = approximately 4 m per 800 m^2 treatment area
Underdrain Present?	Yes	Yes
Submerged Zone with Carbon Present?	Yes	No
Depth	0.4 m	N/A
Advanced Properties		
Filter Media Soil Type	Loamy Sand	Loamy Sand

Notes:

(a) Minimum specified in Council guidelines are 30 mg/kg. However, a lower value was used to account for the relatively low Orthophosphate content in SZ. (This was agreed in consultation with E2DesignLab).

6.3.1.5. *Rainwater Tanks*

The rainwater tank properties used in the previous WSUD study (Cardno, 2011b) were adopted for the new MUSIC model, with the only difference being that the maximum roof area to be drained into the rainwater tanks was assumed to be 50% of the total roof area. The following parameters were therefore adopted for the MUSIC modelling:

- 15 lots per hectare
- 3 kL rainwater tank per lot

- 365 L/day/lot demand. Re-use has been estimated to supply toilet flushing, laundry and garden watering for an average of 3.5 persons/lot.

6.3.1.6. *Buffer Strips*

Buffer strips such as lawns and front nature strips were included in the following models as an additional source control in residential land use areas,

- lot-scale MUSIC model;
- Drainage System NB37detailed MUSIC model; and,
- 1 ha residential area MUSIC model.

The following properties were used in all the above models to represent buffer strips.

- Percentage of upstream area buffered is 80%;
- Buffer area as a percentage of upstream impervious area is 20%; and,
- Exfiltration rate is 0 mm/hr.

6.3.2. MUSIC Models

System-scale MUSIC models were used to estimate the performance of the co-located biofilters and the required footprint areas of supplementary streetscape controls for drainage systems with basins. Additional system-scale MUSIC models were developed for each drainage system that did not drain to a detention basin to estimate the required end-of-pipe stand-alone biofilter footprint area. It should be noted that these system-scale models are only a high-level representation of drainage system. For instance, streetscape controls distributed throughout the catchment are represented as a single node.

The high-level system-scale MUSIC models are not sufficiently detailed to assess the impact of raingardens distributed throughout the catchment on the overall water quality performance. Therefore, a detailed MUSIC model was developed for a single catchment (Drainage System NB37 which does not include a detention basin/co-located biofilter) to confirm the results of the high-level catchment representation. A schematic diagram of the MUSIC model sub-catchments for the Drainage System NB37 is shown in Figure 6.3. The required raingarden footprint in the detailed model was larger than was estimated using the high-level system-scale model. However, due to time and budgetary constraints, it was not possible to develop a detailed model for each drainage system. Furthermore, it is likely that some sub-catchment boundaries will change depending on the final design surface. Therefore, the streetscape control footprint areas required per hectare of residential, commercial and industrial land uses were estimated.

Figure 6.3: Detailed MUSIC model catchments - Drainage System NB37

7. Concept Design of Water Management Infrastructure

This section of the report presents the concept design details of the drainage infrastructure, water quality control structures and creek enhancement works. The concept designs are presented in "drainage system" scale to reflect the integrated nature of the concept design process. There are 62 drainage systems as shown in Figure 7.1 and these drainage systems are categorised into three main groups as follows.

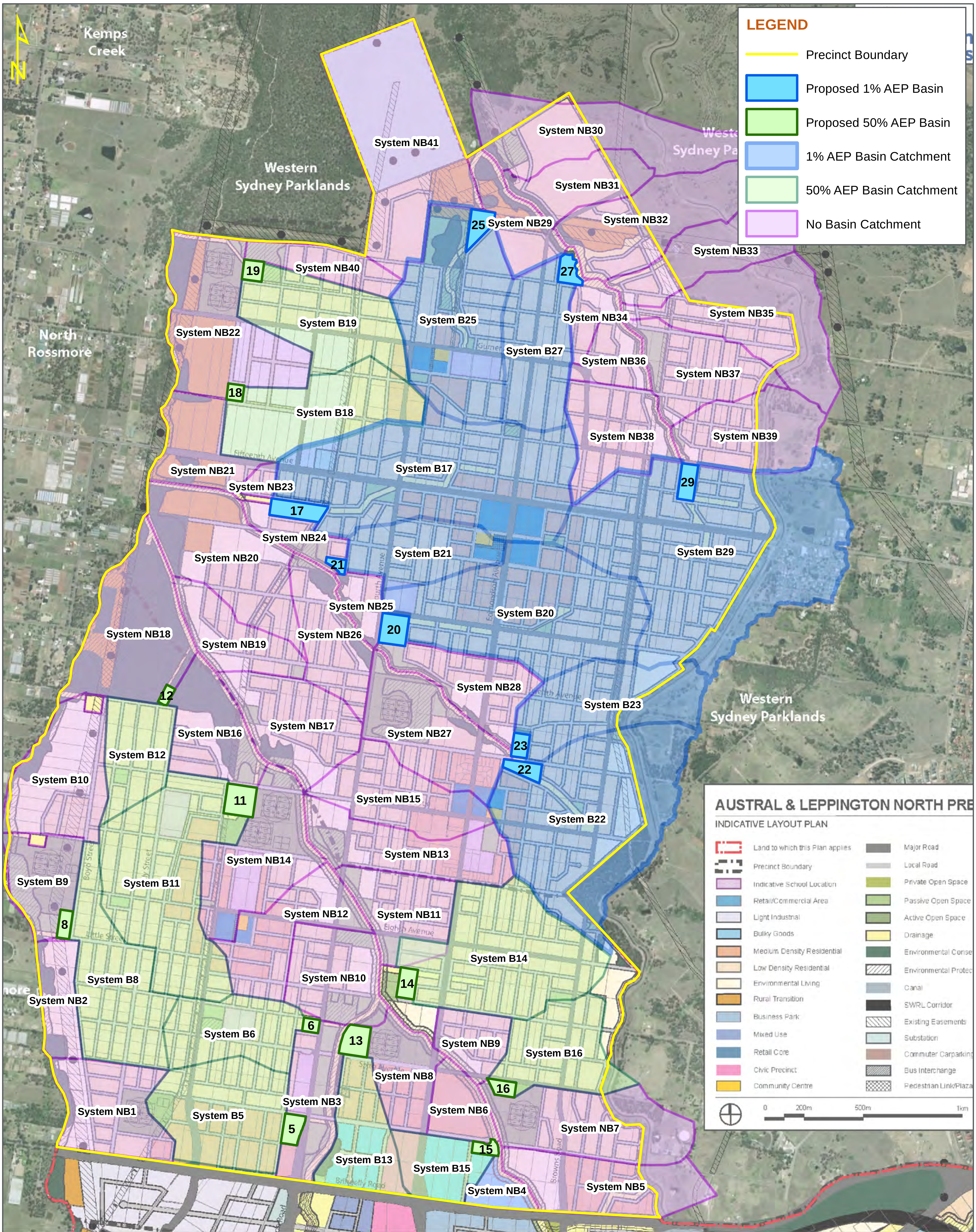
- Drainage systems with 1% AEP basins;
- Drainage systems with 50% AEP basins; and,
- Drainage systems without basins.

A typical drainage system includes trunk drainage pipes and channels, detention basin and water quality controls such as GPT/sedimentation pond and biofilters.

The concept design for culverts along the major creeks and creek enhancement works are presented separately at precinct-scale at the end of this section.

For each of the drainage systems the following information is provided:

A separate section on streetscape source controls is included as these controls (raingardens) are required across the entire development precinct. These will be implemented via a DCP.



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COORDINATE SYSTEM
GDA 1994 MGA Zone 56

FIG NO. 7.1

FIGURE TITLE Map of Drainage Systems

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

7.1. Drainage Systems with 1% AEP Basins

There are eight drainage systems that include 1% AEP basins (Figure 7.2). This includes:

- Drainage System B17
- Drainage System B20
- Drainage System B21
- Drainage System B22
- Drainage System B23
- Drainage System B25
- Drainage System B27
- Drainage System B29

Stormwater runoff is conveyed in these drainage systems via trunk drainage pipes and channels. The 3-month ARI flow is diverted to a biofilter or channel/pipe (basins without co-located biofilters) via GPT for water quality management. The remainder of the flow is directed to the 1% AEP detention basins, which are designed with a multiple outlet to meet the 50% and 1% AEP pre-development discharges.

Drainage system components, concept design constraints and opportunities are presented in the following sections for each drainage system. Detailed concept design Layout plans, long sections and cross sections for the trunk drainage pipes and channels, detention basin and co-located biofilter (if any) in each drainage system can be found in Appendix B. Furthermore, typical details of flow diversion structures , spillways channel landscape and erosion and sediment control measures are also given in Appendix B.

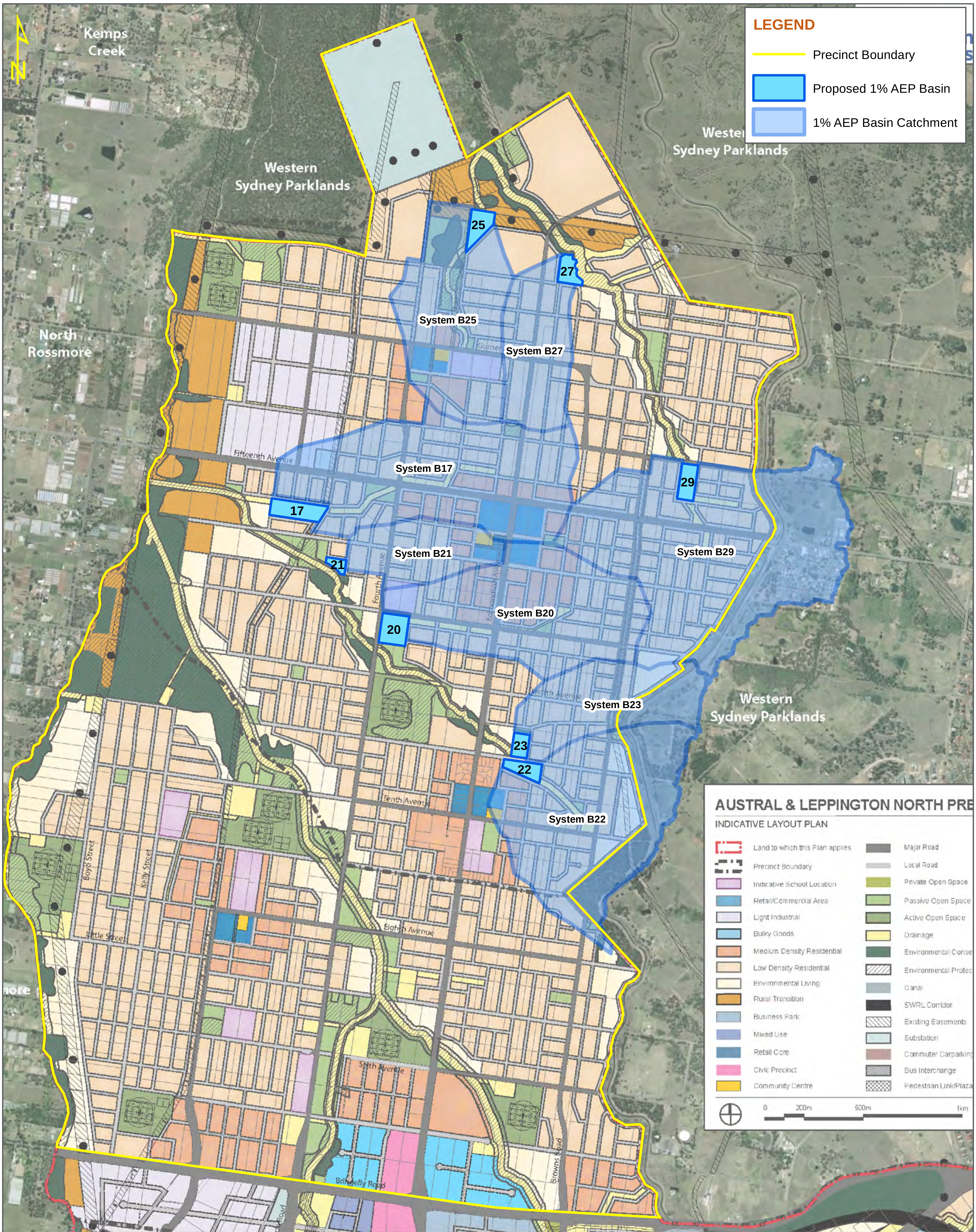

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FIG NO. 7.2

FIGURE TITLE Map of Drainage Systems with 1% AEP Basins

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

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Please refer to Table 7.1 for Austral and Leppington North Precincts ILP zoning legend applicable for the base map in all report figures hereinafter.

Table 7.1: Austral and Leppington North Precincts ILP Zoning Legend applicable for the Base Map in All Report Figures

Colour code	Zone	Colour code	Zone
	Land to which this Plan applies		Major Road
	Precinct Boundary		Local Road
	Indicative School Location		Private Open Space
	Retail/Commercial Area		Passive Open Space
	Light Industrial		Active Open Space
	Bulky Goods		Drainage
	Medium Density Residential		Environmental Conservation
	Low Density Residential		Environmental Protection Overlay
	Environmental Living		Canal
	Rural Transition		SWRL Corridor
	Business Park		Existing Easements
	Mixed Use		Substation
	Retail Core		Commuter Parking
	Civil Precinct		Bus Interchange
	Community Centre		Pedestrian Link/Plaza

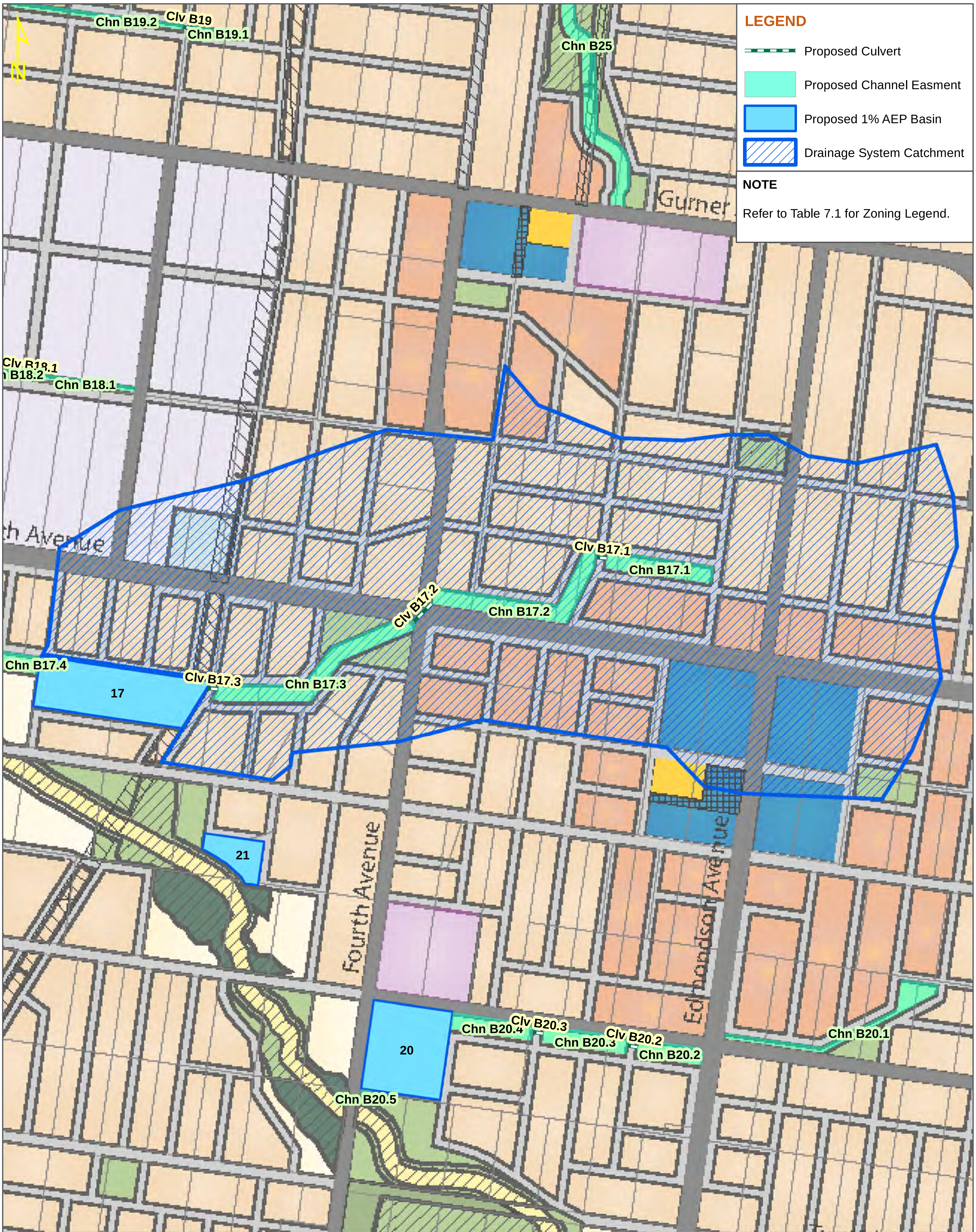
Source: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

7.1.1. Drainage System B17

Drainage system B17 which is located adjacent to the eastern boundary of the precinct drains stormwater from a 73 ha catchment, which discharges into Tributary 2. The drainage system components included in drainage System B17 are shown in Figure 7.3 and summarized in Table 7.2.

Table 7.2: Drainage System B17 Components

Drainage Component	Details
Trunk drainage - open channel	Chn B17.1, Chn B17.2, Chn B17.3 and Chn B17.4
Culverts	
Existing	Clv B17.2 (KC13)
Proposed	Clv B17.1 and Clv B17.3
Detention basin	Basin 17
Water quality controls	
GPT	GPT B17
Biofilter	Bioretention B17



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COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.3

FIGURE TITLE Drainage System B17

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilminin Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

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Design constraints

Design constraints are listed in Table 7.3. Environmental constraints and utility constraints are shown in Figure 7.4.

Table 7.3: Drainage System B17 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	Majority of the basin outlet channel is within the non-certified layer. Furthermore, the location where basin outlet channel discharges onto the Kemps Creek is classified as a key fish habitat area.	This issue is addressed in the REF (SMEC, 2018d). Channel outlet to be designed as per DPI fisheries requirements during detailed design.
Utility conflicts	Refer to Utility Services Investigation Report (SMEC, 2018c).	Refer to Utility Services Investigation Report (SMEC, 2018c).
Deviations from the preferred design parameters	**Trunk Channels** Maximum of 1:4 batter slope or flatter slope was applied in general for the channel sections between the basin and Fifteenth Avenue. No provision of maintenance berm due to limited footprint.	**Trunk Channels** Increase the channel easement width.
	Culverts The available cover Upstream end of Culvert B17.1 and the downstream end of Culvert B17.2 is less than 0.7 m.	**Culverts** Consider alternative options such as locally raised road crest where culvert crossing, adjust creek bed levels to suit lower culvert inverts or provide concrete capping. To be addressed at detailed design.
	Detention basin Endeavour Energy 3-pole structure located bottom left hand corner of the basin's ILP footprint.	The basin batter modified to suit the Endeavour Energy requirements. (no excavation greater than 100mm within 5m of the Endeavour Energy 3-pole structure).
	Water Quality Controls There was not sufficient footprint within the detention basin to include a biofilter that can meet the required water quality targets. The current co-located biofilter is therefore undersized for its catchment. Additional streetscape and source controls to be provided in the catchment.	**Water Quality Controls** Reduce the dependency on the end-of-pipe solution by implementing source control measures and additional WSUD treatment in the catchment. Preliminary estimates of the required supplementary biofilter footprint area are shown on concept design drawings

Constraint type	Details	Possible Resolutions
		and further details on streetscape controls can also be found in Section 7.4.
Geotechnical	Basin site demonstrates soft soil conditions. Building structures in soft ground conditions are problematic as it can lead to long-term settlement of the structure.	In general, and within practical limits, it is recommended that 'soft' to 'firm' natural soils encountered at subgrade level be excavated and replaced with controlled fill. Refer to Geotechnical Interpretive Report (SMEC, 2018a) for details.

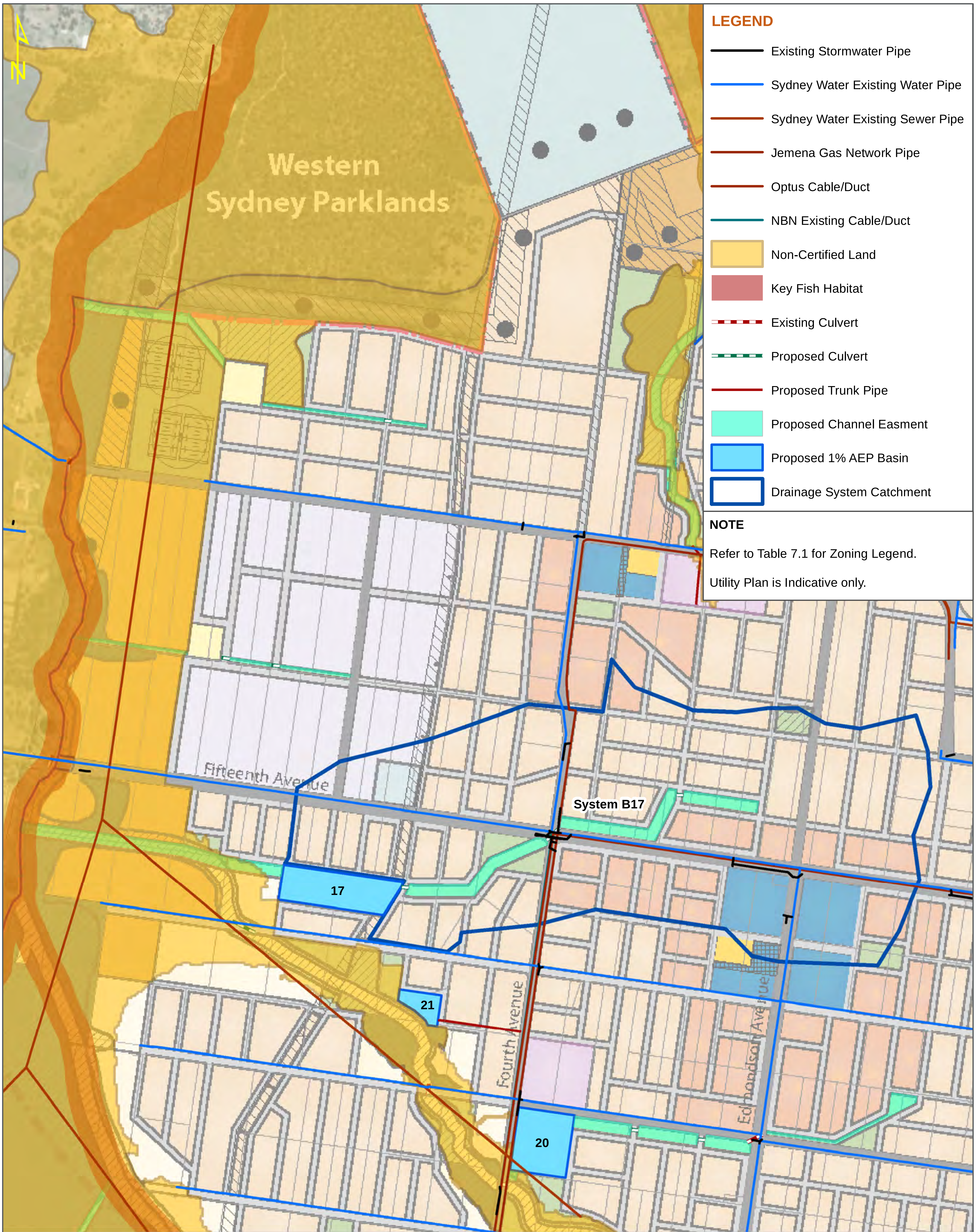

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FIG NO. 7.4	**FIGURE TITLE** Environmental and Utility Constraints - Drainage System B17		
PROJECT NO. 30011388	**PROJECT TITLE** Austral and Leppington North Design of Water Management Infrastructure		
CREATED BY Nilminin Pannipitiya	**SOURCES** Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)		

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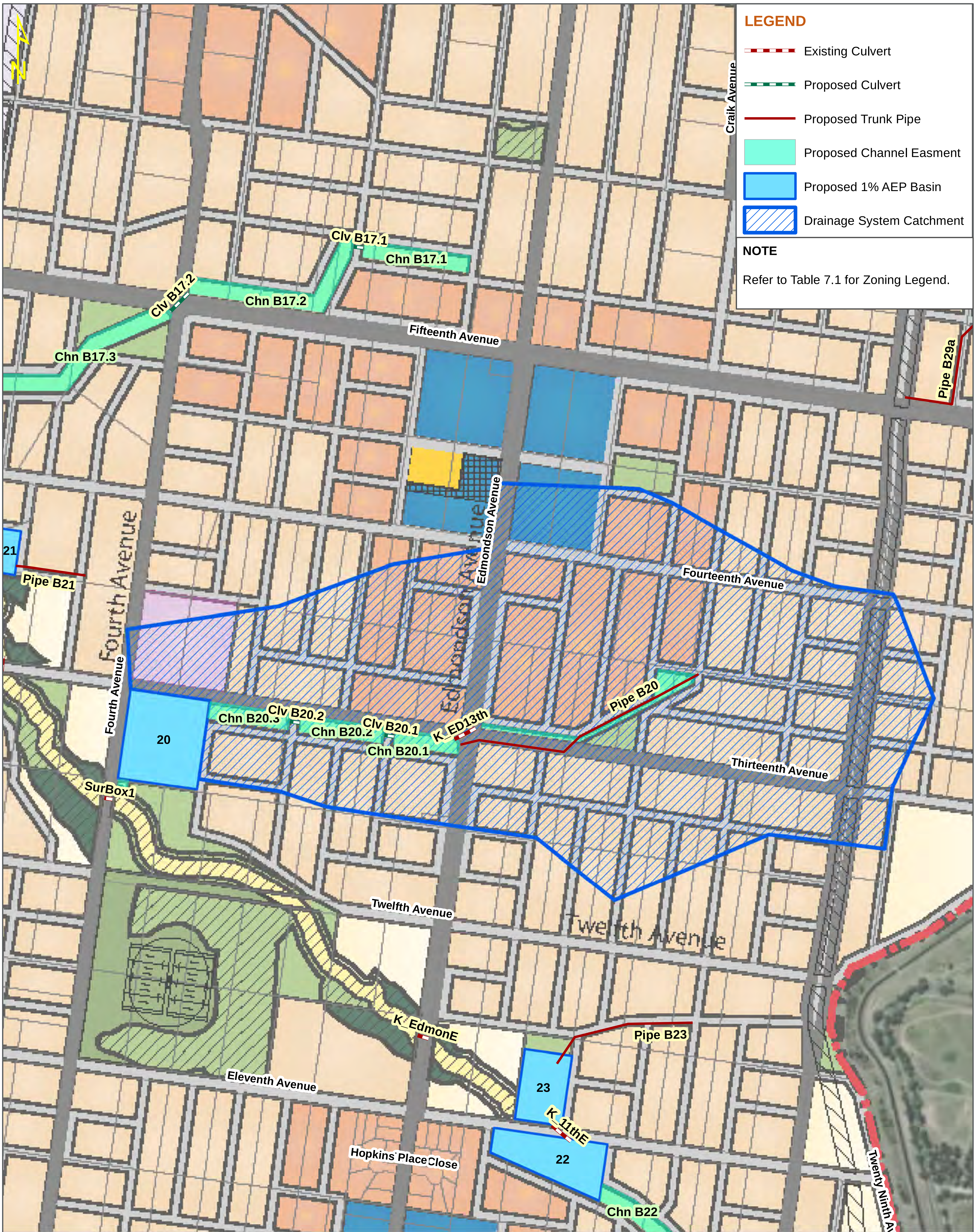
7.1.2. Drainage System B20

Drainage system B20 which is located between Twelfth and Fifteenth Avenue drains stormwater from a 60 ha catchment, which discharges into Tributary 2. The drainage system components included in drainage System B20 are shown in Figure 7.5 and summarized in Table 7.4.

Table 7.4: Drainage System B20 Components

Drainage Component	Details
Trunk drainage – pipe	Pipe B20.1, Pipe B20.2, Pipe B20.3, Pipe B20.4, Pipe B20.5, Pipe B20.6 and Pipe B20.7
Trunk drainage – open channel	Chn B20.1, Chn B20.2 and Chn B20.3
Culverts Existing Proposed	 K_ED13th (Replaced with the proposed trunk pipe B20.7) Clv B20.1 and Clv B20.2
Detention basin	Basin 20
Water quality controls GPT Biofilter	 GPT B20 Bioretention B20



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COORDINATE SYSTEM
GDA 1994 MGA Zone 56

FIG NO. 7.5

FIGURE TITLE Drainage System B20

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

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Design constraints

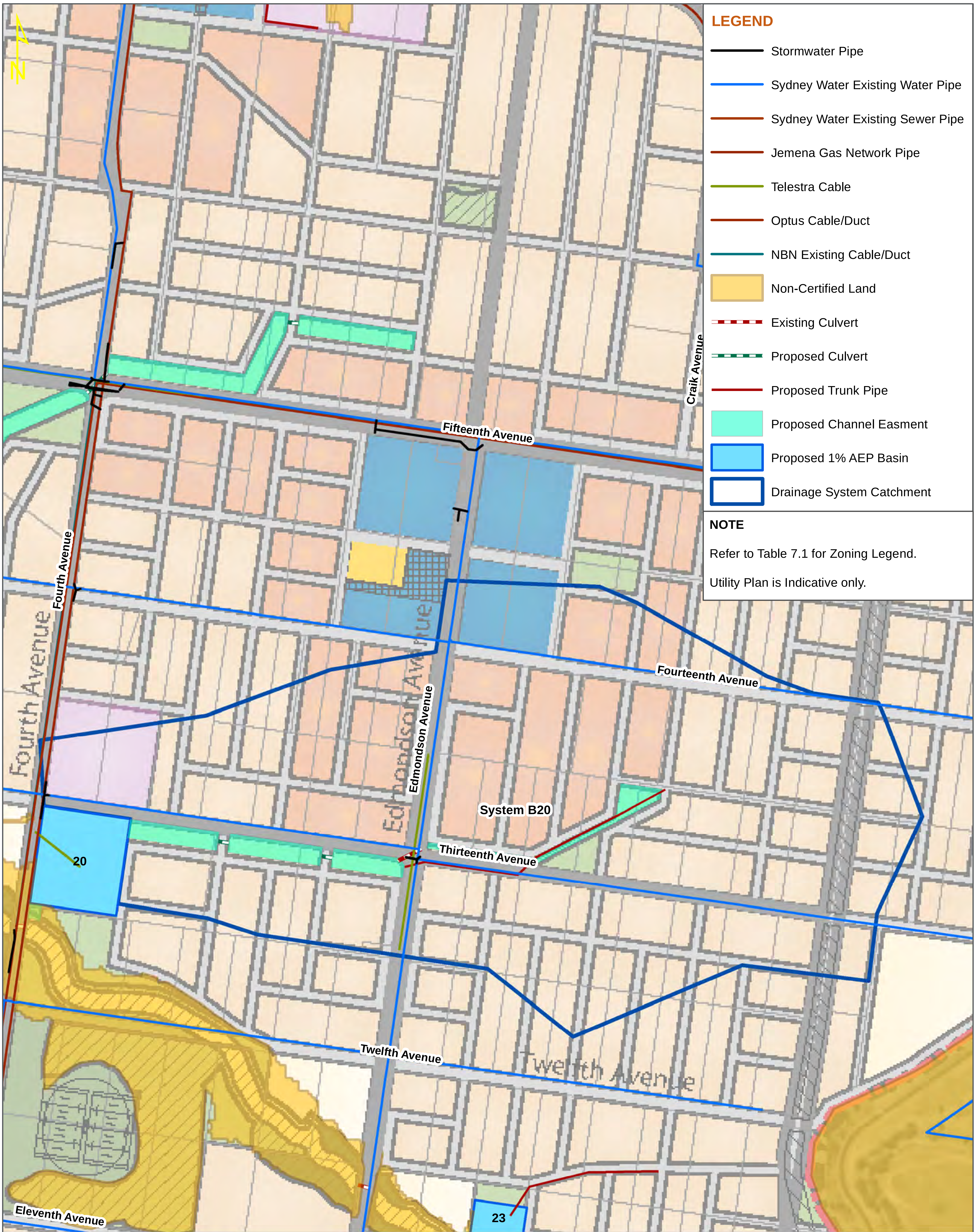
Design constraints are listed in Table 7.5. Environmental constraints and utility constraints are shown in Figure 7.6.

Table 7.5: Drainage System B20 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	The basin outlet is within the non-certified land.	This issue is addressed in the REF (SMEC, 2018d).
Utility conflicts	Refer to Utility Services Investigation Report (SMEC, 2018c).	Refer to Utility Services Investigation Report (SMEC, 2018c).
Deviations from the preferred design parameters	**Trunk Channels** Steeper batters were adopted in the most upstream trunk channel section (East of Edmondson Avenue) due to limited easement width.	**Trunk Channels** This issue was addressed by replacing the channel with RCBC (Pipe B20) as per Council advice.
	Water Quality Controls There was not sufficient footprint within the detention basin to include a biofilter that can meet the required water quality targets. Therefore, the current co-located biofilter is undersized for its catchment. Additional streetscape and source controls to be provided in the catchment. Furthermore, the available hydraulic head was very limited. Therefore, the biofilter extended detention depth was reduced.	**Water Quality Controls** Reduce the dependency on the end-of-pipe solution by implementing source control measures and additional WSUD treatment in the catchment. Preliminary estimates of the required supplementary biofilter footprint area are shown in concept design drawings and further details on streetscape controls can also be found in Section 7.4.
Geotechnical	Basin site demonstrates soft soil conditions. Building structures in soft ground conditions are problematic as it can lead to long-term settlement of the structure.	In general, and within practical limits, it is recommended that 'soft' to 'firm' natural soils encountered at subgrade level be excavated and replaced with controlled fill. Refer to Geotechnical Interpretive Report (SMEC, 2018a) for details.

Design opportunities

As the upstream part of the proposed trunk channel (upstream of the detention basin) was replaced with a RCBC, the ILP footprint allocated for the trunk channel easement could be utilised for streetscape water quality controls. To be investigated further at detail design stage.



DATE 18/09/2018	0 145 290 Meters 1:5,485	**PAGE SIZE** A3	**COORDINATE SYSTEM** GDA 1994 MGA Zone 56
FIG NO. 7.6	**FIGURE TITLE** Drainage System B20		
PROJECT NO. 30011388	**PROJECT TITLE** Austral and Leppington North Design of Water Management Infrastructure		
CREATED BY Nilmini Pannipitiya	**SOURCES** Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)		

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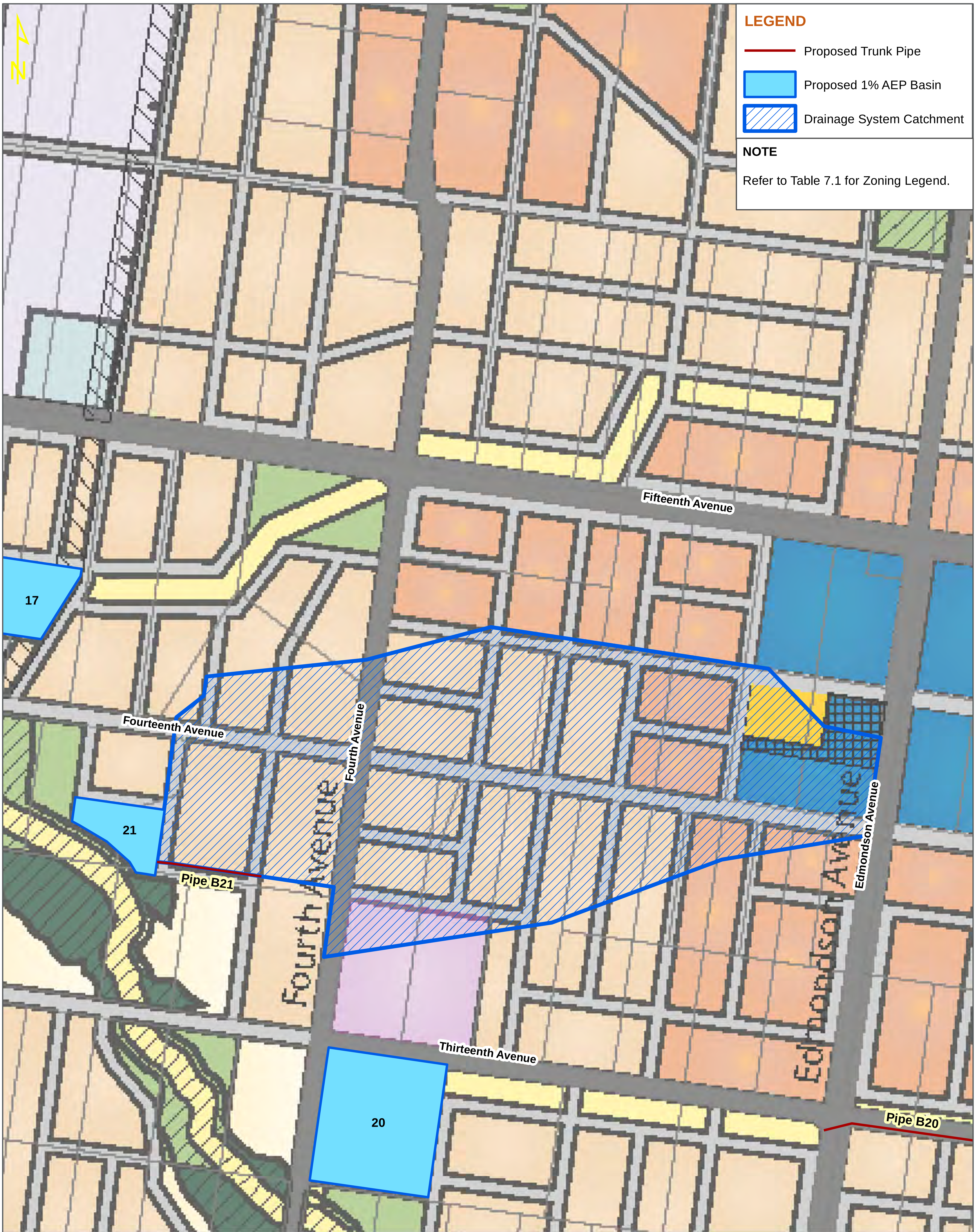
Last updated by: GC13350 on 18/09/2018 at 17:21

7.1.3. Drainage System B21

Drainage system B21 which is located between Thirteenth Avenue and Fifteenth Avenue drains stormwater from a 21 ha catchment, which discharges into Tributary 2. The drainage system components included in drainage System B21 are shown in Figure 7.7 and summarized in Table 7.6.

Table 7.6: Drainage System B21 components

Drainage Component	Details
Trunk drainage – pipes	Pipe B21.1, Pipe B21.2 and Pipe B21.3
Detention basin	Basin 21
Water quality controls GPT	 GPT B21



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COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.7

FIGURE TITLE Drainage System B21

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

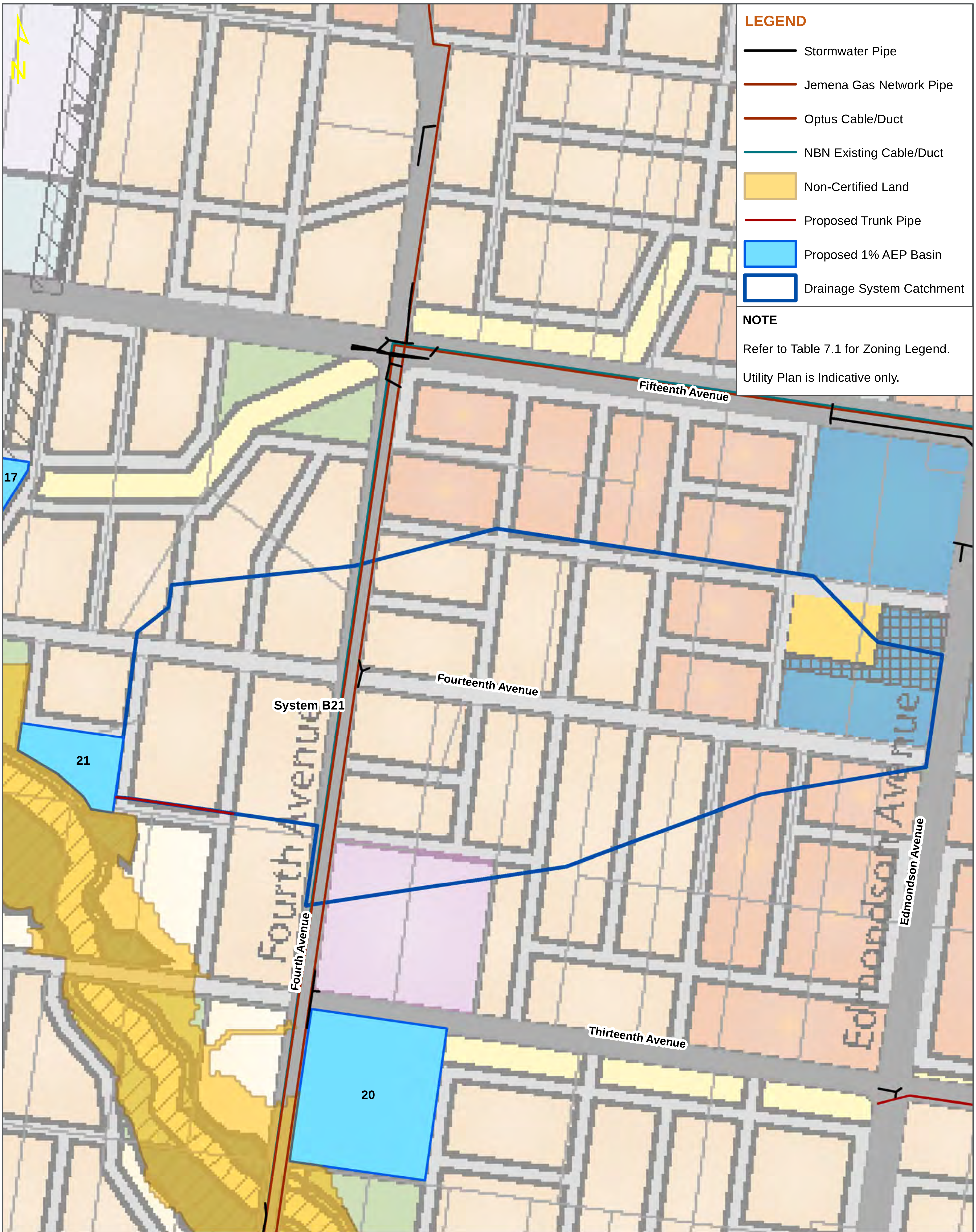
SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

Design constraints

Design constraints are listed in Table 7.7. Environmental constraints and utility constraints are shown in Figure 7.8.

Table 7.7: Drainage System B21 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	The basin discharge point is within the non-certified land (Figure 7.8).	This issue is addressed in the REF (SMEC, 2018d).
Utility conflicts	Refer to Utility Services Investigation Report (SMEC, 2018c).	Refer to Utility Services Investigation Report (SMEC, 2018c).
Deviations from the preferred design parameters	**Trunk Pipes** There are some cover issues in the piped trunk drainage based on the existing surface level. However, these cover issues may not occur when checked against the final design surface (assuming there will be filing to smooth the design surface).	**Trunk Pipes** Check the available cover when the final design surface is available during detail design. If the minimum cover requirement is not met, provide concrete capping.
	Detention Basin Due to the limited footprint allocated for the basin and biofilter, a steeper embankment slope (1:1) was adopted for the preliminary design.	**Detention basin** Resolved the issue by introducing a staggered sandstone step wall to optimise the allocated footprint as per Council advice.
	Water Quality Controls The maximum available hydraulic head between the top of the biofilter extended detention and creek invert was not sufficient to freely drain the biofilter. Therefore, the proposed co-located biofilter is not feasible. As such, the required water quality targets could not be met for this drainage system.	**Water Quality Controls** Implement source control measures and additional WSUD treatment in the catchment. Preliminary estimates of the required supplementary biofilter footprint area are shown on concept design drawings and further details on streetscape controls can also be found in Section 7.4.
Geotechnical	No site-specific constraints. Refer to Geotechnical Interpretive Report (SMEC, 2018a) for general geotechnical conditions relevant to the project area.	



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COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.8

FIGURE TITLE Environmental and Utility Constraints - Drainage System B21

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

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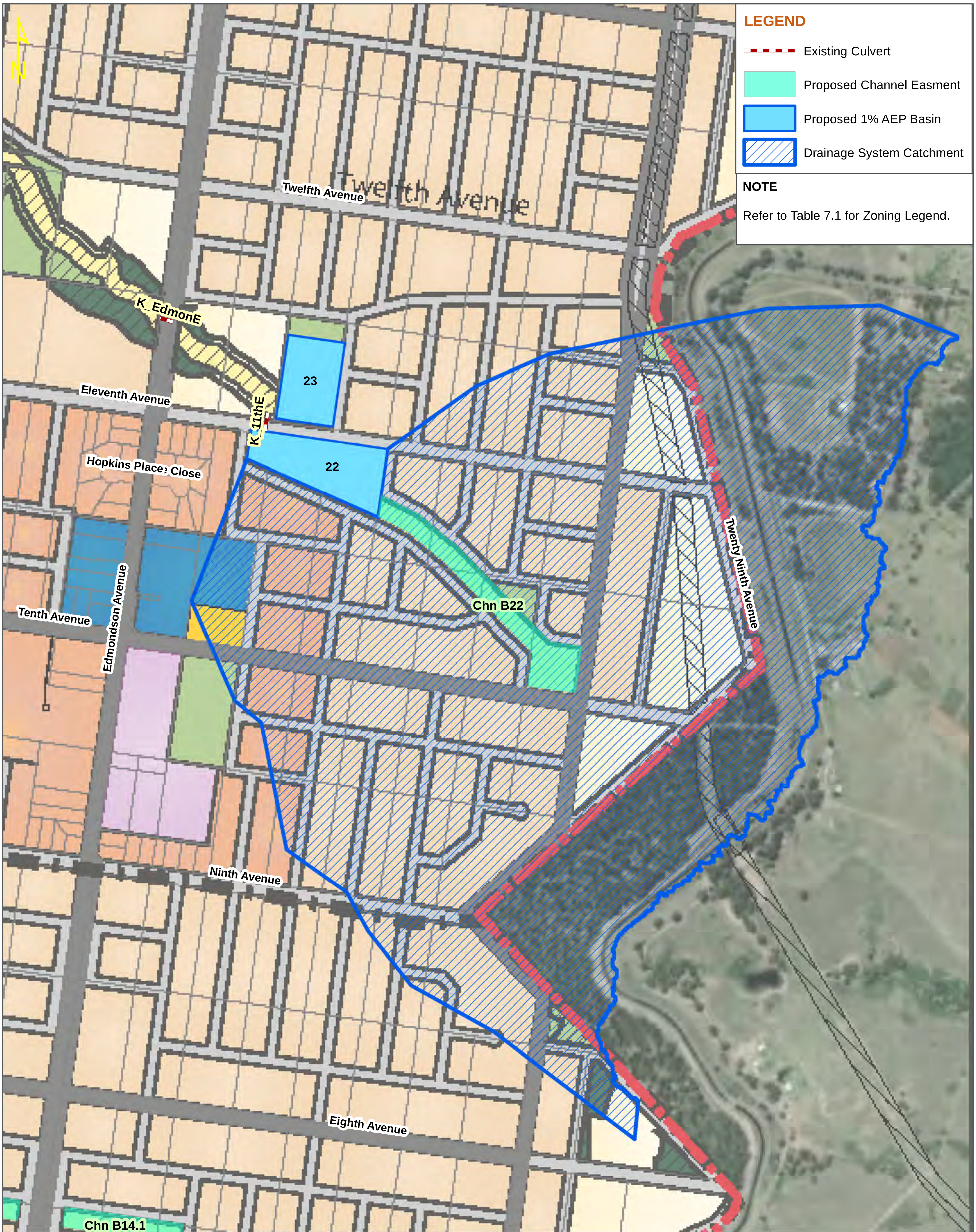
7.1.4. Drainage System B22

Drainage system B22 which is located adjacent to the eastern boundary of the precinct drains stormwater from a 71 ha catchment, which discharges into Tributary 2. The drainage system components included in drainage System B17 are shown in Figure 7.9 and summarized in Table 7.8.

Table 7.8: Drainage System B22 components

Drainage Component	Details
Trunk drainage – open channel	Chn B22
Culvert Existing	 K_11thE
Detention basin	Basin 22
Water quality controls GPT	 GPT B22



DATE 24/09/2018	0 125 250 1:5,000 Meters	PAGE SIZE A3 · COORDINATE SYSTEM GDA 1994 MGA Zone 56
FIG NO. 7.9	FIGURE TITLE Drainage System B22	
PROJECT NO. 30011388	PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure	
CREATED BY Nilmini Pannipitiya	SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)	

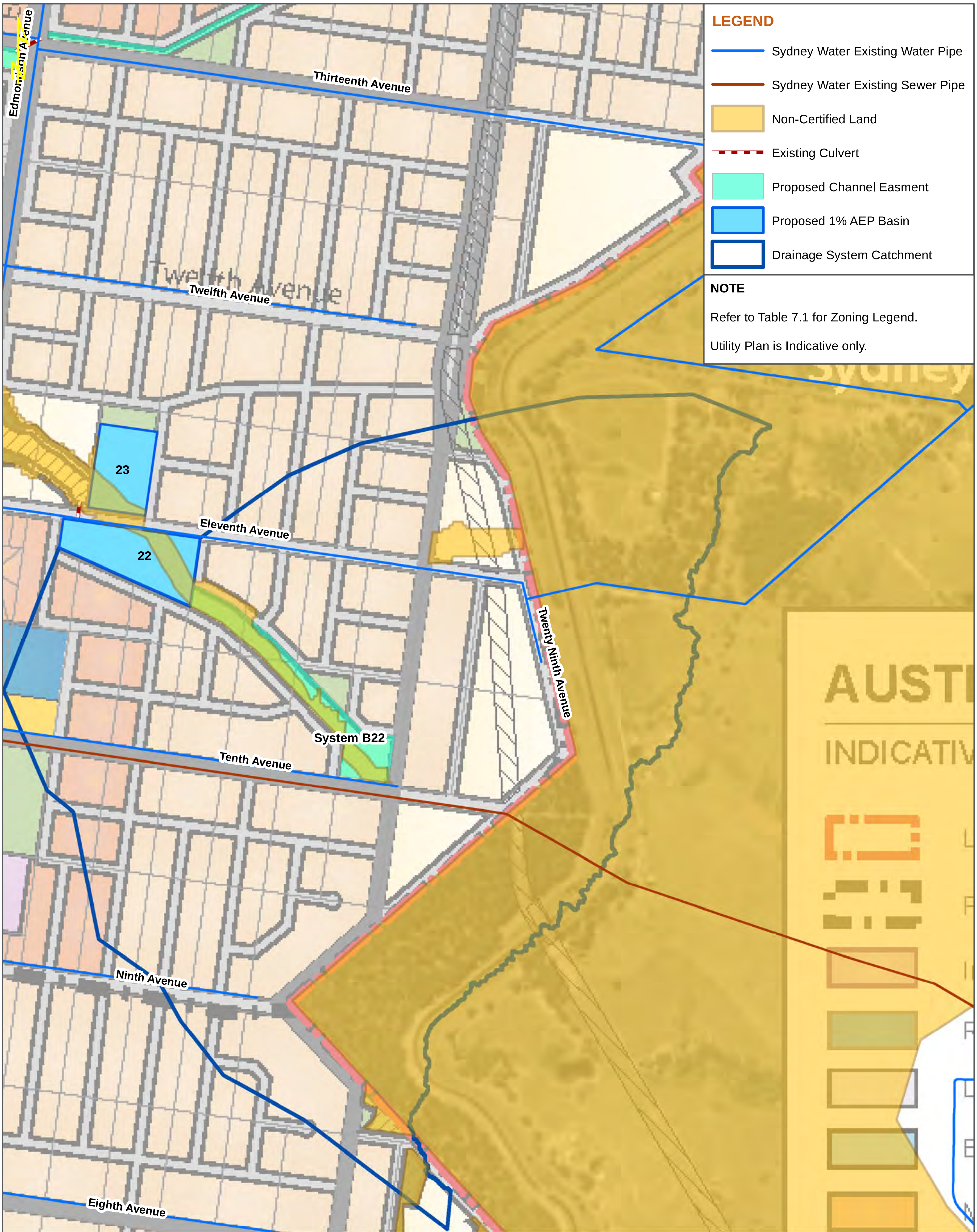
Design constraints

Design constraints are listed in Table 7.9. Environmental constraints and utility constraints are shown in Figure 7.10.

Table 7.9: Drainage System B22 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	The majority of the trunk drainage channel easement and part of the detention basin are within the non-certified land (Figure 7.10).	This issue is addressed in the REF (SMEC, 2018d).
Utility conflicts	Refer to Utility Services Investigation Report (SMEC, 2018c).	Refer to Utility Services Investigation Report (SMEC, 2018c).
Deviations from the preferred design parameters	**Trunk Channels** Channel freeboard towards the downstream end of the channel is less than 500 mm due to tailwater effects and limited footprint.	**Trunk Channels** Increase easement footprint or accept less freeboard.
	Detention Basin Due to the limited footprint allocated for the basin and biofilter, a steeper embankment slope (1:3) was adopted for the preliminary design. Since Basins 22 and 23 are only separated by Eleventh Avenue without any additional easement and Basin 23 is located immediately downstream Basin 22 it restricts the Basin 22 outflow being discharged into the creek via the shortest path, subsequently making the Basin 22 outlet connection expensive. Furthermore, any spillage from Basin 22 will get into Basin 23, and these systems will be operated as a cascade basin system.	**Detention basin** Resolved the issue by introducing a staggered sandstone step wall to optimise the allocated footprint, as per Council advice. Relocate basin 23 further downstream as suggested in Table 7.11. Council confirmed that proposed relocation is not feasible.
	Water Quality Controls The maximum available hydraulic head between the top of biofilter extended detention and creek invert was not sufficient to freely drain the biofilter outflow. Therefore, the proposed co-located biofilter is not feasible. As such, the required water quality targets	**Water Quality Controls** Implement source control measures and additional WSUD treatment in the catchment. Preliminary estimates of required supplementary biofilter footprint area are shown on concept design drawings and further details on streetscape

Constraint type	Details	Possible Resolutions
	could not be met for this drainage system.	controls can also be found in Section 7.4.
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018a) for general geotechnical conditions relevant to project area.	



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COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.10

FIGURE TITLE Environmental and Utility Constraints - Drainage System B22

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

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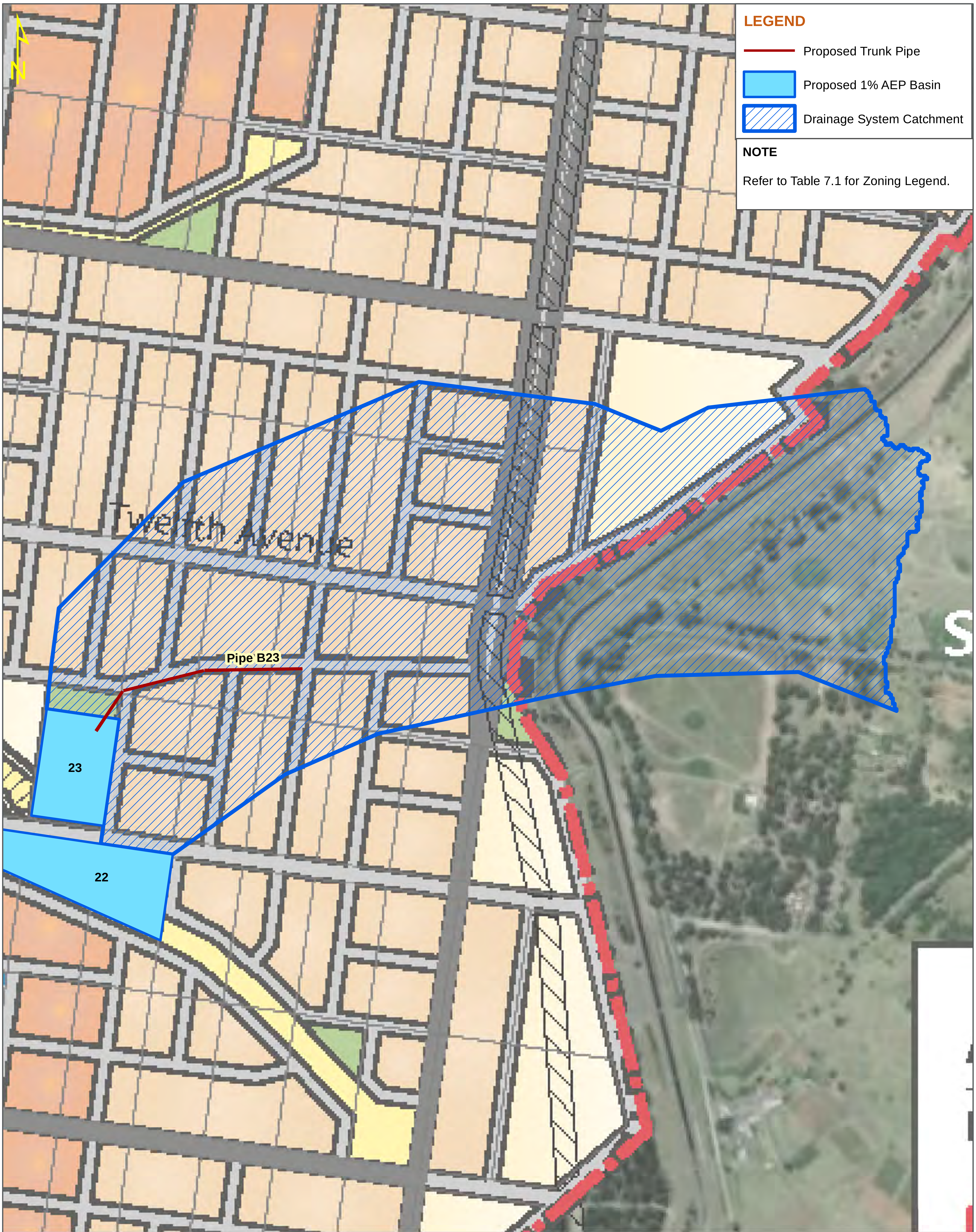
Last updated by: GC13350 on 3/12/2018 at 8:45

7.1.5. Drainage System B23

Drainage system B23 which is located adjacent to the eastern boundary of the precinct drains stormwater from a 30 ha catchment, which discharges into Tributary 2. The drainage system components included in drainage System B17 are shown in Figure 7.11 and summarized in Table 7.10.

Table 7.10: Drainage System B23 components

Drainage Component	Details
Trunk drainage – pipes	Pipe B23.1, Pipe B23.2 and Pipe B23.3
Detention basin	Basin 23
Water quality controls GPT	 GPT B23



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COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.11

FIGURE TITLE Drainage System B23

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

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Last updated by: GC13350 on 22/04/2018 at 14:30

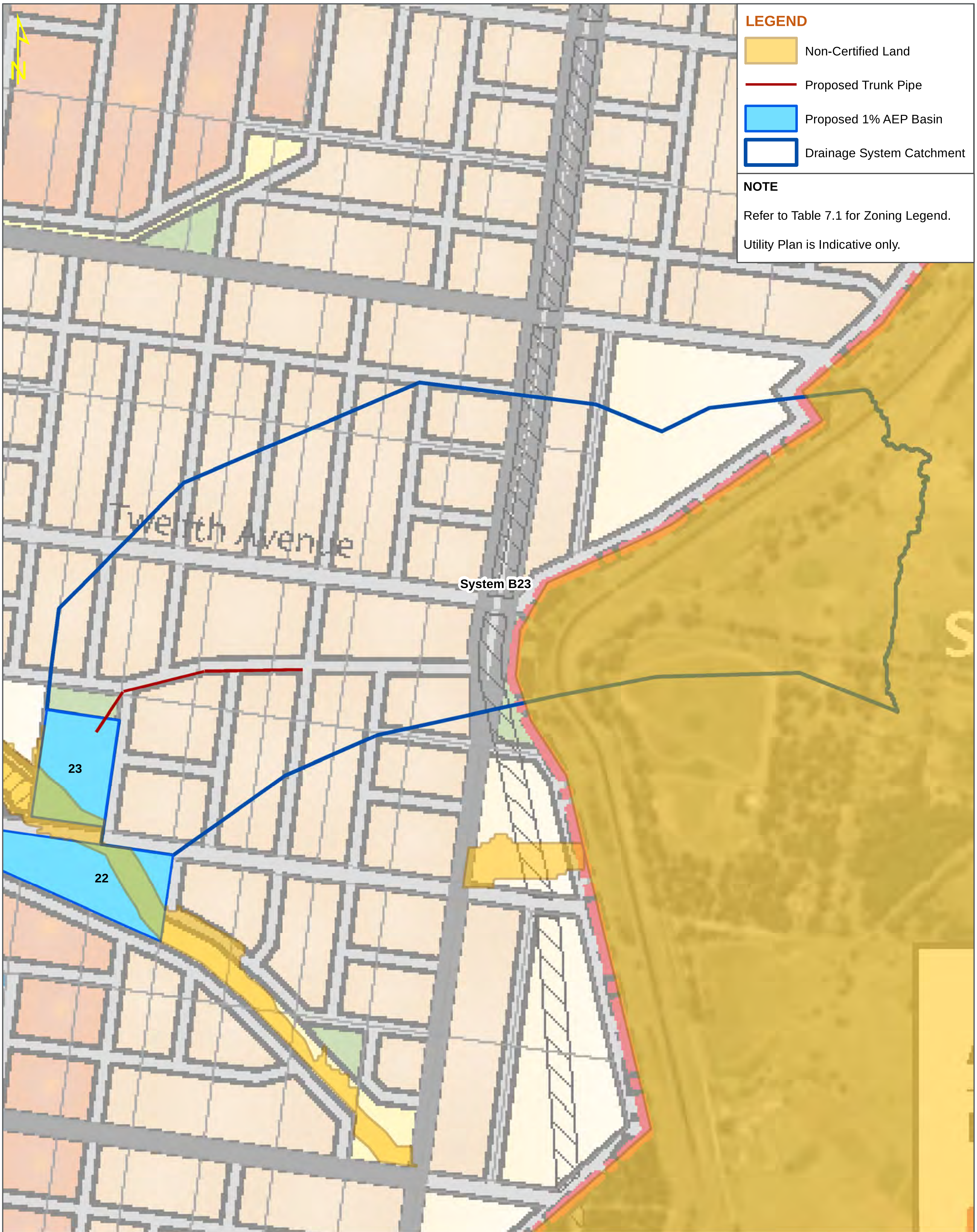
Design constraints

Design constraints are listed in Table 7.11. Environmental constraints are shown in Figure 7.12. There were no identified utility constraints for this drainage system.

Table 7.11: Drainage System B23 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	The basin footprint is partially within the non-certified layer (Figure 7.12).	This issue is addressed in the REF (SMEC, 2018d).
Deviations from the preferred design parameters	**Trunk Pipes** There are some cover issues in the piped trunk drainage based on the existing surface level. However, these cover issues may not occur when checked against the final design surface (assuming there will be filing to smooth the design surface and additional filing up to 1% AEP flood level).	**Trunk Pipes** Check the available cover when the final design surface is available during detail design. If the minimum cover requirement is not met, provide concrete capping.
	Detention basin Due to the limited footprint allocated for the basin and biofilter, a steeper embankment slope (1:3) was adopted for the preliminary design.	**Detention basin** Resolved the issue by introducing a staggered sandstone step wall to optimise the allocated footprint as per Council advice.
	The basin footprint shown in ILP is smaller than the footprint shown in the previous WCM. More specifically the northern boundary of the basin was the additional local road in the WCM study, and passive open space has been added between the local road and the basin. The current location causes some issues with Basin 22 as mentioned in Table 7.9.	Relocate the basin footprint as per the previous WCM study. Council confirmed that proposed relocation is not feasible.
	Water Quality Controls The maximum available hydraulic head between the top of biofilter extended detention and creek invert was not sufficient to freely drain the biofilter outflow. Therefore, the proposed co-located biofilter is not feasible. As such, the required water quality targets could not be met for this drainage system.	**Water Quality Controls** Implement source control measures and additional WSUD treatment in the catchment, especially within the retail/commercial area. Preliminary estimates of required supplementary biofilter footprint area are shown in concept design drawings and further details on

Constraint type	Details	Possible Resolutions
		streetscape controls can also be found in Section 7.4.
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018a) for general geotechnical conditions relevant to project area.	



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COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.12

FIGURE TITLE Environmental and Utility Constraints - Drainage System B23

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

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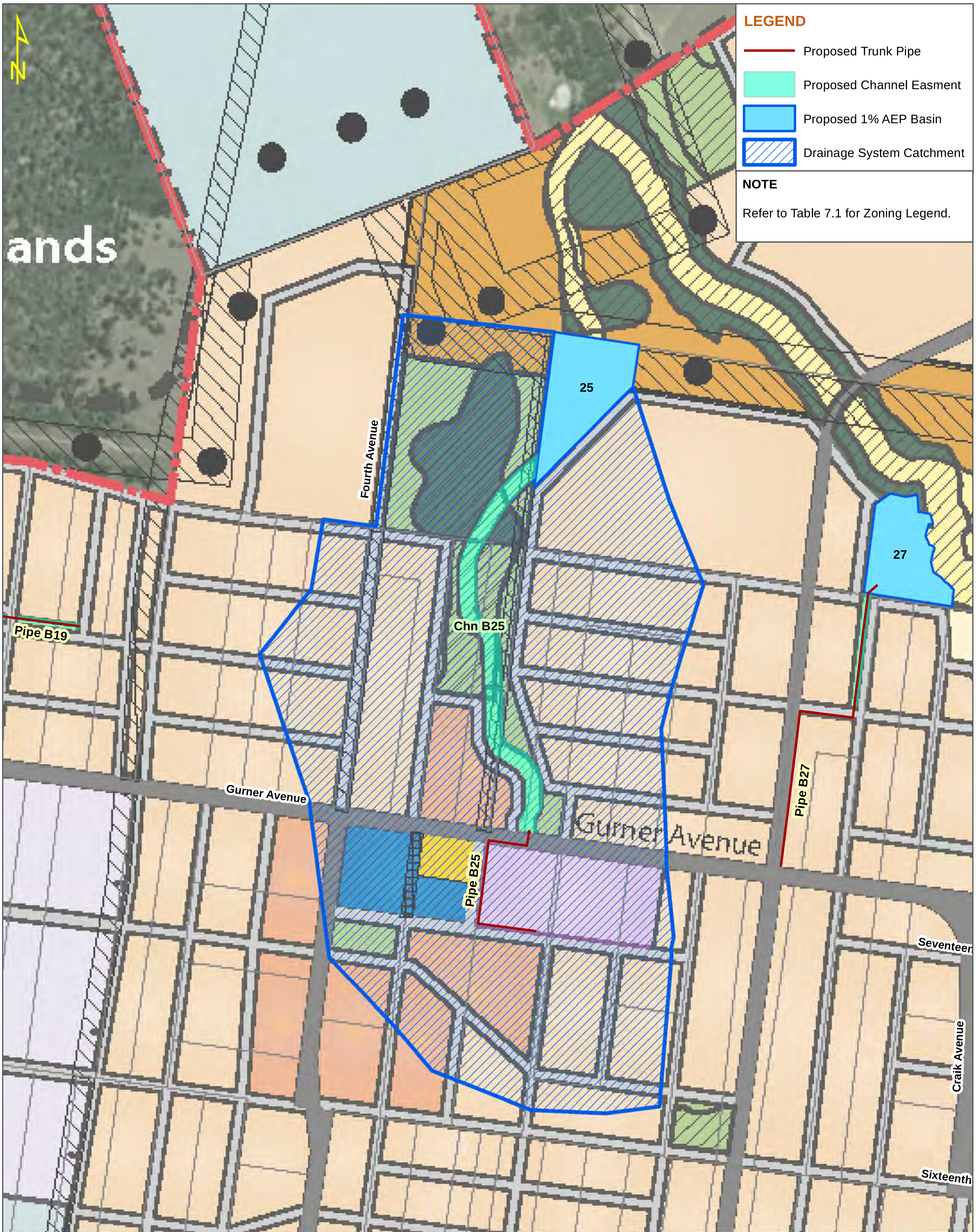
Last updated by: GC13350 on 22/04/2018 at 15:45

7.1.6. Drainage system B25

Drainage system B25 which is located adjacent to the northern boundary of the precinct drains stormwater from a 50 ha catchment, which discharges into Tributary 3. The drainage system components included in drainage System B25 are shown in Figure 7.13 and summarized in Table 7.12.

Table 7.12: Drainage System B25 Components

Drainage Component	Details
Trunk drainage – pipes	Pipe B25.1, Pipe B25.2 and Pipe B25.3
Trunk drainage – open channel	Chn B25
Detention basin	Basin 25
Water quality controls GPT Biofilter	 GPT – B25 Bioretention –B25



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PAGE SIZE A3	**COORDINATE SYSTEM** GDA 1994 MGA Zone 56
FIG NO. 7.13	**FIGURE TITLE** Drainage System B25
PROJECT NO. 30011388	**PROJECT TITLE** Austral and Leppington North Design of Water Management Infrastructure
CREATED BY Nilmini Pannipitiya	**SOURCES** Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

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Last updated by: GC13350 on 2/07/2018 at 17:38

Design constraints

Design constraints are listed in Table 7.13. Environmental constraints and utility constraints are shown in Figure 7.14.

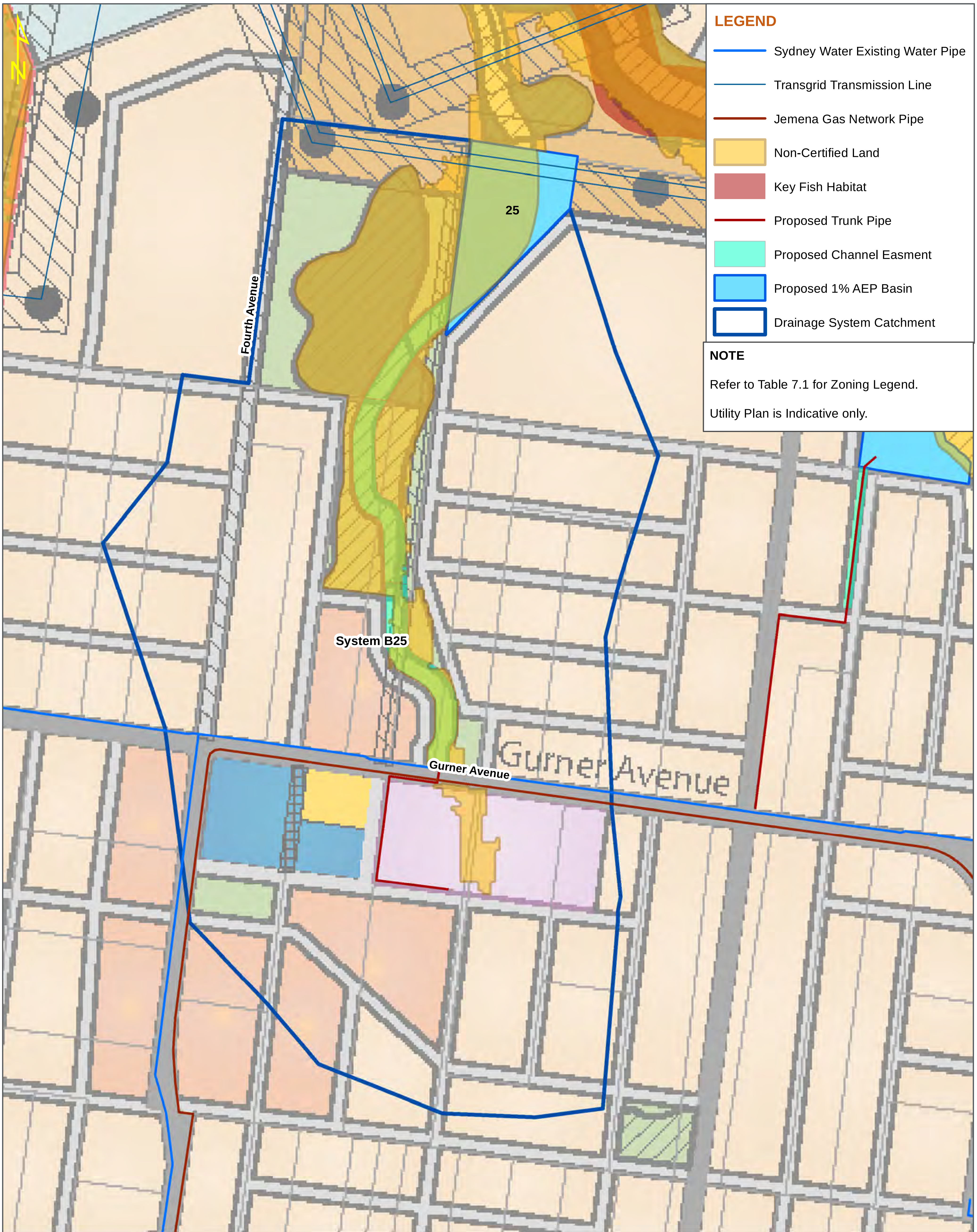
Table 7.13: Drainage System B25 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	The majority of the Basin 25 footprint and trunk drainage channel easement is within the non-certified land.	This issue is addressed in the REF (SMEC, 2018d).
Utility conflicts	Refer to Utility Services Investigation Report (SMEC, 2018c).	Refer to Utility Services Investigation Report (SMEC, 2018c).
Deviations from the preferred design parameters	**Trunk Pipes** There are some cover issues in the piped trunk drainage based on the existing surface level. However, these cover issues may not occur when checked against the final design surface (assuming there will be filing to smooth the design surface and additional filing up to 1% AEP flood level).	**Trunk Pipes** Available cover needs to be checked during detailed design.
	Furthermore, the first part of the trunk pipe was initially designed to follow the overland flow path. The initial layout required a new easement. However, the trunk pipes were realigned as per Council request to align all trunk pipes along existing or future roads. As a result, there is a very deep pit (~5m) between Pipe B25.1 and Pipe B25.2. It could be expensive to construct and maintain this pit and surrounding pipes.	Evaluate the option of providing a new easement or adopting the new alignment with deep pit (safety in design to be considered).
	Trunk Channels For the channel section immediately upstream of the detention basin, it is proposed to adopt wider and shallower channel sections to ensure no backwater impacts from the detention basin, but this is currently limited by the allocated easement width.	**Trunk Channels** Increase the channel easement width sufficient for the proposed channel widening.

Constraint type	Details	Possible Resolutions
	Water Quality Controls There was not sufficient footprint within the detention basin to include a biofilter that can meet the required water quality targets. The current co-located biofilter is therefore undersized for its catchment. Additional streetscape and source water controls to be provided in the catchment.	**Water Quality Controls** Reduce the dependency on the end-of-pipe solution by implementing source control measures and additional WSUD treatment in the catchment. Preliminary estimates of required supplementary biofilter footprint area are shown on concept design drawings and further details on streetscape controls can also be found in Section 7.4.
Geotechnical	Basin site demonstrates soft soil conditions. Building structures in soft ground conditions is problematic as it can lead to long-term settlement of the structure.	In general, and within practical limits, it is recommended that 'soft' to 'firm' natural soils encountered at subgrade level be excavated and replaced with controlled fill. Refer Geotechnical Interpretive Report (SMEC, 2018a) for details.

Design opportunities

Since this detention basin is partly located in the non-certified land, a wetland could be an alternative to the proposed biofilter, as a wetland allows the existing vegetation to be preserved in comparison to a biofilter. However, a relatively large surface area (at least five times larger footprint compared to a biofilter) is required to achieve equivalent stormwater treatment targets replacing the biofilter with a wetland. Even though the stormwater quality targets cannot be met within the basin footprint, a wetland may provide additional ecological benefits such as relatively higher bio-diversity and easy integration with the existing vegetation in comparison to biofilters. If a wetland is adopted, further Source Control measure will be required over and above the area estimated in the current design.



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COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.14

FIGURE TITLE Environmental and Utility Constraints - Drainage System B25

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

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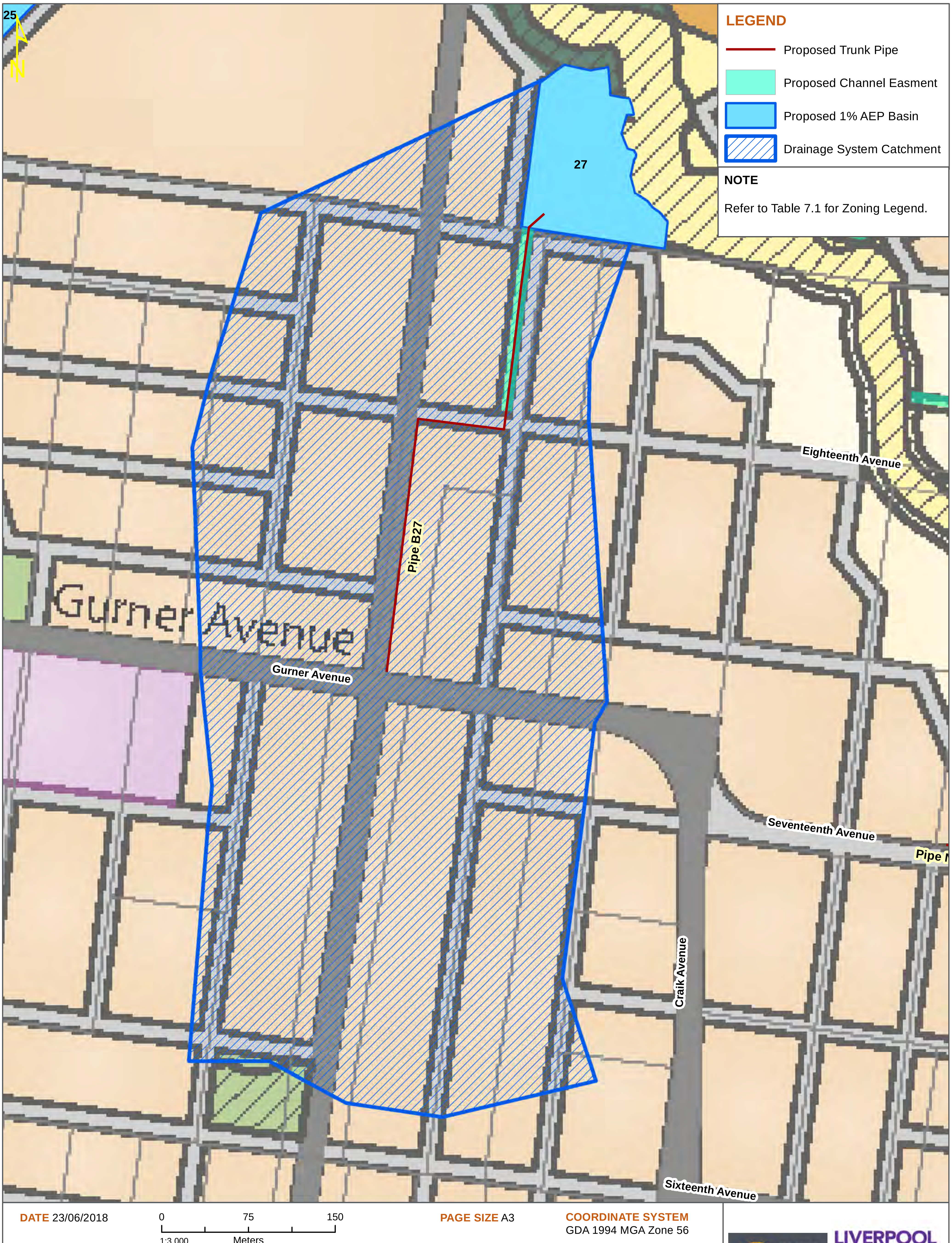
7.1.7. Drainage System B27

Drainage system B27 which is located adjacent to the northern boundary of the precinct drains stormwater from a 27 ha catchment, which discharges into Tributary 3. The drainage system components included in drainage System B27 are shown in Figure 7.15 and summarized in Table 7.14.

Table 7.14: Drainage System B27 Components

Drainage Component	Details
Trunk drainage – pipes	Pipe B27.1, Pipe B27.2 and Pipe B27.3
Detention basin	Basin 27
Water quality controls GPT Biofilter	 GPT B27 Bioretention B27



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COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.15

FIGURE TITLE Drainage System B27

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

Design constraints

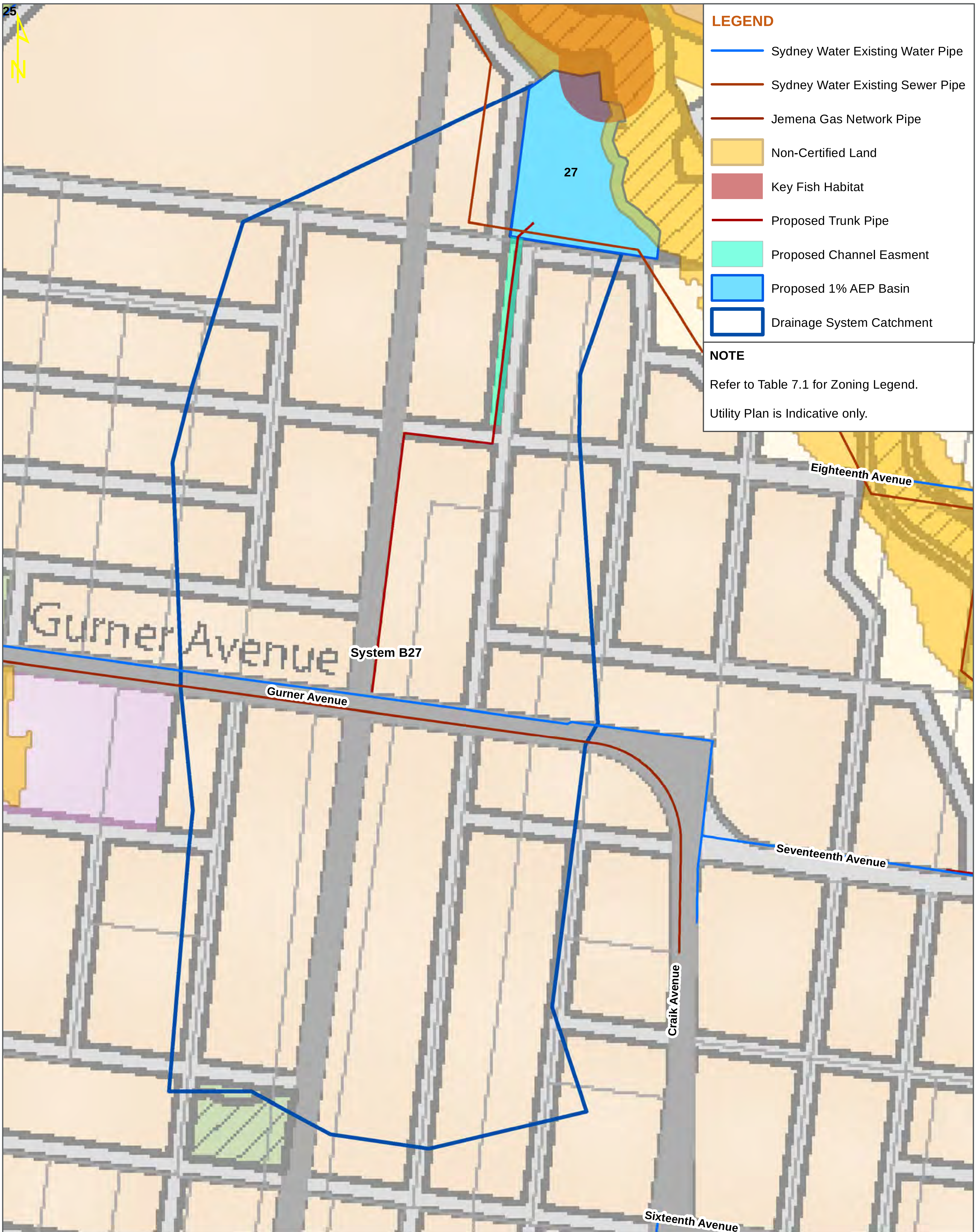
Design constraints are listed in Table 7.15. Environmental constraints and utility constraints are shown in Figure 7.16.

Table 7.15: Drainage System B27 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	The detention basin footprint is partly within the non-certified land and key fish habitat area (Figure 7.16).	This issue is addressed in the REF (SMEC, 2018d).
Utility conflicts	Refer to Utility Services Investigation Report (SMEC, 2018c).	Refer to Utility Services Investigation Report (SMEC, 2018c).
Deviations from the preferred design parameters	**Trunk Pipes** There are some cover issues in the piped trunk drainage based on the existing surface level. However, these cover issues may not occur when checked against the final design surface (assuming there will be filing to smooth the design surface and additional filing up to 1% AEP flood level).	**Trunk Pipes** Available cover to be checked during detailed design against the design surface.
	Trunk Channels The allocated easement width (10 m) was not sufficient for trunk channel.	**Trunk Channels** Trunk channel was replaced with a trunk pipe.
	Water Quality Controls There was not sufficient footprint within the detention basin to include a biofilter that can meet the required water quality targets. The current co-located biofilter is therefore undersized for its catchment. Additional streetscape and source water controls to be provided in the catchment.	**Water Quality Controls** Reduce the dependency on the end-of-pipe solution by implementing source control measures and additional WSUD treatment in the catchment. Preliminary estimates of required supplementary biofilter footprint area are shown on concept design drawings and further details on streetscape controls can also be found in Section 7.4.
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018a) for general geotechnical conditions relevant to project area.	

Design opportunities

Since the trunk channel upstream of the detention basin was replaced with RCBC, the ILP footprint allocated for the trunk channel easement could be utilised for streetscape water quality controls. To be investigated further during detail design stage.



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COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.16

FIGURE TITLE Environmental and Utility Constraints - Drainage System B27

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

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7.1.8. Drainage System B29

Drainage system B29 which is located between Twelfth Avenue and Sixteenth Avenue drains stormwater from a 104 ha catchment, which discharges into Tributary 3. The drainage system components included in drainage System B29 are shown in Figure 7.17 and summarized in Table 7.16.

Table 7.16: Drainage System B29 Components

Drainage Component	Details
Trunk drainage – pipes	Pipe B29a.1, Pipe B29a.2, Pipe B29a.3, Pipe B29a.4, Pipe B29a.5 and Pipe B29a.6 Pipe B29b.1, Pipe B29b.2, Pipe B29b.3 and Pipe B29b.4
Trunk drainage – open channel	Chn B29b.1, Chn B29b.2, Chn B29c
Culvert Existing Proposed	 K_15thEN and K16thEN Clv B29b.2
Detention basin	Basin 29
Water quality controls GPT Sedimentation pond Biofilter	 GPT B29a, GPT B29b and GPT B29c Sedimentation pond B29 Bioretention – B29

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COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.17

FIGURE TITLE Drainage System B29

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

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Last updated by: GC13350 on 2/12/2018 at 14:13

Design constraints

Design constraints are listed in Table 7.17. Environmental constraints and utility constraints are shown in Figure 7.18.

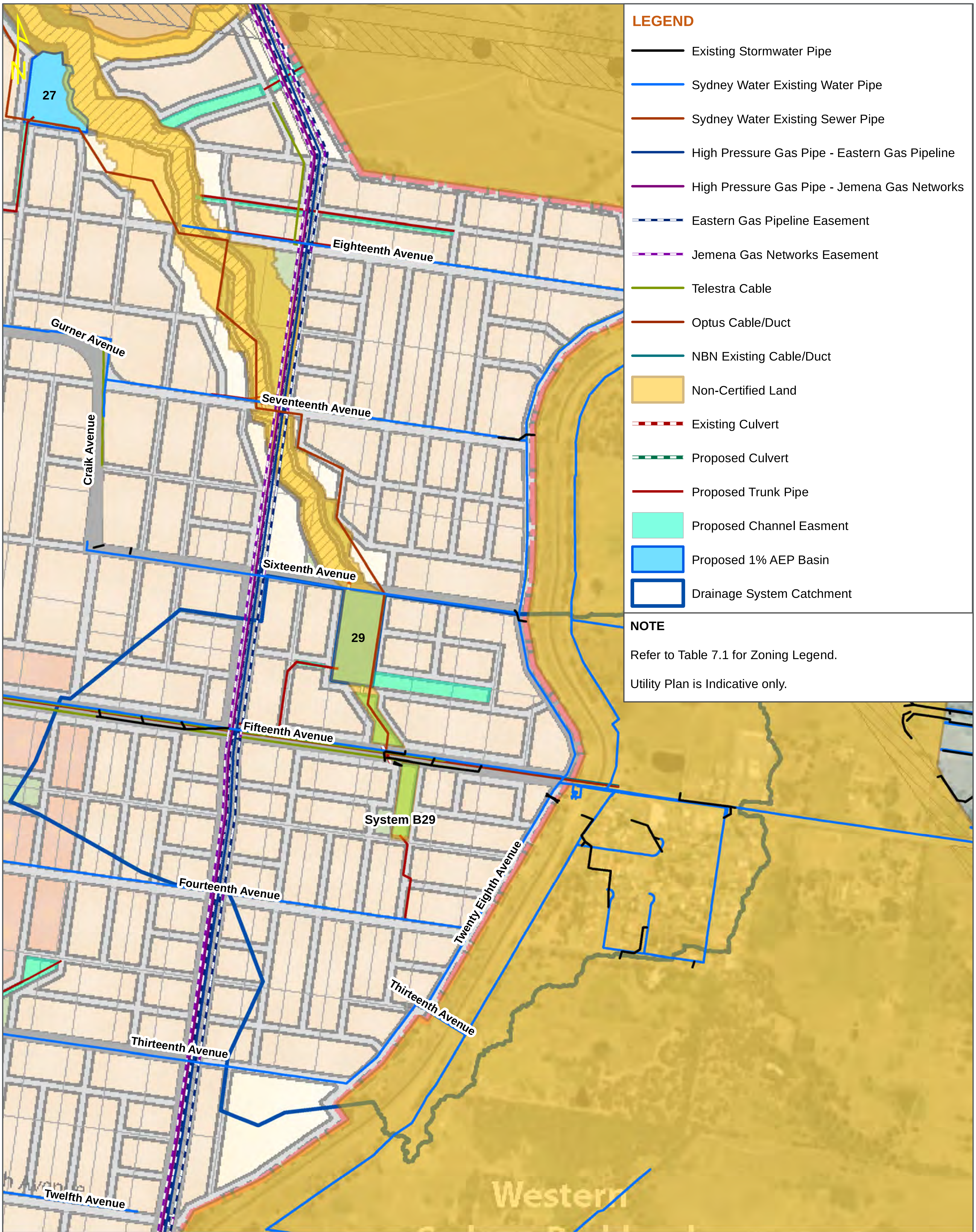
Table 7.17: Drainage System B29 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	The entire detention basin footprint, two of the trunk drainage channels (Chn 29b.1 and Chn 29b.2) easement and the proposed culvert crossing connecting the basin and trunk channel are within the non-certified land.	This issue is addressed in the REF (SMEC, 2018d).
Utility conflicts	Refer to Utility Services Investigation Report (SMEC, 2018c).	Refer to Utility Services Investigation Report (SMEC, 2018c).
Deviations from the preferred design parameters	**Trunk Pipes** There are some cover issues in the piped trunk drainage based on the existing surface level. However, these cover issues may not occur when checked against the final design surface (assuming there will be filing to smooth the design surface and additional filing up to 1% AEP flood level). Furthermore, the first part of the trunk pipe B29a was initially designed to follow the overland flow path. The initial layout required a new easement. However, the trunk pipes were realigned as per Council request to align all trunk pipes along existing or future roads. As a result, there is a very deep pit (~4.5m) between Pipe B29A.2 and Pipe B29A.3. It could be expensive to construct and maintain this pit and surrounding pipes.	**Trunk Pipes** There are some cover issues in the piped trunk drainage based on the existing surface level. However, these cover issues may not occur when checked against the final design surface (assuming there will be filing to smooth the design surface and additional filing up to 1% AEP flood level). Furthermore, the first part of the trunk pipe B29a was initially designed to follow the overland flow path. The initial layout required a new easement. However, the trunk pipes were realigned as per Council request to align all trunk pipes along existing or future roads. As a result, there is a very deep pit (~4.5m) between Pipe B29A.2 and Pipe B29A.3. It could be expensive to construct and maintain this pit and surrounding pipes.
	Trunk Channels This drainage system was originally proposed to be designed with three channels connecting the basin from the eastern, southern and western sides. However, the channel that was located eastern side of the basin does not have adequate easement width (10m)	**Trunk Channels** Channel was replaced by a trunk pipe (Pipe B29a.6)

Constraint type	Details	Possible Resolutions
	Additionally, there was a significant tailwater impact to this narrow channel and the required 500 mm freeboard could not be achievable. No maintenance berm could be provided.	
	Detention Basin Due to the limited footprint allocated for the basin and biofilter, a steeper embankment slope (1:2) was adopted for the preliminary design.	**Detention basin** Resolved the issue by introducing a staggered sandstone step wall to optimise the allocated footprint, as per Council advice.
	Water Quality Controls Basin 29 water quality control layout was complex due to multiple basin inlet points. In order to mitigate potential turbulence/erosion issues, a sedimentation pond is placed at the upstream end of the detention basin before the biofilter. There was not sufficient footprint within the detention basin to include a biofilter that can meet the required water quality targets. The current co-located biofilter is therefore undersized for its catchment. Additional streetscape and source water controls to be provided in the catchment.	**Water Quality Controls** Reduce the dependency on the end-of-pipe solution by implementing source control measures and additional WSUD treatment in the catchment. Preliminary estimates of required supplementary biofilter footprint area are shown in concept design drawings and further details on streetscape controls can also be found in Section 7.4.
Geotechnical	Basin site demonstrates soft soil conditions. Building structures in soft ground conditions is problematic as it can lead to long-term settlement of the structure.	In general, and within practical limits, it is recommended that 'soft' to 'firm' natural soils encountered at subgrade level be excavated and replaced with controlled fill. Refer Geotechnical Interpretive Report (SMEC, 2018a) for details.

Design opportunities

Since one of the trunk channels upstream of the detention basin was replaced with a trunk pipe, the ILP footprint allocated for the trunk channel easement could be utilised for streetscape water quality controls. To be investigated further during the detailed design stage.



DATE 02/12/2018

PAGE SIZE A3

COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.18

FIGURE TITLE Environmental and Utility Constraints - Drainage System B29

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

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7.2. Drainage Systems with 50% AEP Basins

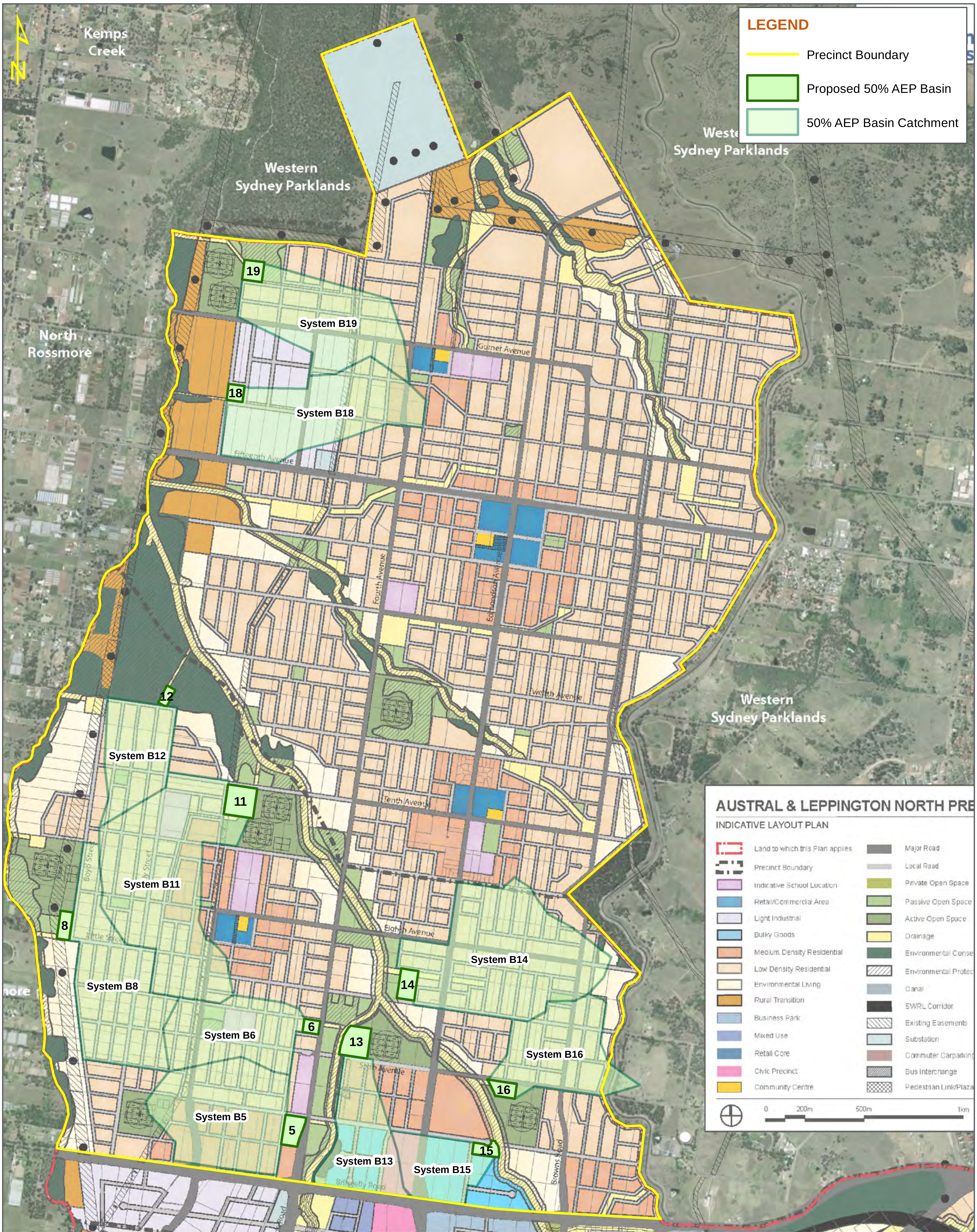
There are eleven drainage systems that include 50% AEP basins (Figure 7.19). This includes:

- Drainage System B5
- Drainage System B6
- Drainage System B8
- Drainage System B11
- Drainage System B12
- Drainage System B13
- Drainage System B14
- Drainage System B15
- Drainage System B16
- Drainage System B18
- Drainage System B19

Stormwater runoff is conveyed in these drainage systems via trunk drainage pipes and channels. Firstly the 3-month ARI flow is diverted to a biofilter via a GPT for water quality management. The remainder of the flow up to the 50% AEP event is diverted to a detention basin, which is designed to meet the 50% AEP pre-development discharge. The remaining flows are conveyed via by-pass pipe/channel to a nearby creek.

Drainage system components, concept design constraints and opportunities are presented in the following sections for each drainage system. Layout plans, long sections and cross sections for the trunk drainage pipes and channels, detention basin and co-located biofilter (if any) in each drainage system can be found in Appendix C. Furthermore, typical details of flow diversion structures, spillways, channel landscape and erosion and sediment control measures are also given in Appendix C.

It was determined that the Basins 9 and 10 are no longer needed for flood mitigation purposes during the concept design (Refer memo dated 9 October 2018). Furthermore, there was not sufficient hydraulic head to operate the proposed end-of-pipe biofilter proposed within the detention basin. Therefore, source controls and streetscape WSUD controls are required to meet the water quality. Refer Section 7.4 for further details on streetscape controls. Hence Drainage System B9 and Drainage System B10 were classified as Drainage Systems Without Basins.



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COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.19

FIGURE TITLE Map of Drainage Systems with 50% AEP Basins

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PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

Location: I:\projects\30011388 - Austral Leppington North Liverpool City Council\009 Deliverables\001 Stormwater Trunk Infrastructure\006 GIS\map\ArcMap for Report\SMEC_A3_LCC_MAP_All_Sub.mxd

Last updated by: GC13350 on 6/12/2018 at 18:25

7.2.1. Drainage System B5

Drainage system B5 which is located adjacent to the western boundary of the precinct drains stormwater from a 36 ha catchment, which discharges into Scalabrini Creek. The drainage system components included in drainage System B5 are shown in Figure 7.20 and summarized in Table 7.18.

Table 7.18: Drainage System B5 Components

Drainage Component	Details
Trunk drainage pipe	Pipe B5.1, Pipe B5.2, Pipe B5.3 and Pipe B5.4
Detention basin	Basin 5
Water quality controls GPT	 GPT B5

DATE 16/05/2018

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COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.20

FIGURE TITLE Drainage System B5

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

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Last updated by: GC13350 on 16/05/2018 at 16:53

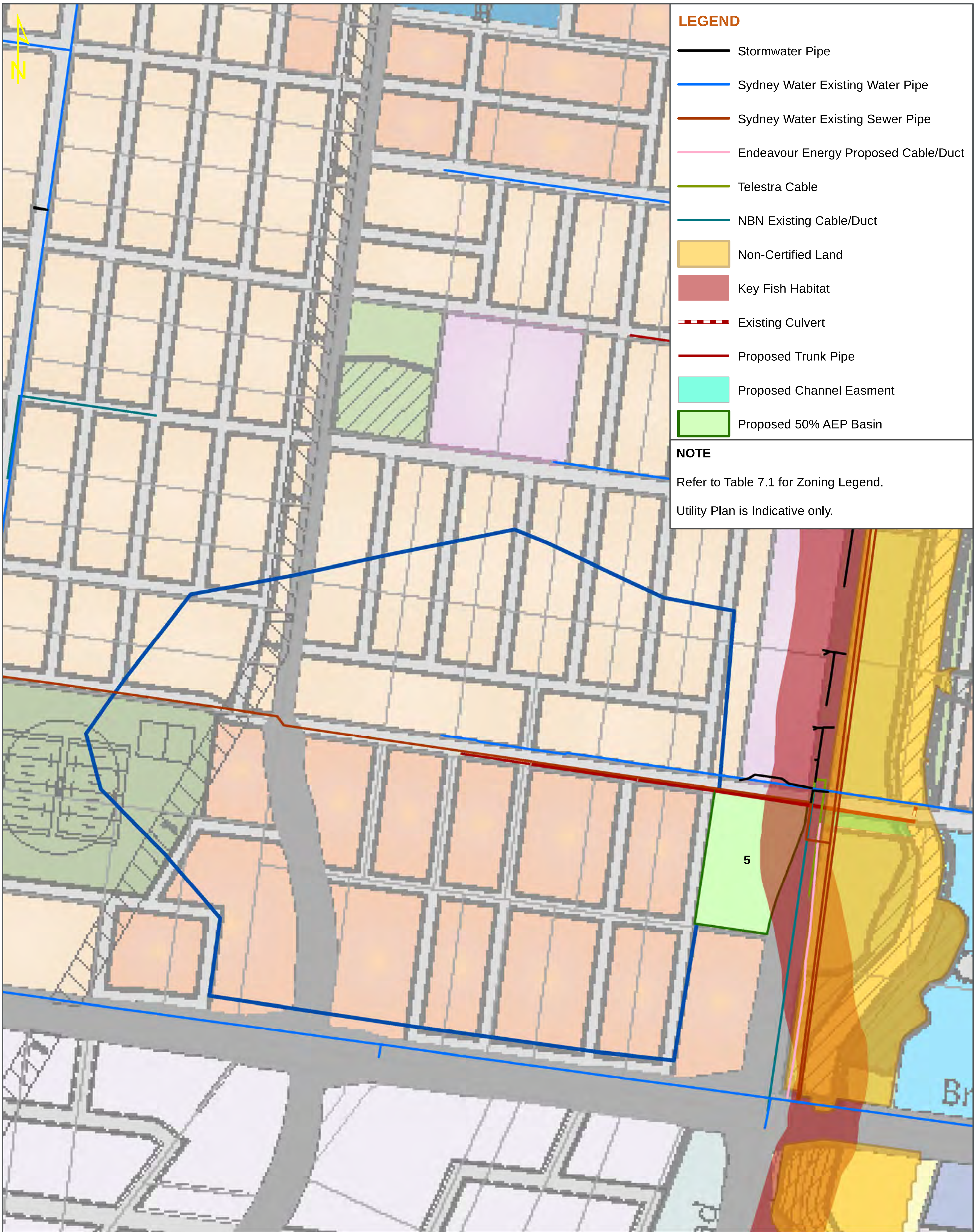
Design constraints

Design constraints are listed in Table 7.19. Environmental constraints and utility constraints are shown in Figure 7.21.

Table 7.19: Drainage System B5 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	The downstream part of the trunk pipe is within the non-certified land. Furthermore, the location where the basin outlet pipe discharges into Scalabrini Creek appear to be classified as a key fish habitat area. However, the current key fish habitat area is shown along the Fourth Avenue. This needs to be confirmed during the detailed design.	This issue is addressed in the REF (SMEC, 2018d). Channel/Pipe outlet to be designed as per DPI fisheries requirements during detailed design.
Utility conflicts	Refer Utility Services Investigation Report (SMEC, 2018c).	Refer Utility Services Investigation Report (SMEC, 2018c).
Deviations from the preferred design parameters	**Trunk Channel** Basin outlet channel was close to a school and a high trafficable road intersection. Therefore, a safety concern was raised by the Council (at site visit 2).	**Trunk Channel** Basin outlet channel was replaced with trunk pipe as per the council request.
	Trunk Pipe The topography of drainage system 5 is relatively flat. Therefore, the complete trunk pipe network was designed as RCBC to obtain the minimum cover of 0.7 m. However, at some locations the existing cover is less than 0.7 m. Therefore, the future road level is required to be increased to achieve minimum cover. There is no cover for Pipe B5.4 and Pipe B5.5 as per the existing ground level. However, this area is to be filled up to 1% AEP flood level, which will provide cover of a minim 0.7 m.	**Trunk Pipe** Available cover to be checked against the finished surface during the detailed design.
	Water Quality Controls The maximum available hydraulic head between the top of the biofilter extended detention and creek invert was not sufficient to freely drain the biofilter outflow. Therefore, the proposed co-	**Water Quality Controls** Implement source control measures and additional WSUD treatment in the catchment. Preliminary estimates of required supplementary biofilter footprint area are

Constraint type	Details	Possible Resolutions
	located biofilter is not feasible. As such, the required water quality targets could not be met for this drainage system.	shown on concept design drawings and further details on streetscape controls can also be found in Section 7.4.
Geotechnical	Basin site demonstrates soft soil conditions. Building structures in soft ground conditions is problematic as it can lead to long-term settlement of the structure.	In general, and within practical limits, it is recommended that 'soft' to 'firm' natural soils encountered at subgrade level be excavated and replaced with controlled fill. Refer Geotechnical Interpretive Report (SMEC, 2018a) for details.



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COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.21

FIGURE TITLE Environmental and Utility Constraints - Drainage System B5

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

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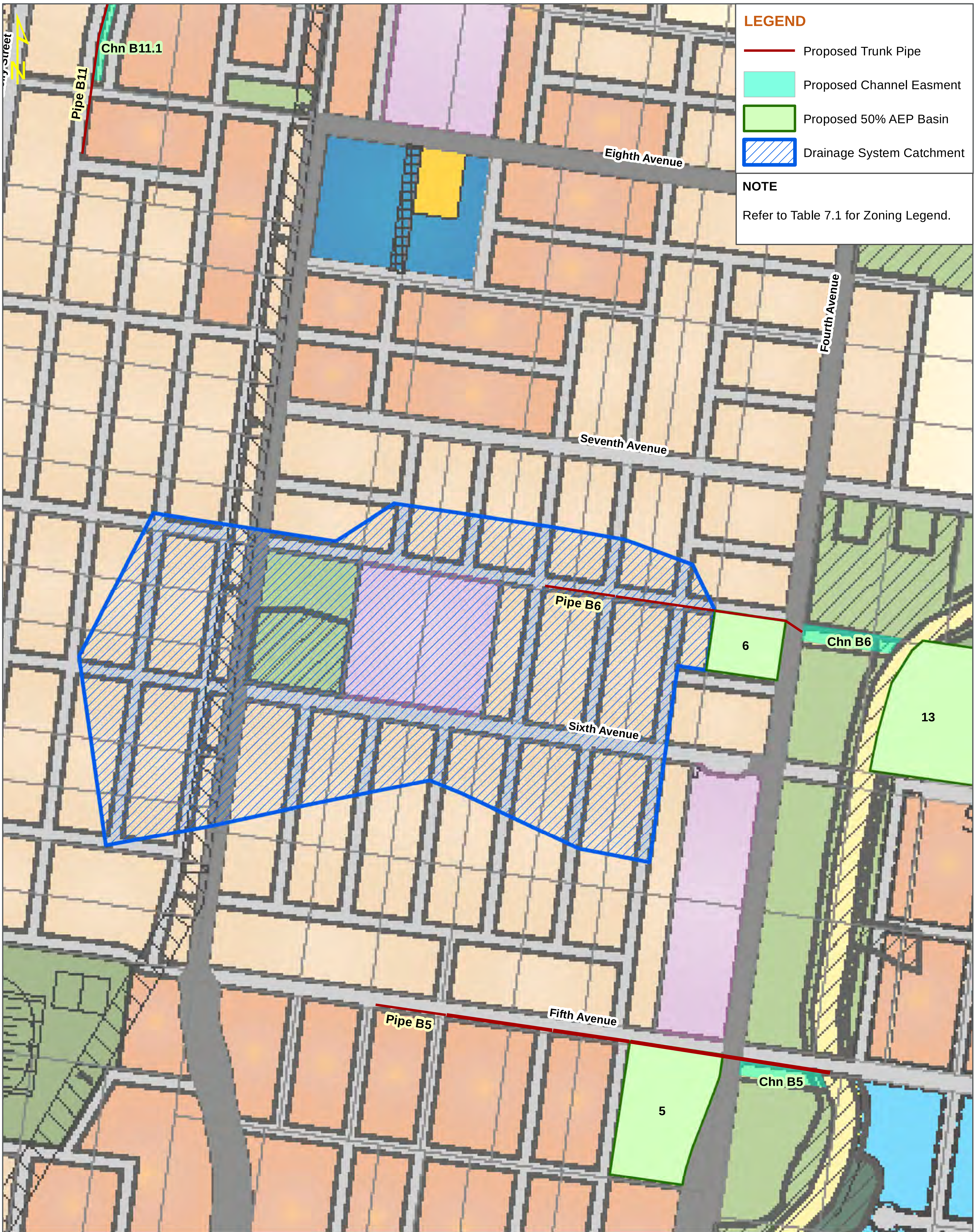
Last updated by: GC13350 on 17/05/2018 at 14:53

7.2.2. Drainage System B6

Drainage system B6, located between Sixth Avenue and Seventh Avenue, drains stormwater from a 22 ha catchment, which discharges into Scalabrini Creek. The drainage system components included in drainage System B6 are shown in Figure 7.22 and summarized in Table 7.20.

Table 7.20: Drainage System B6 Components

Drainage Component	Details
Trunk drainage pipe Trunk drainage channel	Pipe B6.1, Pipe B6.2, Pipe B6.3, Pipe B6.4 and Pipe B6.5 Chn B6
Detention basin	Basin 6
Water quality controls GPT Biofilter	 GPT B6 Bioretention B6



DATE 30/05/2018	0 100 200 1:4,000 Meters	PAGE SIZE A3	COORDINATE SYSTEM GDA 1994 MGA Zone 56
FIG NO. 7.22	FIGURE TITLE Drainage System B6		
PROJECT NO. 30011388	PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure		
CREATED BY Nilmini Pannipitiya	SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)		

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Last updated by: GC13350 on 31/05/2018 at 16:42

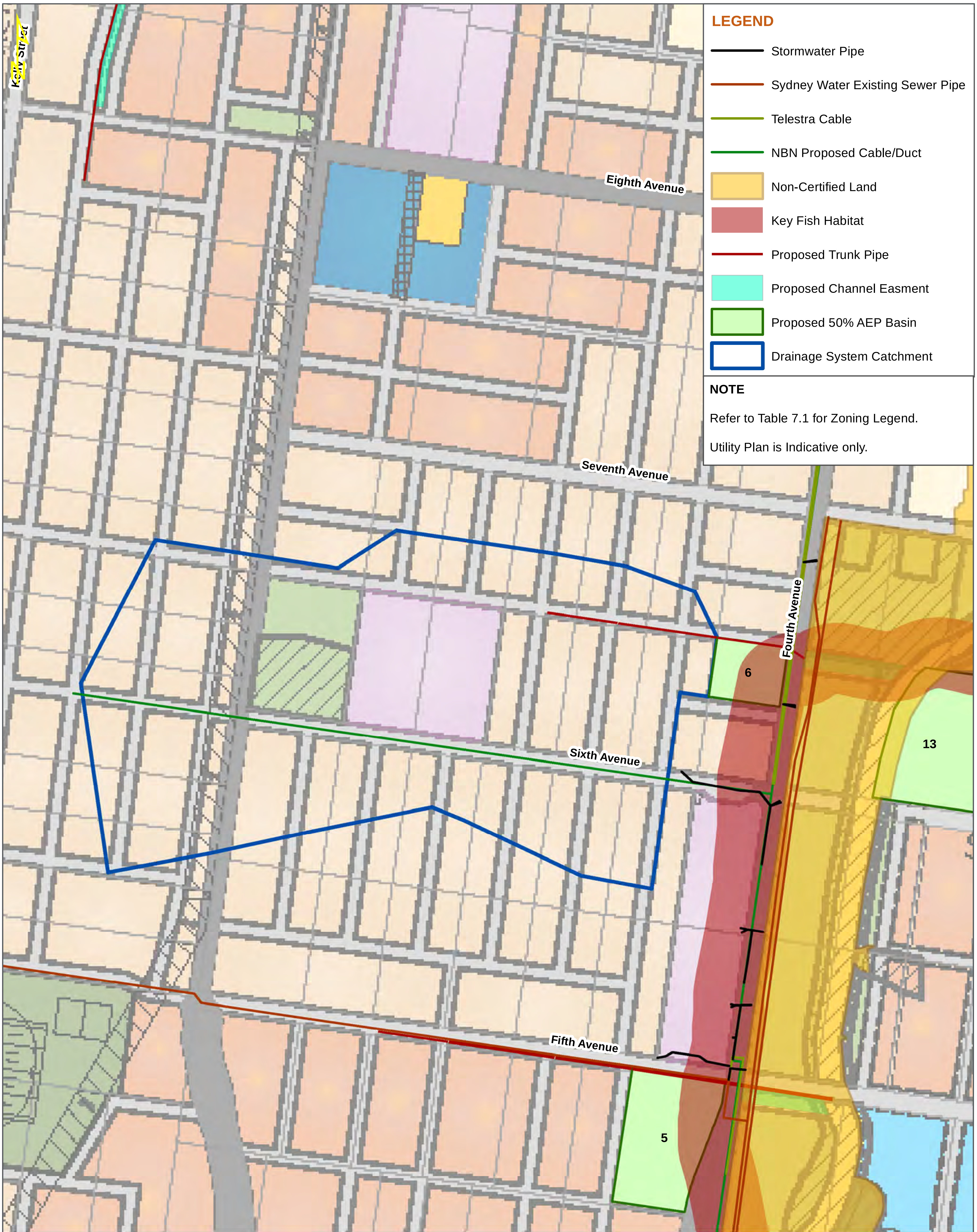
Design constraints

Design constraints are listed in Table 7.21. Environmental constraints and utility constraints are shown in Figure 7.23.

Table 7.21: Drainage System B6 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	The trunk drainage channel is within the non-certified land. Furthermore, the location where the trunk channel discharges into Scalabrini Creek appears to be classified as a key fish habitat area. However, the current key fish habitat area is shown along the Fourth Avenue. This needs to be confirmed during the detailed design.	This issue is addressed in the REF (SMEC, 2018d). Channel outlet to be designed as per DPI fisheries requirements during detailed design.
Utility conflicts	Refer Utility Services Investigation Report (SMEC, 2018c).	Refer Utility Services Investigation Report (SMEC, 2018c).
Deviations from the preferred design parameters	**Trunk Pipe** The drainage system catchment is relatively flat. Therefore, the complete trunk pipe network was designed as RCBC to obtain the minimum cover of 0.7 m. However, there is no cover for Pipe B6.5 and part of Pipe B6.4 as per the existing ground level. However, this area is to be filled up to 1% AEP flood level, which will provide cover of a minim 0.7 m.	**Trunk Pipe** Filled the road level to be equal or greater than 1% AEP flood level. Accordingly, filling made it possible to achieve the minimum cover.
	Detention Basin Due to the limited footprint allocated for the basin and biofilter, a steeper embankment slope (1:2) was adopted for the preliminary design.	**Detention Basin** Resolved the issue by introducing a staggered sandstone step wall to optimise the allocated footprint as per Council advice.
	Water Quality Controls There was not sufficient footprint within the detention basin to include a biofilter that can meet the required water quality targets. The current co-located biofilter is therefore undersized for its catchment. Additional streetscape and source water controls to be provided in the catchment.	**Water Quality Controls** Reduce the dependency on the end-of-pipe solution by implementing source control measures and additional WSUD treatment in the catchment. Preliminary estimates of required supplementary biofilter footprint area are shown on concept design drawings and further details on streetscape controls can also be found in Section 7.4.

Constraint type	Details	Possible Resolutions
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018a) for general geotechnical conditions relevant to project area.	



DATE 31/05/2018	0 105 210 Meters 1:4,000	**PAGE SIZE** A3	**COORDINATE SYSTEM** GDA 1994 MGA Zone 56
FIG NO. 7.23	**FIGURE TITLE** Environmental and Utility Constraints - Drainage System B6		
PROJECT NO. 30011388	**PROJECT TITLE** Austral and Leppington North Design of Water Management Infrastructure		
CREATED BY Nilmini Pannipitiya	**SOURCES** Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)		

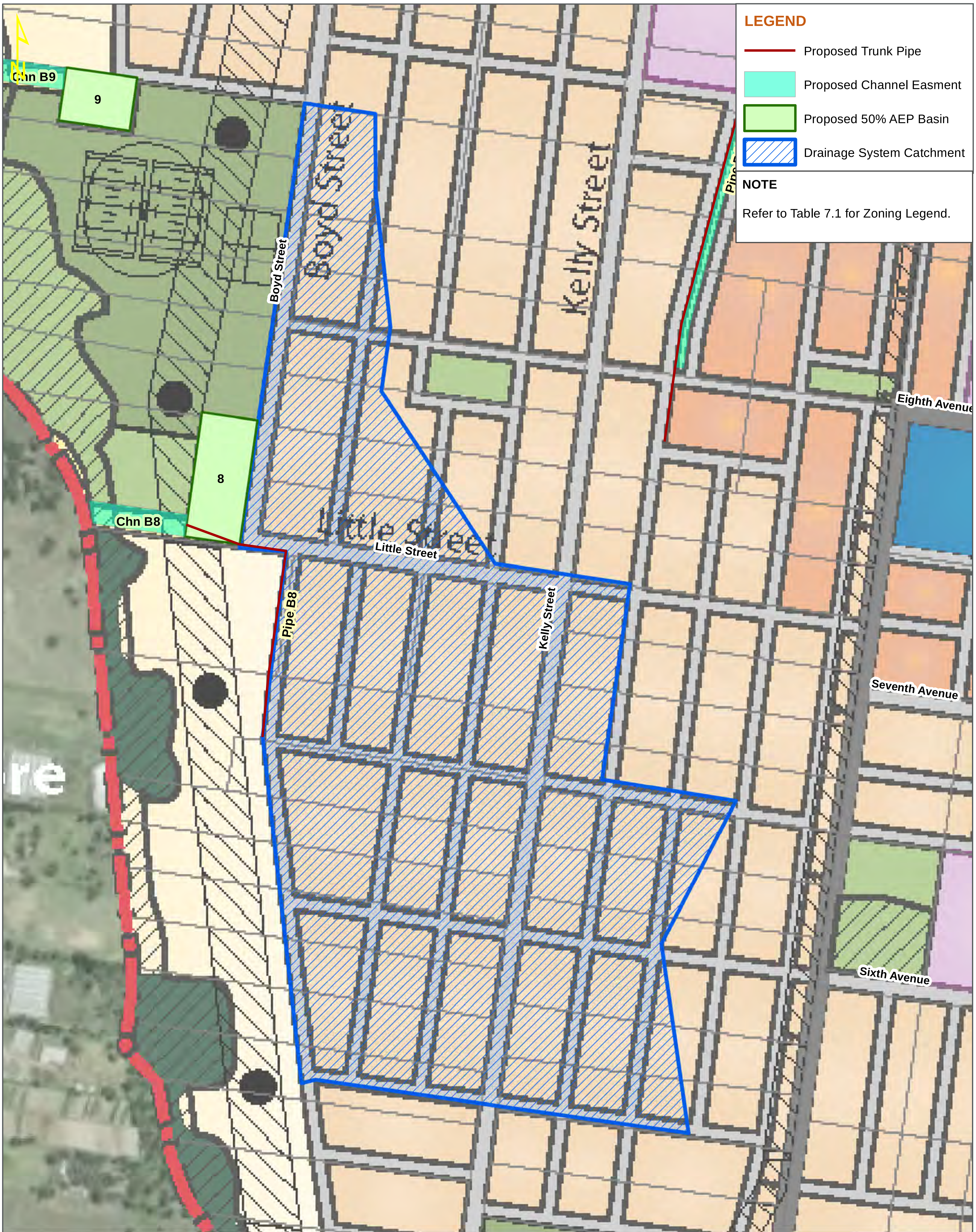
Location: I:\projects\30011388 - Austral Leppington North Liverpool City Council\009 Deliverables\001 Stormwater Trunk Infrastucture\006 GIS\map\ArcMap for Report\SMEC_A3_LCC_MAP_CONST_BASIN50AEP_Sub06.mxd   Last updated by: GC13350 on 31/05/2018 at 16:46

7.2.3. Drainage System B8

Drainage system B8, located near the south-western project boundary, drains stormwater from a 33 ha catchment, which discharges into Kemps Creek. The drainage system components included in drainage System B8 are shown in Figure 7.24 and summarized in Table 7.22.

Table 7.22: Drainage System B8 Components

Drainage Component	Details
Trunk drainage pipe Trunk drainage channel	Pipe B8.1, Pipe B8.2, Pipe B8.3, Pipe B8.4 and Pipe B8.5 Chn B8
Detention basin	Basin 8
Water quality controls GPT Biofilter	 GPT B8 Bioretention B8



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PAGE SIZE A3

COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.24

FIGURE TITLE Drainage System B8

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

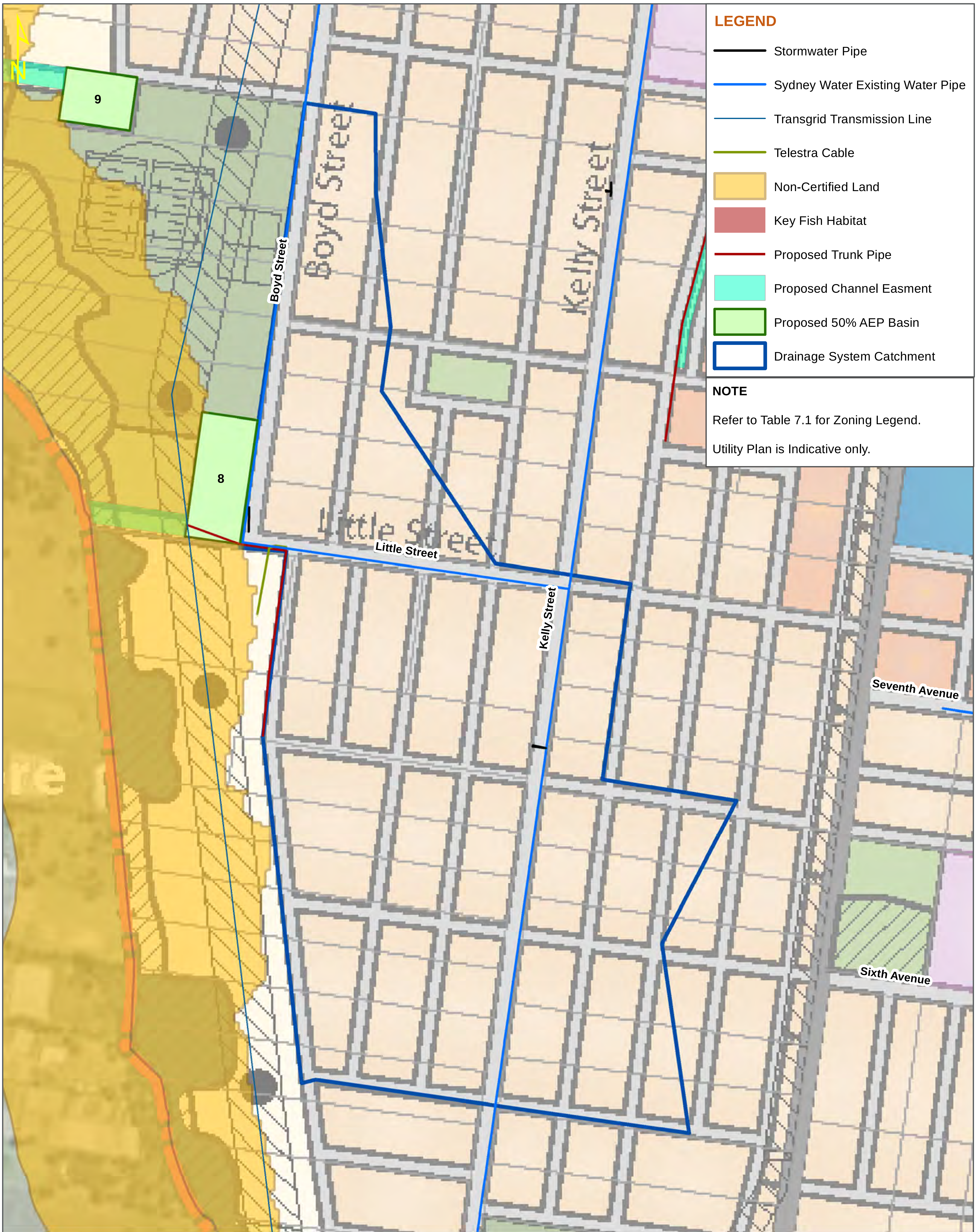
SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

Design constraints

Design constraints are listed in Table 7.23. Environmental constraints and utility constraints are shown in Figure 7.25.

Table 7.23: Drainage System B8 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	Trunk pipe/Basin outlet channel is within the non-certified layer.	This issue is addressed in the REF (SMEC, 2018d).
Utility conflicts	Refer Utility Services Investigation Report (SMEC, 2018c).	Refer Utility Services Investigation Report (SMEC, 2018c).
Deviations from the preferred design parameters	**Trunk Pipe and Channel** The trunk pipe and channel network was set at 0.5% grade. The two main reasons for setting a lower grade were to make sure that the catchment can freely drain to the Kemps Creek discharge point and to obtain the minimum head required for biofilter operation.	**Trunk Pipe and Channel** The adopted minimum grade of 0.5% could be improved during detailed design based on the new finished surface level.
	Detention Basin The TUFLOW model results indicate a relatively high tailwater level for the 50% AEP event and the 1% AEP event.	**Detention Basin** Futher investigations to be carried out during detailed design and provide fencing if the basin is wet.
	Water Quality Controls There was not sufficient footprint within the detention basin to include a biofilter that can meet the required water quality targets. The current co-located biofilter is therefore undersized for its catchment. Additional streetscape and source water controls to be provided in the catchment.	**Water Quality Controls** Reduce the dependency on the end-of-pipe solution by implementing source control measures and additional WSUD treatment in the catchment. Preliminary estimates of required supplementary biofilter footprint area are shown on concept design drawings and further details on streetscape controls can also be found in Section 7.4.
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018a) for general geotechnical conditions relevant to project area.	



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COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.25

FIGURE TITLE Environmental and Utility Constraints - Drainage System B8

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

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7.2.4. Drainage System B9

Drainage system B9, located towards the western project boundary, drains stormwater from a 16 ha catchment, which discharges into Kemps Creek. A 50% AEP detention basin was originally proposed for this drainage system. However, during the concept design it was determined that the basin was no longer required for flood mitigation purposes (Refer memo dated 9 October 2018). Furthermore, there was not sufficient hydraulic head to operate the proposed end-of-pipe biofilter proposed within the detention basin. Therefore, source controls and streetscape WSUD controls are required to meet the water quality targets for this catchment. Refer Section 7.4 for further details on streetscape controls.

7.2.5. Drainage System B10

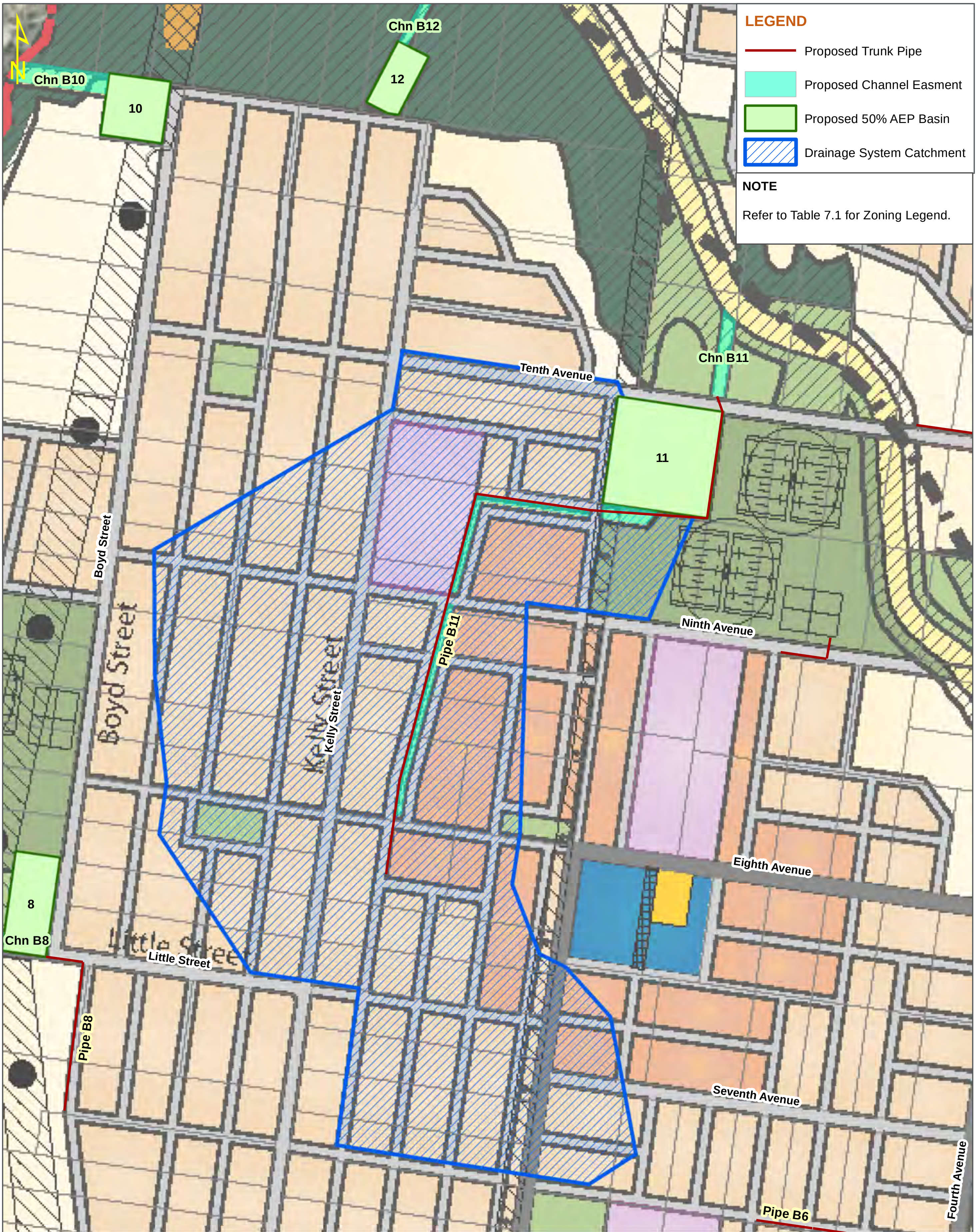
Drainage system B10, located towards the western project boundary, drains stormwater from a 28 ha catchment, which discharges into Kemps Creek. A 50% AEP detention basin was originally proposed for this drainage system. However, during the concept design it was determined that the basin was no longer required for flood mitigation purposes (Refer memo dated 9 October 2018). Furthermore, there was not sufficient hydraulic head to operate the proposed end-of-pipe biofilter proposed within the detention basin. Therefore, source controls and streetscape WSUD controls are required to meet the water quality targets for this catchment. Refer Section 7.4 for further details on streetscape controls.

7.2.6. Drainage System B11

Drainage system B11, located between Sixth Avenue and Tenth Avenue, drains stormwater from a 54 ha catchment, which discharges into Bonds Creek. The drainage system components included in drainage System B11 are shown in Figure 7.26 and summarized in Table 7.24.

Table 7.24: Drainage System B11 Components

Drainage Component	Details
Trunk drainage pipe	Pipe B11.1, Pipe B11.2, Pipe B11.3, Pipe B11.4, Pipe B11.5, Pipe B11.6, Pipe B11.7, B11.8, B11.9, and Pipe B11.10
Trunk drainage channel	Chn B11
Detention basin	Basin 11
Water quality controls	
GPT	GPT B11
Biofilter	Bioretention B11



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COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.26

FIGURE TITLE Drainage System B11

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

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Last updated by: GC13350 on 8/06/2018 at 8:55

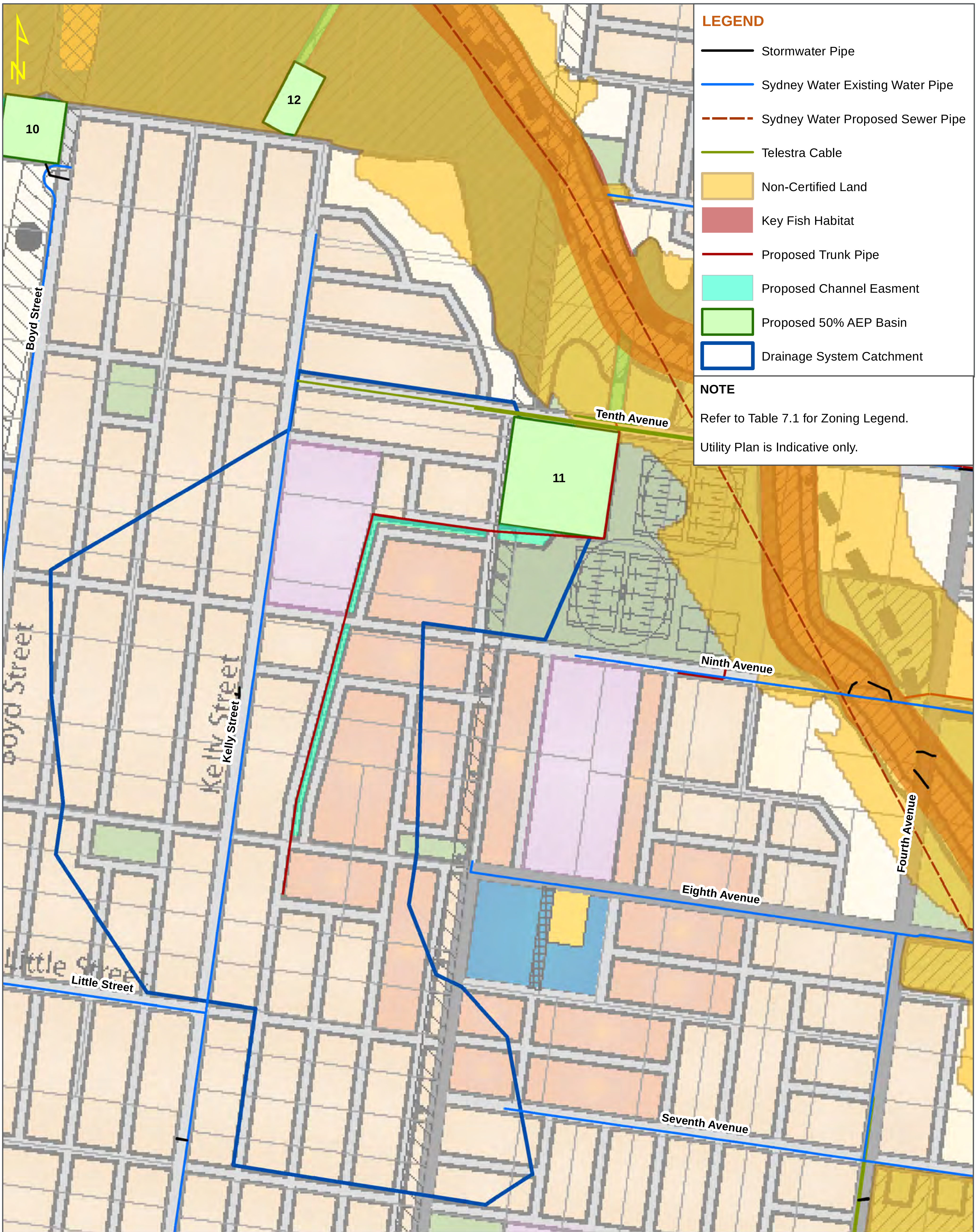
Design constraints

Design constraints are listed in Table 7.25. Environmental constraints and utility constraints are shown in Figure 7.27.

Table 7.25: Drainage System B11 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	The trunk drainage channel (downstream of the basin) and part of the trunk pipe (Pipe B11.10) are within the non-certified land. However, the trunk pipe is within the road reserve of Tenth Avenue. Therefore, no additional land clearing is required for the trunk pipe.	This issue is addressed in the REF (SMEC, 2018d).
	Furthermore, the location where the trunk channel discharges into Bonds Creek is classified as a key fish habitat area.	Channel outlet to be designed as per DPI fisheries requirements during detailed design.
Utility conflicts	Refer Utility Services Investigation Report (SMEC, 2018c).	Refer Utility Services Investigation Report (SMEC, 2018c).
Deviations from the preferred design parameters	**Trunk Channel** The proposed trunk channel (upstream of the detention basin) could not be located within the allocated ILP footprint and achieve the required design parameters (batter slopes no steeper than 1:4 and channel freeboard of 0.5 m). Therefore, this channel section was replaced by RCBC.	**Trunk Channel** Trunk channel upstream of the basin was replaced by RCBC.
	Trunk Pipe Pipe B11.8 grade was set to 0.3% based on downstream channel.	**Trunk Pipe** There is a possibility to increase the pipe grade during detailed design based on final design surface.
	There is not sufficient cover at some locations towards the downstream end of Pipe B11.9 as per the existing ground surface. This cover issue may not occur when checked against the final design surface (assuming there will be filling to smooth the design surface)	Check the available cover once the final design surface is available and if there is not sufficient cover, increase the final design surface to achieve the required minimum cover or provide concrete capping.
	There is not enough cover along the pipe B11.10 towards the downstream end (However, this is within an area that will be filled up to 1% AEP flood level). The	Check the available cover once the final 1% AEP flood level is available and if there is not sufficient cover, apply additional

Constraint type	Details	Possible Resolutions
	cover between the pipe and the final 1% AEP flood levels is lower than the minimum required.	filling to the final design surface to achieve the required minimum cover.
	Water Quality Controls There was not sufficient footprint within the detention basin to include a biofilter that can meet the required water quality targets. The current co-located biofilter is therefore undersized for its catchment. Additional streetscape and source water controls to be provided in the catchment.	**Water Quality Controls** Reduce the dependency on the end-of-pipe solution by implementing source control measures and additional WSUD treatment in the catchment. Preliminary estimates of required supplementary biofilter footprint area are shown on concept design drawings and further details on streetscape controls can also be found in Section 7.4.
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018a) for general geotechnical conditions relevant to project area.	



LEGEND

- Stormwater Pipe
- Sydney Water Existing Water Pipe
- Sydney Water Proposed Sewer Pipe
- Telestra Cable
- Non-Certified Land
- Key Fish Habitat
- Proposed Trunk Pipe
- Proposed Channel Easment
- Proposed 50% AEP Basin
- Drainage System Catchment

NOTE

Refer to Table 7.1 for Zoning Legend.

Utility Plan is Indicative only.

DATE 08/06/2018	0 130 260 Meters 1:5,000	**PAGE SIZE** A3	**COORDINATE SYSTEM** GDA 1994 MGA Zone 56
FIG NO. 7.27	**FIGURE TITLE** Environmental and Utility Constraints - Drainage System B11		
PROJECT NO. 30011388	**PROJECT TITLE** Austral and Leppington North Design of Water Management Infrastructure		
CREATED BY Nilmini Pannipitiya	**SOURCES** Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)		

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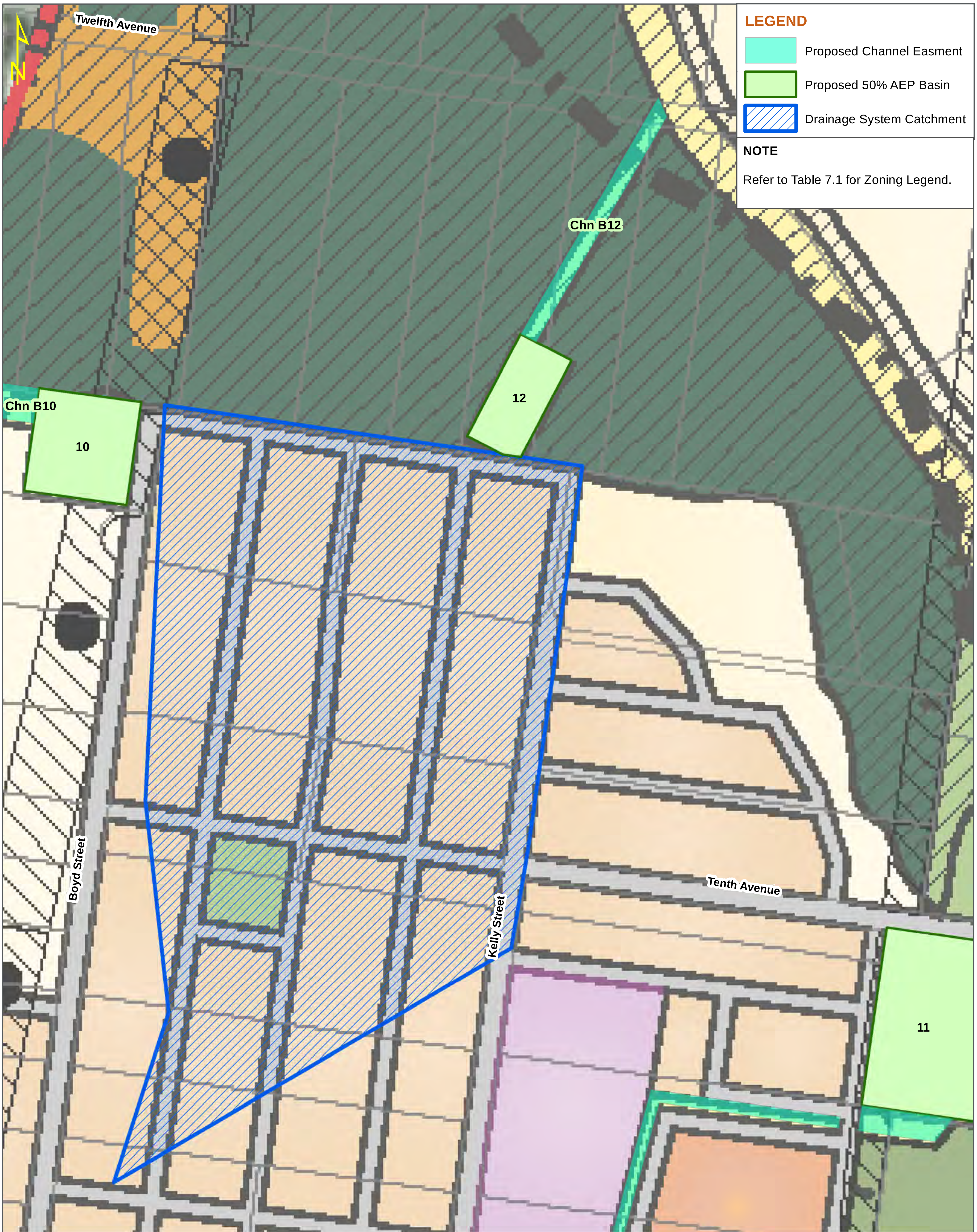
Last updated by: GC13350 on 8/06/2018 at 8:58

7.2.7. Drainage System B12

Drainage system B12, located between Boyd Street and Kelly Street, drains stormwater from a 18 ha catchment, which discharges into Bonds Creek. The drainage system components included in drainage System B12 are shown in Figure 7.28 and summarized in Table 7.26.

Table 7.26: Drainage System B12 Components

Drainage Component	Details
Trunk drainage channel	Chn B12
Detention basin	Basin 12
Water quality controls GPT Biofilter	 GPT B12 Bioretention B12



DATE 23/06/2018

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PAGE SIZE A3

COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.28

FIGURE TITLE Drainage System B12

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

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Location: I:\projects\30011388 - Austral Leppington North Liverpool City Council\009 Deliverables\001 Stormwater Trunk Infrastucture\006 GIS\map\ArcMap for Report\SMEC_A3_LCC_MAP_BASIN50AEP_Sub12.mxd

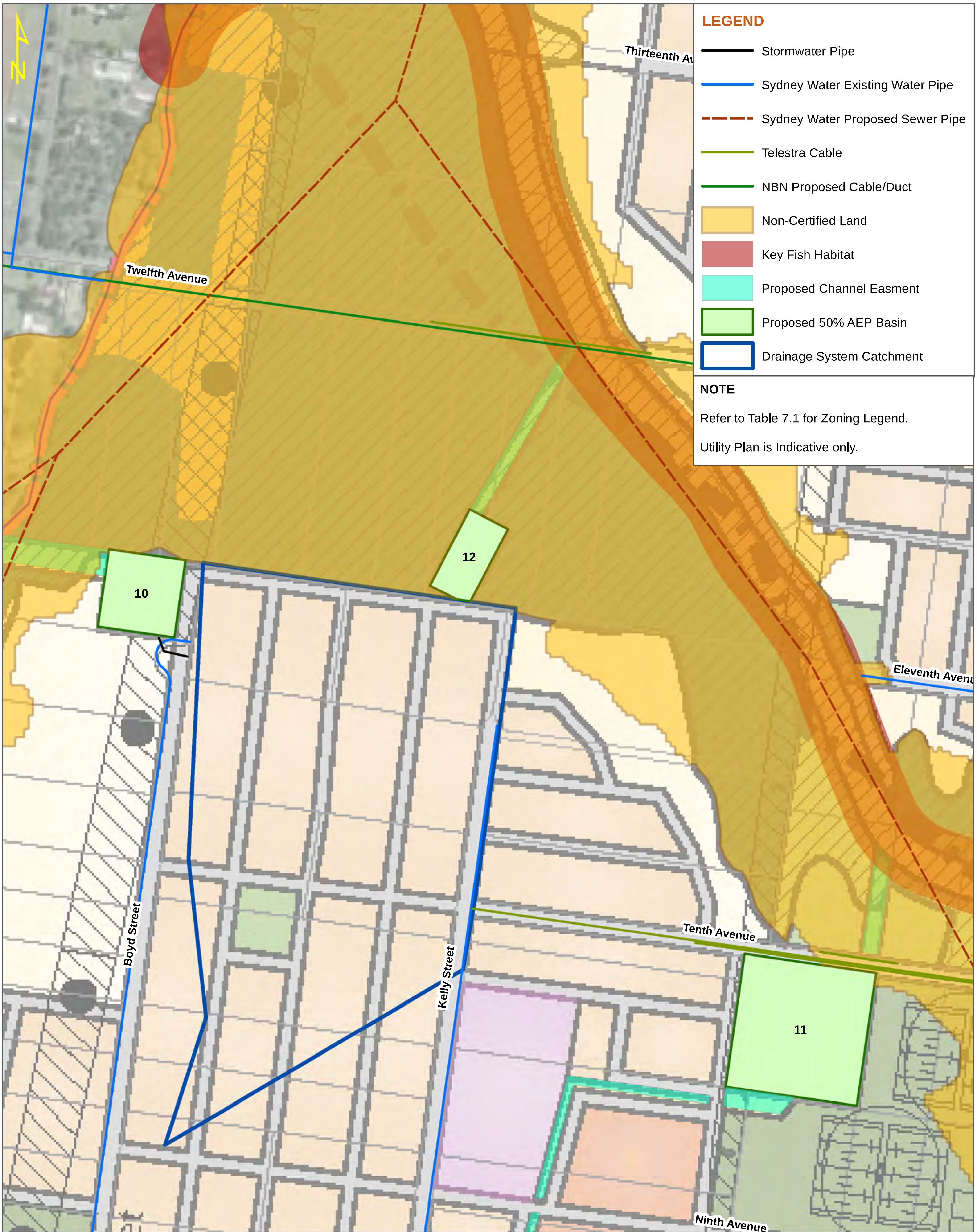
Last updated by: GC13350 on 23/06/2018 at 13:35

Design constraints

Design constraints are listed in Table 7.27. Environmental constraints and utility constraints are shown in Figure 7.29.

Table 7.27: Drainage System B12 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	The basin outlet channel is within the non-certified layer. Furthermore, the location where the basin outlet channel discharges onto the Bonds Creek is classified as a key fish habitat area.	This issue is addressed in the REF (SMEC, 2018d). Channel outlet to be designed as per DPI fisheries requirements during detailed design.
Utility conflicts	Refer Utility Services Investigation Report (SMEC, 2018c).	Refer Utility Services Investigation Report (SMEC, 2018c).
Deviations from the preferred design parameters	**Trunk Channel** Due to the flat terrain, the maximum possible channel bed slope was 0.5%.	**Trunk Channel** There is a possibility to increase the pipe grade during detailed design based on final design surface.
	Detention Basin Due to the limited footprint allocated for the basin and biofilter, a steeper embankment slope (1:2) was adopted for the preliminary design. As per Council advice the embankment batter slope was modified to maintain the standard slope of 1:4 by adding a staggered sandstone step wall at the base.	**Detention Basin** Resolved the issue by introducing a staggered sandstone step wall to optimise the allocated footprint.
	Water Quality Controls There was not sufficient footprint within the detention basin to include a biofilter that can meet the required water quality targets. The current co-located biofilter is therefore undersized for its catchment. Additional streetscape and source water controls to be provided in the catchment.	**Water Quality Controls** Reduce the dependency on the end-of-pipe solution by implementing source control measures and additional WSUD treatment in the catchment. Preliminary estimates of required supplementary biofilter footprint area are shown on concept design drawings and further details on streetscape controls can also be found in Section 7.4.
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018a) for general geotechnical conditions relevant to project area.	



DATE 23/06/2018

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PAGE SIZE A3

COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.29

FIGURE TITLE Environmental and Utility Constraints - Drainage System B12

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

SMEC Member of the Surbana Jurong Group

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Location: I:\projects\30011388 - Austral Leppington North Liverpool City Council\009 Deliverables\001 Stormwater Trunk Infrastucture\006 GIS\map\ArcMap for Report\SMEC_A3_LCC_MAP_CONST_BASIN50AEP_Sub12.mxd

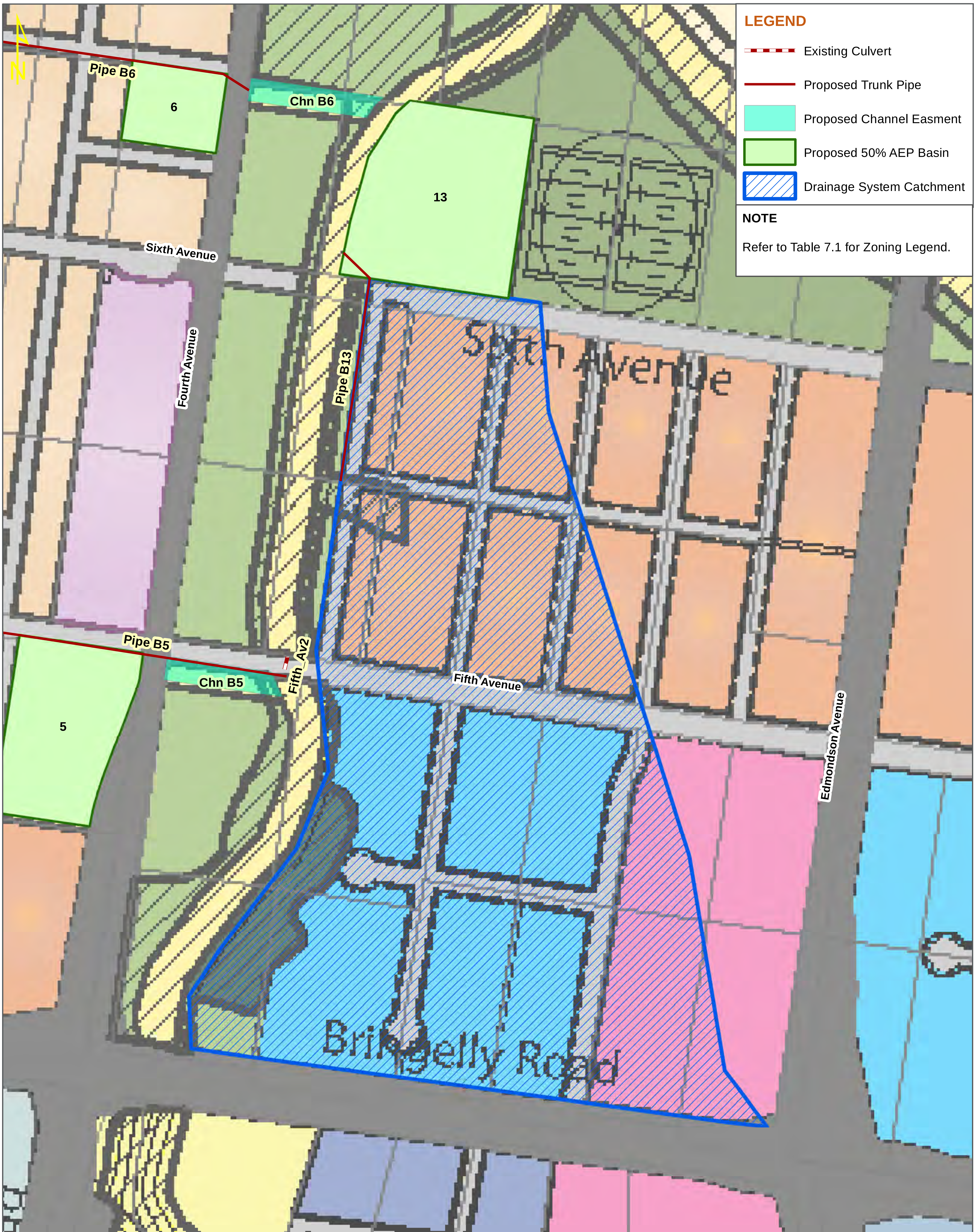
Last updated by: GC13350 on 23/06/2018 at 13:56

7.2.8. Drainage System B13

Drainage system B13, located north of Bringelly Road, drains stormwater from a 21 ha catchment, which discharges into Scalabrini Creek. The drainage system components included in drainage System B13 are shown in Figure 7.30 and summarized in Table 7.28.

Table 7.28: Drainage System B13 Components

Drainage Component	Details
Trunk drainage pipe	Pipe B13.1, Pipe B13.2 and Pipe B13.3
Detention basin	Basin 13
Water quality controls GPT Biofilter	 GPT B13 Bioretention B13



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COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.30

FIGURE TITLE Drainage System B13

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

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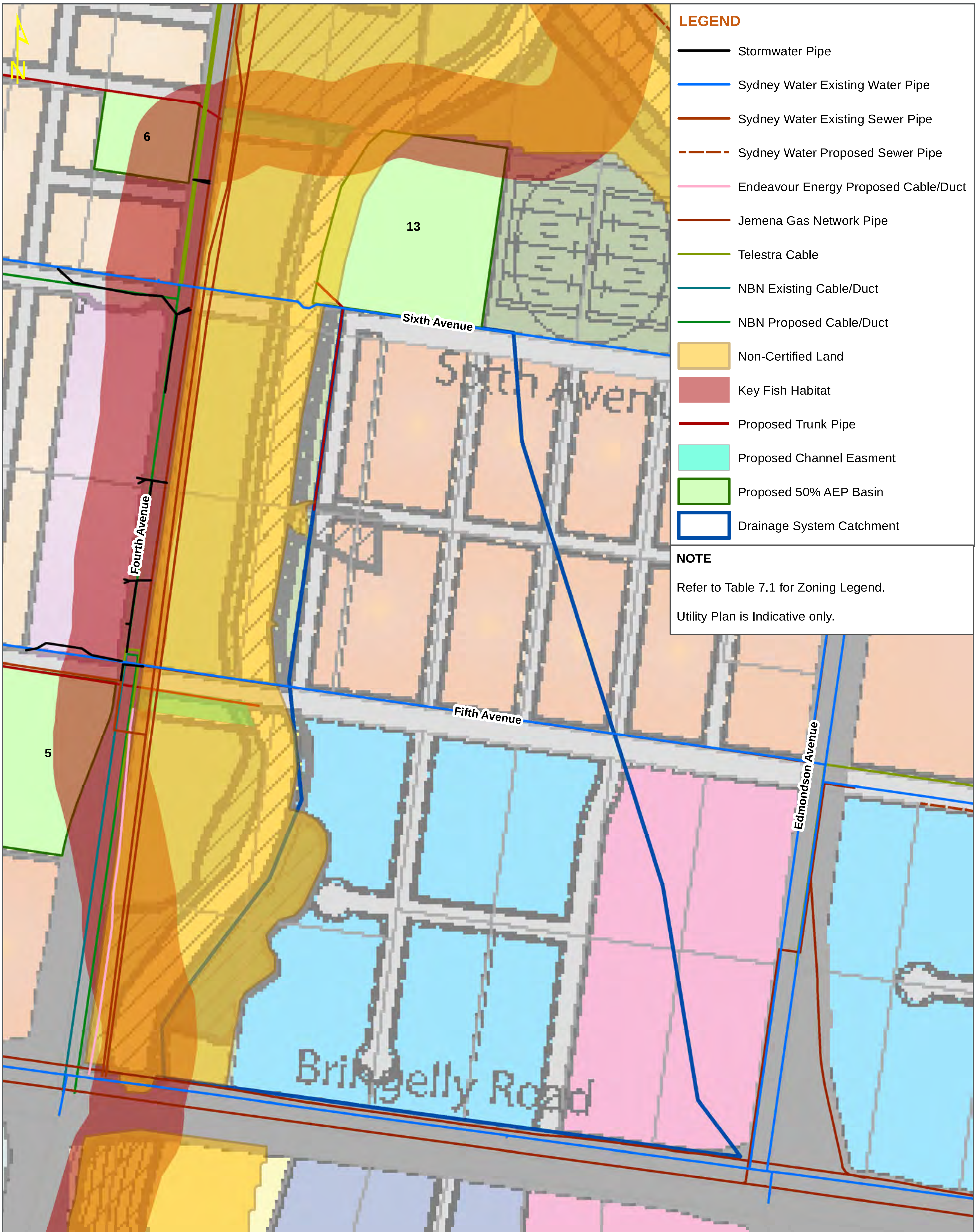
Design constraints

Design constraints are listed in Table 7.29. Environmental constraints and utility constraints are shown in Figure 7.31.

Table 7.29: Drainage System B13 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	Basin ILP footprint is partially within the non-certified layer (approximately 0.3 ha).	This issue is addressed in the REF (SMEC, 2018d).
	Furthermore, the location where the trunk pipe discharges onto the Scalabrini Creek is classified as a key fish habitat area.	Pipe outlet to be designed as per DPI fisheries requirements during detailed design.
	Creek realignment was noted north of the Basin in the ILP.	The creek realignment to be further investigated during precinct development.
Utility conflicts	Refer Utility Services Investigation Report (SMEC, 2018c).	Refer Utility Services Investigation Report (SMEC, 2018c).
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018a) for general geotechnical conditions relevant to project area.	



NOTE

Refer to Table 7.1 for Zoning Legend.

Utility Plan is Indicative only.

DATE 23/06/2018 | Scale 0 – 75 – 150 Meters, 1:3,000 | **PAGE SIZE** A3 | **COORDINATE SYSTEM** GDA 1994 MGA Zone 56

FIG NO. 7.31 | **FIGURE TITLE** Environmental and Utility Constraints - Drainage System B13

PROJECT NO. 30011388 | **PROJECT TITLE** Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya | **SOURCES** Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

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7.2.9. Drainage System B14

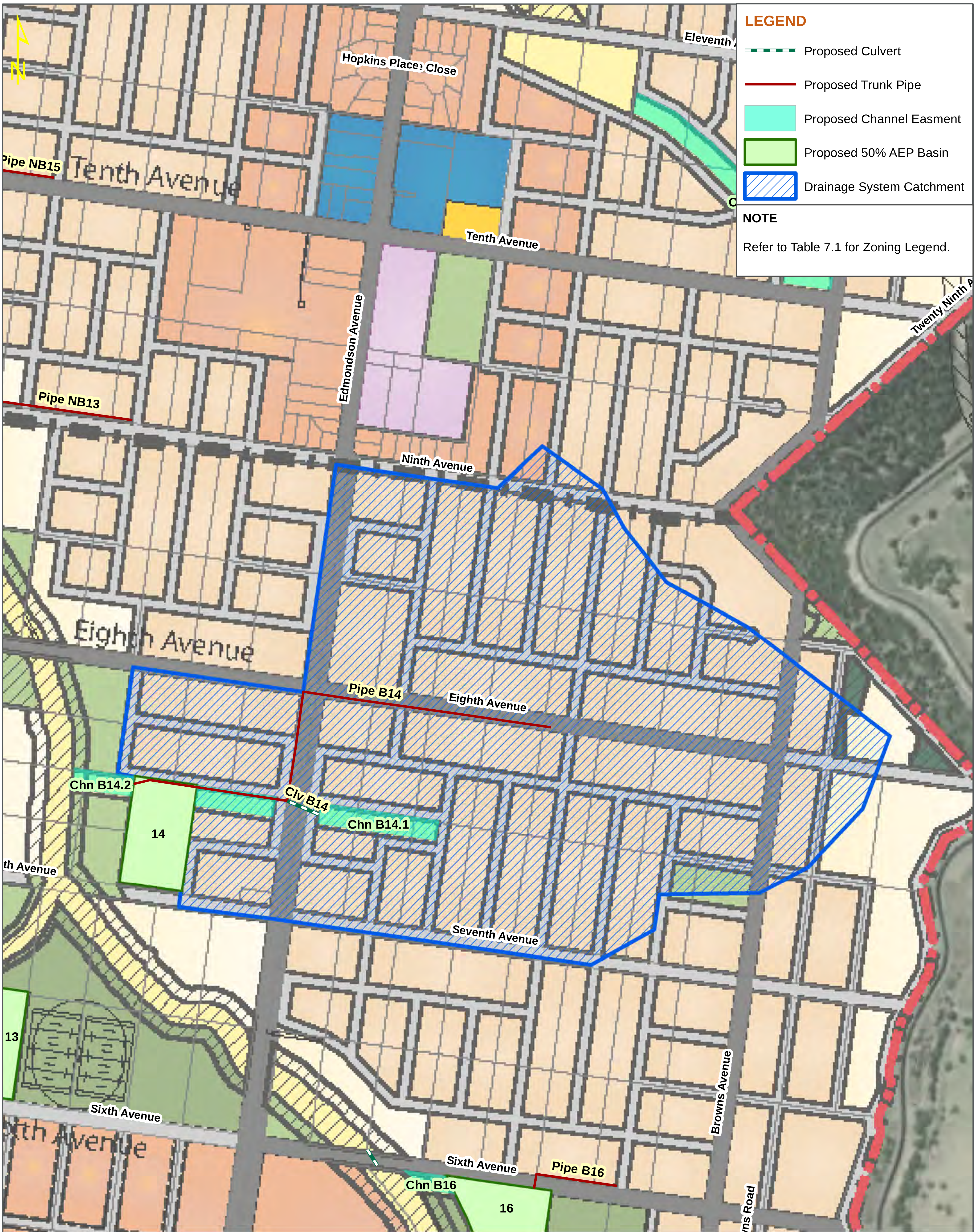
Drainage system B14, located between Seventh Avenue and Ninth Avenue, drains stormwater from a 45 ha catchment, which discharges into Bonds Creek. The drainage system components included in drainage System B14 are shown in Figure 7.32 and summarized in Table 7.30.

Table 7.30: Drainage System B14 Components

Drainage Component	Details
Trunk drainage pipe	Pipe B14.1, Pipe B14.2, Pipe B14.3, Pipe B14.4, Pipe B14.5, Pipe B14.6, Pipe B14.7, Pipe B14.8, Pipe B14.9, Pipe B14.10, and Pipe B14.11
Trunk drainage channel	Chn B14.1 and Chn B14.2
Culvert	
Proposed	Clv B14[1]
Detention basin	Basin 14
Water quality controls	
GPT	GPT B14
Biofilter	Bioretention B14

Note:

1. The proposed culvert is the redesign of existing creek culverts UT_Edmondson and UT_Edmon2. It was mistakenly marked as a proposed culvert.



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PAGE SIZE A3

COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.32

FIGURE TITLE Drainage System B14

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

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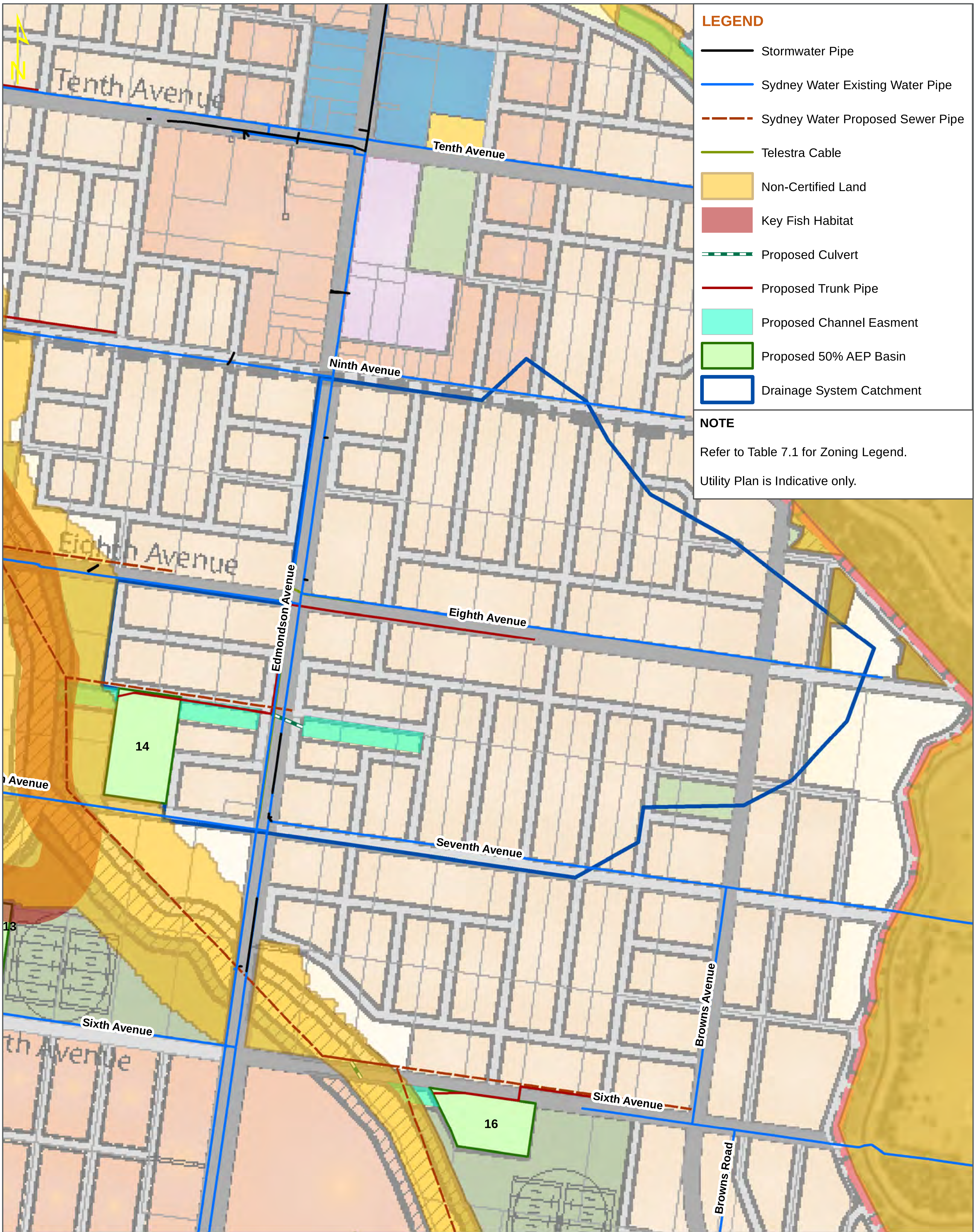
Design constraints

Design constraints are listed in Table 7.31. Environmental constraints and utility constraints are shown in Figure 7.33.

Table 7.31: Drainage System B14 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	The majority of the basin outlet channel is within the non-certified layer. Furthermore, the location where the basin outlet channel discharges onto the Bonds Creek is classified as a key fish habitat area.	This issue is addressed in the REF (SMEC, 2018d). Channel outlet to be designed as per DPI fisheries requirements during detailed design.
Utility conflicts	Refer Utility Services Investigation Report (SMEC, 2018c).	Refer Utility Services Investigation Report (SMEC, 2018c).
Deviations from the preferred design parameters	**Trunk Pipe** The pipe cover is slightly less than the minimum required at some location between Pipe B14.9 and B14.10 (approx. 0.6 m cover). It should also be noted that there are irregularities in the existing land surface. Therefore, it is assumed that there will be some filling to smoothen the ground surface. Subsequently, it is assumed that the current cover issue may not exist when checked against the final design surface.	**Trunk Pipe** Check the available cover against the final design surface and provide additional filling if required during detailed design.
	Trunk Channel Due to complexities of flow diversion, the channel section immediately before the detention basin was replaced with a trunk pipe. The proposed change was also required to maximise the effective basin area within the allocated ILP footprint.	**Trunk Channel** The issue was solved by replacing the channel section immediately before the detention basin with the trunk pipe.
	Water Quality Controls There was not sufficient footprint within the detention basin to include a biofilter that can meet the required water quality targets. The current co-located biofilter is therefore undersized for its catchment. Additional streetscape and source water controls to be provided in the catchment.	**Water Quality Controls** Reduce the dependency on the end-of-pipe solution by implementing source control measures and additional WSUD treatment in the catchment. Preliminary estimates of required supplementary biofilter footprint area are shown on concept design drawings and further details on streetscape controls can also be found in Section 7.4.

Constraint type	Details	Possible Resolutions
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018a) for general geotechnical conditions relevant to project area.	



DATE 19/07/2018

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PAGE SIZE A3

COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.33

FIGURE TITLE Environmental and Utility Constraints - Drainage System B14

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

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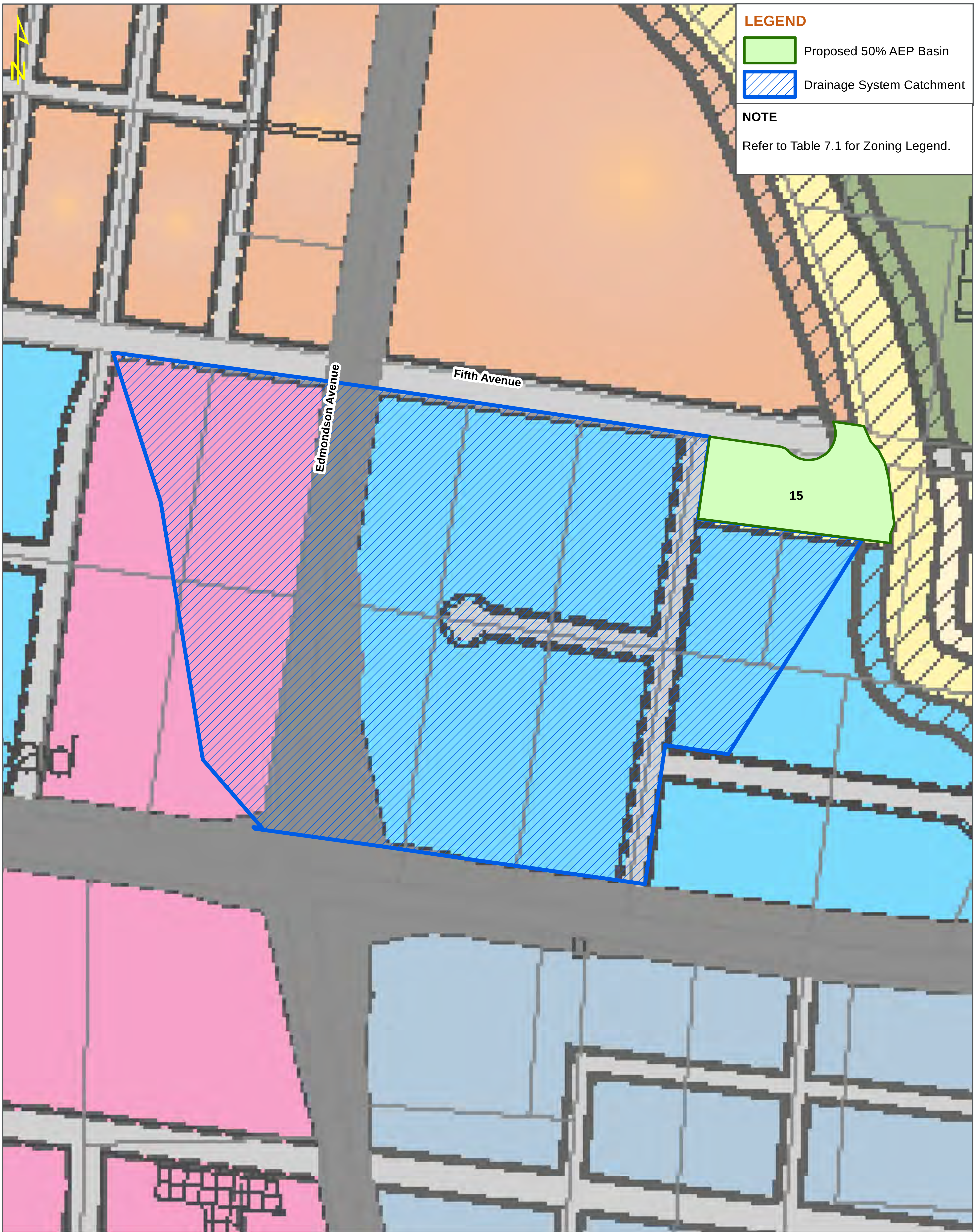
7.2.10. Drainage System B15

Drainage system B15, located north of Bringelly Road, drains stormwater from a 13 ha catchment, which discharges into Bonds Creek. The drainage system components included in drainage System B15 are shown in Figure 7.34 and summarized in Table 7.32.

Table 7.32: Drainage System B15 Components

Drainage Component	Details
Detention basin	Basin 15
Water quality controls GPT Biofilter	 GPT B15 Bioretention B15



DATE 23/06/2018	0 62.5 125 Meters 1:2,500	PAGE SIZE A3	COORDINATE SYSTEM GDA 1994 MGA Zone 56
FIG NO. 7.34	FIGURE TITLE Drainage System B15		
PROJECT NO. 30011388	PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure		
CREATED BY Nilmini Pannipitiya	SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)		

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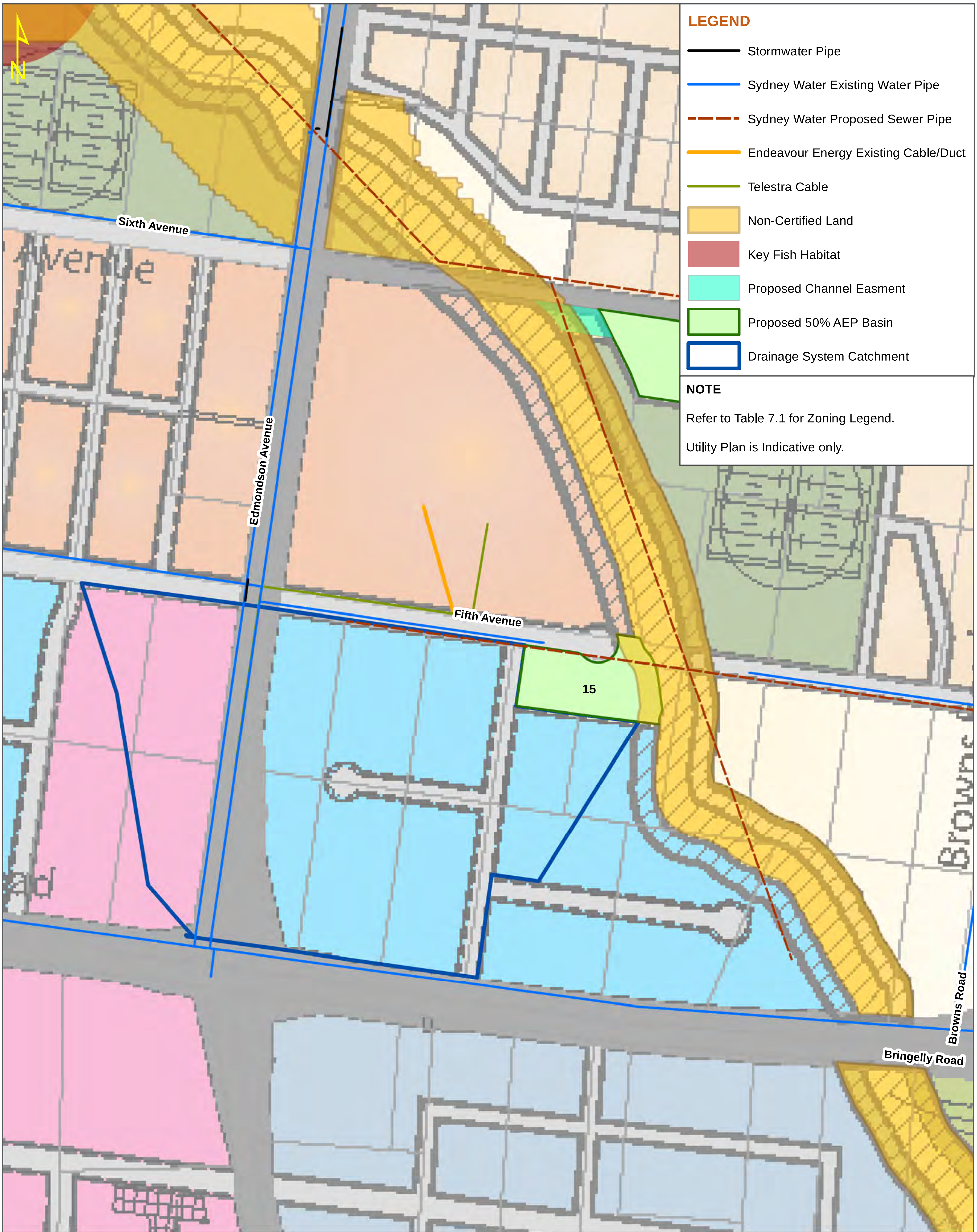
Design constraints

Design constraints are listed in Table 7.33. Environmental constraints and utility constraints are shown in Figure 7.35.

Table 7.33: Drainage System B15 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	Basin ILP footprint is partially within the non-certified layer (approx. 0.2 ha).	This issue is addressed in the REF (SMEC, 2018d).
Utility conflicts	Refer Utility Services Investigation Report (SMEC, 2018c).	Refer Utility Services Investigation Report (SMEC, 2018c).
Deviations from the preferred design parameters	**Detention Basin** Since a minor system to be connected to detention basin and the design of minor systems are out of project scope. Only an indicative size and alignment are shown. Potential inlet location was selected based on the existing contours.	**Detention Basin** Minor Drainage to be designed during detailed Design. Check the suitability of the basin inlet location with regards to minor drainage system connecting to the basin during the detail design stage.
	Water Quality Controls There was not sufficient footprint within the detention basin to include a biofilter that can meet the required water quality targets. The current co-located biofilter is therefore undersized for its catchment. Additional streetscape and source water controls to be provided in the catchment.	**Water Quality Controls** Reduce the dependency on the end-of-pipe solution by implementing source control measures and additional WSUD treatment at upstream parts of the catchment. Preliminary estimates of required supplementary biofilter footprint area are shown on concept design drawings and further details on streetscape controls can also be found in Section 7.4.
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018a) for general geotechnical conditions relevant to project area.	



DATE 23/06/2018	0 87.5 175 Meters 1:3,367	**PAGE SIZE** A3	**COORDINATE SYSTEM** GDA 1994 MGA Zone 56
FIG NO. 7.35	**FIGURE TITLE** Environmental and Utility Constraints - Drainage System B15		
PROJECT NO. 30011388	**PROJECT TITLE** Austral and Leppington North Design of Water Management Infrastructure		
CREATED BY Nilmini Pannipitiya	**SOURCES** Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)		

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Location: I:\projects\30011388 - Austral Leppington North Liverpool City Council\009 Deliverables\001 Stormwater Trunk Infrastucture\006 GIS\map\ArcMap for Report\SMEC_A3_LCC_MAP_CONST_BASIN50AEP_Sub15.mxd

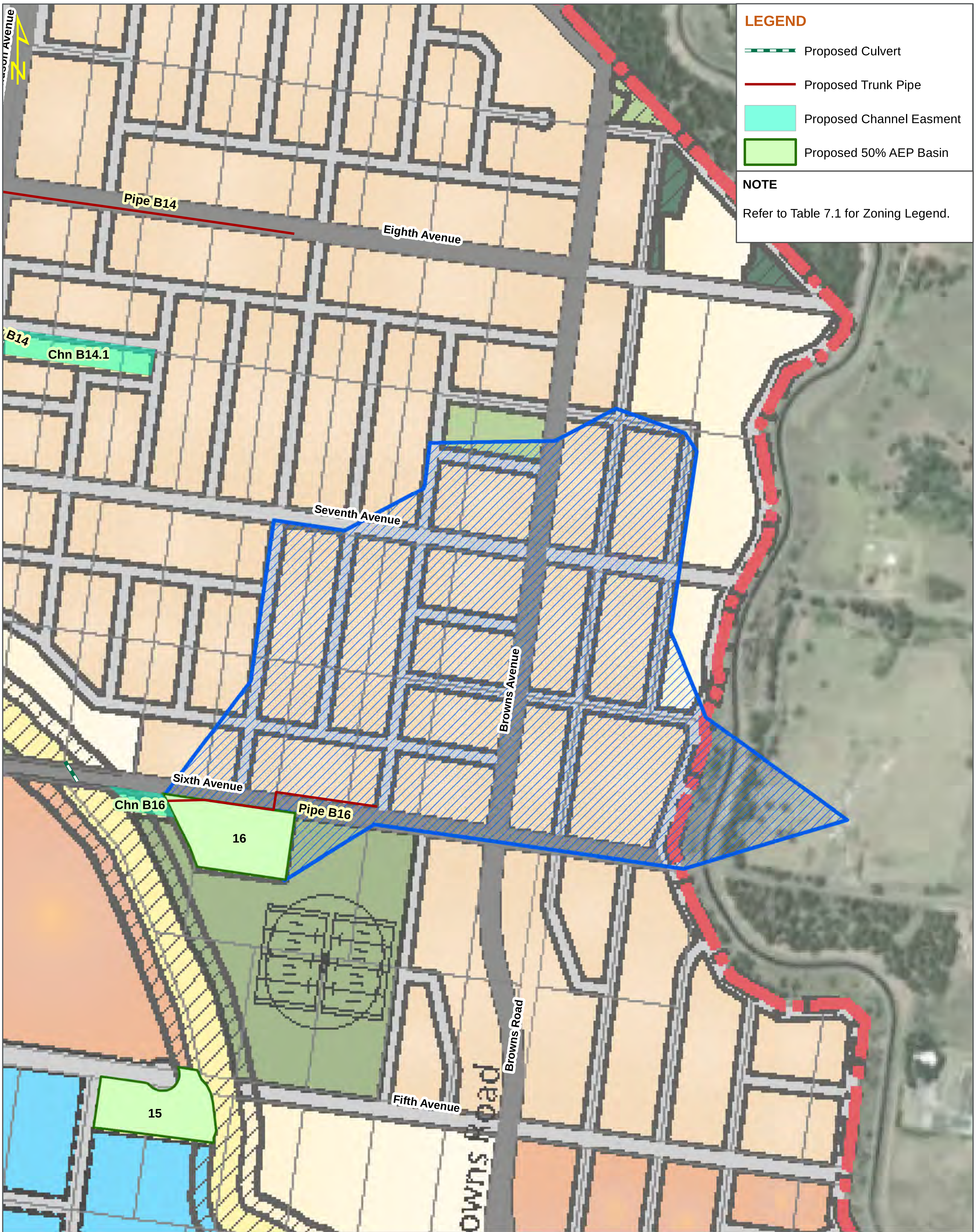
Last updated by: GC13350 on 23/06/2018 at 15:13

7.2.11. Drainage System B16

Drainage system B16, located between Fifth Avenue and Eighth Avenue, drains stormwater from a 25 ha catchment, which discharges into Bonds Creek. The drainage system components included in drainage System B16 are shown in Figure 7.36 and summarized in Table 7.34.

Table 7.34: Drainage System B16 Components

Drainage Component	Details
Trunk drainage pipe Trunk drainage channel	Pipe B16.1, Pipe B16.2, Pipe B16.3 and Pipe B16.4 Chn B16
Detention basin	Basin 16
Water quality controls GPT Biofilter	 GPT B16 Bioretention B16



DATE 23/06/2018	0 100 200 Meters 1:4,000	**PAGE SIZE** A3	**COORDINATE SYSTEM** GDA 1994 MGA Zone 56
FIG NO. 7.36	**FIGURE TITLE** Drainage System B16		
PROJECT NO. 30011388	**PROJECT TITLE** Austral and Leppington North Design of Water Management Infrastructure		
CREATED BY Nilmini Pannipitiya	**SOURCES** Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)		

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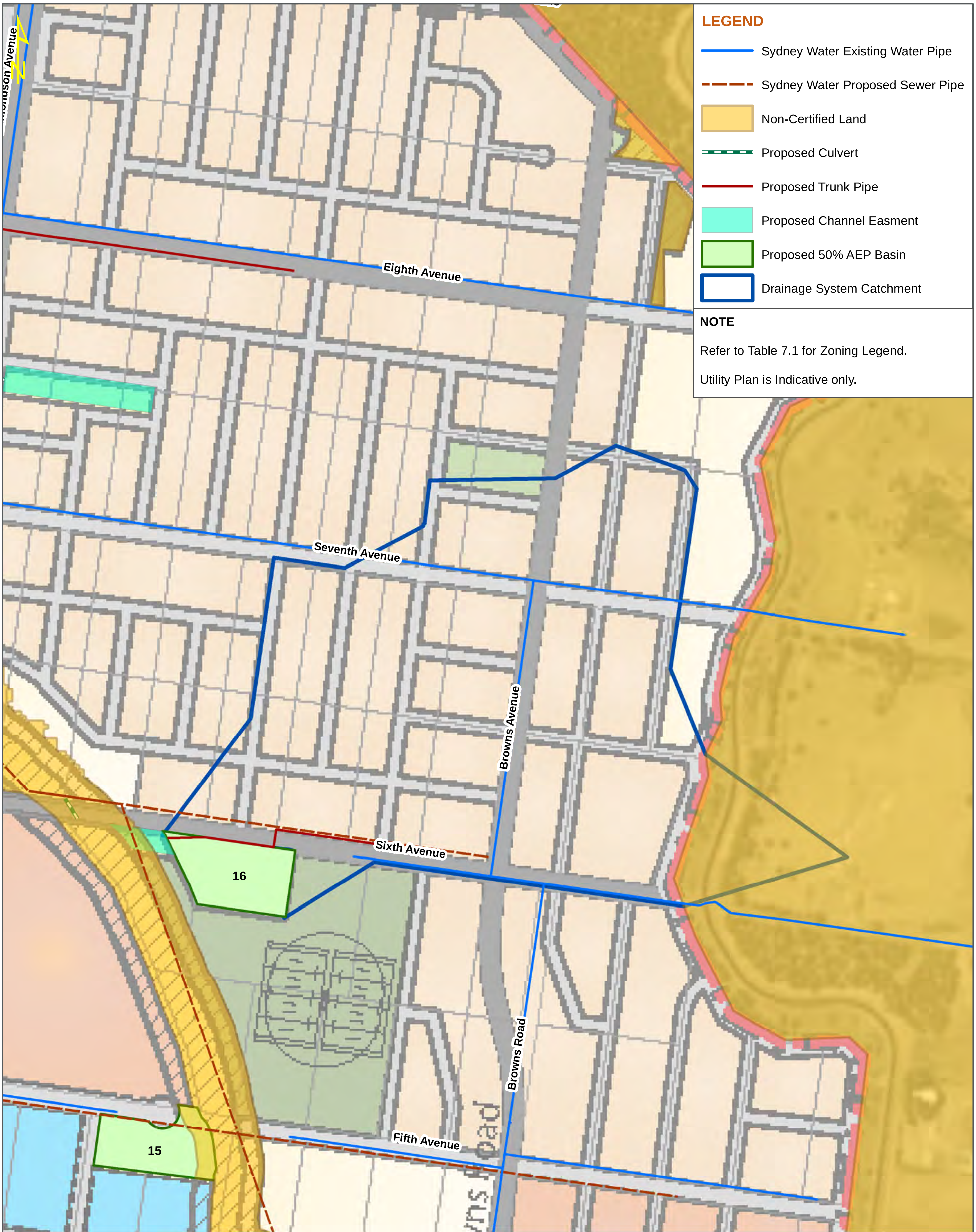
Design constraints

Design constraints are listed in Table 7.35. Environmental constraints and utility constraints are shown in Figure 7.37.

Table 7.35: Drainage System B16 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	The Trunk drainage channel is partly within the non-certified layer.	This issue is addressed in the REF (SMEC, 2018d).
Utility conflicts	Refer Utility Services Investigation Report (SMEC, 2018c).	Refer Utility Services Investigation Report (SMEC, 2018c).
Deviations from the preferred design parameters	**Trunk Pipe** The available cover for the downstream end of the trunk pipe B16.3 and the majority of the trunk pipe B16.4 is not sufficient when compared with the existing ground surface. However, it is proposed to fill the existing ground and the Sixth avenue to tie into basin access path. Therefore, the cover issue may not occur with the final design surface.	**Trunk Pipe** Check the cover when final design surface is available. If the available cover is not sufficient, provide concrete capping.
	Detention Basin Due to the limited footprint allocated for the basin and biofilter, a steeper embankment slope (1:2) was adopted for the preliminary design. As per Council advice the embankment batter slope was modified to maintain the standard slope of 1:4 by adding a staggered sandstone step wall at the base.	**Detention Basin** Resolved the issue by introducing a staggered sandstone step wall to optimise the allocated footprint.
	It is difficult to access basin from the existing road (Sixth Avenue).	It is proposed suggested to elevate investigate the way of providing access from Sixth Avenue to service road surface level to tie into basin access path during detailed design based on the final road design.
	Water Quality Controls There was not sufficient footprint within the detention basin to include a biofilter that can meet the required water quality targets. The current co-located biofilter is therefore undersized for its catchment. Additional streetscape and source water controls to be provided in the catchment.	**Water Quality Controls** Reduce the dependency on the end-of-pipe solution by implementing source control measures and additional WSUD treatment at upstream parts of the catchment.

Constraint type	Details	Possible Resolutions
		Preliminary estimates of required supplementary biofilter footprint area are shown on concept design drawings and further details on streetscape controls can also be found in Section 7.4.
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018a) for general geotechnical conditions relevant to project area.	



DATE 23/06/2018

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1:4,000 Meters

PAGE SIZE A3

COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.37

FIGURE TITLE Environmental and Utility Constraints - Drainage System B16

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

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Location: I:\projects\30011388 - Austral Leppington North Liverpool City Council\009 Deliverables\001 Stormwater Trunk Infrastucture\006 GIS\map\ArcMap for Report\SMEC_A3_LCC_MAP_CONST_BASIN50AEP_Sub16.mxd

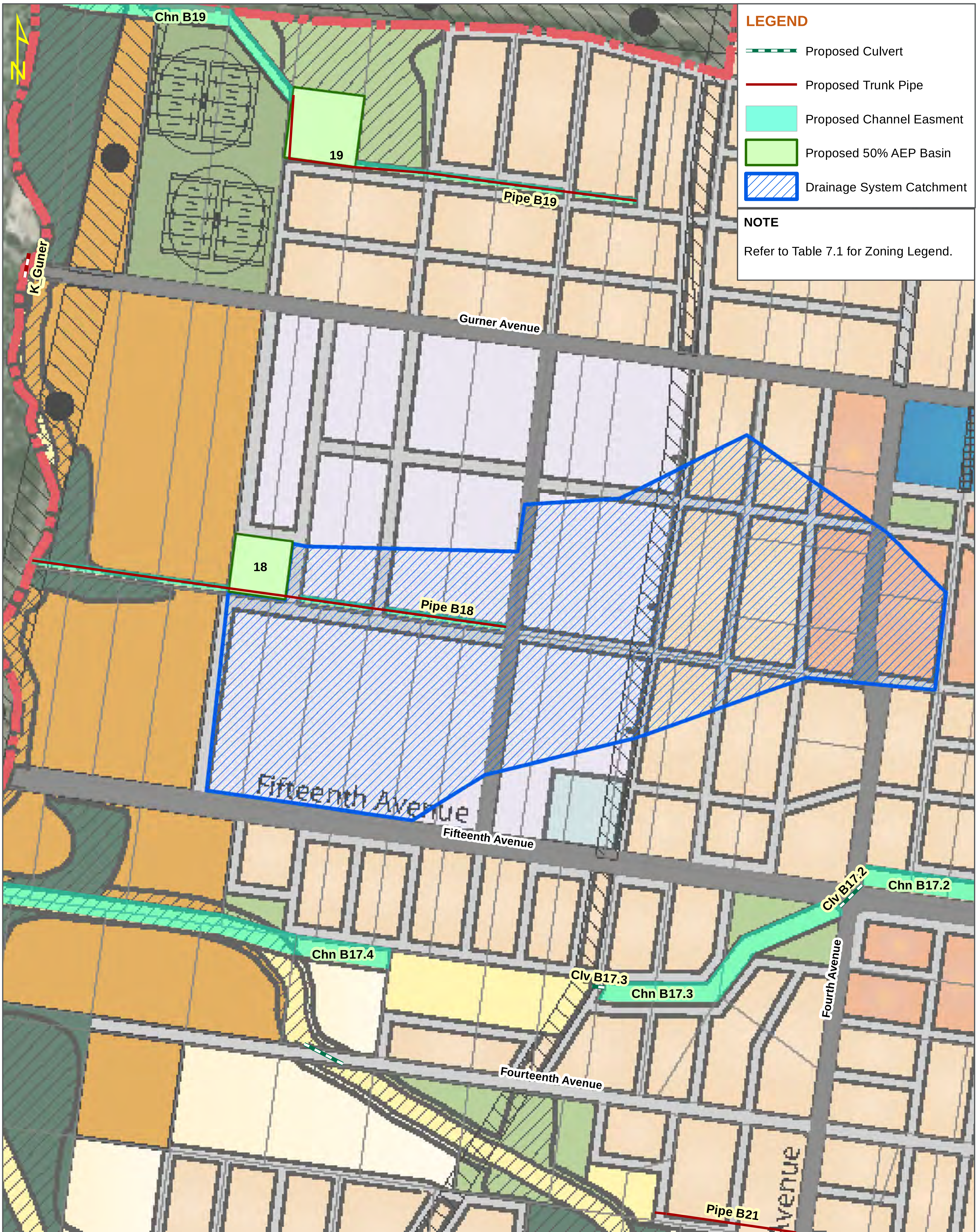
Last updated by: GC13350 on 19/07/2018 at 15:18

7.2.12. Drainage System B18

Drainage system B18, located between Fifteenth Avenue and Gurner Avenue, drains stormwater from a 33 ha catchment, which discharges into Kemps Creek. The drainage system components included in drainage System B18 are shown in Figure 7.38 and summarized in Table 7.36.

Table 7.36: Drainage System B18 Components

Drainage Component	Details
Trunk drainage pipe	Pipe B18.1, Pipe B18.2, Pipe B18.3, Pipe B18.4, Pipe B18.5, Pipe18.6 and Pipe 18.7
Detention basin	Basin 18
Water quality controls GPT Biofilter	 GPT B18 Bioretention B18



DATE 13/06/2018	0 130 260 Meters 1:5,000	**PAGE SIZE** A3	**COORDINATE SYSTEM** GDA 1994 MGA Zone 56
FIG NO. 7.38	**FIGURE TITLE** Drainage System B18		
PROJECT NO. 30011388	**PROJECT TITLE** Austral and Leppington North Design of Water Management Infrastructure		
CREATED BY Nilmini Pannipitiya	**SOURCES** Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)		

Design constraints

Design constraints are listed in Table 7.37. Environmental constraints and utility constraints are shown in Figure 7.39.

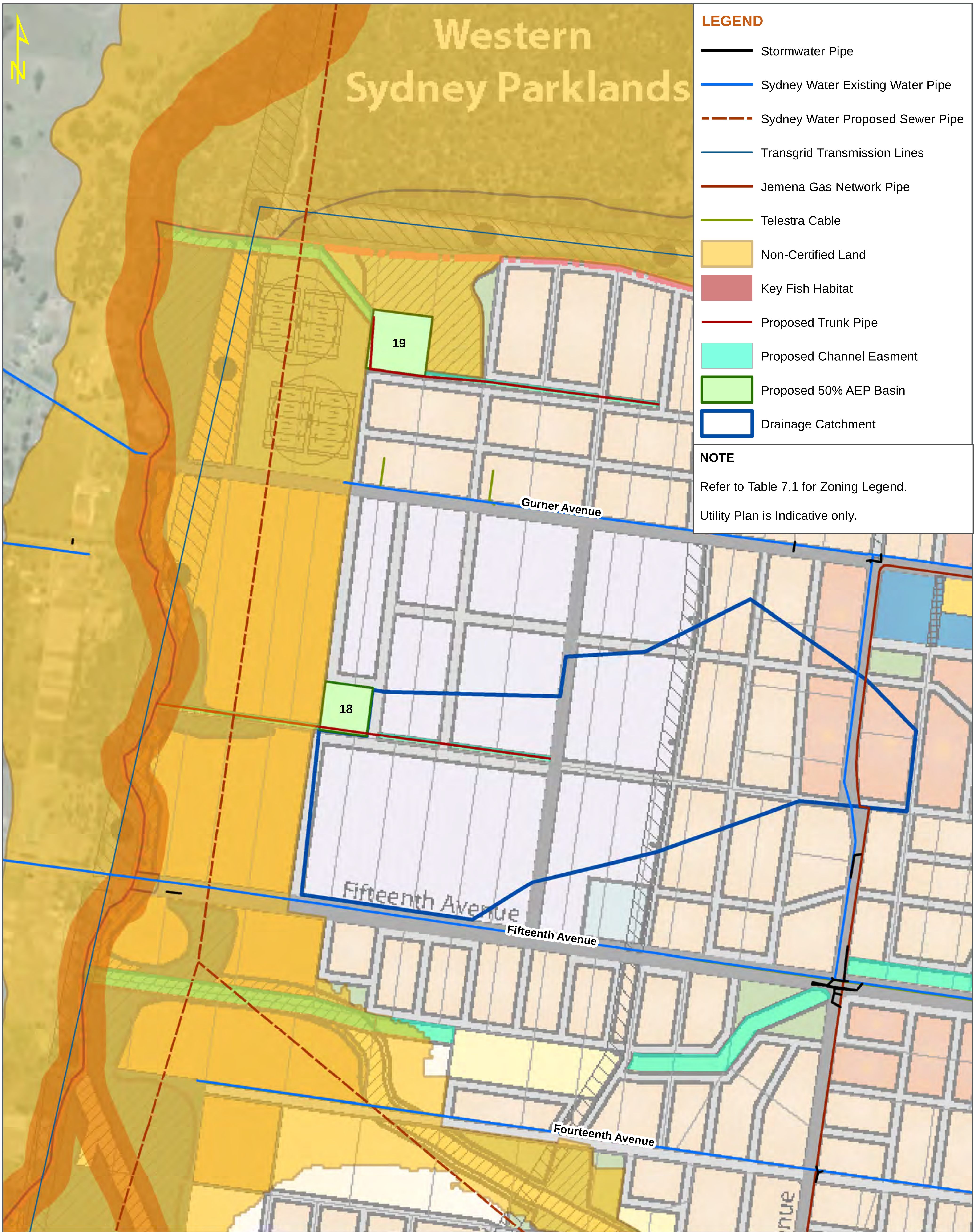
Table 7.37: Drainage System B18 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	The trunk drainage pipe is within the non-certified layer. Furthermore, the location where the trunk channel discharges onto the Kemps Creek is classified as a key fish habitat area.	This issue is addressed in the REF (SMEC, 2018d). Channel outlet to be designed as per DPI fisheries requirements during detailed design.
Utility conflicts	Refer Utility Services Investigation Report (SMEC, 2018c).	Refer Utility Services Investigation Report (SMEC, 2018c).
Deviations from the preferred design parameters	**Trunk Channel** The required trunk channel could not be located within the allocated ILP footprint together with the preferred design parameters (batter slopes no steeper than 1:4 and channel freeboard of 0.5 m).	**Trunk Channel** The complete trunk channel was replaced with RCBC.
	Trunk Pipe There is not sufficient cover at the upstream few meters of Pipe B18.7.	**Trunk Pipe** Since the trunk pipe is within the proposed channel easement, it is assumed that the channel footprint will be offset from the non-certified area. Therefore, additional the filling to be provided until the minimum cover requirements are met.
	The maximum flow above the gutter is 0.22 m in Pipe B18.1. However, as the velocity x depth is less than 0.4 m^2/s and within the channel easement the safety risk is considered low. As the flow above gutter is less than 0.20 m for all downstream pipes.	It is considered up sizing of 200 m pipe length to mitigate 0.02 m extra depth above gutter is not cost effective.
	Water Quality Controls There was not sufficient footprint within the detention basin to include a biofilter that can meet the required water quality targets. The current co-located biofilter is therefore undersized for its catchment. Additional streetscape and source water controls to be provided in the catchment.	**Water Quality Controls** Reduce the dependency on the end-of-pipe solution by implementing source control measures and additional WSUD treatment at upstream parts of the catchment. Preliminary estimates of required supplementary biofilter footprint area are

Constraint type	Details	Possible Resolutions
		shown on concept design drawings and further details on streetscape controls can also be found in Section 7.4.
Geotechnical	Basin site demonstrates soft soil conditions. Building structures in soft ground conditions is problematic as it can lead to long-term settlement of the structure.	In general, and within practical limits, it is recommended that 'soft' to 'firm' natural soils encountered at subgrade level be excavated and replaced with controlled fill. Refer Geotechnical Interpretive Report (SMEC, 2018a) for details.

Design Opportunities

Since the trunk channel upstream of the detention basin was replaced with trunk pipe, the ILP footprint allocated for the trunk channel easement could be utilised for streetscape water quality controls.



NOTE

Refer to Table 7.1 for Zoning Legend.

Utility Plan is Indicative only.

DATE 13/06/2018	0 150 300 Meters 1:6,000	**PAGE SIZE** A3	**COORDINATE SYSTEM** GDA 1994 MGA Zone 56
FIG NO. 7.39	**FIGURE TITLE** Environmental and Utility Constraints - Drainage System B18		
PROJECT NO. 30011388	**PROJECT TITLE** Austral and Leppington North Design of Water Management Infrastructure		
CREATED BY Nilmini Pannipitiya	**SOURCES** Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)		

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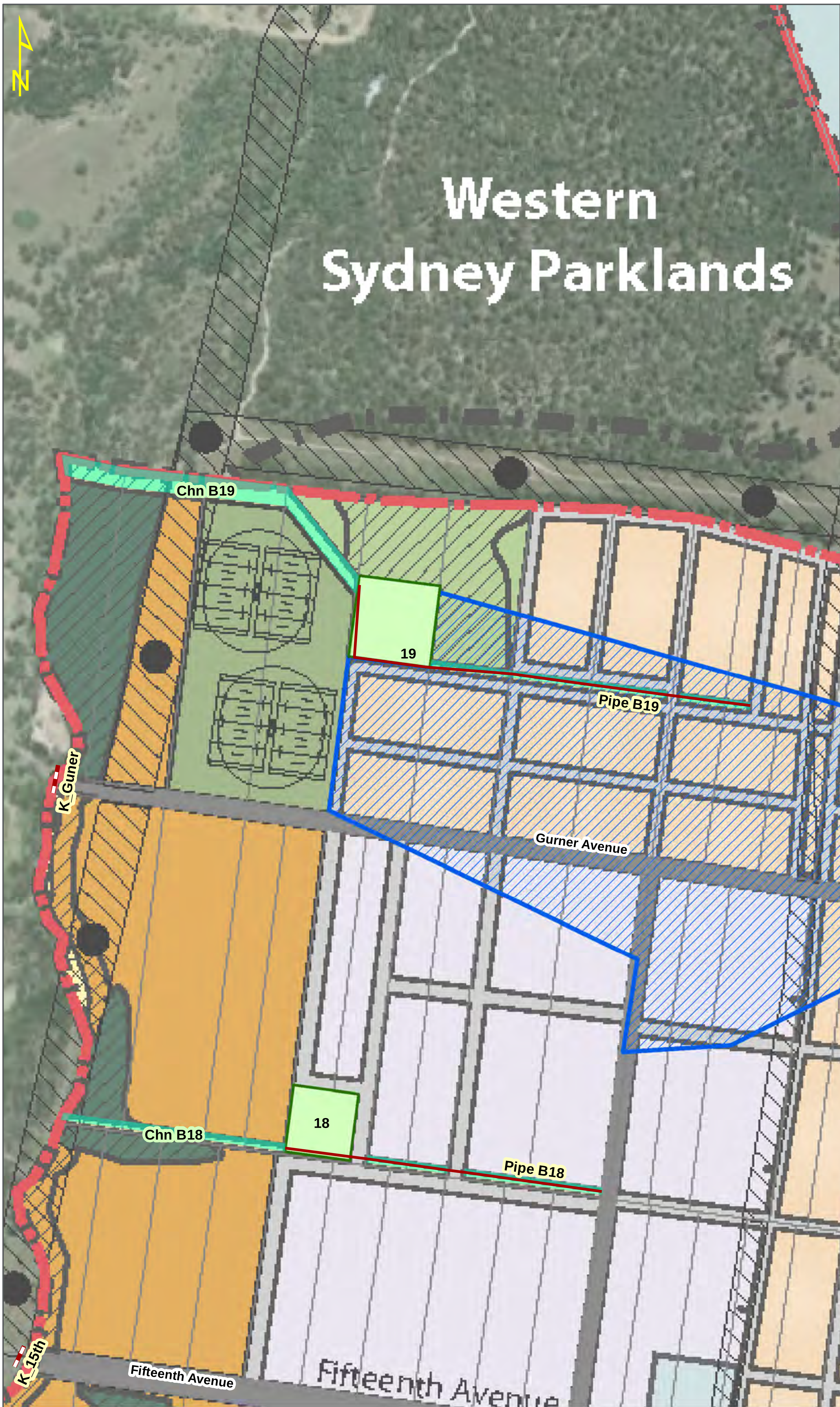
7.2.13. Drainage System B19

Drainage system B19, located near the north western project boundary, drains stormwater from a 31 ha catchment, which discharges into Kemps Creek. The drainage system components included in drainage System B19 are shown in Figure 7.40 and summarized in Table 7.38.

Table 7.38: Drainage System B19 Components

Drainage Component	Details
Trunk drainage pipe Trunk drainage channel	Pipe B19.1, Pipe B19.2, Pipe B19.3, Pipe B19.4, Pipe B19.5, Pipe B19.6, Pipe B19.7 and Pipe B19.8 Chn B19
Detention basin	Basin 19
Water quality controls GPT Biofilter	 GPT B19 Bioretention B19



LEGEND

- Existing Culvert
- Proposed Trunk Pipe
- Proposed Channel Easment
- Proposed 50% AEP Basin
- Drainage System Catchment

NOTE

Refer to Table 7.1 for Zoning Legend.

DATE 08/06/2018	0 130 260 Meters 1:5,000	PAGE SIZE A3	COORDINATE SYSTEM GDA 1994 MGA Zone 56
FIG NO. 7.40	FIGURE TITLE Drainage System B19		
PROJECT NO. 30011388	PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure		
CREATED BY Nilmini Pannipitiya	SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)		

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Design constraints

Design constraints are listed in Table 7.39. Environmental constraints and utility constraints are shown in Figure 7.41.

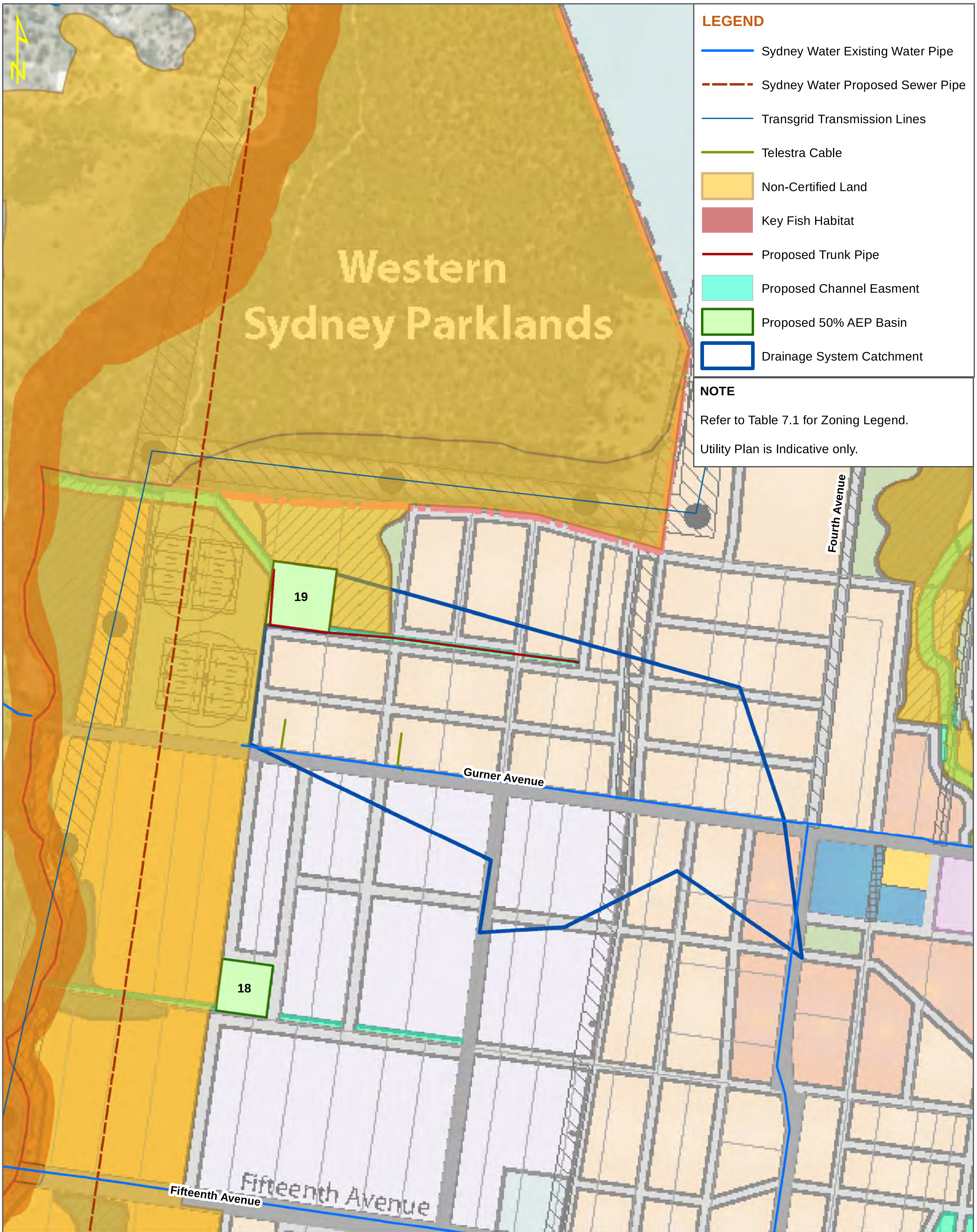
Table 7.39: Drainage System B19 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	The trunk drainage channel (downstream of the basin) is within the non-certified layer. Furthermore, the location where the trunk channel discharges onto the Kemps Creek is classified as a key fish habitat area.	This issue is addressed in the REF (SMEC, 2018d). Channel outlet to be designed as per DPI fisheries requirements during detailed design.
Utility conflicts	Refer Utility Services Investigation Report (SMEC, 2018c).	Refer Utility Services Investigation Report (SMEC, 2018c).
Deviations from the preferred design parameters	**Trunk Channel** The required trunk channel (upstream of the detention basin) could not be located within the allocated ILP footprint together with the preferred design parameters (batter slopes no steeper than 1:4 and channel freeboard of 0.5 m). Additionally, due to flat nature of the land between the detention basin and the creek discharge point, it was not possible to maintain the preferred minimum slope of 0.5% at some section of the trunk channel downstream of the basin.	**Trunk Channel** Trunk channel upstream of the basin was replaced by RCBC. Channel slope was set to 0.3% where required. The channel slope could be improved during detailed design.
	Trunk Pipe There is not sufficient cover for the by-pass trunk pipes (Pipe B19.7 and PipeB19.8) as per the existing ground level. However, this area is to be filled up to the proposed basin crest level which will satisfy the minim cover requirements. Additionally, in order to be connected to the downstream trunk channel, by-pass trunk pipe grade was set to ~0.3%.	**Trunk Pipe** Position by-pass trunk pipes along the basin embankment.
	Detention Basin There was not sufficient footprint available for the co-located biofilter when the basin batter slope was set to 1:4.	**Detention Basin** In order to obtain more footprint at the basin invert, the embankment batter slope was modified to maintain the

Constraint type	Details	Possible Resolutions
		standard slope of 1:4 by adding a staggered sandstone step wall at the base.
	Water Quality Controls There was not sufficient footprint within the detention basin to include a biofilter that can meet the required water quality targets. The current co-located biofilter is therefore undersized for its catchment. Additional streetscape and source water controls to be provided in the catchment. Furthermore, the available hydraulic head was very limited. Therefore, the biofilter extended detention depth needed to be reduced.	**Water Quality Controls** Reduce the dependency on the end-of-pipe solution by implementing source control measures and additional WSUD treatment at upstream parts of the catchment. Preliminary estimates of required supplementary biofilters are shown on concept design drawings and further details on streetscape controls can also be found in Section 7.4.
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018a) for general geotechnical conditions relevant to project area.	

Design Opportunities

Since the trunk channel upstream of the detention basin was replaced with RCBC, the ILP footprint allocated for the trunk channel easement could be utilised for streetscape water quality controls.



DATE 08/06/2018

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1:5,612 Meters

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COORDINATE SYSTEM GDA 1994 MGA Zone 56

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FIG NO. 7.41

FIGURE TITLE Environmental and Utility Constraints - Drainage System B19

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

7.3. Drainage Systems without Basins

There are 43 drainage systems that do not drain to a detention basin as shown in Figure 7.42. Two drainage Systems (B9 and B10), which were originally proposed as detention basin systems, are also included in this category as these systems no longer have detention basins. Two drainage systems (NB2 and NB18) were excluded from the concept design as they have limited development (zoned for environmental living/conservation) within the certified land.

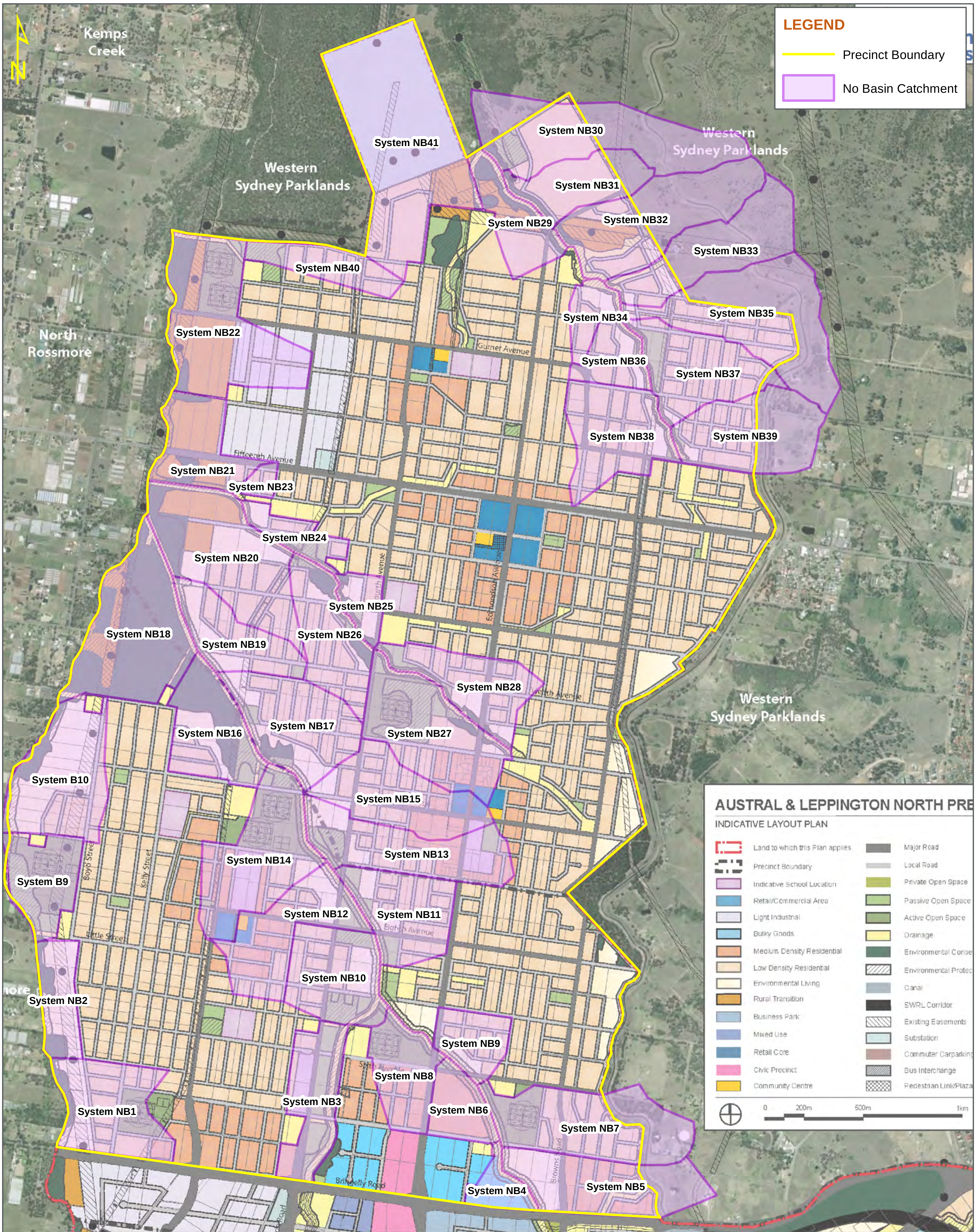
Out of 41 drainage systems, only the following eight systems have either trunk drainage (pipe or channel). The remaining drainage systems only have minor drainage systems.

- Drainage System NB5
- Drainage System NB13
- Drainage System NB14
- Drainage System NB15
- Drainage System NB33
- Drainage System NB35
- Drainage System NB37
- Drainage System NB38

Layout plans, long sections and cross sections for the trunk drainage pipes and channels, in the above mentioned drainage systems as well as erosion and sediment control measures can be found in Appendix D.

In addition to the trunk drainage and minor drainage systems, streetscape raingardens/tree pits will be implemented throughout these drainage systems to manage stormwater quality. The streetscape controls would be implemented via a DCP, rather than funded via Section 94 Contribution Plans.

The streetscape controls replace the end-of-pipe biofilters that were proposed in the original WCM study (Cardno, 2012b). Refer to Section 7.4 for general guidance related to streetscape controls which are to be applied throughout the precinct in both drainage systems with basins and drainage systems without basins.



DATE 06/12/2018	0 150 300 600 900 Meters 1:18,000	**PAGE SIZE** A3	**COORDINATE SYSTEM** GDA 1994 MGA Zone 56
FIG NO. 7.42	**FIGURE TITLE** Map of Drainage Systems without Basins		
PROJECT NO. 30011388	**PROJECT TITLE** Austral and Leppington North Design of Water Management Infrastructure		
CREATED BY Nilmini Pannipitiya	**SOURCES** Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)		

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Location: I:\projects\30011388 - Austral Leppington North Liverpool City Council\009 Deliverables\001 Stormwater Trunk Infrastucture\006 GIS\map\ArcMap for Report\SMEC_A3_LCC_MAP_All_Sub.mxd

Last updated by: GC13350 on 6/12/2018 at 18:27

7.3.1. Drainage System NB5

Drainage system NB5 which is located at the South eastern corner of the project boundary drains stormwater from a 26 ha catchment, which discharges into Bonds Creek.

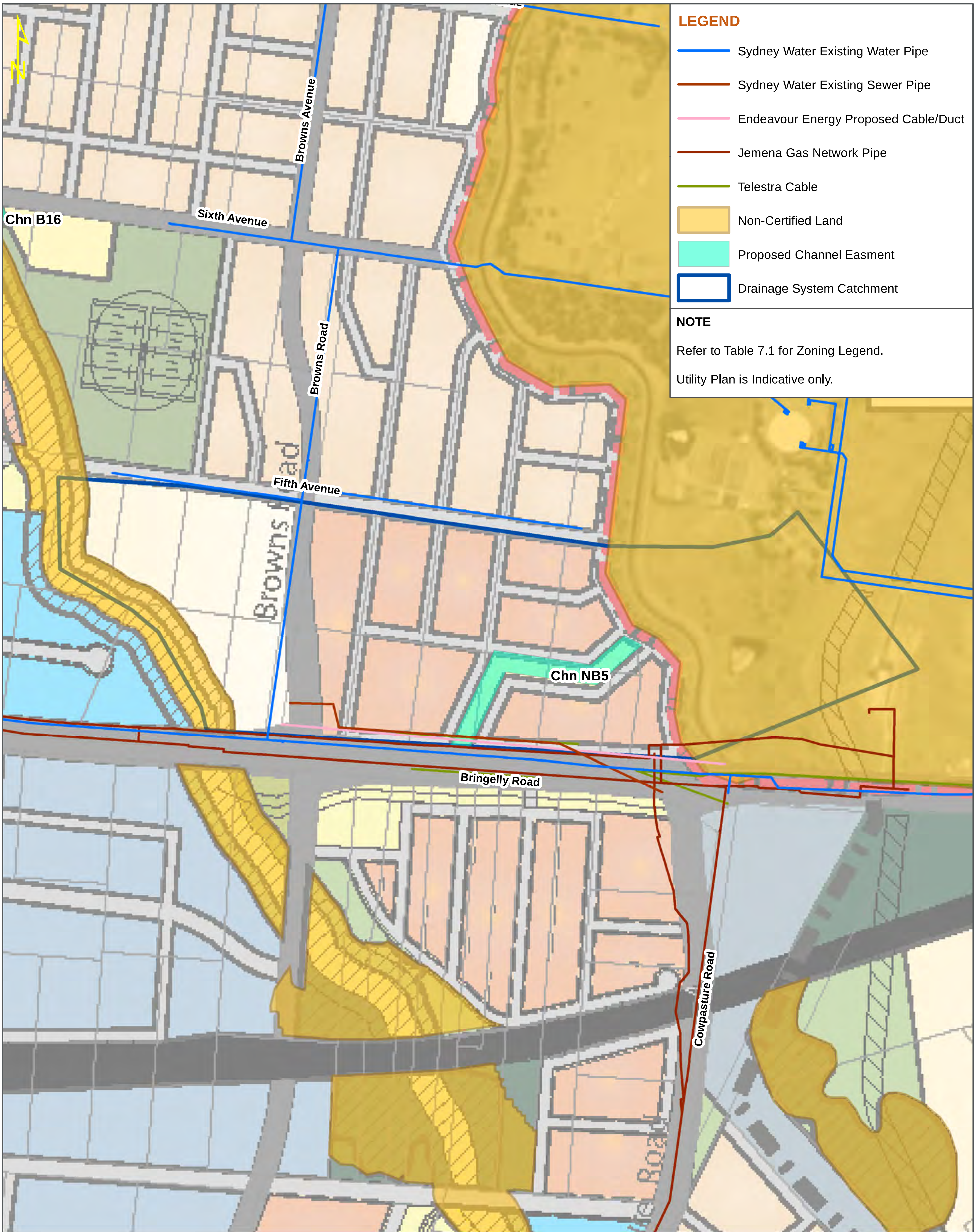
The trunk drainage channel included in drainage System NB5 is shown in Figure 7.43.

Design constraints

Design constraints are listed in Table 7.40. Environmental constraints and utility constraints are shown in Figure 7.43.

Table 7.40: Drainage System NB5 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	N/A	N/A
Utility conflicts	Refer Utility Services Investigation Report (SMEC, 2018c).	Refer Utility Services Investigation Report (SMEC, 2018c).
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018) for general geotechnical conditions relevant to project area.	



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PAGE SIZE A3

COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.43

FIGURE TITLE Environmental and Utility Constraints - Drainage System NB5

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

Location: I:\projects\30011388 - Austral Leppington North Liverpool City Council\009 Deliverables\001 Stormwater Trunk Infrastucture\006 GIS\map\ArcMap for Report\SMEC_A3_LCC_MAP_CONST_NoBASIN_Sub05.mxd

Last updated by: GC13350 on 1/12/2018 at 16:54

7.3.2. Drainage System NB13

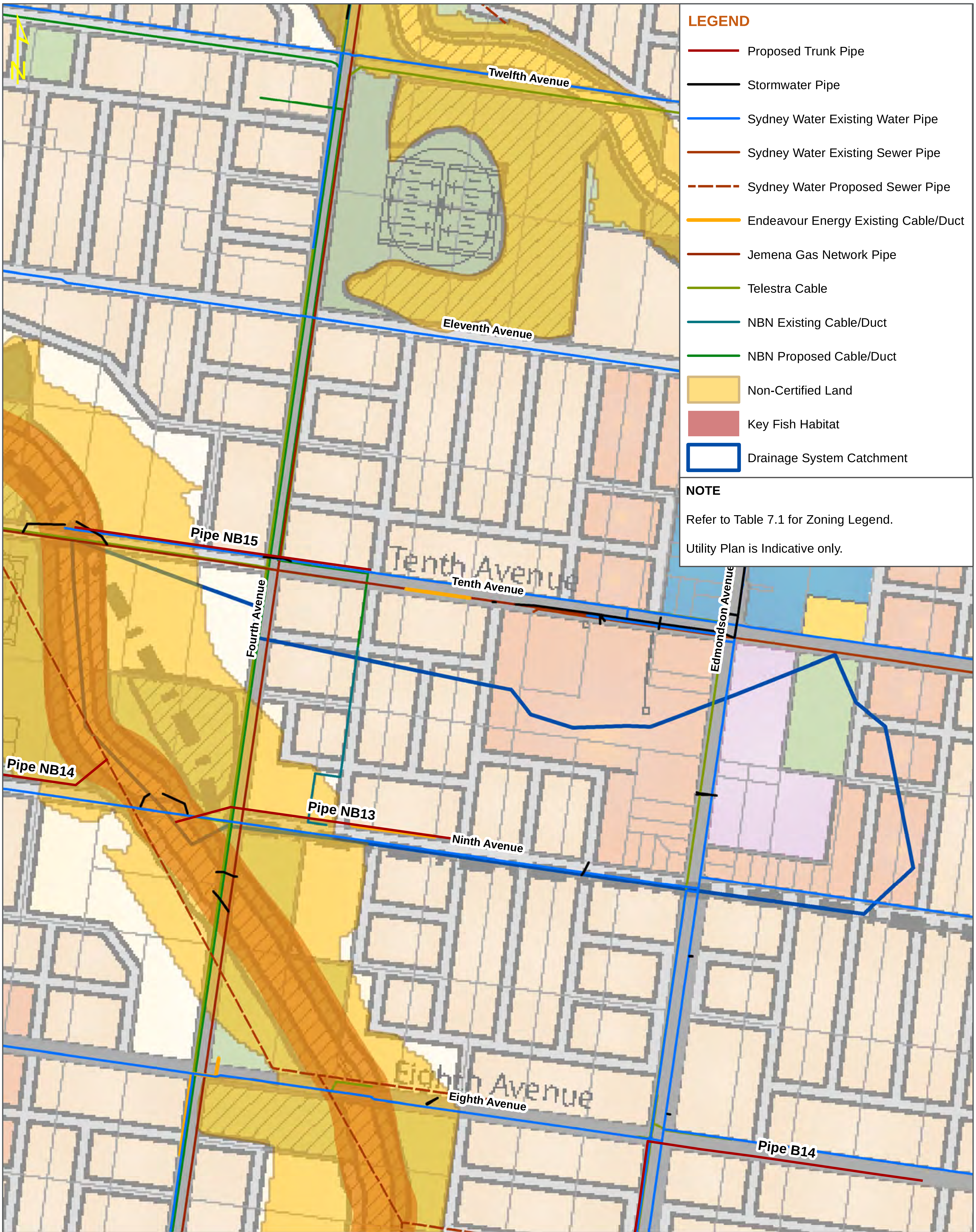
Drainage system NB13 which is located between Ninth Avenue and Tenth Avenue drains stormwater from a 25 ha catchment, which discharges into Bonds Creek. The trunk drainage channel included in drainage System NB13 is shown in Figure 7.44.

Design constraints

Design constraints are listed in Table 7.41: Drainage System NB13 Design Constraints. Environmental constraints and utility constraints are shown in Figure 7.44.

Table 7.41: Drainage System NB13 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	Nearly half of the trunk pipe is within non-certified land. Trunk pipe discharges an area classified as to key fish habitat.	This issue is addressed in the REF (SMEC, 2018d). Pipe outlet to be designed as per DPI fisheries requirements during detailed design.
Utility conflicts	Refer Utility Services Investigation Report (SMEC, 2018c).	Refer Utility Services Investigation Report (SMEC, 2018c).
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018) for general geotechnical conditions relevant to project area.	



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PAGE SIZE A3

COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.44

FIGURE TITLE Environmental and Utility Constraints - Drainage System NB13

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

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7.3.3. Drainage System NB14

Drainage system NB14 which is located between Seventh Avenue and Ninth Avenue drains stormwater from a 30 ha catchment, which discharges into Bonds Creek. The trunk drainage channel included in drainage System NB14 is shown in Figure 7.45.

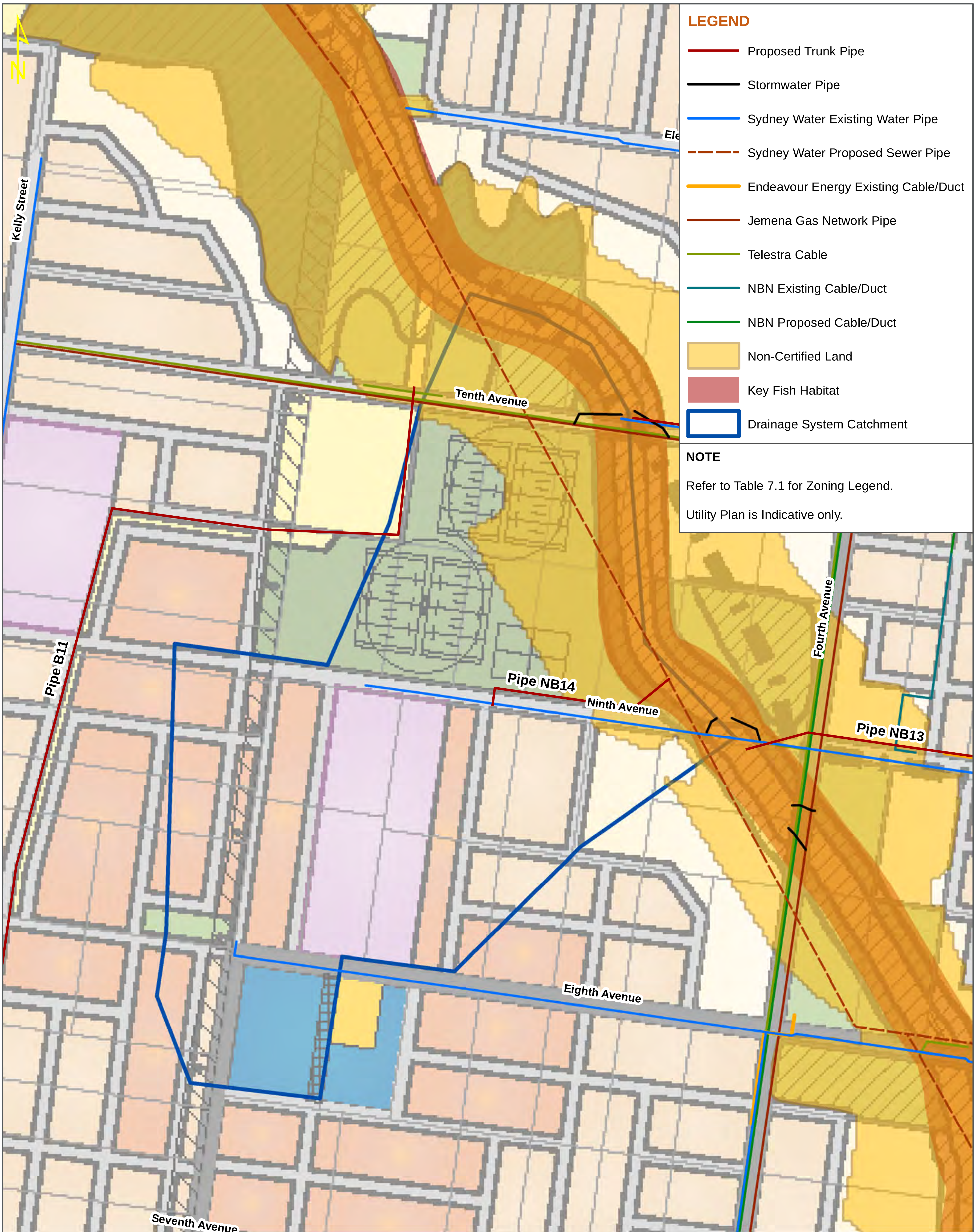
The following sections outline the specific design constraints and opportunities applicable to drainage system NB14.

Design constraints

Design constraints are listed in Table 7.42: Drainage System NB14 Design Constraints. Environmental constraints and utility constraints are shown in Figure 7.45.

Table 7.42: Drainage System NB14 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	Nearly half of the trunk pipe is within non-certified land. Trunk pipe discharges an area classified as to key fish habitat.	This issue is addressed in the REF (SMEC, 2018d). Pipe outlet to be designed as per DPI fisheries requirements during detailed design.
Utility conflicts	Refer Utility Services Investigation Report (SMEC, 2018c).	Refer Utility Services Investigation Report (SMEC, 2018c).
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018) for general geotechnical conditions relevant to project area.	



DATE 01/12/2018	0 100 200 Meters 1:4,000	**PAGE SIZE** A3	**COORDINATE SYSTEM** GDA 1994 MGA Zone 56
FIG NO. 7.45	**FIGURE TITLE** Environmental and Utility Constraints - Drainage System NB14		
PROJECT NO. 30011388	**PROJECT TITLE** Austral and Leppington North Design of Water Management Infrastructure		
CREATED BY Nilmini Pannipitiya	**SOURCES** Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)		

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7.3.4. Drainage System NB15

Drainage system NB15 which is located between Ninth Avenue and Eleventh Avenue drains stormwater from a 24 ha catchment, which discharges into Bonds Creek. The trunk drainage pipe (Pipe NB15) included in drainage System NB15 is shown in Figure 7.46.

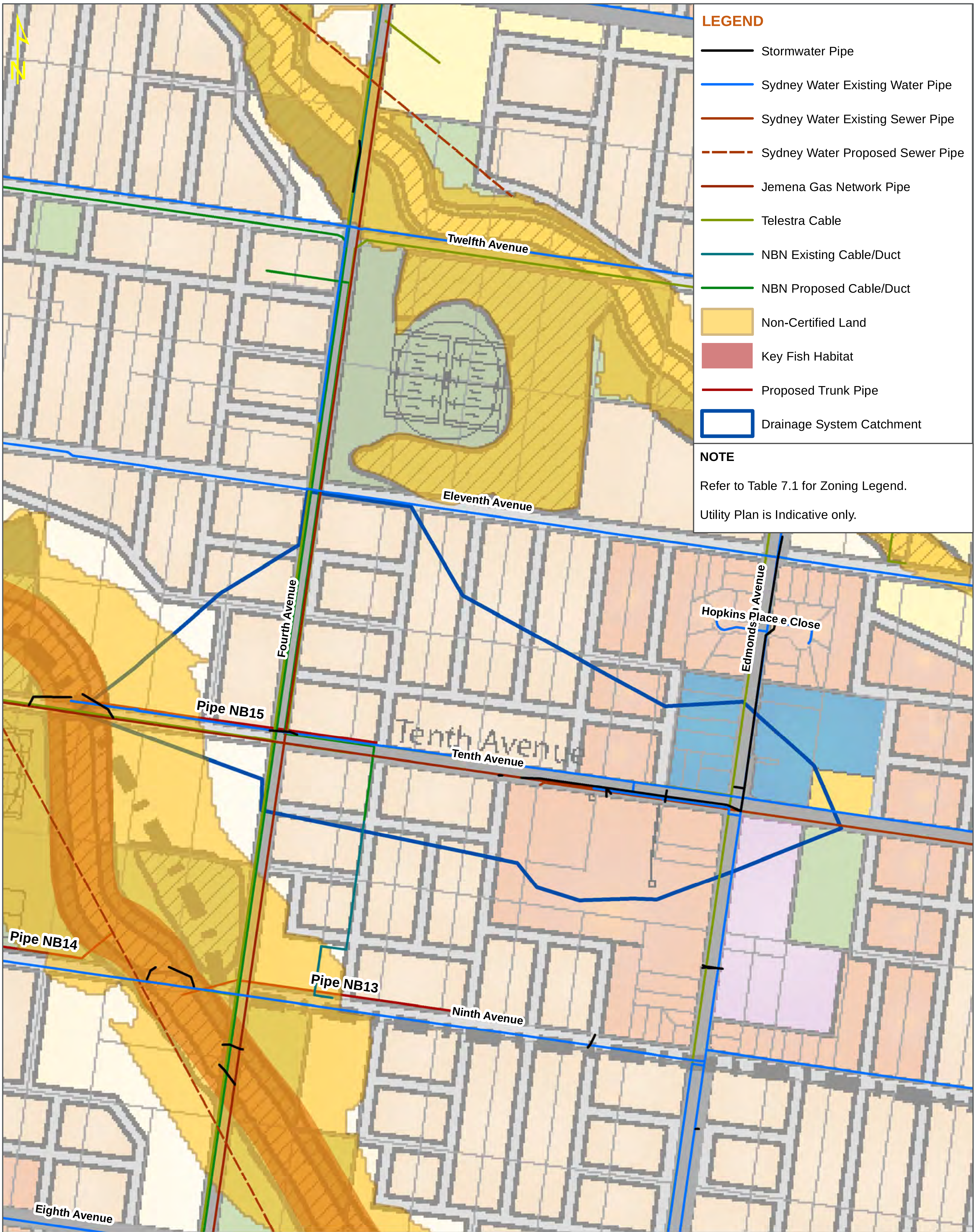
The following sections outline the specific design constraints and opportunities applicable to drainage system NB15.

Design constraints

Design constraints are listed in Table 7.43: Drainage System NB15 Design Constraints. Environmental constraints and utility constraints are shown in Figure 7.46.

Table 7.43: Drainage System NB15 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	Nearly half of the trunk pipe is within non-certified land. Trunk pipe discharges an area classified as to key fish habitat.	This issue is addressed in the REF (SMEC, 2018d) Pipe outlet to be designed as per DPI fisheries requirements during detailed design.
Utility conflicts	Refer Utility Services Investigation Report (SMEC, 2018c).	Refer Utility Services Investigation Report (SMEC, 2018c).
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018) for general geotechnical conditions relevant to project area.	



DATE 01/12/2018	0 115 230 Meters 1:4,500	PAGE SIZE A3	COORDINATE SYSTEM GDA 1994 MGA Zone 56
FIG NO. 7.46	FIGURE TITLE Environmental and Utility Constraints - Drainage System NB15		
PROJECT NO. 30011388	PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure		
CREATED BY Nilmini Pannipitiya	SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)		

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Last updated by: GC13350 on 1/12/2018 at 16:59

7.3.5. Drainage System NB33

Drainage system NB33 which is located adjacent to northern project boundary drains stormwater from a 25 ha catchment, which discharges into Tributary 3. The trunk drainage pipe (Pipe NB33) and channel (Chn NB33) included in drainage System NB33 are shown in Figure 7.47.

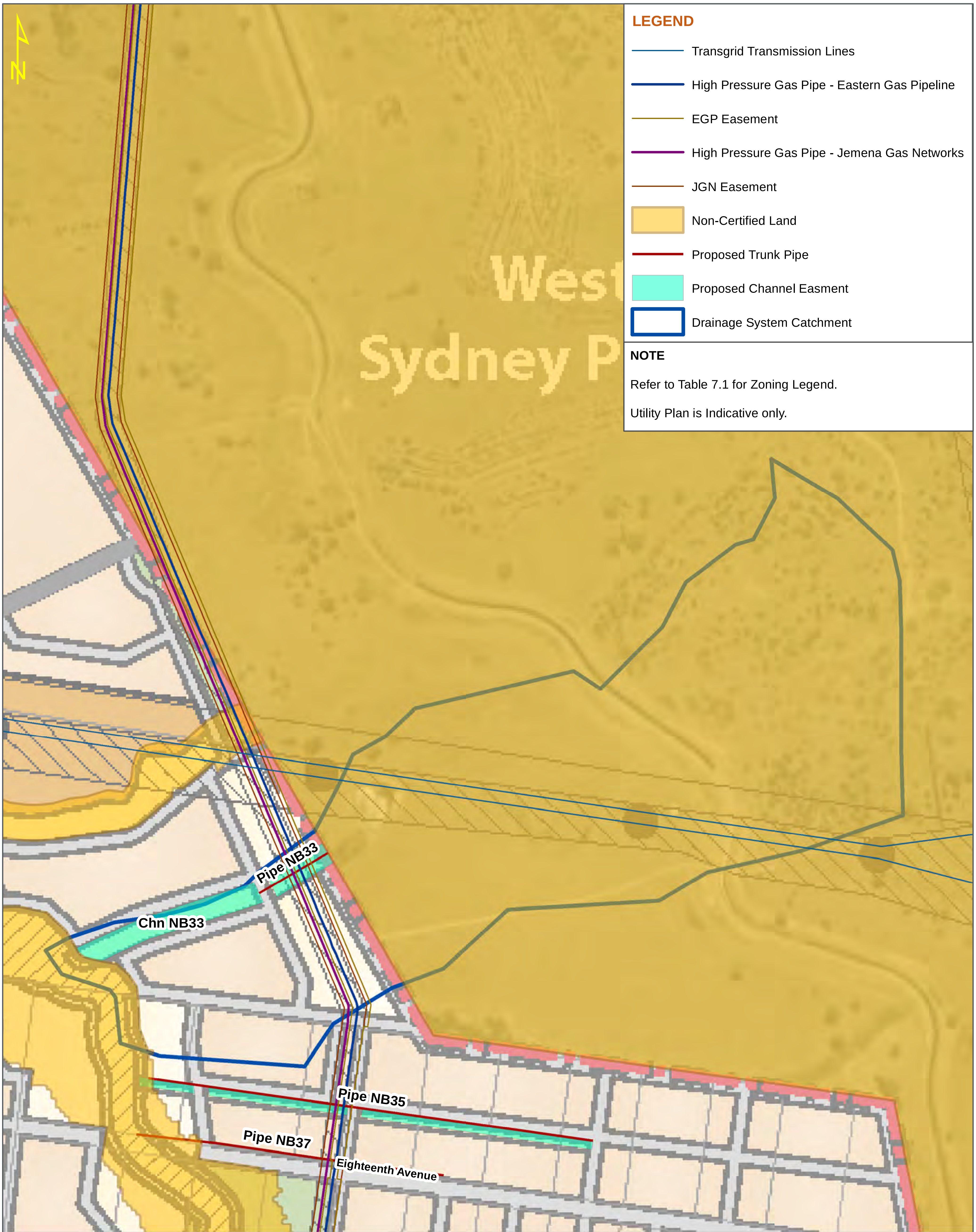
The following sections outline the specific design constraints and opportunities applicable to drainage system NB33.

Design constraints

Design constraints are listed in Table 7.44: Drainage System NB33 Design Constraints. Environmental constraints and utility constraints are shown in Figure 7.47.

Table 7.44: Drainage System NB33 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	N/A	N/A
Utility conflicts	Refer Utility Services Investigation Report (SMEC, 2018c).	Refer Utility Services Investigation Report (SMEC, 2018c).
Deviations from the preferred design parameters	**Trunk Pipe** Due to relatively flat terrain, the downstream end of the pipe has only 0.5% grade. Furthermore, the maximum available cover up to existing ground level is less than the minimum required cover.	**Trunk Pipe** Localised filling to be provided near the downstream end of the pipe to achieve at least 0.4 m cover and apply a concrete capping.
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018) for general geotechnical conditions relevant to project area.	



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PAGE SIZE A3

COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.47

FIGURE TITLE Environmental and Utility Constraints - Drainage System NB33

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

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Last updated by: GC13350 on 1/12/2018 at 17:02

7.3.6. Drainage System NB35

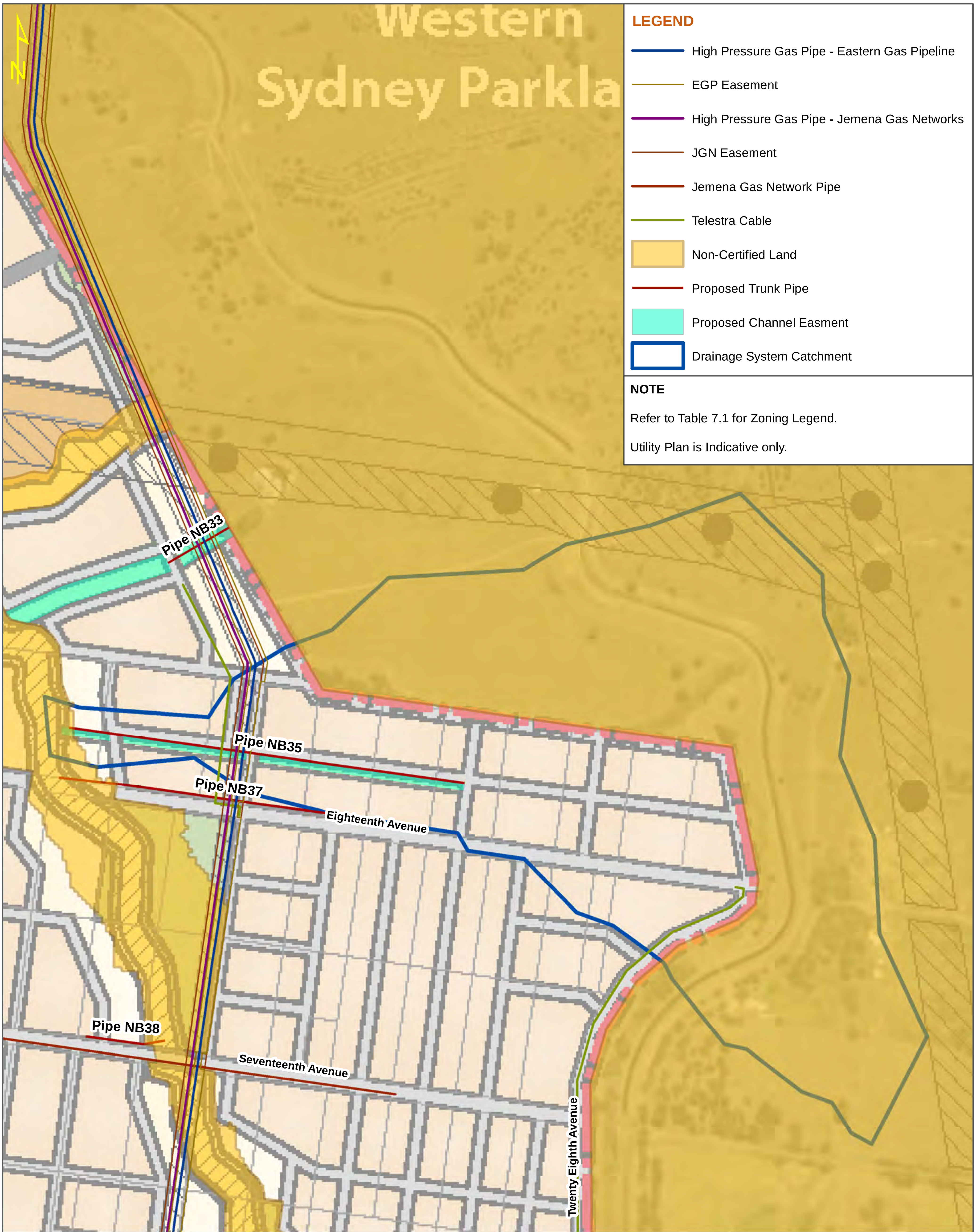
Drainage system NB35 which is located adjacent to Eighteenth Avenue drains stormwater from a 38 ha catchment, which discharges into Tributary 3. The trunk drainage channel included in drainage System NB35 is shown in Figure 7.48.

Design constraints

Design constraints are listed in Table 7.45: Drainage System NB35 Design Constraints. Environmental constraints and utility constraints are shown in Figure 7.48.

Table 7.45: Drainage System NB35 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	Downstream end of the trunk pipe is within the non-certified land.	This issue is addressed in the REF (SMEC, 2018d).
Utility conflicts	Refer Utility Services Investigation Report (SMEC, 2018c).	Refer Utility Services Investigation Report (SMEC, 2018c).
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018) for general geotechnical conditions relevant to project area.	



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PAGE SIZE A3

COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 7.48

FIGURE TITLE Environmental and Utility Constraints - Drainage System NB35

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

Location: I:\projects\30011388 - Austral Leppington North Liverpool City Council\009 Deliverables\001 Stormwater Trunk Infrastucture\006 GIS\map\ArcMap for Report\SMEC_A3_LCC_MAP_CONST_NoBASIN_Sub35.mxd

Last updated by: GC13350 on 1/12/2018 at 17:09

7.3.7. Drainage System NB37

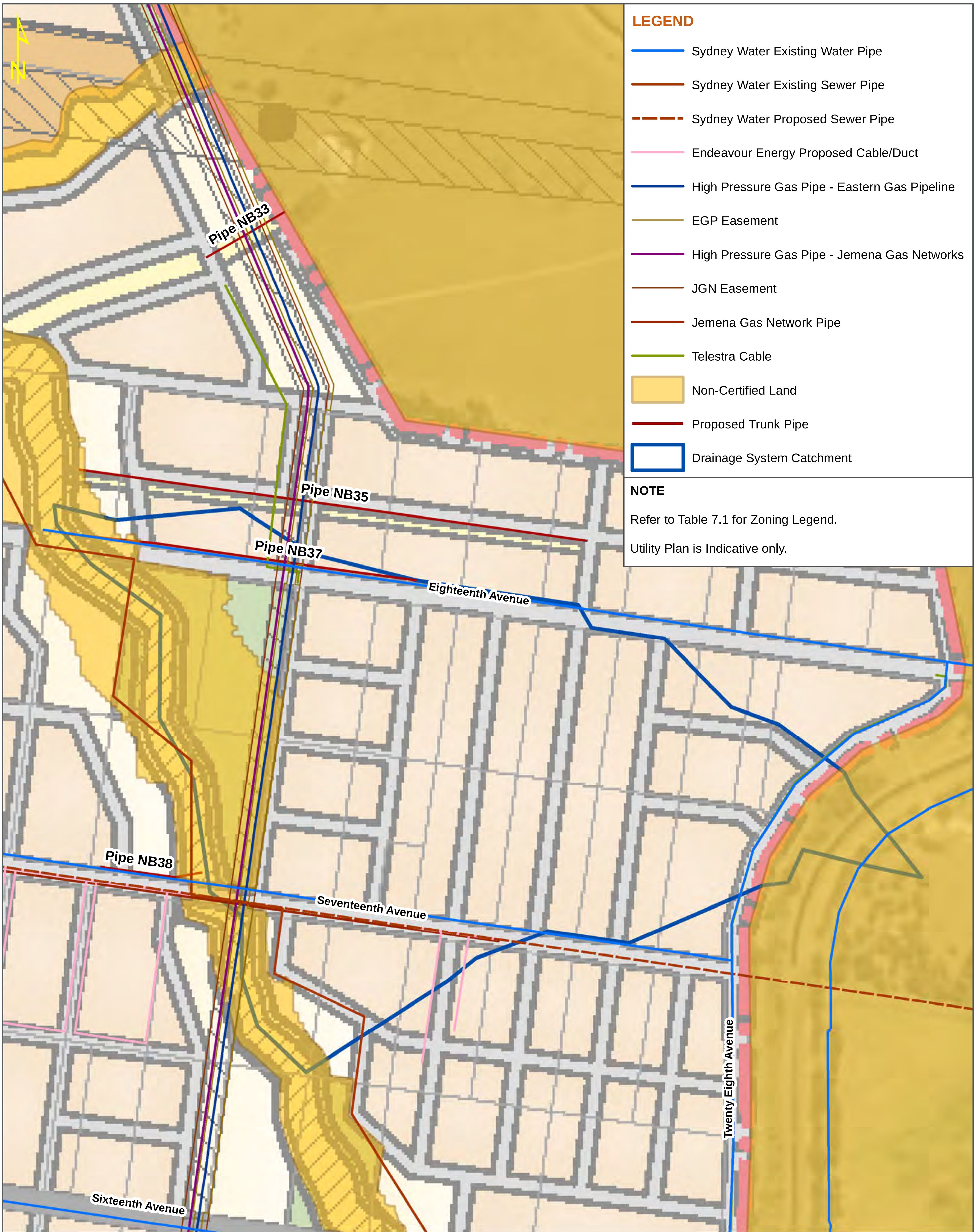
Drainage system NB37 which is located adjacent to northeastern project boundary drains stormwater from a 23 ha catchment, which discharges into Tributary 3. The trunk drainage channel included in drainage System NB37 is shown in Figure 7.49.

Design constraints

Design constraints are listed in Table 7.46: Drainage System NB37 Design Constraints. Environmental constraints and utility constraints are shown in Figure 7.49.

Table 7.46: Drainage System NB37 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	Downstream end of the trunk pipe is within the non-certified land.	This issue is addressed in the REF (SMEC, 2018d).
Utility conflicts	Refer Utility Services Investigation Report (SMEC, 2018c).	Refer Utility Services Investigation Report (SMEC, 2018c).
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018) for general geotechnical conditions relevant to project area.	



NOTE

Refer to Table 7.1 for Zoning Legend.

Utility Plan is Indicative only.

DATE 01/12/2018	Scale: 0 – 90 – 180 Meters, 1:3,500	**PAGE SIZE** A3	**COORDINATE SYSTEM** GDA 1994 MGA Zone 56
FIG NO. 7.49	**FIGURE TITLE** Environmental and Utility Constraints - Drainage System NB37		
PROJECT NO. 30011388	**PROJECT TITLE** Austral and Leppington North Design of Water Management Infrastructure		
CREATED BY Nilmini Pannipitiya	**SOURCES** Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)		

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Location: I:\projects\30011388 - Austral Leppington North Liverpool City Council\009 Deliverables\001 Stormwater Trunk Infrastucture\006 GIS\map\ArcMap for Report\SMEC_A3_LCC_MAP_CONST_NoBASIN_Sub37.mxd

Last updated by: GC13350 on 1/12/2018 at 17:07

7.3.8. Drainage System NB38

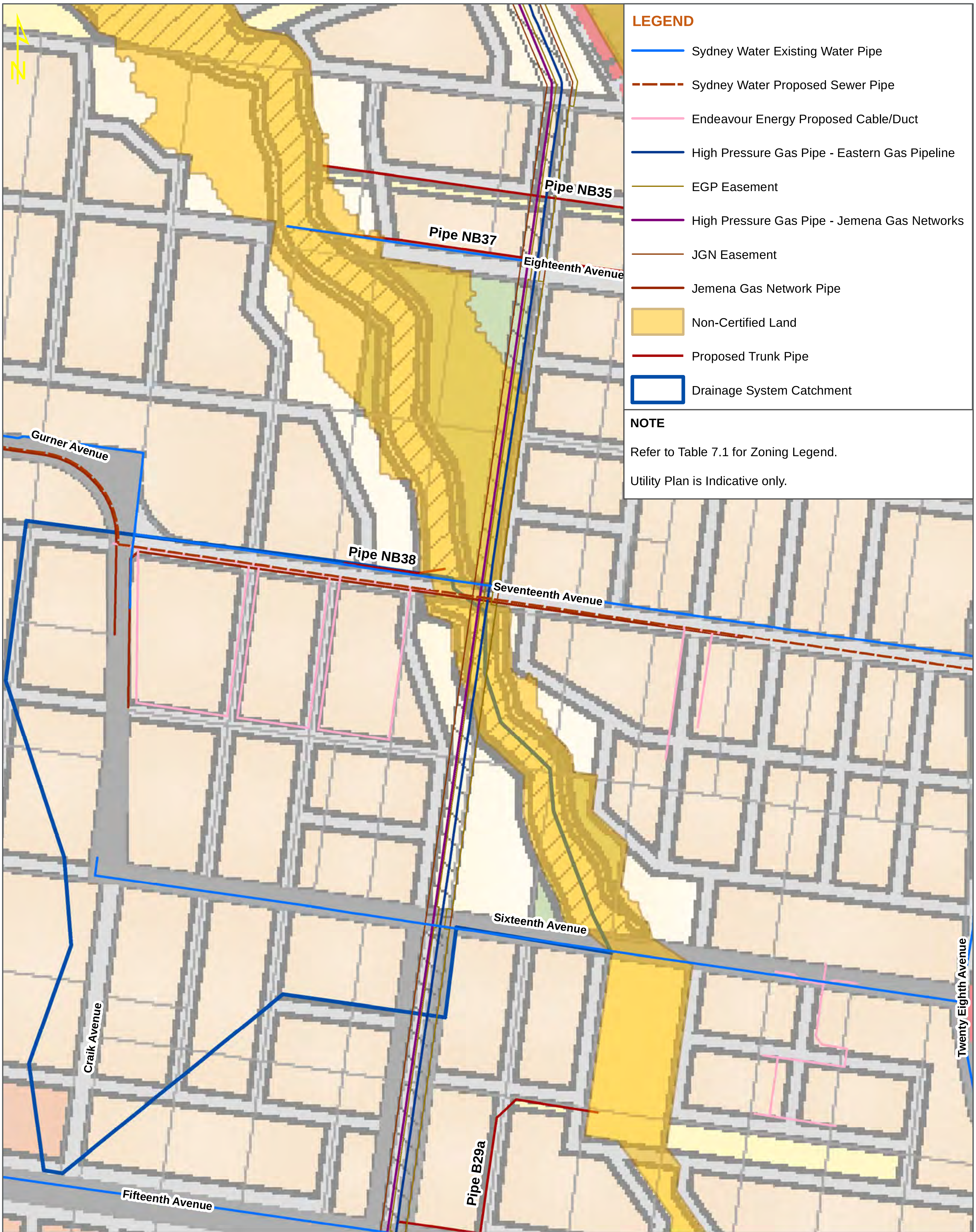
Drainage system NB38 which is located south of Seventeenth Avenue stormwater from a 23 ha catchment, which discharges into Tributary 3. The trunk drainage channel included in drainage System NB38 is shown in Figure 7.50.

Design constraints

Design constraints are listed in Table 7.47: Drainage System NB38 Design Constraints. Environmental constraints and utility constraints are shown in Figure 7.50.

Table 7.47: Drainage System NB38 Design Constraints

Constraint type	Details	Possible Resolutions
Environmental	Downstream end of the trunk pipe is within the non-certified land.	This issue is addressed in the REF (SMEC, 2018d).
Utility conflicts	Refer Utility Services Investigation Report (SMEC, 2018c).	Refer Utility Services Investigation Report (SMEC, 2018c).
Geotechnical	No site-specific constraints. Refer Geotechnical Interpretive Report (SMEC, 2018) for general geotechnical conditions relevant to project area.	



DATE 19/11/2018	0 90 180 Meters 1:3,500	**PAGE SIZE** A3	**COORDINATE SYSTEM** GDA 1994 MGA Zone 56
FIG NO. 7.50	**FIGURE TITLE** Environmental and Utility Constraints - Drainage System NB38		
PROJECT NO. 30011388	**PROJECT TITLE** Austral and Leppington North Design of Water Management Infrastructure		
CREATED BY Nilmini Pannipitiya	**SOURCES** Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)		

Location: I:\projects\30011388 - Austral Leppington North Liverpool City Council\009 Deliverables\001 Stormwater Trunk Infrastucture\006 GIS\map\ArcMap for Report\SMEC_A3_LCC_MAP_CONST_NoBASIN_Sub38.mxd

Last updated by: GC13350 on 1/12/2018 at 17:11

7.4. Streetscape Source Controls

Streetscape source controls are to be provided as the sole means of managing stormwater quality throughout the 41 drainage systems shown in Figure 7.42 as well as the drainage Systems with basins that cannot accommodate a co-located biofilter (i.e. drainage systems B5, B21, B22 and B23). Additionally, streetscape controls are to be provided as supplementary treatment in drainage systems with basins, excluding drainage system B13 and the four drainage systems that do not have a co-located biofilter (as noted above).

The recommended streetscape source controls for the Austral and Leppington North Precincts are raingardens and tree pits. Additionally, low-flow sections of the trunk drainage channels could also be utilised as swales. The following section summarises the minimum specifications and design requirements for the recommended streetscape source controls.

For drainage systems with biofilters (co-located within detention basins) the required raingarden area has been defined as a percentage of total catchment. Whereas for drainage systems without co-located biofilters, a minimum footprint area, based on land use and development area, has been developed.

7.4.1. Minimum Specifications and Design Requirements

Raingardens or streetscape biofilters shall comply with the following minimum specifications and current best practice guidelines:

- Minimum extended detention depth of 100 mm;
- Maximum extended detention depth of 300 mm;
- Minimum filter media depth of 0.6 metre;
- Vegetation shall be selected from the VMP (see section 8) and shall be of a height suitable for sight lines and traffic calming, fully integrated into the streetscape;
- Filter media composition in accordance with the current Biofilter Adoption Guidelines (Payne, et al., 2015);
- Saturated hydraulic conductivity shall be 50 to 200 mm/hr;
- To be fully lined; and,
- Overflows shall be directed to the local drainage system.

A typical streetscape raingarden design is shown in Figure 7.51. Council envisage implementing raingardens at 4-way intersections and it is estimated that a 252 m^2 raingarden footprint could be fitted in a 4-way intersection. However, the final design will be very site-specific depending on flow paths, gutter flows, catchment areas and local drainage system details.

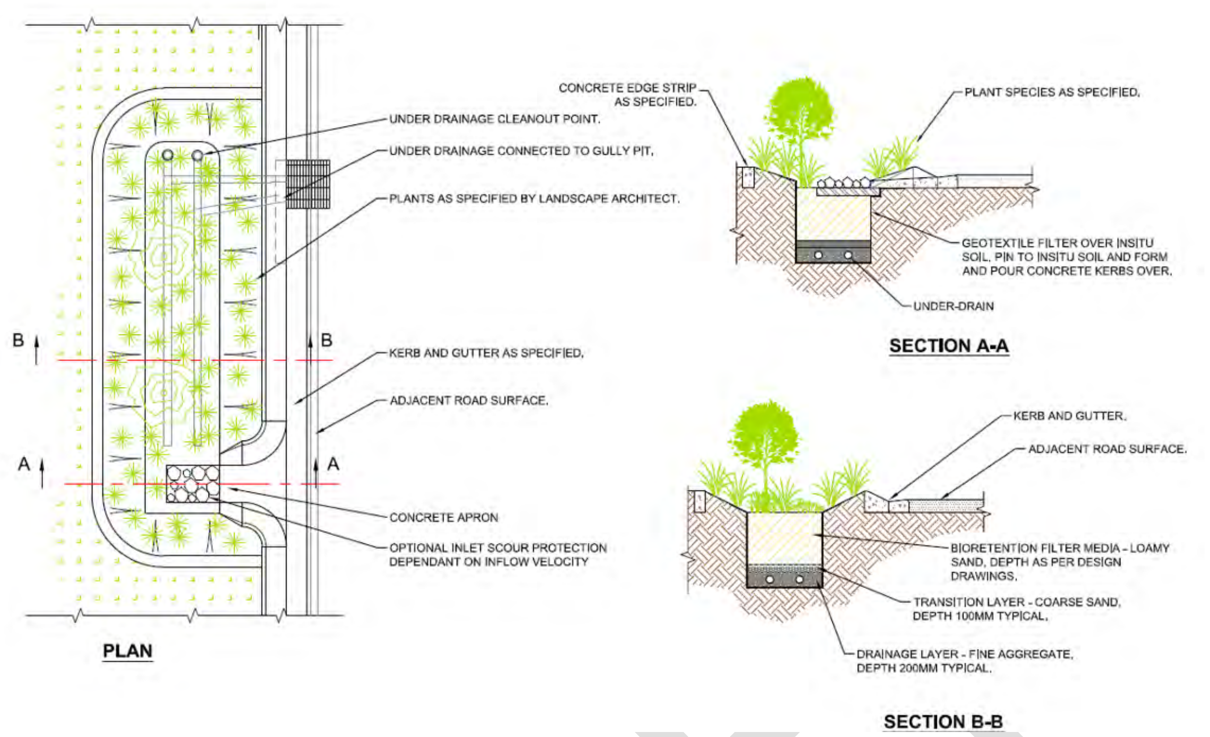


Figure 7.51: Typical Raingarden Details. Adopted from Moreton Bay Regional Council WSUD Drawings (MBRC, 2013)

Where insufficient treatment is provided using intersection raingarden systems, tree pits will be required to ensure the water quality objectives are met. A typical tree pit design is shown in Figure 7.52.

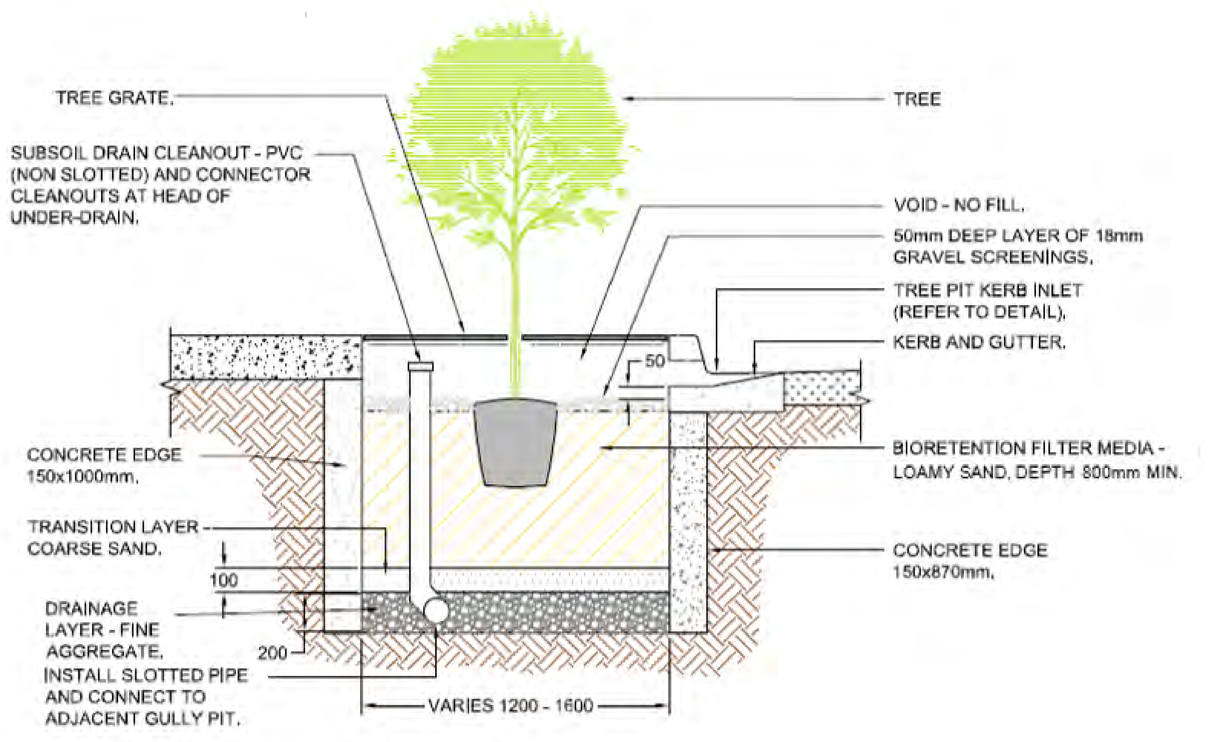


Figure 7.52: Typical Tree pit Bioretention Details. Adopted from Moreton Bay Regional Council WSUD Drawings (MBRC, 2013)

The tree pits shall comply with the following minimum specifications and current best practice guidelines:

- Maximum extended detention depth of 100 mm;
- Minimum filter depth of 0.8 metre;
- A tree shall be selected with moderate to high water needs to be planted within the pit in accordance with Councils tree planting policy;
- Filter composition in accordance with the current Biofilter Adoption Guidelines (Payne, et al., 2015);
- Saturated hydraulic conductivity shall be 50 to 200 mm/hr;
- To be fully lined;
- Subsoil drainage shall be provided with a cleanout inspection opening;
- Overflows shall be directed to the local drainage system; and,
- Shall be constructed upstream of the local drainage inlet pits.

The biofiltration systems (raingardens and tree pits) shall not be operational until more than 85% of the contributing catchment is fully developed and soils are stabilised.

Catchments with Streetscape Raingardens only

Table 7.48 summarises the minimum streetscape raingarden footprint areas to meet the required water quality targets in each drainage systems without co-located biofilters. This is specified on a per hectare basis for the development area.

Table 7.48: Minimum Raingarden Footprint per Hectare by Land Use in Drainage Systems without Co-located biofilters

Land use	Overall Imperviousness	Minimum Raingarden Footprint[1]
Residential[2]	85%	120 m^2/ha
Commercial	100%	150 m^2/ha
Industrial	90%	155 m^2/ha

Notes:

1. It is assumed that an equivalent minimum rainwater tank capacity of 45 kL per hectare is provided (i.e. 3000 L rainwater tank per lot for a development density of 15 lots per hectare).
2. It is assumed that additional pre-treatment will be provided by buffer strips such as residential lawns/front nature strips. If additional pre-treatment provided by buffer strips are not considered a minimum raingarden footprint area of 145 m2/ha

Catchments with Co-located Biofilters and Supplementary Raingardens

A preliminary estimate of the required streetscape raingarden footprint areas required for drainage systems with basins are shown on the Concept Design Drawings (See Appendix B and Appendix C). It should be noted that these areas were derived from system-scale MSUIC modelling without taking into account the impact of distributed raingardens throughout the catchment. A subsequent comparison of the detailed vs system-scale MUSIC model developed for Drainage System NB37, revealed that the system-scale MUSIC model raingarden footprint area is smaller than that of the distributed model.

Since it is not possible to develop a detailed MUSIC model for each drainage system during the concept design stage (no data on minor drainage systems and final urban form), a simplified approach was adopted to estimate the required supplementary streetscape controls in drainage systems with co-located biofilters. It was from the MUSIC modelling that estimated a total biofilter footprint area (both co-located biofilters and streetscape raingardens) of 1.5% of the contributing catchment area is required to meet the required water quality targets. The current estimate is in accordance with Council WSUD guidelines, which specifies that the stormwater bioretention systems are to be approximately 1 -2.5% of the contributing catchment area. Furthermore, the current best practice guidelines (Payne, et al., 2015; LANDCOM, 2009) also recommend similar biofilter area to catchment ratios.

The co-located biofilter footprint area was subtracted from the estimated 1.5% of the total catchment area to obtain the estimated supplementary streetscape biofilter area. The streetscape raingarden footprint area was expressed as a percentage of the total catchment. Even though there were some slight variations among different drainage systems, it was observed that the required supplementary raingarden footprint is, on average, 1% of the contributing catchment area. The only exception to the above estimate was the Drainage System B11, which only requires a supplementary raingarden to be sized to 0.5% of the drainage system catchment area.

7.4.2. Development Control Plan Inclusion

It is recommended that the streetscape controls and lot-scale controls discussed in this chapter are included in the DCP for the Austral Leppington development. This section provides guidance and details that can be included in the DCP. The recommended text is linked to the existing DCP - Liverpool Growth Centre Precinct Development Control Plan (2016). In particular, the recommendation for the inclusions in the DCP (Department of Planning and Environment, 2016) are:

- Section 2.3.2 Water Cycle Management, item 5 on page 20
- Section 3.3.1 Street Network Layout and Design, item 14 on page 56
- Section 5.3.2 Solar Access, Weather Protection and Energy Efficiencies, item 14 on page 131
- Section 6.5 Ecological Development, page 153
- Section 6.3.1 Streetscape and Allotment Frontages.

Water cycle management

In Section 2.3.2 Water Cycle management item 5 should be replaced with:

5. The development requires the construction of water quality treatment infrastructure. The infrastructure is to be constructed in accordance with the guidelines below and Council's Engineering Specification. The applicant must demonstrate that the proposed infrastructure will achieve the water quality targets in Table 2-1 unless the following measures are implemented in the developed area.

5.1 Catchment scale controls are to be provided in the stormwater detention basins in accordance with the detailed design for the proposed development in areas classified as 'Co-located biofilters only' and 'Co-located biofilters and streetscape control', as shown in Figure 2-1.

5.2 In addition to the catchment-scale controls specified in 5.1, a streetscape bioretention (raingardens and tree pits) footprint area equivalent to 1% to the development area is to be provided in areas classified as 'Co-located biofilters and streetscape' in Figure 2-1.

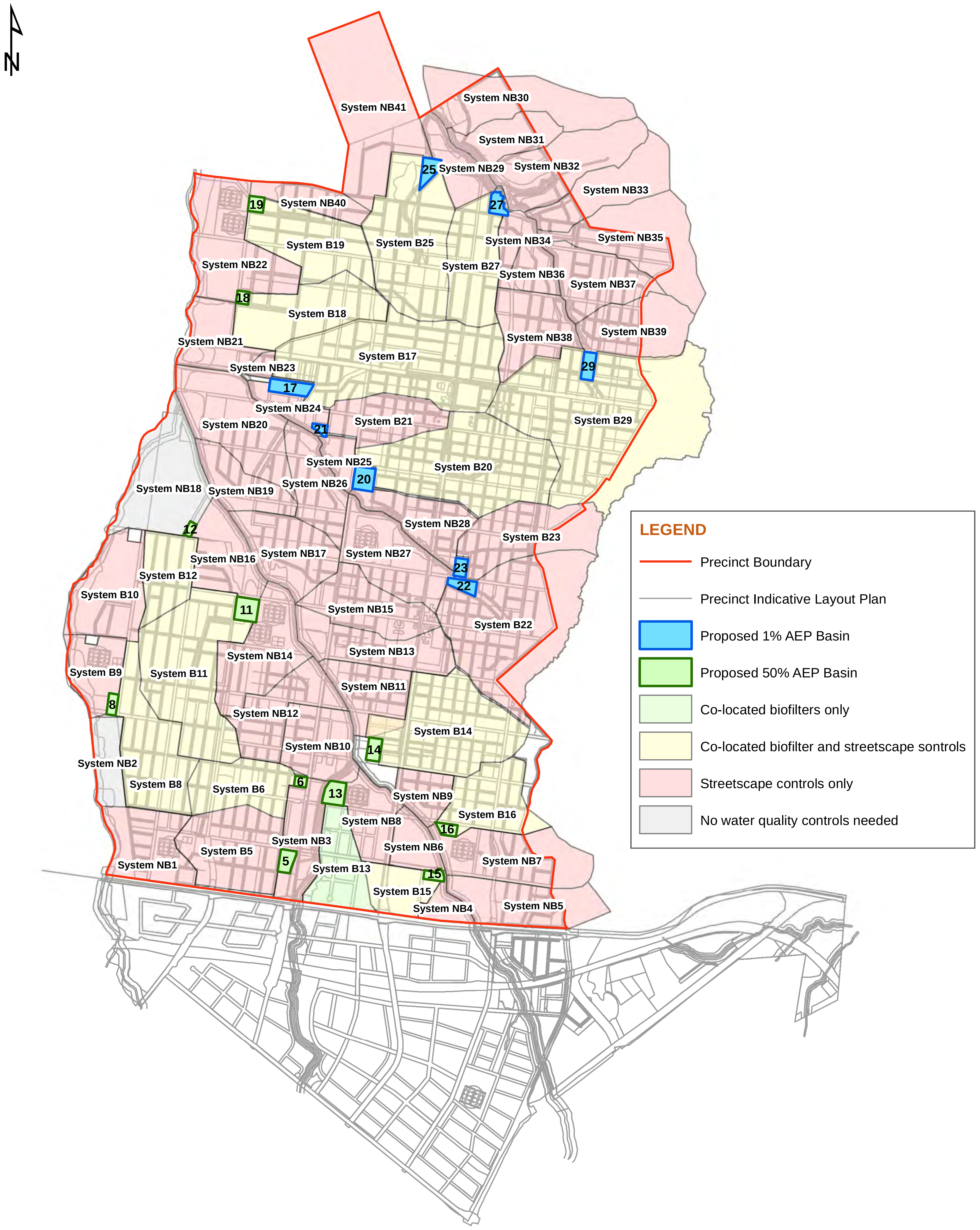
5.3 For all other development areas within the Austral and Leppington precincts (see 'Streetscape only' in Figure 2-1) streetscape controls (raingardens and tree pits) are to be provided as detailed in Table 2-2.

Table 2-2: Minimum Raingarden Footprint per Hectare by Land Use in 'Streetscape only' Areas

Land use	Overall Imperviousness	Minimum Raingarden Footprint[1]
Residential[2]	85%	120 m^2/ha
Commercial	100%	150 m^2/ha
Industrial	90%	155 m^2/ha

Notes:

1. An equivalent minimum rainwater tank capacity of 45 kL per hectare to be provided (i.e. 3000 L rainwater tank per lot for a development density of 15 lots per hectare) as per Section 5.3.2.
2. Additional pre-treatment is to be provided by buffer strips such as residential lawns/front nature strips. If no additional pre-treatment is provided by buffer strips, a minimum raingarden footprint area of 145 m^2/ha should be provided.



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COORDINATE SYSTEM GDA 1994 MGA Zone 56

FIG NO. 2 - 1

FIGURE TITLE Proposed Water Quality Control Strategy for the Austral and Lepptington North Precincts (North of Bringelly Road)

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

Streetscape intersection source controls

In Section 3.3.1 Street Network Layout and Design item 14 should be replaced with the following:

14. Except where otherwise provided for in this DCP, all streets and roundabouts are to be designed and constructed in accordance with the minimum requirements set out in Council's Engineering Specifications and where possible will include bioretention systems. For example, the 4-way intersections will include a minimum of 252 m^2 of bioretention systems to meet the water quality objectives for the catchment. The bioretention systems shall be designed in accordance with the following specification.

Bioretention systems or raingardens are to be constructed as part of traffic calming and streetscape controls at intersections. The systems will be designed with the above minimum specifications and current best practice guidelines as follows:

- Minimum extended detention depth of 100 mm
- Maximum extended detention depth of 300 mm
- Minimum filter media depth of 0.6 metre
- Vegetation shall be selected from the VMP (see section 8.2) and shall be of a height suitable for sight lines and traffic calming, fully integrated into the streetscape
- Filter composition and saturated hydraulic conductivity in accordance with the current Biofilter Adoption Guidelines (Payne, et al., 2015)
- Saturated hydraulic conductivity shall be 50 to 200 mm/hr
- To be fully lined
- Overflows shall be directed to the local drainage system

Biofiltration systems will not be operational until more than 85% of the contributing catchment is fully developed and soils are stabilised.

Where insufficient treatment is provided using intersection bioretention systems, tree pits will be required to ensure the water quality objectives in Table 2-1 are met. The tree pits shall comply with the following:

- Maximum extended detention depth of 100 mm
- Minimum filter depth of 0.8 metre
- A tree shall be selected with moderate to high water needs to be planted within the pit in accordance with Councils tree planting policy
- Filter composition in accordance with the current Biofilter Adoption Guidelines (Payne, et al., 2015)
- Saturated hydraulic conductivity shall be 50 to 200 mm/hr
- To be fully lined
- Subsoil drainage shall be provided with a cleanout inspection opening
- Overflows shall be directed to the local drainage system
- To be constructed upstream of the local drainage inlet pits

Tree pits will not be operational until more than 85% of the contributing catchment is fully developed and soils are stabilised.

In addition, the following items should be added:

- The subdivision is required to meet the water quality targets in Table 2-1 using intersection street scape controls and lot scale rainwater harvesting. Where this is insufficient, street tree retention pits are required to provide the additional treatment and be designed in accordance with the specifications.

Lot scale source controls

In Section 5.3.2 Solar Access, Weather Protection and Energy Efficiencies on page 132, item 14 should include:

14. Rainwater collected from roof areas is to be used for non-potable uses including toilet flushing, laundries and cleaning.

In addition, for residential developments the following should be added:

Rainwater tanks are to be provided for residential lots as follows:

- a minimum of 3kL tank per lot, or
- other such mechanisms as will achieve a 40% reduction in potable water use, as agreed to by Council.

Ecological Sustainable Development for Employment Lands and Subdivisions

In section 6.5 Ecological Development on page 153, the following text should be amended.

1. Development Applications are required to demonstrate consideration of:
   - implementing total water cycle management by including measures that reduce consumption of potable water for non-potable uses, minimise site run-off and promote water harvesting and re-use. The harvesting for non-potable uses is required to have a minimum storage volume of 3 kL.

Streetscape and Allotment Frontages

Finally, section 6.3.1 Streetscape and Allotment Frontages should include:

- Except where otherwise provided for in this DCP, all streets and roundabouts are to be designed and constructed in accordance with the minimum requirements set out in Council's Engineering Specifications and where possible will include bioretention systems. For example, the 4-way intersection will include a minimum of 252 m^2 of bioretention systems to meet the water quality objectives for the catchment. The bioretention systems shall be designed in accordance with the following specification:
  - Minimum extended detention depth of 100 mm;
  - Maximum extended detention depth of 300 mm;
  - Minimum filter media depth of 0.6 metre;
  - Vegetation shall be selected from the VMP (see section 8) and shall be of a height suitable for sight lines and traffic calming, fully integrated into the streetscape;
  - Filter composition in accordance with the current Biofilter Adoption Guidelines (Payne, et al., 2015);
  - Saturated hydraulic conductivity shall be 50 to 200 mm/hr;
  - Shall be fully lined;
  - Overflows shall be directed to the local drainage system; and,

  Biofiltration systems will not be operational until more than 85% of the contributing catchment is fully developed and soils are stabilised.

7.4.3. Section 94 Modifications

The section 94 Contribution Plan was reviewed in relation to the removal of the end of pipe bio-filtration systems in the non-basin catchments. It was found that Section 4.4 will require revision and update to reflect the changes in the modelling and basin design. In addition, the costing was examined in Section 5 Work Schedules and Map. The following changes are required:

- Basin 9 (B9) and Basin 10 (B10) acquisition cost will need to be removed from page 67;
- Basin 9 (B9) and Basin 10 (B10) construction cost will need to be removed from page 67;
- Channels (DC2, DC4, DC5, DC13, DC16A, DC34, DC36, DC38, DC29a, DC49, DC68 and DC69) have been changed to a trunk drainage pipe and costs will need to be revised on page 68. Indicative costing is included in the cost estimates (see Section 9);
- Channel DC10 and DC 11 acquisition cost will need to be removed from page 66;
- Channel DC10 and DC11 construction cost will need to be removed from page 68;
- The footprint area no longer required for the above channels can be allocated for source control as per Section 7.4.2; and,
- Remove the bioretention facilities for catchment not draining to basins cost from page 69 onwards.

7.5. Creek culverts

There are 29 existing culverts along the creeks within the project area. Based on the discussions with Council and a review of the ILP and the proposed amendments to the ILP road layout (received from Council on 8 February 2018), 14 existing culverts were removed from the concept design scope. Table 7.49 provides the justification for the proposed culvert removal at each location.

In addition, the redesign of six existing culverts was reported in Sections 7.1 and 7.2 as they are located within the drainage systems with either 1% or 50% AEP basins. Therefore, the following culverts are no longer classified as creek culverts:

- UT_Edmondson along unnamed tributary at Edmondson Avenue within Drainage System B14
- UT_Edmon2 along unnamed tributary at Edmondson Avenue within Drainage System B14
- KC13 along Unnamed Tributary at Thirteenth Avenue within Drainage System B17
- K_11thE Tributary 2 at Eleventh Avenue within Drainage System B22
- K_15thEN along Tributary 3 at Fifteenth Avenue within Drainage System B29
- K_16thEN along Tributary 3 at Fifteenth Avenue within Drainage System B29

In summary, nine existing culverts were redesigned and an additional three new culverts were proposed based on the ILP. The 12 creek culvert locations are shown on Figure 7.53 and summarized in Table 7.50. The Concept Design Drawings of the creek culverts are included in Appendix E.

Deviations from the preferred culvert design parameters and identified environmental constraints for each creek culvert are summarised in Table 7.50. Refer to Utility Services Investigation Report (SMEC, 2018) for utility constraints identified for all creek culverts.

Table 7.49: Review of proposed culvert removal along creeks

Proposed Culvert Removal		SMEC Review/Response
Culvert ID	Location	
SurvBrd	Fifth Avenue – Bonds Creek[1]	Culvert to be removed as there is no road crossing shown in the ILP.
SurP1	Twelfth Avenue – Tributary 2 [1]	Culvert to be removed as there is no road crossing shown in the ILP.
KC14	Fourteenth Avenue – Tributary 3	The existing culvert crossing (KC14) at Fourteenth Avenue and Tributary 3 is no longer needed as there is no overland flow path shown in ILP. Therefore, this culvert was removed from the analysis.
UT_Fourth1	Fourth Avenue – unnamed tributary	There is no overland flow path shown in the ILP at this location. Therefore, the culvert is removed.
UT_Fourth2	Fourth Avenue – unnamed tributary	There is no overland flow path shown in the ILP at this location. Therefore, the culvert is removed.
K_10thE	Tenth Avenue – Tributary 2	There is no overland flow path shown in the ILP at this location. Therefore, the culvert is removed.

Proposed Culvert Removal		SMEC Review/Response
Culvert ID	Location	
B_Ninth	Ninth Avenue – Bonds Creek	There is no road crossing shown in the ILP at this location. Therefore, the culvert is removed.
K_18thEN	Eighteenth Avenue – Tributary 3	There is no road crossing shown in the ILP at this location. Therefore, the culvert is removed.
K_TwevthE	Twelfth Avenue – Kemps Creek	There is no road crossing shown in the ILP at this location. Therefore, the culvert is removed.
K_15th	Fifteenth Avenue – Kemps Creek	Potential bridge site. Therefore, out of project scope.
K_Gurner	Gurner Avenue – Kemps Creek	Potential bridge site. Therefore, out of project scope.
K_ED13th	Thirteenth Avenue – unnamed tributary	This culvert was replaced with Trunk pipe B20.
UT_Tenth	Tenth Avenue – unnamed tributary	This culvert was replaced with Trunk pipe B11.
B_Edmon2	Edmondson Avenue – Bonds Creek	This culvert is no longer needed as it is included in the redesign of creek culvert "B_Edmon1".

Note:

1. Locations confirmed by Council on 15 March 2018
2. Culvert Fifth_AV1 (Fifth Avenue – Scalabrini Creek) was originally identified by Council for removal. However, there is a road crossing at this particular location as per the current ILP. Furthermore, no road closures are indicated in the proposed amendments to the ILP road layout. Therefore, the existing culvert was included in the concept design.

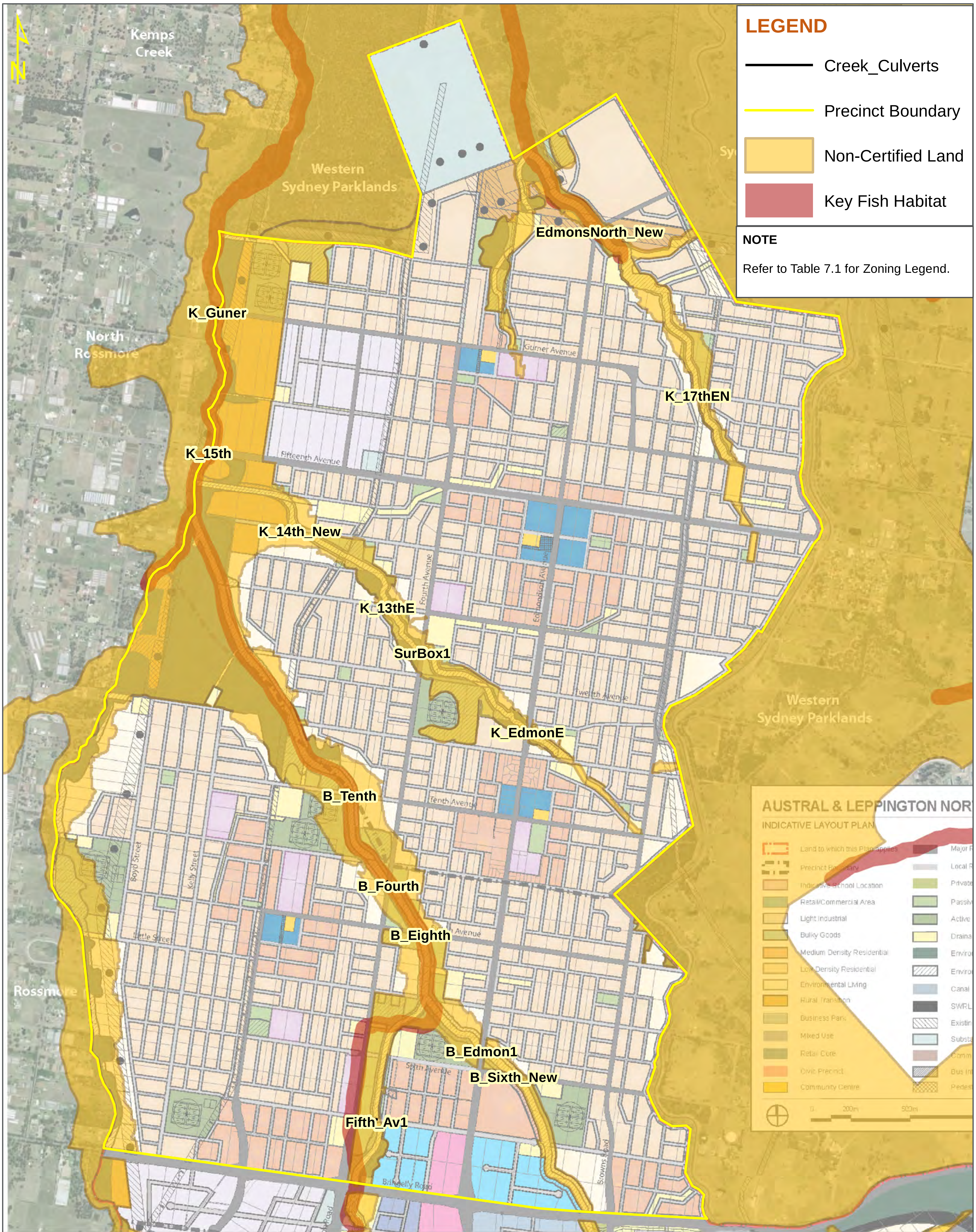

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FIG NO. 7.53	**FIGURE TITLE** Creek Culverts		
PROJECT NO. 30011388	**PROJECT TITLE** Austral and Leppington North Design of Water Management Infrastructure		
CREATED BY Nilmini Pannipitiya	**SOURCES** Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)		

SMEC Member of the Surbana Jurong Group

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Location: I:\projects\30011388 - Austral Leppington North Liverpool City Council\009 Deliverables\001 Stormwater Trunk Infrastucture\006 GIS\map\ArcMap for Report\SMEC_A3_LCC_MAP_CreekCulverts.mxd

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Table 7.50: Creek Culverts and Design Constraints

Creek Culvert ID	Creek	Road Crossing	Culvert Type	Deviation from the preferred design parameters and resolutions	Environmental Constraints and resolutions
B_Sixth_New	Bonds creek	Sixth Avenue	Proposed/New	The culvert was at 0.3% grade based on existing survey. This could be improved during detailed design by investigating opportunities to lowering the culvert outlet.	• Non-certified land This issue is addressed in the REF (SMEC, 2018d).
B_Edmon1	Bonds Creek	Edmondson Avenue	Existing culvert redesign	The culvert was at 0.17% grade based on existing survey. This could be improved during detailed design by investigating opportunities to adjust creek bed levels. There is not sufficient cover. Consider alternative solutions such as adjust creek bed levels, locally raise road crest levels or concrete cap.	N/A
B_Eighth	Bonds creek	Eighth Avenue	Existing culvert redesign	The culvert was at 0.12% grade based on existing survey. This could be improved during detailed design by investigating opportunities to adjust creek bed levels.	• Non-certified land This issue is addressed in the REF (SMEC, 2018d). • Key fish habitat Culvert was designed as per DPI fisheries requirements.
B_Fourth	Bonds creek	Fourth Avenue	Existing culvert redesign	N/A	• Non-certified land This issue is addressed in the REF (SMEC, 2018d). • Key fish habitat

Creek Culvert ID	Creek	Road Crossing	Culvert Type	Deviation from the preferred design parameters and resolutions	Environmental Constraints and resolutions
					Culvert was designed as per DPI fisheries requirements.
B_Tenth	Bonds creek	Tenth Avenue	Existing culvert redesign	There is not sufficient cover. Consider alternative solutions such as adjust creek bed levels, locally raise road crest levels or concrete cap.	• Non-certified land This issue is addressed in the REF (SMEC, 2018d). • Key fish habitat Culvert was designed as per DPI fisheries requirements.
Fifth_Av1	Scalabrini creek	Fifth Avenue	Existing culvert redesign	N/A	• Non-certified land This issue is addressed in the REF (SMEC, 2018d). • Key fish habitat Culvert was designed as per DPI fisheries requirements.
K_13thE	Tributary 2	Thirteenth Avenue	Existing culvert redesign	There is not sufficient cover. Consider alternative solutions such as adjust creek bed levels, locally raise road crest levels or concrete cap.	• Non-certified land This issue is addressed in the REF (SMEC, 2018d).
K_14th_New	Tributary 2	Fourteenth Avenue	Proposed/New	There is not sufficient cover. Consider alternative solutions such as adjust creek bed levels, locally raise road crest levels or concrete cap.	• Non-certified land This issue is addressed in the REF (SMEC, 2018d).
K_Edmone	Tributary 2	Edmondson Avenue	Existing culvert redesign	There is not sufficient cover. Consider alternative solutions such as adjust creek	• Non-certified land

Creek Culvert ID	Creek	Road Crossing	Culvert Type	Deviation from the preferred design parameters and resolutions	Environmental Constraints and resolutions
				bed levels, locally raise road crest levels or concrete cap.	This issue is addressed in the REF (SMEC, 2018d).
Surbox1	Tributary 2	Fourth Avenue	Existing culvert redesign	N/A	• Non-certified land This issue is addressed in the REF (SMEC, 2018d).
EdmonsNorth_New	Tributary 3	future road near northern project boundary	Proposed/New	N/A	• Non-certified land This issue to be addressed in the proposed REF. • Key fish habitat Culvert was designed as per DPI fisheries requirements.
K_17thEN	Tributary 3	Seventeenth Avenue	Existing culvert redesign	N/A	• Non-certified land This issue is addressed in the REF (SMEC, 2018d).

7.6. Creek enhancement works

In order to maximise development potential, flood fringe areas within the ILP can be filled to the 1% AEP flood level, provided it is outside the 'non-certified' land. Figure 7.54 shows the extent of creek enhancement (i.e. filling) as well as where roads will need to be raised above the 1% AEP flood event.

The TUFLOW model was modified to include the proposed creek enhancement works and the raised road levels. This was an iterative process as follows:

- All urban areas (e.g., residential commercial and industrial) were initially elevated by 0.8 m above the current ground level. This was chosen as the filling was typically only occurring where 1% AEP depths were less than 0.3 m (i.e. 0.3 m of water + 0.5 m freeboard = 0.8 m). They were subsequently raised further if it was found that the water was extending across them during the 1% AEP flood. The goal was to ensure the urban areas were ultimately elevated above the 1% AEP flood level.
- Roadways were elevated to the 1% AEP flood level and were subsequently elevated further if they were found to be overtopped. In general, this was only required for roadways the immediately adjoin the creeks.

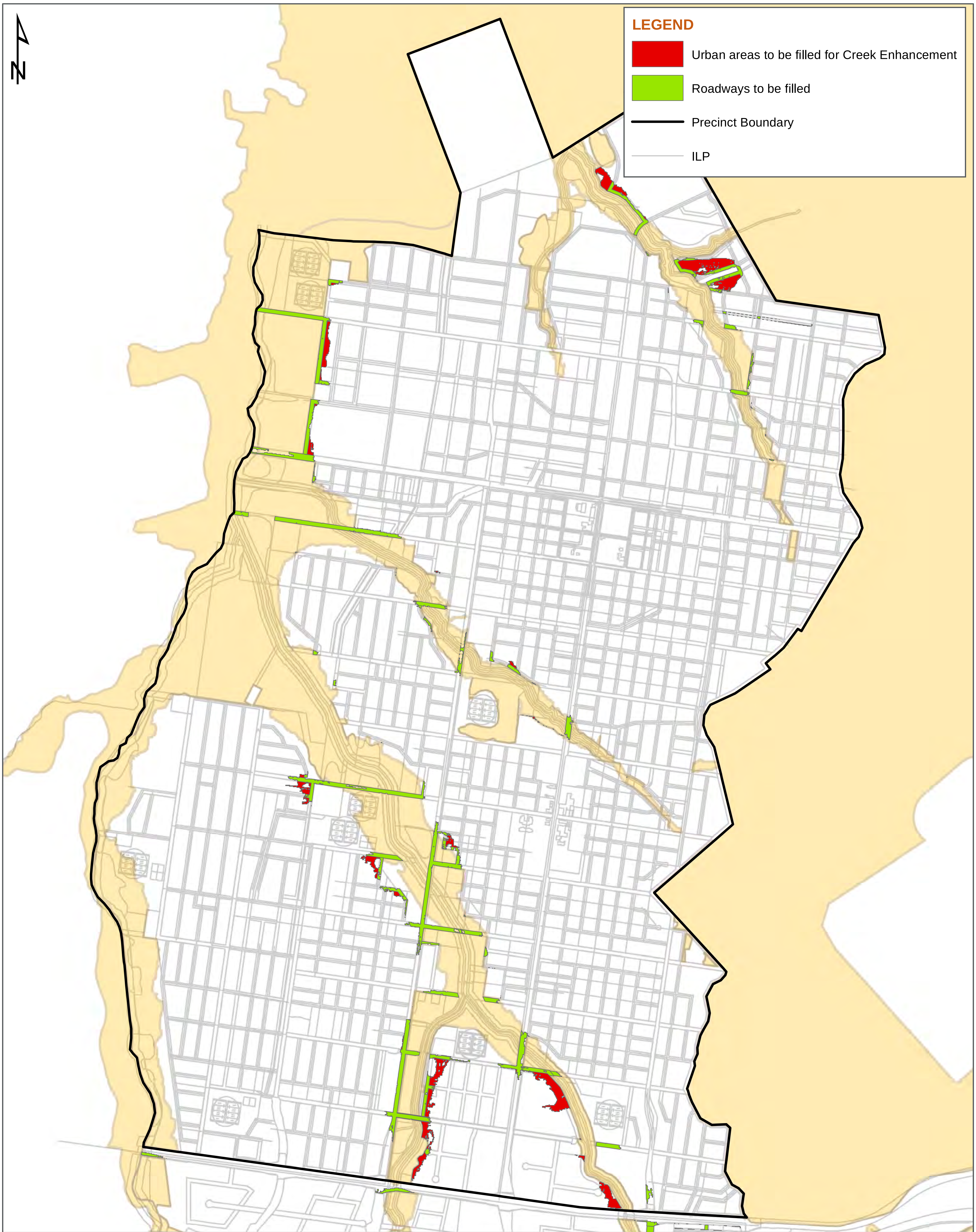

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FIG NO. 7.54

FIGURE TITLE Areas to be filled as per the Creek Enhancement Works

PROJECT NO. 30011388

PROJECT TITLE Austral and Leppington North Design of Water Management Infrastructure

CREATED BY Nilmini Pannipitiya

SOURCES Base map reference: DCP- Liverpool Growth Centre Precincts March 2013 (Austral and Leppington North - Schedule 1)

SMEC Member of the Surbana Jurong Group

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8. Vegetation Management Plan

As part of the works, it is a requirement that a VMP be prepared on a precinct-scale to facilitate a coordinated approach to land management, particularly in riparian zones. The purpose of a VMP includes:

- Establish an overarching strategy for vegetation management across the precinct;
- Inform the management of impacts on vegetation during construction activities;
- Guide revegetation and rehabilitation of riparian zones following completion of works; and,
- Coordinate management of the riparian zones and associated passive recreation zones.

The VMP included below outlines the vegetation strategy for the study area, including:

- Description of existing vegetation;
- Description of vegetation proposed, including in biofilters, wetland distribution channels and street trees; and,
- Provision of management actions and maintenance/monitoring requirements for the vegetation

8.1. Existing Vegetation

Cardno (2012a) identified three threatened ecological communities associated with the Cumberland Plain. The Cumberland Plain is characterised by the presence of low rolling hills and valleys within the rain shadow area between the Blue Mountains and the east coast of Australia.

Cumberland Plain Woodland - Shale Plains Woodland

Shale Plains Woodland is the more common form of Cumberland Plain Woodland occurring on the gently undulating Wianamatta Shale plains of the Cumberland Plain. Shale Plain Woodlands typically have Grey Box (*E. moluccana*), Forest Red Gum (*E. tereticornis*), Spotted Gum (*Corymbia maculata*) and Thin-leaved Stringybark (*E. eugenioides*) in the overstorey. The shrub layer is typically dominated by Bursaria spinosa and the understorey is generally associated with grasses (*Themeda australis*, *Microlaena stipoides var. stipoides*) and herbs (*Dichondra repens*, *Brunonniella australis*, *Desmodium varians*).

Cumberland Plain Woodland - Shale Hills Woodland

Shale Hills Woodland is similar to the Shale Plains Woodland, particularly in terms of its understorey layer. The key difference between the two is the tendency for Shale Hills Woodland to be located upon elevated and sloping terrain, as opposed to the flat undulating terrain occupied by Shale Plains Woodland. The canopy layer also differs between the two with Shale Hills Woodland typically also having Narrow-leaved Ironbark (*E. crebra*).

Sydney Coastal River Flat Forest - Alluvial Woodland

This community is located along minor watercourses and terraces adjacent to riparian forests. While comprised of many species found within Cumberland Plain Woodland, Alluvial Woodland is characterised by the presence of Cabbage Gum (*E. amplifolia*), Forest Red Gum (*E. tereticornis*) and Swamp Oak (*Casuarina glauca*).

Shale-Gravel Transitional Forest

This transitional forest typically grades into Cumberland Plain woodland communities as gravel content decreases. The canopy of Shale-Gravel Transitional Forest is dominated by the Broad-leaved Ironbark

(*E. fibrosa*) and associated with the presence of Grey Box (*E. moluccana*) and Forest Red Gum (*E. tereticornis*). Paperbarks (*Melaleuca decora*) are common in the sub-canopy layer.

8.2. Proposed Vegetation

All propagated plant stock is to be from locally collected seed sources, that is, local provenance. Vegetation works are designed to restore the natural floristics and structure of the in-situ or natural vegetation community.

Vegetation works are designed to either completely restore areas devoid of native vegetation or will enhance water management infrastructure works. Staged planting of canopy species and shrubs are to be planted initially, with the introduction of groundcovers, native grasses, herbs and climbers being deferred for twelve months. This approach allows for natural recruitment of these species. Note that poor soil conditions will inhibit natural regeneration and ground preparation may be required in combination with a direct drilling program.

A minimum of twenty-five endemic native species are to be established consisting of a broad mix of groundcover, shrub, vine, sub-canopy and canopy species. A target of 60% for native vegetation cover applies at the end of Year 1, and 90% of native vegetation cover at the end of Year 2. Native vegetation cover is to be monitored every six months. Plantings are to be replaced if more than a 10% loss of stock occurs.

A weed control program is to be implemented on an ongoing basis to harness the site's underlying potential for natural recovery. If natural regeneration is expected to be slow or non-existent, direct seeding and further revegetation works may be required by the project ecologist or Council.

All vegetation stock is to be sourced from on site or existing similar vegetation areas in close proximity to the site. This is known as local provenance collected material. The use of site-adapted local seed for propagation is best for restoring pre-existing plant communities and conserving local biodiversity. It is also more likely to lead to a successful self-perpetuating plant community, as local provenance seed is adapted to local soils, climatic conditions and ecological processes.

The following section documents the proposed vegetation for water quality control structures such as biofilters, wetland distribution channels (within detention basins) and tree pits. Separate VMPs are provided for biofilters and the wetland distribution channel. This is necessary as biofilters and distribution channels operate under different conditions, i.e. the biofilter is subjected to intermittent wetting and drying whereas the distribution channel is subjected to fluctuating water levels. The VMPs below are based on the current best practice guidelines at the time of reporting (Water by Design, 2014; 2017; Payne, et al., 2015).

8.2.1. Co-located Biofilters and streetscape raingardens (excluding Wetland Distribution Channel)

Biofilters have a dense cover of healthy, actively growing plants. The main function of vegetation is to provide physical, chemical and biological treatment. Vegetation also enhance ecological and aesthetic values.

The key plant attributes that influence pollutant uptake and long-term plant survival in bioretention systems include:

- **Root structure** – Plants with fibrous root systems are more effective in bioretention systems than those with tap root systems. A mix of shallow and deep-rooted plants will maximise the bioretention systems' capacity to remove pollutants at all depths.
- **Growth rate and plant size** – Both fast and slow growing plant species are required in bioretention systems. Fast growing plants tend to be smaller with high nutrient demands, allowing rapid establishment and pollutant uptake. They also provide full coverage of the filter

media, which is important to protect the filter media from scour and weeds. Their short growing cycles replenish organic material in the filter media. Slow growing plants are typically larger with well-developed root systems and gradually increase pollutant uptake and storage capacity.

- **Tolerance to wetting and drying cycles** – To maintain year-round vegetative cover, plants must be able to tolerate prolonged dry periods as well as periodic inundation. Semi-aquatic plant species adapted to longer periods of inundation should not be used because they are generally not suited to the dry conditions between rainfall events.

Designing a planting plan to meet these objectives requires consideration of vegetation types, planting style, species diversity, planting density, planting set-out, timing of planting, and the type of mulch to be applied. This section contains recommendations for each of these aspects.

8.2.1.1. *Species Selection and Vegetation Types*

Ground covers, shrubs and trees are to be used in biofilters with at least 50% of the biofilter plant species are to be comprised of plants that are known to be effective in pollutant removal performance. The remainder could be comprised of commercially available varieties or amenity plant species.

An extensive list of plant effective plants species is documented in:

- Blacktown Council Standard Drawings (Sheet 12: Bioretention Landscaping: Preferred Planting List) (BCC, 2017)
- Water by Design Guidelines (Table 19) (Water by Design, 2014)
- Biofilter Adoption guidelines (Table 15: Effective List) (Payne, et al., 2015)

A list of other species that may be used to enhance aesthetics and amenity value is documented in:

- Blacktown Council Standard Drawings (Sheet 12: Bioretention Landscaping: Alternative Plant List) (Blacktown City Council,
- Water by Design Guidelines (Table 20) (Water by Design, 2014)
- Biofilter Adoption guidelines (Table 15: Poor Performers List) (Payne, et al., 2015)

The plant species listed in Blacktown City Council drawings is given priority as these species were specifically chosen for Western Sydney Conditions. Council landscape strategies or plant selection guidelines are also to be considered when choosing suitable species. A combined list of core plant species are shown in Table 8.1 and alternative species are shown in Table 8.2.

Table 8.1 - Preferred Biofilter Plant Species (extracted from Water by Design (2014), Payne et al. (2015), Blacktown City Council (2017))

Species Name	Common Name	Type of Vegetation	Height (mm)	Plant Density Per Square Metre (m^2)	Planting Zone
Austrostipa stipoides[1]	N/A	Tufted perennial grass	1200	8 - 10	Biofilter
Baloskion / Restio pallens[1]	N/A	Dioecious perennial herb	1000	8 - 10	Biofilter
Banksia robur	Swamp banksia	Small tree		1 per 2 - 100 m^2	Biofilter & Batters
Baumea juncea	Bare twig-rush or tussock swamp twig rush	Groundcover		8 - 12	Biofilter
Baumea rubiginosa	Soft twig rush, flat leaf twig rush and common twig rush	Groundcover		8 - 12	Biofilter
Bolboschoenus caldwellii[1]	N/A	Rhizomatous tufted perennial	1000	8 - 10	Biofilter
Bolboschoenus fluviatilus[1]	Marsh Clubrush	Rhizomatous tufted perennial	2500	8 - 10	Biofilter
Callistemon sieberi	River bottlebrush	Shrub		1 per 2 - 20 m^2	Biofilter & Batters
Carex appressa[1,3]	Tall Sedge	Tufted short rhizomatous	1200	8 - 10	Biofilter
Carex fascicularis[1]	Tassel Sedge	Tufted rhizomatous perennial	1000	8 - 10	Biofilter
Carex tereticaulis	Rush Sedge	Groundcover		8 - 12	Biofilter
Casuarina cunninghamiana	River sheoak	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Casuarina glauca	Swamp oak	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Cyperus polystachyos[1]	N/A	Tufted perennial, short rhizome	600	8 - 10	Biofilter

Species Name	Common Name	Type of Vegetation	Height (mm)	Plant Density Per Square Metre (m^2)	Planting Zone
Daviesia ulicifolia[1]	Gorse Bitter Pea	Small shrub	2000	1 per 2 m^2	Biofilter & Batters
Dianella longifolia[1]	Blueberry Lily	Perenial rhizomatous tufted herb	1000	8 - 10	Batters & Landscape
Dianella revoluta[1]	Blue Flax-Lily	Tufted perennial herb	1000	8 - 10	Biofilter
Ficina nodosa[1,3]	Knobby Club Rush	Rhizomatous perennial	1000	8 - 10	Biofilter
Gahnia filum[1]	Chaffy Saw-sedge	Tussock forming perennial	1000	8 - 10	Biofilter
Goodenia ovata	Hop goodenia	Shrub		<1	Biofilter
Imperata cylindrica	Blady grass	Groundcover grass	500-900	6 - 8	Biofilter & Batters
Juncus amabilis	Gentle Rush	Groundcover		8 - 12	Biofilter
Juncus flavidus	Yellow Rush	Groundcover		8 - 12	Biofilter
Juncus kraussii[1]	Sea Rush	Tussock, rhizomatous perennial	1000	8 - 10	Biofilter
Juncus pallidus[1]	Pale Rush	Groundcover		8 - 10	Biofilter
Juncus subsecundus	Finger Rush	Groundcover		8 - 12	Biofilter
Juncus usitatus[1,3]	Common Rush	Tufted short rhizomatous	1000	8 - 10	Biofilter
Lachnagrostis billardierei[1]	N/A	Erect perennial grass	700	8 - 10	Biofilter
Lachnagrostis filiformis[1]	N/A	Erect perennial grass	700	8 - 10	Biofilter
Lepidosperma laterale	Variable sword-sedge	Groundcover sedge		6 - 8	Biofilter & Batters

Species Name	Common Name	Type of Vegetation	Height (mm)	Plant Density Per Square Metre (m^2)	Planting Zone
Leptospermum continentale	Prickly tea-tree	Shrub		<1	Biofilter
Leptospermum liversidgei	Olive tea-tree	Shrub		1 per 2 - 20 m^2	Biofilter & Batters
Lomandra filiformis[1]	Wattle Mat-rush	Perennial tussock	500	8 - 10	Batters & Landscape
Lomandra hystrix	River mat-rush	Groundcover herb		6 - 8	Biofilter & Batters
Lomandra leucocephala	Woolly Mat-Rush	Groundcover herb		6 - 8	Biofilter & Batters
Lomandra longifolia[1]	Tanika, Spiny Mat-rush	Perennial weeping tussock	700	8 - 10	Batters & Landscape
Lophostemon suaveolens	Swamp Mahogany	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Melaleuca bracteata	Black tea-tree	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Melaleuca ericifolia	Swamp paperbark	Shrub		<1	Biofilter
Melaleuca erubescens[1]	Pink Honey Myrtle	Hard, rough barked shrub	2000	1 per 2 m^2	Biofilter & Batters
Melaleuca incana	Grey honey-myrtle	Shrub		<1	Biofilter
Melaleuca lateritia	Robin redbreast bush	Shrub		<1	Biofilter
Melaleuca linariifolia	Flax-leaved paperbark	Small tree		1 per 2 - 100 m^2	Biofilter & Batters
Melaleuca quinquenervia	Broad-leaved paper bark	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Melaleuca thymifolia	Thyme honey myrtle	Shrub		1 per 2 - 20 m^2	Biofilter & Batters
Melaleuca viridiflora	Broad leaved tea-tree	Small tree		1 per 2 - 100 m^2	Biofilter & Batters

Species Name	Common Name	Type of Vegetation	Height (mm)	Plant Density Per Square Metre (m^2)	Planting Zone
Microlaena stipoides[1]	Weeping Grass	Slender, tufted perennial grass	700	8 - 10	Batters & Landscape
Pennisetum alopecuroides[1,2]	Swamp Foxtail Grass	Clumping tussocks perennial	1500	8 - 10	All
Poa labillardieri[1]	Eskdale, Tussock Grass	Densely tufted perennial grass	600	8 - 10	Biofilter
Rytidosperma tenuior, Austrodanthonia tenuior, Danthonia tenuior[1,3]	Wallaby Grass	Tufted perennial grass	1200	8 - 10	Biofilter
Schoenoplectus mucronatus[1]	N/A	Tufted perennial	1000	8 - 10	Biofilter
Themeda australis	Kangaroo grass	Groundcover grass		6 - 8	Biofilter & Batters
Themeda trianda, Themeda australis[1,3]	Kangaroo Grass	Densely tufted leafy perennial	1200	8 - 10	Biofilter

Notes:

1. Priority species. Known to be suitable for Western Sydney conditions.
2. Strongly self-seeding. Seek Council advice before use.
3. 40% of coverage shall comprised with these plants.

Table 8.2 - Alternative Biofilter Plant Species (extracted from Water by Design (2014), Payne et al. (2015), Blacktown City Council (2017))

Species Name	Common Name	Type of Vegetation	Height (mm)	Plant Density Per Square Metre (m^2)	Planting Zone
Acacia suaveolens	Sweet wattle	Shrub		8 - 10	Biofilter
Aidia racemosa	Archer Cherry	Shrub		1 per 2 - 20 m^2	Biofilter & Batters
Albizia canescens	Townsville siris	Tree		1 per 2 - 100 m^2	Biofilter & Batters

Species Name	Common Name	Type of Vegetation	Height (mm)	Plant Density Per Square Metre (m^2)	Planting Zone
Allocasurina littoralis	Black sheoak, black she-oak, and river black-oak	Tree		<1	Biofilter
Alphitonia excelsa	Red ash	Shrub		1 per 2 - 20 m^2	Biofilter & Batters
Astartea scoparia	Common astartea	Shrub		<1	Biofilter
Atractocarpus fitzalanii	Native Gardenia	Shrub		1 per 2 - 20 m^2	Biofilter & Batters
Austrodanthonia caespitosa	Common wallaby-grass, ringed wallaby-grass, and white-top	Groundcover		8 - 12	Biofilter
Austromyrtus dulcis	Midgen berry	Shrub		1 per 2 - 20 m^2	Biofilter & Batters
Austrostipa setacea[1]	Corkscrew Grass	Tufted perennial grass	800	8 - 10	Biofilter
Banksia marginata	Silver Banksia and Honeysuckle	Shrub		<1	Biofilter
Bothriochloa pertusa	Indian couch	Turf[2]		N/A	Biofilter & Batters
Breynia oblongifolia	False coffee bush	Shrub		1 per 2 - 20 m^2	Biofilter & Batters
Buckinghamia celsissima	Ivory curl flower	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Callistemon viminalis	Weeping bottle brush	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Casuarina equisetifolia	Coast She Oak	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Chionanthus ramiflora	Native olive	Tree		1 per 2 - 100 m^2	Biofilter & Batters

Species Name	Common Name	Type of Vegetation	Height (mm)	Plant Density Per Square Metre (m^2)	Planting Zone
Colubrina asiatica	Latherleaf	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Cordyline manners-suttoniae	Giant palm lily	Shrub		1 per 2 - 20 m^2	Biofilter & Batters
Corymbia tesselaris	Moreton Bay Ash	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Cupaniopsis anacardioides	Beach tuckeroo	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Cymbopogan refractus[1]	Barbed Wire Grass	Tufted perennial grass	1000	8 - 10	Biofilter
Cyperus gymnocaulos	Spiny flatsedge	Groundcover		8 - 12	Biofilter
Cyperus laevigatus[1]	N/A	Rhizomatous perennial	600	8 - 10	Biofilter
Dianella revoluta	Blueberry lily, blue flax-lily, black anther flax-lily or spreading flax-lily	Groundcover		8 - 12	Biofilter
Dianella tasmanica	Tasman Flax-lily, Tasmanian Flax-lily	Groundcover		8 - 12	Biofilter
Dichantheum sericeu[1]	Queensland Bluegrass	Tufted warm season perennial	1200	8 - 10	Biofilter
Dichelachne micrantha[1]	Shorthair Plume Grass	Tufted perennial grass	1200	8 - 10	Biofilter
Dodonaea viscosa[1]	Sticky Hop Bush	Small shrub to tree	8000	1 per 2 m^2	Batters & Landscape
Echinopogon ovatus[1]	Forest Hedgehog Grass	Rhizomatous perennial	1200	8 - 10	Biofilter
Entolasia stricta[1]	Wiry Panic Grass	Shrubby rhizomatous perennial	800	8 - 10	Biofilter
Eragrostis leptostachya[1]	Paddock Lovegrass	Loosely tufted perennial	1000	8 - 10	Biofilter

Species Name	Common Name	Type of Vegetation	Height (mm)	Plant Density Per Square Metre (m^2)	Planting Zone
Eucalyptus raveretiana	Black ironbox	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Eucalyptus tereticornis	River blue gum	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Eugenia reinwardtiana	Cedar Bay cherry	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Fimbristylis dichotoma	Common fringe sedge	Groundcover sedge		6 - 8	Biofilter & Batters
Fimbristylis ferruginea	Rusty fringe sedge	Groundcover sedge		6 - 8	Biofilter & Batters
Fimbristylis tristachya		Groundcover sedge		6 - 8	Biofilter & Batters
Fuirena umbellata		Groundcover sedge		6 - 8	Biofilter & Batters
Gahnia aspera	Saw sedge	Groundcover sedge		6 - 8	Biofilter & Batters
Gahnia seiberiana	Red-fruit saw-sedge	Groundcover sedge		6 - 8	Biofilter & Batters
Gahnia trifida	Coastal saw-sedge	Groundcover		8 - 12	Biofilter
Ganophyllum falcatum	Scaly ash	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Goodenia ovata[1]	Hop Goodenia	Erect, ascending or prostate shrub	2000	1 per 2 m^2	Biofilter & Batters
Hakea laurina	Kodjet, pin-cushion hakea, and emu bush	Shrub		<1	Biofilter
Hibiscus heterophyllus	Native rosella	Shrub		1 per 2 - 20 m^2	Biofilter & Batters
Hypocalymma angustifolium	Myrtle	Shrub		<1	Biofilter

Species Name	Common Name	Type of Vegetation	Height (mm)	Plant Density Per Square Metre (m^2)	Planting Zone
Juncus kraussii	Salt marsh rush, sea rush, jointed rush, matting rush or dune slack rush	Groundcover		8 - 12	Biofilter
Juncus polyanthemus	Striated rush	Groundcover sedge		6 - 8	Biofilter & Batters
Juncus usitatus	Common rush	Groundcover sedge	1000	6 - 8	Biofilter & Batters
Leptospermum polygalifolium	Wild May	Shrub		1 per 2 - 20 m^2	Biofilter & Batters
Leucophyta brownii	Cushion Bush	Shrub		<1	Biofilter
Livistona decora	Weeping Cabbage Palm	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Lomandra confertifolia	Dwarf mat rush	Groundcover sedge		6 - 8	Biofilter & Batters
Lomandra longifolia	Tanika, Spiny Mat-rush	Groundcover		8 - 12	Biofilter
Lophostemon grandiflorus	Northern Swamp Box	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Melaleuca dealbata	Blue leaved paperbark	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Melaleuca fluviatilis	Weeping Tea Tree	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Melaleuca leucadendra	Weeping Tea Tree	Tree		1 per 2 - 100 m^2	Biofilter & Batters
Melastoma malabathricum	Blue tongue	Shrub		1 per 2 - 20 m^2	Biofilter & Batters
Microlaena stipoides	Weeping grass	Groundcover		8 - 12	Biofilter
Mimusops elengi	Red Coondoo, Tanjong Tree	Tree		1 per 2 - 100 m^2	Biofilter & Batters

Species Name	Common Name	Type of Vegetation	Height (mm)	Plant Density Per Square Metre (m^2)	Planting Zone
Myoporum acuminatum	Coastal boobialla	Shrub		1 per 2 - 20 m^2	Biofilter & Batters
Paspalum distichum	Water couch	Turf[2]		N/A	Biofilter & Batters
Paspalum vaginatum	Salt water couch	Turf[2]		N/A	Biofilter & Batters
Poa labillardieri	Tussock grass	Groundcover		8 - 12	Biofilter
Poa poiformis	Coast tussock-grass or blue tussock-grass	Groundcover		8 - 12	Biofilter
Poa sieberiana	Grey tussock-grass and snow grass	Groundcover		8 - 12	Biofilter
Pomaderris paniculosa	Scurfy pomaderris	Shrub		<1	Biofilter
Rhynchospora corymbosa	Matamat	Groundcover sedge		6 - 8	Biofilter & Batters
Rytidosperma caespitosum	Common Wallaby Grass, Ringed Wallaby Grass	Groundcover		8 - 12	Biofilter
Scleria polycarpa	Many-fruited sedge grass	Groundcover sedge		6 - 8	Biofilter & Batters
Sporobolus virginicus	Seashore dropseed, marine couch, sand couch, salt couch grass, saltwater couch, coastal rat-tail grass, and nioaka	Groundcover		8 - 12	Biofilter
Waterhousea floribunda	Weeping Lily-pily	Tree		1 per 2 - 100 m^2	Biofilter & Batters

Species Name	Common Name	Type of Vegetation	Height (mm)	Plant Density Per Square Metre (m^2)	Planting Zone
Xanthorrhoea fulva	Swamp grass tree	Shrub		1 per 2 - 20 m^2	Biofilter & Batters
Zoysia macrantha	Zoysia	Turf[2]		N/A	Biofilter & Batters

Notes

1. Priority species. Know to be suitable for western Sydney conditions.
2. Turf species are not as effective at stormwater treatment due to their shallower root systems and shoot length

8.2.1.2. *Planting densities*

The recommended plating density is 8 -12 plants/m^2 for groundcovers, and less than 1 plant/m^2 for shrubs and trees (Payne, et al., 2015; Water by Design, 2014). Seedlings or direct seeding can be used. As the success rate of direct seeding cannot be guaranteed, direct seeding is only to be used to complement planting seedlings.

8.2.1.3. *Set out*

Wetter and drier zones occur in both large and small biofilters. Therefore, appropriate species are to be selected from each zone. Particularly in larger biofilters proposed for the current project, the areas furthest away from the inlets may not be inundated during small rain events. The plants in these areas should therefore be hardy and tolerant of drying conditions. Particularly, deep-rooted plants are recommended as the deep roots enable utilisation of SZ water during the extended dry weather periods. Additionally, biofilter embankment batters are to be planted with species that are tolerant to drier conditions. The plants near the inlets may be frequently inundated and potentially impacted by high flow velocities and sediment loads. Therefore, robust species with relatively rapid growth are recommended for the inlet zone.

Groundcover is to be distributed across the surface of the bioretention systems to minimise the risk of bare patches developing if one species fails. The recommended approach is to use small clumps of 5–10 plants of the same species to ensure propagation can readily occur. The placement of trees and shrubs involve a random distribution to provide shade cover and weed suppression and clumping of several trees and shrubs of the same species, as would occur naturally.

8.2.1.4. *Use of mulch*

Use of mulch is not recommended for biofilters (Payne, et al., 2015; Blacktown City Council, 2017). Organic mulches are at risk of floating and clogging outlets and leaching nutrients. Gravel mulch can avoid the abovementioned constraints. However, it restricts plant spread, increases stress on plant due to heat retention, and severely impedes removal of accumulated sediment.

8.2.1.5. *Time of planting and establishment*

In temperate climates, planting should generally be undertaken late in winter or early in spring to allow sufficient time for plant establishment before summer. As per Blacktown City Council guidelines (BCC, 2017) the recommended time of planting should be no later than fourteen days following installation of the filter media. Plant establishment and watering should take place during the first twelve months.

It is also crucial to co-ordinate planting with the catchment development. Planting should be delayed until the majority of the development activity has been completed. Sediment controls must be implemented to protect the biofilter during catchment development.

8.2.2. Wetland Distribution Channel

The main role of the plant species used for the wetland distribution channel is to provide local biodiversity (habitat for mosquito predators) and to enhance aesthetics. Additionally, these plant species may also provide some pollutant removal depending on the species selected. The following content of the wetland VMP was extracted from the Wetland Technical Design Guideline (Water by Design, 2017).

8.2.2.1. *Species Selection and Vegetation Types*

Plants are to be placed along the wetland distribution channel embankment slope. The lower part of the embankment is constantly under water whereas the top part of the embankment is only periodically inundated. Therefore, two planting zones are used:

- Lower slopes – Macrophyte zone vegetation (normal water level (NWL) to -0.5 m)
  - Shallow marsh (NWL to -0.2 m)
  - Deep marsh (NWL -0.2m to NWL -0.5m)
- Upper slopes – Ephemeral better vegetation (NWL to +0.3 m)

The key plant attributes that influence the long-term persistence of the macrophyte vegetation includes:

- adaptations to grow in water (as emergent or submerged plant forms);
- ability to tolerate periods of inundation;
- presence of rhizomatous root systems (facilitates spreading rather than clumped forms);
- Perennial rather than annual; and,
- simple vertical leaves (e.g. *Baumea spp*) which provide a high surface area for biofilm growth and interaction with the water column.

The ephemeral batter zone is regularly inundated during the wet season as water levels in the wetland fluctuate in response to rainfall events. The vegetation planted in the ephemeral batter generally comprised of plant species adapted to regular wetting and drying sequences, including grasses, rushes, sedges and herbs.

A diverse range of plant species, including plant species known to be successful in constructed wetlands, will ensure a higher likelihood of successful plant establishment, additional water treatment benefits and resilience to changing conditions. Wetland Design Guidelines (Water by Design, 2017) provide a list of plant species that are known to be effective and ineffective in stormwater treatment (Refer to Tables 12 and 13 in Wetland Design Guideline (Water by Design, 2017)). A list of species known to be effective in treatment are shown in Table 8.3 and a list of alternative species are provided in Table 8.4. Since the stormwater treatment is only a secondary objective, it is possible to use any combination of plant species in the wetland distribution channel. However, any of the selected plant species must:

- be suitable for the local landscape and ecology;
- be suitable for the predicted wetting and drying regime (where applicable);
- be of local provenance (where applicable); and,
- meet Council requirements.

Table 8.3 - Plant species with high treatment performances that are suitable for Wetland Distribution Channel (Extracted from Water by Design (2017))

Species Name	Common Name	Life-Form	Height (mm)	Planting Density (Plants/m²)	Planting Zone[1]
Actinoscirpus grossus	Giant Bur Rush	Emergent macrophyte	1200-2000		SM, DM
Baumea articulata	Jointed Twig-rush	Emergent macrophyte	1000-2000	4 - 6	DM
Bolboschoenus caldwellii	Sea Club-rush	Emergent macrophyte	300-900	4 - 6	SM
Bolboschoenus fluviatalis	Marsh Club-rush	Emergent macrophyte	1000-2000	4 - 6	DM
Cladium procerum	Leafy twig-rush	Emergent macrophyte	1000-2500	4 - 6	SM, DM
Eleocharis acuta	Common Spike-rush	Emergent macrophyte	300-700	6 - 8	SM
Eleocharis dulcis	Chinese Water Chestnut	Emergent macrophyte	800-1500	6 - 8	SM, DM
Eleocharis equisetina	Spike-rush	Emergent macrophyte	500-1000	6 - 8	SM
Eleocharis sphacelata	Tall Spike-rush	Emergent macrophyte	500-2000	6 - 8	DM
Lepironia articulata	Grey Rush	Emergent macrophyte	600-2300	4 - 6	SM, DM
Phragmites australis	Common reed	Emergent macrophyte	1500-3000	4 - 6	SM, DM
Schoenoplectus subulatus	Shore Club-rush	Emergent macrophyte	600-2000	6 - 8	SM, DM
Schoenoplectus validus	River Club-rush	Emergent macrophyte	600-1600	6 - 8	SM

Notes:

1. SM – Submerged marsh, DM – Deep marsh

Table 8.4 - Alternative plant species for Wetland Distribution Channel (Extracted from Water by Design (2017))

Species Name	Common Name	Life-Form	Height (mm)	Planting Density (Plants/m²)	Planting Zone[1]
Baumea arthrophylla[3]	Fine Twig-rush	E	800-1000	6 - 8	EB, SM
Bacopa monnieri[3]	Bacopa	G	80	6 - 8	EB
Baloskion pallens[3]	Cord Rush	G	500-1000	6 - 8	EB
Baloskion tetraphyllum[3]	Tassel Cord-rush	G	500-1600	6 - 8	EB
Baumea juncea[3]	Bare Twig-rush	E	500-900	6 - 8	EB, SM
Baumea rubiginosa[3]	Soft Twig-rush	E	500-1100	6 - 8	EB
Carex appressa	Tall Sedge	E	900	6 - 8	EB
Carex fasicularis[3]	Tassel Sedge	E	500-1000	6 - 8	SM
Carex gaudichadiana[3]	Tufted sedge	E	300-500	6 - 8	SM
Carex polyantha[3]	Creek Sedge	E	1000	6 - 8	EB
Cynodon dactylon	Common couch	G	250	6 - 8	EB
Cyperus alopecuroides	Foxtail Flat Sedge	E	1000-2000	4 - 6	EB, SM
Cyperus exaltatus[3]	Giant Sedge	E	1000-2000	6 - 8	SM
Cyperus gunnii[3]	Flecked Flat Sedge	E	1500	6 - 8	EB
Cyperus javanicus	Javanese Flat Sedge	E	600	6 - 8	EB
Cyperus polystachyos	Bunchy Sedge	E	600	6 - 8	EB
Eclipta prostrata	White Eclipta	G	300	4 - 6	EB
Eleocharis geniculata	Nodding Spike-rush	E	500-600	6 - 8	EM
Ficnia nodosa	Knobby Club-rush	E	500-1000	6 - 8	EB

Species Name	Common Name	Life-Form	Height (mm)	Planting Density (Plants/m²)	Planting Zone[1]
Gahnia clarkei	Tall Saw-sedge	G	1000-2000	4 - 6	EB
Gahnia siberiana	Red-fruited Sword Sedge	G	1500-3000	4 - 6	EB
Imperata cylindrica	Blady Grass	G	500-900	6 -8	EB
Ischaemum australe[3]	Southern Grass	G	1200	4 - 6	EB, SM
Ischaemum rugosum[3]	Ribbed Muraina Grass	G	1200	4 - 6	EB, SM
Isolepis inundata[3]	Swamp Club-rush	E	400	6 - 8	SM
Juncus flavidus	Yellow Rush	E	1000	6 - 8	EB
Juncus krausii	Sea Rush	E	500-1500	6 - 8	EB, SM
Juncus pristmatocarpus[3]	Branching Rush	E	400-500	6 - 8	EB, SM
Juncus usitatus[3]	Common Rush	E	400-1100	6 - 8	EB
Leersia hexandra	Swamp Rice Grass	G	400-1200	6 - 8	EB, SM
Lepidosperma longitudinale	Common Sword- sedge	G	600-2000	6 - 8	EB
Leptochloa neesii[3]	Umbrella Canegrass	G	600-1500	6 - 8	EB, SM
Leptospermum liversidgei	Lemon-scented Tea-tree	SH			EB
Lomandra hystrix	River Mat Rush	G	1200	4 - 6	EB
Lomandra longifolia	Spiny-headed Mat Rush	G	1000	4 - 6	EB
Ludwigia peploides[3]	Water Primrose	E	400	4 - 6	EB
Myriophyllum verrucosum	Red Water Milfoil	S	NA	1	DM, SU

Species Name	Common Name	Life-Form	Height (mm)	Planting Density (Plants/m^2)	Planting Zone[1]
Oryza australiensis[3]	Native Rice	G	1200	6 - 8	EB
Persicaria decipiens[3]	Slender Knotweed	G	300-500	6 - 8	EB
Persicaria strigosa[3]	Spotted Knotweed	G	350-600	6 - 8	EB
Phylidrium lanuginosum	Woolly Water Lily	E	500-1000	2 - 4	SM
Poa labillardieri	Tussock Grass	G	800-1300	6 - 8	EB
Pseudoraphis spinescens[3]	Spiny Mud Grass	G	250-500	6 - 8	EB
Schoenoplectus mucronatus	Bog Bulrush	E	350-1000	6 - 8	SM

Notes:

1. Planting zones: EB - Ephemeral batter, SM – Submerged marsh, DM – Deep marsh;
2. Life form: - E - Emergent macrophyte, S – Submerged marsh, G – Groundcover, SH – shrub
3. Wet edge only

8.2.2.2. *Planting densities*

The recommended planting densities for each species to enable 80% plant coverage within the wetland distribution channel within two growing seasons are shown in Table 8.3 and Table 8.4.

8.2.2.3. *Set out*

The planting set-out for the vegetation planted along the wetland distribution channel embankment must minimise the risk of bare patches developing if one species fails. A minimum of two plant species must be used in each zone (macrophyte and ephemeral batter).

8.2.3. Street Trees

The use of street trees as part of a water management strategy also provides significant aesthetic value, especially where green space is limited. Successful design for incorporating street trees realises a number of key benefits, including:

- Reduction in required water volumes and frequency of watering, which in turn leads to improved resilience and longevity of trees through period of drought;
- Reduction in pollutant loads in stormwater runoff; and,
- Reduction in volumes of stormwater runoff.

8.2.3.1. *Species Selection and Vegetation Types*

A list of trees that are known to perform well in an urban setting as in the climate of Western Sydney, which would be suitable for tree pits is included in Table 8.5.

Table 8.5: Council Preferred Species for Street Trees and Tree Pit Biofilters

Species Name	Common Name
Lophostemon confertus	Brush Box
Melaleuca linariifolia	Snow in Summer Tea Tree
Melaleuca bracteata	Black Tea Tree
Tristaniopsis laurina	Water Gum
Brachychiton populneus	Kurrajong Tree
Corymbia citriodora	Lemon Scented Gum
Glochidion ferdinandi	Cheese Tree

8.3. Management Actions

The vegetation management actions (Table 8.6) are aimed at providing a management framework for enacting relevant rehabilitation, maintenance, monitoring and review works reasonably required for the conservation of the riparian corridor.

Table 8.6 – Vegetation management actions

Management actions	Responsibility
Pre-construction	
An erosion and sediment control plan is to be prepared and implemented in accordance with *Soils and Construction – Manager Urban Stormwater (Landcom), Environmental Protection Agency (EPA) Pollution Control Manual for Urban Stormwater and Department of Housing Manual Urban Erosion and Sediment Control.*	Project Manager
Formation of a site management team and development of supervision and consultation processes. This would as a minimum include a project ecologist and site manager.	Project Manager
Erection of erosion control fencing.	Site Manager / Contractor / Project Ecologist
Identification and installation of primary and secondary exclusion fencing.	Project Manager
Installation of sediment basins and nutrient filter devices (if necessary).	Site Manager / Contractor
Commencement of primary weed control.	Site Manager / Contractor / Project Ecologist
Commencement of primary restoration works and initiation of brush, seed collection and propagation contracts.	Site Manager / Project Ecologist
Identify if there are any habitat trees on site, hollows to be relocated if required.	Project Ecologist
Conduct a site inspection and mark vegetation to be removed and fence and mark vegetation to be protected.	Site Manager / Project Ecologist
Fence trees and vegetation to be retained, ensuring fencing is outside the tree protection zone(s). Install branch and trunk protection where construction works are in very close proximity to trees.	Site Manager / Contractor / Project Ecologist
Construction	
Supervision of vegetation and tree removal and management works.	Site Manager / Project Ecologist

Management actions	Responsibility
Monitor erosion control measures (monthly – especially after heavy rain) and replace if required.	Site Manager / Contractor
Waste removal and soil amelioration works to control weed infestations and provide suitable restoration soil base.	Site Manager / Contractor / Project Ecologist
Commencement of secondary weed control and maintenance weed control	Site Manager / Contractor
Maintenance of fencing and signage around protected vegetation	Site Manager / Contractor
Installation or protective border or fence or pathway surrounding the riparian zone	Site Manager / Contractor / Project Ecologist
Continuation of primary restoration and revegetation works	Project Ecologist
Post - construction	
Enrichment planting within revegetation areas.	Site Manager / Project Ecologist
Continuation of regeneration and weed control	Site Manager / Contractor / Project Ecologist
Monitoring of retained vegetation at six (6) months, twelve (12) months, two (2) and three (3) years post construction stage.	Site Manager / Project Ecologist
Conduct maintenance beyond three (3) years as required	Site Manager / Contractor / Project Ecologist

8.4. Implementation of Management Actions

Responsibility for implementation of the management actions will rest with the proponent for a minimum period of two (2) years commencing from the completion of primary restoration works.

All personnel are to be briefed at the site induction on the tree protection locations and other relevant information, including the fact that the fencing is not to be removed. Trees to be removed are to be felled away from any tree protection zones(s).

The proponent shall engage suitably qualified contractors to undertake vegetation management activities. Appropriate qualifications and experience for contractors will be established as part of the detailed management plans for each reserve.

Noxious weeds are to be continuously suppressed and, if possible, eradicated from the riparian embankments and adjoining waterways in accordance with noxious weed control guidelines and permits issued by NSW Department of Primary Industries.

8.5. Maintenance and monitoring

Maintenance activities are aimed at providing a framework for the upkeep of bushland areas inclusive of riparian corridors. Maintenance of all revegetation areas is to continue for a period of two (2) years after completion of primary restoration works. Maintenance activities include:

- Weed control
- Waste control
- Watering and vegetation maintenance
- Repairs to protection and sedimentation fencing
- Cleaning of any permanent sedimentation structures and traps.

It is recommended that regular monitoring inspections be undertaken at six (6) monthly intervals, post completion of revegetation works. This will allow the determination of the condition of the vegetation, prioritise ongoing regeneration works and may include identification of any areas suffering from disturbance or in need of rehabilitation, weed control, stabilisation or other maintenance. Following six monthly progress reports, a joint inspection with relevant Council staff will be undertaken to ensure reporting is consistent with on ground works.

Monitoring is to determine if all priorities for restoration are being completed appropriately, to review the progress of any restoration tasks and to identify whether contingency actions are required to enhance the native vegetation composition and / or control weed infestations. Monitoring is to include:

- Repeatable before and after photographs – Take the photo from the same point in the same direction using the same equipment.
- Aerial photos to record broad-scale changes – Compare historical aerial photography to gauge the spread and changes in vegetation cover over time.
- Vegetation condition maps showing boundaries of weed infestations and assessed condition of areas based on weed densities.
- Collect and prepare plant lists for both native and exotic species taking note of any rare or endangered plant.
- Establish permanent quadrats and / or transects to enable quantitative recording of factors such as species densities and diversity and extent of cover.
- Record any new techniques or approaches being trialled.
- Record hours and categories of work.
- Prepare reports.

9. Quantities and Costing

Concept cost estimates have been developed for the proposed water management infrastructure, based on the detailed concept designs. The final costing will be subjected to completion following detailed design. This costing is provided for planning purposes only.

9.1. Assumptions and exclusions

The cost estimates have been categorised with the appropriate confidence intervals where possible, and allowances for inherent and contingent risks have been defined and included. The low and high estimated costs for the project are included in the cost estimates spreadsheets which were submitted separately.

The inherent contingency risk for both the total delivery and total project costs is 10%, which falls within the recommended rate of 7-10% for concept design estimates. The contingency risk is justified and explained in section 0.

9.1.1. Assumptions

The following general assumptions have been made for the cost estimates:

- Estimated quantities are based upon SMEC detailed concept design drawings, as specified for each individual costing.
- Rates are generally based on information from the Australian Construction Handbook (Rawlinsons Quantity Surveyors and Construction Cost Consultants, 2018).
- Costings are in Australian dollars (2018) and do not allow for future inflation.
- All pipes/culverts are concrete Class 4 rubber ring jointed.
- GPTs are costed at the unit price only.
- Total cut to disposal is assumed, with contaminated soil transported to an approved landfill (Low-level contamination, i.e. General Solid Waste) within 10 km, with an allowance for an additional 10 km of cartage to Eastern Creek Landfill.
- Rates for dewatering assume "average duration" for the required period, assumed to be 6 months.
- Temporary site fencing is assumed to be required for a period of 6 months.
- Junction pits are assumed 900 mm x 900 mm x 900 mm deep with 150 mm base and walls, with an additional rate required per additional 100 mm of depth in excess of 900 mm. The rate for the pit includes excavation, backfilling, benching, channels, step irons and connections to pipes.
- The rate for soil for disposal is assumed as excavated to reduce levels in clay and deposit in spoil heaps within 1 km.
- All soil required for fill is assumed to be won from the cut on site.
- Subsoil drainage has been included, but will need to be confirmed in Detailed Design.
- Assumed no 'heath' or soft ground conditions encountered, removed and/or replaced.

9.1.2. Exclusions

The following exclusions apply to the cost estimates:

- Consultant's fees;
- Utility/services investigation, relocation or protection;
- Geotechnical investigations;
- GPT testing prior to construction;
- Detailed topographic survey;
- Rock, clay or waterlogged soils in bulk earthworks encountered, removed and/or replaced;
- Statutory and consultancy fees for all approvals (e.g. environmental etc.);
- Construction setout & survey;
- Work as executed survey & documentation;
- Site insurances;
- Internal road drainage;
- All landscaping and planting (excluding bioretention basin) for distribution channel batter slopes and trunk channel batter slopes;
- Management or maintenance of the basins;
- Preparation of a Site Management Plan or Environmental Management Plan;
- Rates for demolition do not include an allowance for disposal of material off-site, or disposal of contaminated waste;
- Traffic management only covers the cost of the Traffic management plan and excludes the cost for traffic controlling during construction; and,
- Sandstone block unit rates do not allow for delivery costs.

9.2. Specific costs and rates

During the concept design process, a work breakdown structure was developed to ensure all the major types of work and services as shown on the drawings were identified. Based on the drawings detailed calculations have been carried out to determine the volumes or quantities of each item.

The volume of cut and fill was computed separately by determining the volume between the finished surface level of the works and the required excavation levels using the 12d output.

The unit rates used in the cost estimates are based on the following:

- Information SMEC has from other similar projects;
- Information supplied by Council for completed projects of a similar nature (Cardno, 2013);
- Rawlinson Construction Handbook (Rawlinsons Quantity Surveyors and Construction Cost Consultants, 2018); and
- Costs obtained from various suppliers.

The reference rates for items used were compared for each costed item and the most appropriate rate selected for use as the base rate in the BoQ.

9.3. Inherent risk and contingency

9.3.1. Inherent risk

An inherent risk profile to the cost has been applied of between 80% and 160%. The cost estimation has been conducted by a suitably qualified person, but not a Quantity Surveyor. Hence there is uncertainty around the quantities and costings. The inherent risk has been lowered if and when a direct quote or costing was obtained from a supplier, and the risk profile was raised, where there are inherent uncertainties in the method proposed or large unknowns.

9.3.2. Cost of contingent risk

The contingent risk of 10% has been adopted as the methodology applied by the contractors are highly variable and it is difficult to justify a greater level of confidence.

In addition, a significant item of contingency risk is associated with the disposal of excess excavation material from the site. It is envisaged that this material would need to be transported off-site to an approved landfill (assumed to be Eastern Creek Landfill) and disposed of as low level contaminated material (i.e. "General Solid Waste"). However, this is based on the findings from the Phase 1 Contamination Assessment Report (SMEC, 2018b). A more detailed Phase 2 assessment may allow the material to be reclassified and/or the disposal volumes to be reduced.

9.4. Cost Estimates

Table 9.1 outlines the cost estimates for each of the drainage systems with 1%AEP basins, 50% AEP basins, non-basin and creek culvert systems. Detailed cost estimates and rates tables can be found in the cost estimates spreadsheets submitted separately. The disposal cost has been reported separately as it is such a significant component of the overall cost, which could potentially be reduced if the material is used on site and/or reclassified.

Table 9.1: Cost Estimates Summary

ID	S94 Construction Cost[1] (Year 2018)	Preliminary Cost excluding Disposal Cost[2] (excluding GST)	Disposal Cost[3] (excluding GST)
Drainage Systems with 1% AEP Basins			
Drainage System B17	$9,730,000	$8,965,000	$35,689,000
Drainage System B20	$7,827,000	$5,786,000	$5,097,000
Drainage System B21	$1,118,000	$1,084,000	$1,433,000
Drainage System B22	$3,963,000	$2,781,000	$14,403,000
Drainage System B23	$1,394,000	$1,742,000	$2,255,000
Drainage System B25	$3,673,000	$3,991,000	$11,408,000
Drainage System B27	$2,444,000	$2,702,000	$4,392,000
Drainage System B29	$7,067,000	$5,772,000	$14,205,000
Drainage Systems with 50% AEP Basins			
Drainage System B5	$4,266,000	$3,447,000	$8,468,000
Drainage System B6	$1,377,000	$2,468,000	$6,208,000

ID	S94 Construction Cost[1] (Year 2018)	Preliminary Cost excluding Disposal Cost[2] (excluding GST)	Disposal Cost[3] (excluding GST)
Drainage System B8	$2,099,000	$2,436,000	$6,718,000
Drainage System B11	$6,526,000	$6,961,000	$9,829,000
Drainage System B12	$1,496,000	$1,138,000	$2,874,000
Drainage System B13	$2,472,000	$2,833,000	$9,444,000
Drainage System B14	$3,829,000	$6,028,000	$11,791,000
Drainage System B15	$1,398,000	$1,177,000	$1,568,000
Drainage System B16	$1,199,000	$2,859,000	$5,709,000
Drainage System B18	$3,258,000	$4,457,000	$2,203,000
Drainage System B19	$5,301,000	$4,444,000	$5,843,000
Drainage Systems without Basins			
Drainage System NB5	$673,000	$1,049,000	$7,772,000
Drainage System NB13		$928,000	$738,000
Drainage System NB14		$673,000	$502,000
Drainage System NB15		$1,254,000	$736,000
Drainage System NB33		$784,000	$329,000
Drainage System NB35	$933,000	$1,340,000	$1,230,000
Drainage System NB37		$870,000	$571,000
Drainage System NB38		$414,000	$201,000
Creek Culverts			
B_Sixth_New	$126,000	$1,712,000	$1,357,000
B_Edmon1		$2,186,000	$1,307,000
B_Eighth	$6,038,000	$841,000	$657,000
B_Fourth	$6,317,000	$1,049,000	$600,000
B_Tenth	$273,000	$1,103,000	$733,000
EdmonsNorth_New		$1,049,000	$52,000
Fifth_Av1	$257,000	$1,259,000	$415,000
K_13thE	$3,728,000	$150,000	$96,000
K_14th_New	$512,000	$432,000	$206,000
K_17thEN	$450,000	$557,000	$342,000
K_Edmone		$405,000	$271,000
Surbox1	$3,780,000	$456,000	$265,000

Notes:

1. S94 Costs (LCC, 2014) adjusted at 3% Consumer Price Index for four years.
2. Preliminary Cost includes the construction cost and the project management cost, but no inherent contingency risk.
3. Disposal cost includes contingency risk.

10. Safety Considerations

The design is being developed to provide a safe operational environment, as well as taking into consideration the safety of personnel and the general public during construction, operation, maintenance and demolition of the project. Risks have been identified and populated in the safety in design (SiD) register during the development of the project. A copy of the SiD register has been included in Appendix F.

SiD is achieved through internal reviews, compliance with the Liverpool City Council design and construction guidelines and specifications. Any residual risks or unresolved issues remaining at completion of the concept design will be documented and provided to the Liverpool City Council for appropriate consideration during the detailed design and construction stages and for future maintenance planning and demolition.

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Appendix A Rainfall and Loss Parameters from ARR2016 Data HUB

Date issued: 27 April 2017

Version: Version 2016_v1

Location:

Requested coordinate:	Latitude	-33.9262	Longitude	150.8072
Nearest grid cell:	Latitude	-33.9375	Longitude	150.8125

Region Information

Data Category	Region
River Region	Hawkesbury River
ARF Parameters	SE Coast
Temporal Patterns	East Coast South

IFD Rainfall Depths

Frequent and Infrequent Events

Duration	Annual Exceedance Probability (AEP)						
	63.20%	50%#	20%*	10%	5%	2%	1%
1 min	1.99	2.26	3.11	3.71	4.3	5.1	5.72
2 min	3.23	3.62	4.9	5.82	6.71	7.95	8.93
3 min	4.5	5.05	6.86	8.15	9.41	11.2	12.5
4 min	5.67	6.39	8.72	10.4	12	14.2	15.9
5 min	6.73	7.6	10.4	12.4	14.3	17	19.1
10 min	10.7	12.2	16.9	20.1	23.3	27.7	31
15 min	13.4	15.2	21.1	25.1	29.2	34.6	38.8
20 min	15.3	17.4	24.1	28.8	33.4	39.6	44.4
25 min	16.8	19.1	26.4	31.5	36.6	43.4	48.7
30 min	18.1	20.5	28.3	33.7	39.1	46.4	52.1
45 min	20.9	23.6	32.5	38.6	44.8	53.1	59.7
1 hour	23	25.9	35.5	42.2	48.8	58	65.2
1.5 hour	26.2	29.5	40	47.5	55	65.4	73.6
2 hour	28.8	32.3	43.7	51.9	60.1	71.5	80.5

Duration	Annual Exceedance Probability (AEP)						
	63.20%	50%#	20%*	10%	5%	2%	1%
3 hour	33.1	37.1	50	59.3	68.7	81.9	92.4
4.5 hour	38.5	43.1	58.1	68.9	80	95.5	108
6 hour	43.1	48.3	65.3	77.6	90.2	108	122
9 hour	50.8	57.2	78.1	93	109	130	147
12 hour	57.4	64.9	89.2	107	125	149	169
18 hour	68.1	77.5	108	130	153	183	207
24 hour	76.6	87.7	124	150	176	211	239
30 hour	83.6	96.1	137	167	196	235	266
36 hour	89.5	103	148	181	214	256	289
48 hour	98.8	114	166	204	241	289	325
72 hour	111	129	189	233	277	331	372
96 hour	119	138	203	249	297	354	398
120 hour	124	144	210	258	308	366	411
144 hour	127	147	214	261	312	370	416
168 hour	130	150	215	261	313	371	416

Note:

The 50% AEP IFD does not correspond to the 2 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 1.44 ARI.

* The 20% AEP IFD does not correspond to the 5 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 4.48 ARI.

Very Frequent Events

Duration	Exceedance per Year (EY)							
	12EY	6EY	4EY	3EY	2EY	1EY	0.5EY#	0.2EY*
1 min	0.809	0.931	1.15	1.31	1.55	1.99	2.51	3.18
2 min	1.36	1.58	1.95	2.21	2.58	3.23	4.02	5
3 min	1.85	2.16	2.68	3.06	3.58	4.5	5.61	7
4 min	2.28	2.67	3.33	3.81	4.49	5.67	7.09	8.89
5 min	2.66	3.12	3.91	4.48	5.3	6.73	8.44	10.6
10 min	4.1	4.8	6.06	6.98	8.32	10.7	13.5	17.2
15 min	5.07	5.94	7.5	8.65	10.3	13.4	16.9	21.5
20 min	5.82	6.8	8.59	9.9	11.8	15.3	19.3	24.6
25 min	6.42	7.5	9.45	10.9	13	16.8	21.2	27
30 min	6.92	8.09	10.2	11.7	14	18.1	22.8	28.9
45 min	8.1	9.45	11.9	13.6	16.2	20.9	26.2	33.1
1 hour	8.99	10.5	13.1	15	17.9	23	28.8	36.2
1.5 hour	10.3	12.1	15	17.2	20.4	26.2	32.7	40.8
2 hour	11.4	13.3	16.6	19	22.5	28.8	35.9	44.6
3 hour	13.1	15.2	19	21.8	25.8	33.1	41.2	51
4.5 hour	15	17.5	21.9	25.2	29.9	38.5	47.8	59.3
6 hour	16.6	19.3	24.3	28	33.3	43.1	53.6	66.6
9 hour	19.1	22.3	28.2	32.6	39	50.8	63.5	79.6
12 hour	21.1	24.7	31.4	36.4	43.8	57.4	72	91
18 hour	24.2	28.5	36.5	42.5	51.4	68.1	86	110
24 hour	26.5	31.4	40.5	47.3	57.5	76.6	97.4	126
30 hour	28.4	33.8	43.7	51.1	62.4	83.6	107	140
36 hour	29.9	35.7	46.3	54.4	66.5	89.5	115	151
48 hour	32.1	38.7	50.5	59.4	72.9	98.8	127	169
72 hour	34.9	42.4	55.9	66.1	81.5	111	143	193
96 hour	36.5	44.4	59.1	70.1	86.8	119	153	207
120 hour	37.2	45.4	61	72.7	90.3	124	160	214
144 hour	37.6	45.8	62.2	74.5	92.8	127	164	218
168 hour	37.7	45.8	62.9	75.6	94.5	130	166	219

Note:

The 50% AEP IFD does not correspond to the 2 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 1.44 ARI.

* The 20% AEP IFD does not correspond to the 5 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 4.48 ARI.

Temporal Patterns

Due to large size of the dataset, a separate spreadsheet is provided.

Storm Losses

Data

Note:

Burst Loss = Storm Loss - Preburst

These losses are only for rural use and are NOT FOR USE in urban areas.

Storm Initial Losses = 37.0 mm

Storm Continuing Losses = 2.3 mm/h

Note:

Storm continuing loss of 1.9 mm/h was used for the system-scale models.

Median Pre-Burst Depths and Ratios

[PREBURST]	AEP (%)					
min (h)	50	20	10	5	2	1
60 (1.0)	0.8 (0.031)	1.1 (0.032)	1.3 (0.032)	1.5 (0.031)	1.5 (0.026)	1.5 (0.023)
90 (1.5)	1.7 (0.059)	1.5 (0.038)	1.4 (0.03)	1.3 (0.023)	1.3 (0.021)	1.4 (0.019)
120 (2.0)	0.0 (0.0)	0.7 (0.016)	1.2 (0.023)	1.6 (0.027)	1.5 (0.022)	1.5 (0.018)
180 (3.0)	1.5 (0.04)	3.1 (0.063)	4.2 (0.071)	5.3 (0.077)	3.7 (0.045)	2.4 (0.027)
360 (6.0)	3.4 (0.071)	12.3 (0.189)	18.3 (0.235)	23.9 (0.265)	19.4 (0.18)	16.1 (0.132)
720 (12.0)	1.3 (0.021)	4.3 (0.048)	6.3 (0.058)	8.1 (0.065)	15.6 (0.104)	21.2 (0.125)
1080 (18.0)	1.0 (0.013)	5.7 (0.052)	8.8 (0.067)	11.7 (0.076)	13.9 (0.075)	15.5 (0.074)
1440 (24.0)	0.0 (0.0)	4.2 (0.034)	7.0 (0.046)	9.7 (0.054)	13.0 (0.061)	15.4 (0.064)
2160 (36.0)	0.0 (0.0)	1.6 (0.01)	2.6 (0.014)	3.6 (0.017)	5.2 (0.02)	6.4 (0.022)
2880 (48.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.0 (0.003)	1.7 (0.005)
4320 (72.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

The following burst losses were adopted in the system-scale modelling. For the burst losses adopted in the precinct-scale modelling, refer to Austral and Leppington North Design of Water Management Infrastructure - Hydrologic and Hydraulic Modelling of Detailed Concept Detention Basin Designs (CSS, 2018a).

Since the storm losses given in ARR Data Hub are only for rural use and are not for use in urban areas, the rural storm loss was reduced by 40% based upon recommendations in Book 5 of ARR2016 to account for the fact that the existing and future catchments will comprise a significant non-rural proportion. Therefore, the following burst losses used for the pre-development and post-development models.

For pre-development case models

Burst loss = Storm loss – preburst

[PREBURST] min (h)	Burst Loss AEP (%)					
	50	20	10	5	2	1
60 (1.0)	36.2	35.9	35.7	35.5	35.5	35.5
90 (1.5)	35.3	35.5	35.6	35.7	35.7	35.6
120 (2.0)	37.0	36.3	35.8	35.4	35.5	35.5
180 (3.0)	35.5	33.9	32.8	31.7	33.3	34.6
270 (4.5)	34.6	29.3	25.8	22.4	25.5	27.8
360 (6.0)	33.6	24.7	18.7	13.1	17.6	20.9
540 (9.0)	34.7	28.7	24.7	21.0	19.5	18.4
720 (12.0)	35.7	32.7	30.7	28.9	21.4	15.8
1080 (18.0)	36.0	31.3	28.2	25.3	23.1	21.5
1440 (24.0)	37.0	32.8	30.0	27.3	24.0	21.6
1800 (30.0)	37.0	34.1	32.2	30.4	27.9	26.1
2160 (36.0)	37.0	35.4	34.4	33.4	31.8	30.6
2880 (48.0)	37.0	37.0	37.0	37.0	36.0	35.3
4320 (72.0)	37.0	37.0	37.0	37.0	37.0	37.0

For post-development case models

Busrt Loss = 0.6 Storm loss - preburst*

[PREBURST] min (h)	Burst Loss					
	AEP (%)					
	50	20	10	5	2	1
60 (1.0)	21.4	21.1	20.9	20.7	20.7	20.7
90 (1.5)	20.5	20.7	20.8	20.9	20.9	20.8
120 (2.0)	22.2	21.5	21.0	20.6	20.7	20.7
180 (3.0)	20.7	19.1	18.0	16.9	18.5	19.8
270 (4.5)	19.8	14.5	11.0	7.6	10.7	13.0
360 (6.0)	18.8	9.9	3.9	0*	2.8	6.1
540 (9.0)	19.9	13.9	9.9	6.2	4.7	3.6
720 (12.0)	20.9	17.9	15.9	14.1	6.6	1.0
1080 (18.0)	21.2	16.5	13.4	10.5	8.3	6.7
1440 (24.0)	22.2	18.0	15.2	12.5	9.2	6.8
1800 (30.0)	22.2	19.3	17.4	15.6	13.1	11.3
2160 (36.0)	22.2	20.6	19.6	18.6	17.0	15.8
2880 (48.0)	22.2	22.2	22.2	22.2	21.2	20.5
4320 (72.0)	22.2	22.2	22.2	22.2	22.2	22.2

Note:

*negative loss value (-1.7) was replaced by 0

Interim Climate Change Factors

Values are of the format temperature increase in degrees Celsius (% increase in rainfall)

Year	RCP 4.5	RCP 6	RCP 8.5
2030	0.892 (4.5%)	0.775 (3.9%)	0.979 (4.9%)
2040	1.121 (5.6%)	1.002 (5.0%)	1.351 (6.8%)
2050	1.334 (6.7%)	1.28 (6.4%)	1.765 (8.8%)
2060	1.522 (7.6%)	1.527 (7.6%)	2.23 (11.2%)
2070	1.659 (8.3%)	1.745 (8.7%)	2.741 (13.7%)
2080	1.78 (8.9%)	1.999 (10.0%)	3.249 (16.2%)
2090	1.825 (9.1%)	2.271 (11.4%)	3.727 (18.6%)

Note:

RCP - Representative Concentration Pathway

ARR recommends the use of RCP4.5 and RCP 8.5 values

18.6% increase in rainfall (2090 climate change scenario) was selected to test climate change impact in the project.

Appendix B Concept Design Drawings – Drainage Systems with 1% AEP Basins

Appendix C Concept Design Drawings – Drainage Systems with 50% AEP Basins

Appendix D Concept Design Drawings – Drainage Systems without Basins

Appendix E Concept Design Drawings – Creek Culverts

Appendix F Safety in Design Register

Safety in Design

Project Name:	Austral and Leppington North Water Management Infrastructure
Date:	21/11/2018

This report identifies potential hazards, assigns a risk rating, and records the design measures implemented to minimise risk for this specific project. Based on the control methods being implemented, a residual risk rating is consequently developed.

The intent of the design control measures with respect to risk is to Eliminate, Reduce, Inform and Control. Any safety issues unresolved through design are also identified for their appropriate management..

This design report assumes that during the detailed design, construction & maintenance phases of the project, Council will engage experienced and competent personnel as part of the respective tender evaluation process.

Regardless of the following identified hazards, risks and control measures in the design safety analysis, it is the Head Contractor's obligation to prepare and implement site specific safe work method statements for construction activities.

The risks identified in this risk assessment are project and site specific risks. These risks are not generic or common risks associated with general construction works, rather they are risks which would not be easily recognized by a reasonably competent contractor.

Other generic risks, which are typical to particular construction activities are to be identified and managed by the client and/or construction contractors.

In accordance with the Work Health and Safety Act 2011, the Client must provide a copy of this Safety in Design Report to the Principal Contractor.

								If not eliminated Score residual risk		
PHASE	**Discipline**	**RISK REGISTER -Construction- Operations- Maintenance** **POTENTIAL RISK**		**RISK OWNER**	**POTENTIAL CONSEQUENCES**	**TREATMENT PLAN** **Elimination Measure, Design Initiative or Control**	**IS THE RISK ELIMINATED YES/NO**	Residual Risk Likelihood (0-5)	Residual Risk Consequence (0-5)	Risk Level
Construction										
Construction	General	Deep excavations adjacent to live traffic	Areas with grade & height separation	Construction Contractor	Items falling off vehicles into excavation work areas and striking workers	Construction staging, temporary catch screens, offsets and barriers	no	1	4	4
Construction	General	Extra construction vehicle movements	Site constraints and staging result in additional site movements.	Construction Contractor	Collisions and congestion	Mass haul, traffic control and vehicle movement plan, staging design to take into account volumes and movement. Maximise movements within site. Manage time of deliveries and materials.	no	2	3	6
Construction	General	Demolition adjacent to traffic and property	Site constraints	Construction Contractor	Damage to properties / vehicles	Risk assessments to be undertaken for each blasting activity. Condition surveys of properties in blasting area.	no	2	3	6
Construction	General	Contaminated materials, electrical hazards and unknown services.	Poisoning, electrocution, environmental damage.	Construction Contractor	Poisoning, electrocution, environmental damage.	Undertake detailed pre-demo review	no	2	4	8
Construction	General	Work adjacent to live traffic	Conflict between general public and site operations	Construction Contractor	Vehicle accidents, injury to occupants	Ensure adequate traffic management is in place		2	3	6
Construction	General	Exposed ends of starter bars through construction joints in insitu concrete drainage structures.	Injuries on site.	Construction Contractor	Increased risk to construction crews	Ensure caps are placed on exposed bars.	no	1	3	3
Construction	General	Under / Above Ground Services	Striking Services during construction	Construction Contractor	Disruptions to live traffic, construction and increased risk to construction crews, damage causing break in communication, gas, water or other services	Ensure an investigation is carried out and all services identified. Relocate services where practicable. Isolate any live cables.	no	2	4	8
Construction	General	Removing existing structures	Heavy weight, dust hazzard	Construction Contractor	Back injury, eye damage	Insure maximum weight lifted is not above standard maximum ensure protective clothing is warn during removal process	no	2	2	4
Construction	General	Removing existing tree stumps	Injuries on site.	Construction Contractor	Increased risk to construction crews	Ensure contractor removes tree safetly and to standard practice.	no	1	2	2
Construction	General	Working adjacent to high voltage power lines and high pressure gas mains	Potential for accidents involving construction workers	Construction Contractor	Increased potential for accidents, including electrocution	Ensure adequate TCPs and safe working conditions are implemented. Including adherence to service provider guidelines (eg TransGrid and Jemena).	no	3	4	12
Construction	Drainage	Public entering culvert under Road during a storm event	Potential injury from hazardous flow levels	Construction Contractor	Drowning	Provide entrance grates to U/S and D/S ends of culverts to prevent access	no	2	5	10
Construction	Drainage	Public entering swale during a storm event	Potential injury from hazardous flow levels	Construction Contractor	Drowning	Provide appropriate flood hazard signage at swale locations	no	2	5	10
Construction	Drainage	Public being in close proximity to basin weirs during storm event	Potential injury from hazardous flow levels	Construction Contractor	Drowning	Provide appropriate flood hazard signage at weirs	no	2	5	10
Construction	Drainage	Public using basins open space during storm event	Potential injury from fall/slip and drowning	Construction Contractor	Drowning	Provide appropriate flood hazard signage at footpath entrances to basin + fencing during construction	no	2	5	10

PHASE	**Discipline**	**RISK REGISTER -Construction- Operations- Maintenance** POTENTIAL RISK		**RISK OWNER**	**POTENTIAL CONSEQUENCES**	**TREATMENT PLAN Elimination Measure, Design Initiative or Control**	**IS THE RISK ELIMINATED YES/NO**	Residual Risk Likelihood (0-5)	Residual Risk Consequence (0-5)	Risk Level
Operational										
Operational	General	Speeding of vehicles along local roads near drainage structures	Accidents involving construction workers whilst implementing adjoining works	Council/Construction Contractor	Potential for accidents involving construction workers whilst implementing adjoining works	Lower speed on local roads when adjoining works occur	no	2	3	6
Operational	Drainage	Deep water (Basins and channels)	Drowning	Council/Designer	Increased risk to public	Depth of water less than 1.2m for 20% AEP event. Provide fence and/or appropriate flood hazard signage	no	2	5	10
Operational	Drainage	Steep Batters (Basin and channels)	Potential injury from fall/slip and drowning	Council/Designer	Increased risk to public	Design batter slopes at maximum 1:4 grade and/or provide sandstone block wall. Provide fence and/or appropriate flood hazard signage	no	2	5	10
Operational	Drainage	Overland Flow Lines	Potential injury from fall/slip/drowning	Council/Designer	Increased risk to public	Design overland flow for VxD<0.4m^2/s and Depth <0.2m. Provide appropriate flood hazard signage	no	2	3	6
Operational	Drainage	Open Culverts	Potential injury from fall/slip/drowning	Council/Designer	Increased risk to public	Provide entrance grates to U/S and D/S ends of culverts to prevent access	no	2	4	8
Operational	Drainage	Crossing the road near drainage structures	Conflict of vehicles and pedestrians crossing road.	Construction Contractor	Increased risk to pedestrians	Provide safe areas and adequate visibility	no	2	2	4
Operational	Drainage	Large multicell culverts near residential areas, redirecting flows	Redirecting flood water affecting local residents near Albion Park Interchange	Designer	Safety risk to local residents	Hydrology modelling to define impact of introduction of banks of culverts, afflux checked in detailed design	no	2	2	4
Operational	Drainage	Children playing in multicell culverts	Children trapped during flood event	Designer	Drowning	Consider limiting access to culverts in detailed design with alterations to fencing.	no	2	5	10
Operational	Drainage	Blockage of large culverts due to debris during flood events	Flood debris blocks culvert, causing water to back up and flow over the road	Designer	Flood water on road causing accidents	Culverts designed to cater for blockage as per ARR2016 / council requirements. Maintenance plan should be put in place for the culverts to ensure the culverts are cleared regulary.	no	2	3	6
Operational	Drainage	Public using basins	Potential injury from fall/slip on sand stone steps	Council	Increased potential for accidents	Undertake Safety Audit and Provide appropriate signage	no	2	2	4
Operational	Drainage	Distraction during temporary works	Drivers distracted by excessive or inadequate signage	Council/contractor	Increased potential for accidents	Ensure design complies with relevant standard. Undertake thorough Safety Audit	no	1	4	4
Operational	Drainage	Crossing the road near drainage structures	Heavy rain \ Flash flood	Risk of falling into basins and channels (incidents due to poor vision)	Increased potential for accidents	Provide appropriate flood hazard signage and safety barriers	no	2	3	6
Maintenance										
Maintenance	Drainage	Confined spaces	Inadequate training/equipment	Council/Contractor	Increased potential for accidents	Confined space training for maintenance staff	no	2	4	8
Maintenance	Drainage	Maintenance crew entering basin	Potential injury from fall/slip on sand stone steps	Council/Contractor	Increased potential for accidents	Undertake Safety Audit and Provide appropriate signage	no	2	2	4
Maintenance	Drainage	Inadequate maintenance access	Inadequate provision in the maintenance access strategy.	Council/designer	Vehicles accessing or parked in unsafe areas in lieu of properly design options such as ramp diverges being struck.	Maintenance access strategy to be developed in consultation with LCC Maintenance. Plus provide access steps/rungs/ladders in GPTs and other pits.	no	2	2	4

Key for Designers Risk Assessment

Table A-1 Qualitative Measures of Likelihood or Frequency

LEVEL	MEASURE	CRITERIA TO BE USED TO ESTABLISH RATING
5	Almost Certain	Will occur. Circumstances or situations are likely to arise often throughout the development's lifecycle period which provides the opportunity for crystallisation of risk. Expect frequent, regular occurrences.
4	Likely	Likely to occur more than once in the development's lifecycle period but not an 'everyday' occurrence. Preconditions will arise at times throughout the period.
3	Possible	Likely to occur at least once but not expected to occur much more that this in the development's lifecycle period.
2	Unlikely	Not likely to occur in the development's lifecycle period. A small, but remote chance of occurrence due to circumstances / situations that could arise.
1	Remote	Would only occur in highly exceptional circumstances that are unlikely to exist in any phase of the development's lifecycle period. Extremely remote chance of occurrence in development's lifecycle period. 'Once in a lifetime' event.

Table A-2 Qualitative Measures of Impact – Consequence Severity

LEVEL	IMPACT	EXAMPLE OF CONSEQUENCE
1	Insignificant	No injuries; no environmental impact.
2	Minor	First Aid; environmental release immediately contained.
3	Moderate	Medical Treatment; environmental release not immediately contained with no detrimental effects.
4	Major	Lost Time and/or long term Injury/Illness; environmental release not immediately contained with toxic effects.
5	Severe	Fatality; release to the environment with long term/permanent toxic effects.

CONSEQUENCE

LIKELIHOOD OR FREQUENCY	Insignificant 1	Minor 2	Moderate 3
Almost Certain	Mod	High	Extreme
Likely	Mod	Mod	High
Possible	Low	Mod	High
Unlikely	Low	Low	Mod
Remote	Low	Low	Low

Table A-3 Risk Matrix for Determination of Risk Level

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