Government of **Western Australia**
Department of **Water**

Forrestdale main drain arterial drainage strategy

Looking after all our water needs

Department of Water

November 2009

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The Water Corporation was the project manager for the development of this plan prior to the establishment of the Department of Water.

For more information about this report contact the team leader of urban drainage planning, Drainage and Waterways Branch, Department of Water.

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Summary

This final *Arterial drainage strategy* has been prepared by the Water Corporation for the Department of Water. It provides the details of the *Arterial drainage strategy* for the Forrestdale main drain catchment discussed in the *Southern River integrated land and water management plan* (Department of Water 2009).

The *Arterial drainage strategy* presents the Department of Water's guidance for the Water Corporation, City of Armadale, City of Gosnells, Western Australian Planning Commission, land developers and other state agencies about water management issues to help development proceed within the Forrestdale main drain catchment area.

The *Arterial drainage strategy* and the *Southern River integrated land and water management plan* (Department of Water 2009) also assist in integrating land and water planning as required by *Statement of planning policy no. 2.9: water resources* (Western Australian Planning Commission 2004) and outlined in *Better urban water management* (Department of Planning and Infrastructure, Department of Water, Western Australian Local Government Authority and Department of Environment, Water, Heritage and the Arts 2008).

All water management strategies, local structure plans, local planning scheme amendments and subdivision plans prepared for areas of proposed new development should demonstrate compliance with the strategies, objectives and design criteria detailed in this document.

A summary plan and checklist for developers has been developed and included with this document.

A regional scale controlled groundwater level is established and advice for developers and stakeholders for the management of groundwater quantity and quality within the Forrestdale main drain catchment area is given.

Figure 3 shows the strategy, which was developed based on the sustainability approach considering environmental, economic and social issues in the study area.

1 Introduction

The *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Figure 1) (Western Australian Planning Commission 2001) provides a guide to the future development and management of key environmental issues for the locality of Southern River in the City of Gosnells and Forrestdale, Brookdale and Wungong in the City of Armadale.

The *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) describes potential development areas, road networks, major community facilities, conservation and parks and recreation reserves, and a neighbourhood structure. It also provides proposals for the implementation of the plan including zoning mechanisms, staging, and financial and management arrangements.

However, the *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) did not fully address drainage and environmental issues and in February 2001, the Water and Rivers Commission commissioned JDA consultant hydrologists to undertake the development of *the Southern River/Forrestdale/Brookdale/Wungong district structure plan urban water management strategy* (JDA 2002).

In reviewing the *Urban water management strategy* (JDA 2002) the Environmental Protection Authority advised that it favoured a staged approach to development based on precautionary principles that would allow for monitoring of the impacts of development on water quality and hydrology and subsequent retrofitting of constructed drainage infrastructure if required. Consequently the Environmental Protection Authority sought assurances regarding the implementation of the *Urban water management strategy* (JDA 2002) and requested that a memorandum of understanding (MOU) be prepared and signed by all agencies involved in the implementation of the *Urban water management strategy* (JDA 2002). The MOU was signed in October 2003.

Under the MOU, the Water Corporation has undertaken the coordination and project management of the development of the *Southern River integrated land and water management plan* (Department of Water 2009) in consultation with all parties. In order to provide the surface water management section of this plan, a technical working group was established by the MOU steering committee to develop the recommendations of the *Urban water management strategy* (JDA 2002) into an *Arterial drainage strategy* for the Forrestdale main drain catchment.

The scope of the *Southern River integrated land and water management plan* (Department of Water 2009) covers all aspects of total water cycle management, including:

- protection of significant environmental assets within the structure plan area, including meeting water requirements and managing potential impacts from development

- water demands, supply options, opportunities for conservation and demand management measures and wastewater management
- surface runoff, including peak event (flood) management and the application of water sensitive urban design principles for frequent events
- groundwater, including the impact of urbanisation, variation in climate, installation of drainage to reduce groundwater levels, potential impacts on the environment and the potential to use groundwater as a resource
- water quality management, which includes source control of pollution inputs by catchment management, acid sulfate soil management, control of contaminated discharges from industrial areas and management of nutrient exports from surface runoff and groundwater through structural measures.

The *Southern River integrated land and water management plan* (Department of Water 2009) and this *Arterial drainage strategy* for the Forrestdale main drain catchment form the drainage and water management plan within the state government planning framework, as defined in *Better urban water management* (Department of Planning and Infrastructure, Department of Water, Western Australian Local Government Authority and Department of Environment, Water, Heritage and the Arts 2008) and outlined in Figure 2 below.

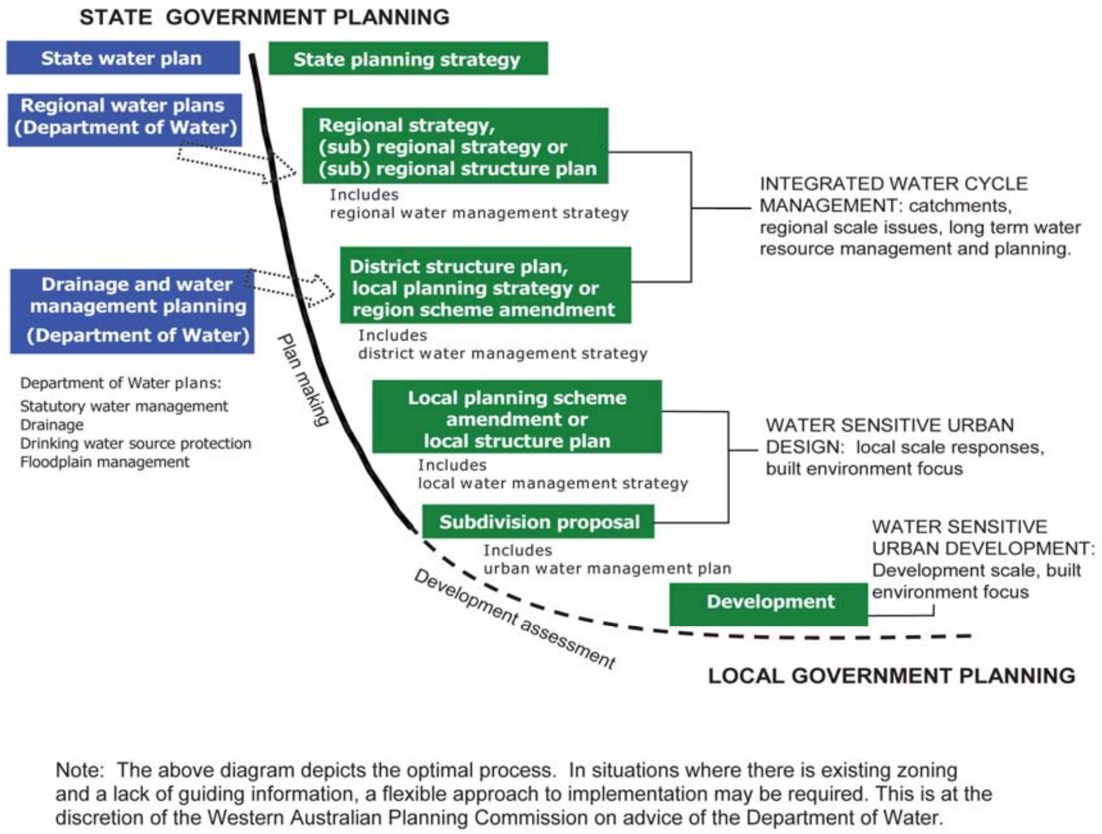


Figure 2 Planning framework integrating drainage planning with land planning processes

This document presents the proposed *Arterial drainage strategy* for the Forrestdale main drain catchment in accordance with the responsibilities for drainage planning assigned to the Department of Water by the state government.

1.1 Planning background

In addition to *Better urban water management* (Department of Planning and Infrastructure, Department of Water, Western Australian Local Government Authority and Department of Environment, Water, Heritage and the Arts 2008), the *Arterial drainage strategy* uses the following documents to define its key principles and objectives:

- *Liveable neighbourhoods – Edition 4 (*Western Australian Planning Commission 2007)
- *State planning policy no. 2.9: water resources* (Western Australian Planning Commission 2004)
- *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001).

1.2 Previous studies

A number of key investigations have been undertaken in the Forrestdale locality. It is the aim of this *Arterial drainage strategy* to incorporate information from all of these studies and present design criteria and management strategies.

The *Southern River/Forrestdale/Brookdale/ Wungong district structure plan urban water management strategy* was completed in 2002 by JDA consultant hydrologists. It presented stormwater management strategies for the study area and some of the proposed strategies have been incorporated into this study.

Regional-scale groundwater modelling was completed by Rockwater Pty Ltd in 2005 for the Water Corporation to assess any impacts from variations in climate or planned development in the study area.

An evaluation of the impact of water releases from stormwater arterial drainage on Forrestdale wetlands has been completed by GHD (2007) for the Water Corporation.

The study area has been assessed for acid sulfate soil risk, the results of which are presented in *Planning bulletin no. 64: acid sulfate soils* (Western Australian Planning Commission 2003).

Preliminary investigation into the ecological water requirements of selected wetlands on the Forrestdale main drain alignment (ENV 2007) has been undertaken.

Environmental water requirements of groundwater dependent ecosystems have not yet been published for this area.

1.3 Summary plan and checklist

Figure 3 provides an overview of the Forrestdale main drain catchment *Arterial drainage strategy* addressing stormwater quantity management. A checklist to assist developers in the preparation of local water management strategies has also been developed.

The checklist provides a summary of items to be addressed by developers in the preparation of local water management strategies for assessment by the City of Armadale or the City of Gosnells when an application for a local structure plan is lodged.

The checklist should be completed and signed by a suitably qualified professional and submitted to the local government with the local water management strategy for assessment when an application for a local structure plan is lodged.

Local water management strategy checklist for developers

The checklist provides a summary of items to be addressed by developers in the preparation of local water management strategies for assessment by the City of Armadale or the City of Gosnells when an application for a local structure plan is lodged.

The checklist should be completed and signed by a suitably qualified professional and submitted to council together with the local water management strategy.

Applicant:……

Name of structure plan:………………………………………………………………………………………………………

Version of structure plan: ……………………………………………………………………………………………………

Contact: ……

Address: ……

Telephone number:…………………………Email: …………………………………………………………………………

Authorised Signature: ………………………………………………………………………………………………………

Date:……

	Item	Submission		Assessment	
		Document ref. 1	Comments2	Compliance	Comment
1.0 Introduction					
1.1	Drainage and water management principles and design objectives for this structure plan				
1.2	Planning background (subject land)				
1.3	Previous studies (related to drainage and water)				
2.0 Proposed	development				
2.1	Key elements of structure plan				
2.2	Previous land use and potential sources of contamination				
2.3	Finished lot levels – (determined by greater of 100 year flood protection criteria or minimum separation of building foundations to MGL or a groundwater level approved by the Department of Water)				
2.4	Assessment of risk undertaken				
3.0	Existing site characteristics				
3.1	Topography and landform identified				
3.2	Environmental geology of the site identified (including soil types, ASS and PASS)				
3.3	Soil hydraulic conductivity and infiltration capacity of the site identified				
3.4	Groundwater levels, flows and quality of the site mapped (include identification and monitoring of any local or regional groundwater bores)				
3.5	Surface water flows and quality of the site identified (include flow monitoring of existing drainage)				
3.6	Environmental assets and water-dependent ecosystems mapped				
3.7	Indigenous sites identified				
3.8 Existing	infrastructure and constraints to design identified (include management strategies for any identified constraints)				
3.9	Site water balance pre-development and post-development identified				
3.10	Water sustainability initiatives				
4.0 Storm	water management				
4.1	Pre- and post-development hydrology (1-year, 5-year and 100-year ARI events)				
4.2	1-year ARI event managed for ecological protection in accordance with the *Integrated land and water management plan*				
4.3	5-year ARI event managed for serviceability in accordance with the *Integrated land and water management plan*				
4.4	100-year ARI event managed for flood protection in accordance with the *Integrated land and water*				

[1] Identify the section in the local structure plan in which this item has been addressed. It is possible that some items are not applicable and if this is the case, please put an explanation in the comments section.

[2] Please make comments as to the applicability of this criterion.

	management plan (include flow paths and emergency access routes and fully identify flood plain and protection measures)				
4.5	Finished lot levels at minimum of 0.5m above 100-year ARI flood levels.				
4.6	POS credits identified				
4.7	Water quality management BMPs to achieve design targets: Vegetated bioretention systems sized at 2% of the constructed impervious area they receive runoff from OR to achieve: at least 80% reduction of total suspended solids at least 60% reduction of total phosphorus at least 45% reduction of total nitrogen at least 70% reduction of gross pollutants				
5.0 Groundwater management					
5.1	Groundwater level management strategy				
5.2	Bioretention system, subsurface drainage and drainage inverts				
5.3	Subsurface drainage design				
5.4	Groundwater management strategies to achieve: at least 60% reduction of total phosphorus at least 45% reduction of total nitrogen				
5.5	Discharge to water-dependent ecosystems				
5.6	Specifications for imported fill (where proposed)				
5.7	Finished lot levels at a minimum of 0.8 m above the phreatic line				
6.0 Monitoring					
6.1	Monitoring programs commenced 2 years prior to proposed development				
6.2	Monitoring/sampling to follow Australian Standards				
6.3	Monitoring/sampling locations				
6.4	Water quality parameters to be monitored (refer to *Integrated land and water management plan)*				
6.5	Monitoring program to include a contingency action plan to manage risk				
7.0 Implementation					
7.1 Commitments					
7.2 Maintenance schedules					
7.3	Roles and responsibilities (for pre-development, during construction and all periods post-development)				
7.4 Funding					
7.5 Review					

2 Pre-development environment

Documents referred to for background information include:

- *Forrestdale main drain arterial drainage scheme technical report* (Water Corporation 2007)
- *Southern River/Forrestdale/Brookdale/Wungong district structure plan urban water management strategy* (JDA 2002)
- *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001)
- *Planning bulletin no. 64: acid sulfate soils (*Western Australian Planning Commission 2003)
- *Swan coastal geomorphic wetland mapping*
- *Aboriginal Heritage Act 1972* and *Register of aboriginal sites* (Department of Indigenous Affairs)

2.1 Study area

The Forrestdale main drain catchment is located 20 km south of Perth, and has an area of approximately 54 km^2. Approximately 19 km^2, or one third of the total catchment area forms the Forrestdale Lake subcatchment. The Forrestdale main drain discharges into the Southern River, approximately 6 km upstream of its confluence with the Canning River. The catchment lies within the boundaries of the City of Gosnells and the City of Armadale (Figure 4).

The existing land use of the catchment (Figure 5) is predominantly rural/agricultural with large areas of regional open space. The majority of rural land is used for the agistment of horses and grazing of cattle. There are relatively few residential areas, with Forrestdale townsite and the kennel zone alongside Ranford Road being the most significant of these.

Substantial areas of rural land and regional open space are wetland areas with much of the catchment being subject to periodic inundation from annual groundwater fluctuations. Existing rural residential properties in the catchment have been constructed on pads to prevent flooding.

There are two kennel zones currently situated within the Forrestdale main drain catchment: one at the corner of Ranford Road and Wright Road, which is approximately 0.3 km^2 in size; and a second, considerably larger area to the east of Ranford Road of approximately 0.9 km^2, which is bisected by the Forrestdale main drain.

Forrestdale townsite covers approximately 0.6 km^2 and is mainly situated to the south of Armadale Road on the northern edge of Forrestdale Lake. The town remains partially unsewered and therefore has the potential to adversely affect the water quality of Baileys branch drain and the Forrestdale main drain.

2.2 Geotechnical information

The catchment is located on the Swan Coastal Plain and is predominantly flat with levels varying from 28 m Australian height datum (AHD) in the west sloping gently to the north and east, to around 18 m AHD at the Southern River, which forms the eastern boundary of the catchment (Figure 6).

2.3 Soils

The superficial geology of the area includes degraded, low dunes of Bassendean sand with low-lying interdunal areas.

The base of the superficial formation generally slopes downwards to the west, steeply from around 0 m AHD near Southern River gradually down to about -20 m AHD beneath the centre of the Jandakot mound. The superficial formations generally consist of sandy sediments (a thin layer of Bassendean sand overlying Gnangara sand) with small isolated pockets of clayey sediments (Guildford clay) (Rockwater 2005).

The Ascot formation, consisting of fossiliferous limestone and calcareous sand with some clay, generally lies at the base of the superficial formations. There is commonly a 'coffee rock' (variably-cemented ferruginous sand) layer up to 17 m thick below the water table (Rockwater 2005).

Where intersected, the top of the underlying Leederville formation (cretaceous sediments) generally consists of siltstone or shale. The superficial formations are underlain by the Kardinya shale member of the Osborne formation in the west and north.

Average hydraulic conductivities of the superficial formations have been estimated as ranging from 1.1-8.9 m/d in the area underlain by Gnangara sand (and Ascot formation), and 0.5-5.3 m/d in areas of Guildford clay (Rockwater 2005).

Acid sulfate soils

The Western Australian Planning Commission's *Planning bulletin no. 64: acid sulfate soils* (2003), which is based upon a review of existing geomorphological, geological and hydrological information, indicates that the majority of the Forrestdale main drain catchment has a moderate to low risk of containing actual acid sulfate soils and potential acid sulfate soils (Figure 7). However, some portions of the catchment have a high risk, including some areas where modifications to the Forrestdale main drain and Baileys branch drain are proposed.

Investigations will be needed to identify areas of acid sulfate soils and these areas will require an acid sulfate soil management plan to be prepared in accordance with the strict amelioration standards set out in *Planning bulletin no. 64: acid sulfate soils* (Western Australian Planning Commission 2003).

2.4 Environmental assets and water-dependent ecosystems

The location of Bush Forever sites and *Environmental protection policy (Swan Coastal Plain) 1992* wetlands are identified in Figure 8. These have been considered in developing the proposals for modifications to the Forrestdale main drain and Baileys branch drain. However, these sites do not necessarily represent all occurrences of rare or endangered species within the catchment. A more detailed environmental assessment by a qualified consultant should be undertaken prior to the commencement of vegetation clearance.

Forrestdale Lake is listed under the Ramsar convention as a wetland of international significance, as well as being a conservation category wetland and an *Environmental protection policy (Swan Coastal Plain) 1992* lake. The entire lake is contained within Bush Forever site no. 345.

Balannup Lake is a conservation category wetland and an *Environmental protection policy (Swan Coastal Plain) 1992* lake, and is contained within Bush Forever site no. 413.

The Forrestdale main drain catchment also contains many other substantial Bush Forever sites and numerous wetlands classified as conservation category wetlands or resource enhancement wetlands including:

- Baileys wetland – conservation category wetland within Bush Forever site no. 342
- Harrisdale swamp – conservation category wetland within Bush Forever site no. 253
- Southern River floodplain wetland – conservation category wetland within Bush Forever site no. 464
- Kennels wetland – conservation category wetland within Bush Forever site no. 465
- Lander Road swamp – conservation category wetland
- Confluence wetland – conservation category wetland within Bush Forever site no. 342
- Nicholson Road wetland – conservation category wetland within Bush Forever site no. 262
- Gerty Way wetland – resource enhancement wetlands adjacent to Bush Forever site no. 340
- Forrestdale Business Park wetland – conservation category wetland
- East Forrestdale palusplain – conservation category wetland within Bush Forever site no. 345.

The Department of Environment and Conservation has recorded the presence of several priority and declared rare flora species within the catchment boundary.

In addition, there are three claypan threatened ecological communities and one Muchea limestone threatened ecological community within the catchment boundary.

The locations of these sites are identified in Figure 8 and have been considered in developing the proposals for modifications to the main drainage system.

2.5 Social considerations

The *Aboriginal Heritage Act 1972* was introduced in Western Australia in 1972 to protect aboriginal heritage. The Act recognises Aboriginal peoples' strong relationships to the land, which may go back many thousands of years.

The Act provides automatic protection for all places and objects in Western Australia that are important to Aboriginal people because of connections to their culture. These places and objects are referred to as aboriginal sites.

The Department of Indigenous Affairs maintains a *Register of aboriginal sites* as a record of places and objects of significance to which the Act applies. The presence of an aboriginal site places restrictions on what can be done to the land. Anyone who wants to use land for research, development or any other cause should investigate whether there is an aboriginal heritage site on the land.

The Minister for Indigenous Affairs is responsible for the administration of the Act. Under the Act it is an offence for anyone to excavate, damage, destroy, conceal or in any way alter an aboriginal site without the Minister's permission. The Department of Indigenous Affairs assists the Minister in the administration of the Act. The *Register of aboriginal sites* identifies several sites of indigenous significance in the Forrestdale main drain catchment. These sites are mostly concentrated around the Southern River and its flood plain, but also include Forrestdale Lake and other smaller sites around the catchment.

The locations of these sites are identified in Figure 8 and have been considered in developing the proposals for modifications to the main drainage system. None of the proposals for Water Corporation drains that are described in this report are expected to impact on these sites. However, an assessment should be undertaken by a qualified consultant to determine whether a more thorough aboriginal heritage investigation of the *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) area needs to be undertaken for any specific location to identify unregistered sites.

The design of modifications to the main drainage system has considered the potential for public amenity usage of areas within and adjacent to proposed drainage facilities. Flood storage areas have been designed to be kept dry, except during extreme storm events, and will be landscaped to provide the community with public open spaces with multiple potential uses.

2.6 Surface water

The modelled existing drainage system is shown in Figure 9. Approximately one third of the total catchment area forms the Forrestdale Lake subcatchment. Forrestdale Lake is linked to the Forrestdale main drain via a high level overflow on the eastern side of the lake. The top water level of Forrestdale Lake has to reach a level of 23.75 m AHD before overflowing into the main drainage system downstream.

Forrestdale main drain

Forrestdale main drain connects Forrestdale Lake to the Southern River. It was constructed as a rural drain in the 1970s to manage the regional groundwater level and prevent the Westfield wastewater treatment site from being flooded.

The Forrestdale main drain has levee banks along much of its length and it passes through or adjacent to a number of Bush Forever sites and conservation category wetlands.

Baileys branch drain

Baileys branch drain connects the existing Forrestdale townsite to the Forrestdale main drain upstream of Ranford Road. It was constructed in conjunction with the Forrestdale main drain for the purpose of managing regional groundwater and preventing flooding within the townsite. The drain is also contained in levees for much of its length and passes adjacent to Bush Forever site no 342. The Dumsday Drive compensation basin is located within the townsite at the head of this drain.

Keane Road branch drain

The Keane Road branch drain is connected to the Forrestdale main drain south of Armadale Road with the purpose of alleviating flooding of the Westfield wastewater treatment site.

Local authority drains

The James drain, which drains the area west of Forrestdale Lake, passes through major wetlands upstream and downstream of Nicholson Road before discharging into Forrestdale Lake.

The Forrestdale Lake south drain is largely undefined and although it is quite substantial at the Nicholson Road crossing, it quickly reduces in size and is replaced by indistinct overland flow to Forrestdale Lake.

Balannup Lake is linked to the Balannup Lake drain via a high level overflow from the north of the lake. The drain overflows to the Lander Road swamp and flows through a very large floodplain upstream of Southern River Road before it joins the Forrestdale main drain just upstream of Holmes Street.

Balannup drain drains the catchment upstream of Nicholson Road and discharges into Baileys branch drain approximately 300 m upstream of its confluence with the Forrestdale main drain via a 600 mm connection pipe. Harrisdale Swamp discharges into Balannup drain which then flows through Bush Forever site no. 342, where its depth becomes very shallow.

The Precinct 4 north and south drains are small and indistinct drains, which disappear before reaching the Southern River or Forrestdale main drain near the Tonkin Highway.

Murphy's drain is a small drain east of the Tonkin Highway with overflows regularly occurring into adjacent rural land before flowing to the Forrestdale main drain upstream of Allen Road.

System capacity

Long section drawings of the main drainage routes within the catchment are presented in Figures 10a to 10j.

Modelling indicates that the main drainage system comprising the Forrestdale main drain, Baileys branch drain and Keane Road branch drain can generally contain the three-year average recurrence interval storm event with approximately 300 mm freeboard to the top of the bank.

The 10-year average recurrence interval storm event can generally be conveyed within the Water Corporation main drainage system, although no freeboard is available. Elsewhere in the catchment, on local authority drains there is significant flooding during the 10-year average recurrence interval storm event.

During the 100-year average recurrence interval storm event the levee banks of the main drainage system are overtopped, contributing to the inundation of extensive areas of rural land, Bush Forever sites, and wetlands.

There is little difference between the 10 and 100-year average recurrence interval storm event discharges from the Forrestdale main drain to the Southern River, due to the large storage volumes that are retained within the catchment during a major storm event in naturally occurring floodplains and wetlands.

High tailwater conditions in the Southern River (levels equivalent to the 25-year flood event has been used for the purposes of this study), when combined with a major storm event, have a large effect on the Forrestdale main drain. Floodwater extends into very large natural floodplains on the Forrestdale main drain downstream of Holmes Street and on the Balannup Lake drain upstream of Southern River Road and at its confluence with the Forrestdale main drain.

Environmental aspects

The inundation of wetland areas is caused by a combination of direct runoff from the local catchment area into low-lying land and overland flooding of runoff from a wider catchment area via nearby drains, and also due to elevated groundwater levels.

The Balannup drain and Baileys branch drain contribute to the periodic inundation of Baileys Wetland within Bush Forever site no. 342, in events of greater than three-year average recurrence interval. This inundation occurs mainly due to the throttling influence of the Baileys branch drain connection to the Forrestdale main drain, with water backing up the shallow drains upstream and overflowing into the wetland.

The Forrestdale main drain and Baileys branch drain contribute to the periodic inundation of several other wetlands in events of greater than 10-year average recurrence interval.

Some of the local authority drains in the catchment contribute to wetland inundation in events more frequent than the one-year average recurrence interval.

The contribution of surface runoff to the inundation of wetlands is, however, relatively minor compared with the depth and extent of inundation due to high groundwater levels experienced each year, particularly during wet periods such as shown in Figure 11.

Conclusions

The existing drainage system has insufficient capacity to convey the 10-year average recurrence interval event under existing development conditions. The 10-year event is expected to result in significant flooding in the catchment, with overtopping of local authority drains and insufficient freeboard in the Water Corporation main drainage system.

The results of groundwater modelling predict that during wet years (e.g. 1915–1931) the area inundated by shallow groundwater is substantially greater than the area predicted to be inundated by surface runoff resulting from the 10-year or 100-year rainfall event.

Surface water quality

The Forrestdale main drain is within the catchment for the Southern River, which the Swan River Trust has identified as a priority catchment in its *Healthy rivers action plan* (Swan River Trust 2008). The Environmental Protection Authority has previously advised that a condition for development in the district structure plan area is the demonstration that development can be managed to meet the environmental objectives and targets for the Southern River catchment, documented in the Swan River Trust's Healthy Rivers Program.

The Swan River Trust's Healthy Rivers Program is a key instrument for the implementation of the *Swan and Canning Rivers Management Act 2006* which protects waterways such as the Southern River, as well as the Swan and Canning rivers, for their significance as important ecosystems and valuable recreational waterways. The Swan River Trust has developed short and long-term end-of-catchment water quality targets for nutrient concentrations in tributaries of the Swan-Canning river system.

The long-term targets for nutrient concentrations in the Southern River are 1.0 mg/L total nitrogen and 0.1 mg/L total phosphorus. Typical existing concentrations measured in the Forrestdale main drain are 3.2 mg/L total nitrogen and 0.5 mg/L total phosphorous.

The Swan River Trust has accepted that, although the Healthy Rivers Program targets represent long-term management targets, the agreed condition for development is that there is to be no deterioration in water quality in the Forrestdale main drain or the Southern River.

2.7 Groundwater

Groundwater flows

The Forrestdale main drain catchment is situated in an area of very shallow groundwater immediately to the east of the Jandakot mound. There are extensive areas in the catchment where the groundwater rises to the surface for extended periods.

As well as the obvious implications this has for fill requirements with proposed development, drainage designs will also need to consider likely changes in groundwater and their impact on both capacity and functionality of the main drainage system. Drainage in the catchment is inextricably linked to the groundwater. The Forrestdale main drain and Baileys branch drain were originally constructed to control regional winter groundwater levels with direct and indirect (overland) connections existing between lakes/wetlands in the catchment and the drainage system.

Groundwater modelling

Rockwater Pty Ltd carried out regional groundwater modelling of the Forrestdale main drain catchment in 2005. The modelling study investigated changes to groundwater levels that would result from urban development under three climate scenarios:

- dry rainfall period (post-1975) – 788 mm
- very wet period (1915–1931 rainfall) – approximately 1200 mm
- very dry period (1994–1995) – 690 mm

The report discusses the seasonal variability of groundwater levels in the catchment stating that the average annual groundwater fluctuation in the catchment are generally in the range 1.2 to 2 m, increasing to 2 to 2.5 m near drains and in areas of Guildford clay.

Modelled pre-development maximum groundwater level contours (788 mm annual rainfall scenario) are presented in Figure 11 (Rockwater 2005).

The results of the regional groundwater model have been incorporated into the InfoWorks surface water model by the application of winter peak starting water levels in wetlands and key sections of the drainage system. These starting water levels provide an assessment of the drainage system's ability to manage significant rainfall events at times of peak groundwater as well as an indication of the base flow within the drain at these times.

The predicted winter peak starting water levels in a selection of key wetlands are presented in Table 1 below for the various pre-development scenarios that were studied.

The environmental impact of groundwater interaction with wetlands and drains is discussed in Section 4.

Table 1 Groundwater model calculated wetland water levels (m AHD)

Location	788 mm rainfall (788 mm)		High (1920s) rainfall (approx. 1200 mm)		Low rainfall (690 mm)	
	Summer minimum	**Winter peak**	**Summer minimum**	**Winter peak**	**Summer minimum**	**Winter peak**
Forrestdale Lake (Bush Forever site no. 345)	21.5	22.5	21.6	23.2	21.4	22.2
Balannup Lake (Bush Forever site no. 413)	19.9	21.7	20.1	22.5	19.8	21.3
Harrisdale swamp (Bush Forever site no. 253)	24.3	25.2	26.4	26.9	23.7	24.4
Baileys wetland (Bush Forever site no. 342)	20.0	21.5	20.0	22.9	19.9	21.3
Kennels wetland (Bush Forever site no. 465)	19.9	20.8	19.9	21.7	19.9	20.7
Confluence wetland (Bush Forever site no. 342)	20.1	21.1	20.3	22.3	20.1	20.9
Gerty Way wetland (Adj Bush Forever site no. 340)	19.7	19.9	19.7	21.3	23.3	20.9
Lander swamp	19.0	21.3	19.4	23.5	18.9	20.9
East Forrestdale palusplain (Bush Forever site no. 345)	21.3	22.4	21.4	23.1	21.1	22.1
Gibbs Rd swamp (Bush Forever site no. 344)	23.8	25.2	24.7	27.3	23.5	24.4

3 Proposed development

3.1 Key elements of the structure plan

The *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) as shown on Figure 1 designates 16 km^2 of the Forrestdale main drain catchment for medium density residential development (mainly allowable housing density of 15 per hectare (R15) with approximately 25 per cent allowable housing density of 25 per hectare (R25)), 3 km^2 for light industrial use, and 2 km^2 for mixed business/ commercial, community facilities, and village and neighbourhood centres.

The remainder of the *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) area is to form public open space or remain rural with conservation areas and environmental management areas protected. The kennels zone to the east of Ranford Road will remain unchanged. Some areas have been identified in the *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) for possible future development, but it is believed unlikely that they will be required for urbanisation within the next 30 years.

The *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) describes proposed land use change from the existing mainly rural land use to mainly urban land use (Figure 1). This change in land use will result in increased runoff during large (major) rainfall events that will require upgrades to the drainage system.

The drainage upgrade strategy, previously recommended by the *Urban water management strategy* (JDA 2002) and endorsed by the Environmental Protection Authority, proposed widening the Forrestdale main drain and Baileys branch drain for their entire lengths, to create a meandering ‘living stream’ style drain within a broad multiple use corridor. Whilst this approach may be both aesthetically desirable and hydraulically achievable, there are a number of constraints within the catchment that limit its potential for adoption:

- Several sections of drain pass through or adjacent to Bush Forever sites. Modifications to Bush Forever sites require referral to the Environmental Protection Authority.
- Sections of the Forrestdale main drain (most notably through the kennels zone downstream of Ranford Road) are closely bounded by developed private properties.

In developing this drainage strategy, the locations of these constraints have been identified as well as several other alternative areas where there are more feasible opportunities for increased widening or storage.

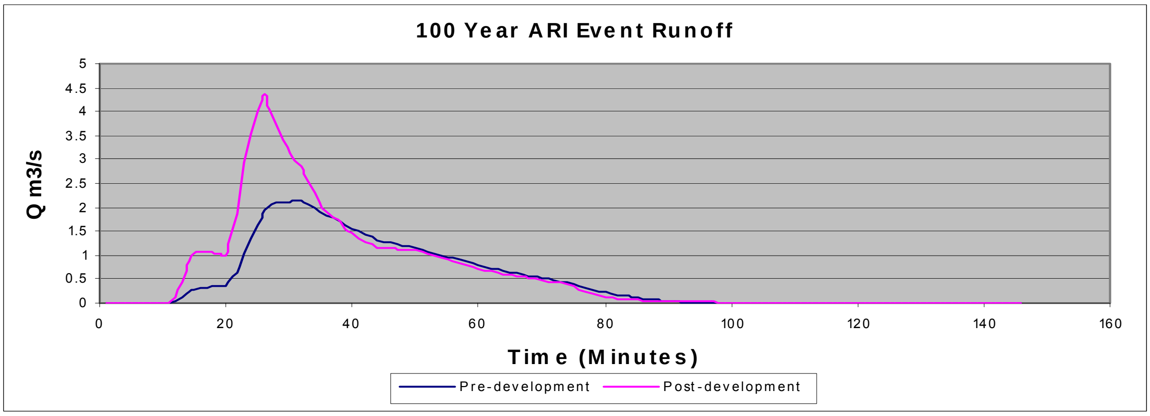
4 Protection of environmental assets

The following strategies have been developed to protect and enhance the value of environmental assets in the *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) area.

Minimise changes to hydrology to prevent impacts on watercourses and wetlands

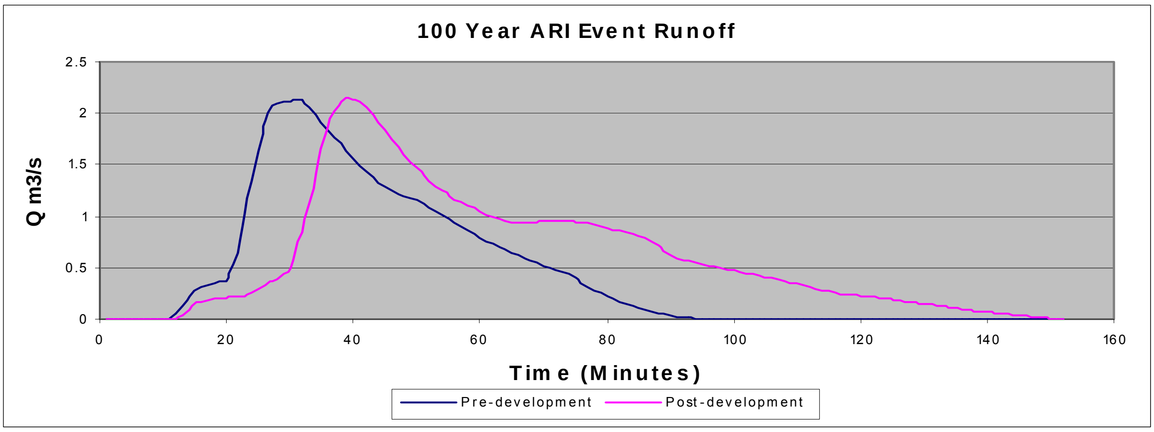
Changes in land use from rural to urban may lead to local increases in peak flows and volumes of runoff due to increases in impervious area (Figure 12). Large increases in peak flows and volumes have the potential to adversely impact on receiving environments by causing erosion and increasing the period of inundation of vegetation.

Figure 12 Typical pre- and post-development runoff hydrograph comparison.



Surface water management should ensure that urban development does not increase the peak flows discharging to receiving environments, although there may be increases in total runoff volumes (Figure 13). Development should also ensure that watercourses and wetlands do not dry out due to over-abstraction of water resources or lowering of groundwater levels.

Figure 13 Typical pre- and post-development runoff hydrograph comparison, with compensated post-development flows.



Manage and restore watercourses and wetlands

The *Southern River/Forrestdale/Brookdale/Wungong district structure plan* area includes several significant wetlands and Bush Forever sites that are considered high-value environmental assets that should be protected. Some parts of the existing drainage system are located in or adjacent to these areas and flow over these wetlands during storm events.

To evaluate the environmental impact of any upgrade to the drainage system, it is necessary to determine any changes to the hydrologic regime of these wetlands. The hydrologic regime of a wetland can be characterised by the frequency, depth (or extent) and duration of any inundation.

A separate study of the interaction of surface water runoff and the wetlands of the Forrestdale main drain catchment has been carried out and is presented in *Evaluating the impact of water releases from stormwater arterial drainage on Forrestdale wetlands* (GHD 2007). The study concluded that the discharge of additional flood flows to Forrestdale wetlands during infrequent (> 10 year average recurrence interval event) storm events will have no significant impact on the hydrology of these wetlands.

This conclusion is based on the following:

- An examination of the available data for Gibbs Road Swamp and Forrestdale Lake supports the conclusion of previous studies (Environmental Resources Management Group 2000) that wetland water levels are largely determined by regional groundwater levels.
- Temporary increases in wetland water level due to surface flows during storm events (< 0.3 m) are insignificant compared to the seasonal fluctuations in water level due to groundwater (1.0-2.0 m), the annual variability in maximum water levels (standard deviation 0.25 m) and long-term decline in water level due to drying climate (0.2-0.5 m).
- Areas temporarily inundated by surface water inflows will usually be inundated by seasonal groundwater rises later in the same year. Only if a major storm event occurs when the wetland is at its annual maximum water level will the additional inflows lead to an increase in the maximum water level that year. The probability of a 100-year average recurrence interval storm event coinciding with the annual maximum wetland water levels is considerably less than one in 100 years.

Regional and local groundwater levels are maintained by the requirement for existing drain inverts to be maintained and not lowered, and for new drain inverts to be located at or above a groundwater level endorsed by the Department of Water. This requirement also includes subsurface drainage, which in all developments will be located at or above a groundwater level endorsed by the Department of Water.

The duration of water level changes due to surface water inflows during infrequent storm events can be managed by hydraulic control structures that can discharge surface water from the wetland to the drainage system after the storm event has passed, as discussed in Section 5.2.

The performance of these structures can be specified in consultation with environmental managers and can include sufficient flexibility to allow future changes, including modification to allow the diversion of surface flows from the drainage system to the wetlands to maintain the hydrologic regime during dry periods.

There are other potentially more significant impacts on wetland water levels than the proposed infrequent discharges from the Forrestdale main drain, including decreasing groundwater levels due to long-term climate change and additional groundwater abstraction. Careful management of drainage discharges to wetlands offers the opportunity to manage the hydrology of the wetlands during dry periods or in times of decreasing groundwater levels by diverting surface flows from the drainage system, protecting those wetland systems.

The short-term impacts of construction of the preferred option will be managed by ensuring that appropriate investigation and mitigation procedures are followed at all times prior to and during construction.

Additional management strategies and design criteria for the protection of environmental assets are presented in the *Southern River integrated land and water management plan (*Department of Water 2009*)*.

5 Stormwater management strategy

The key objectives for surface water management are:

- protection of wetlands and waterways from the impacts of urban runoff
- protection of infrastructure and assets from flooding and inundation

5.1 Floodplain management

Mitigate flooding to manage risks to human life and property

Planning measures recommended are:

- New dwellings in proposed and existing residential areas should have their floor levels elevated 500 mm above the 100-year average recurrence interval flood level.
- New industrial or commercial premises should have their floor levels elevated 500 mm above the 100-year average recurrence interval flood level.
- To provide egress for emergency services major arterial roads with immunity to the 100-year average recurrence interval flood level should be identified. Other residential streets should be designed to be serviceable up to the five-year average recurrence interval flood event.
- The design of the new urban areas should incorporate current best practice in water sensitive urban design to mitigate the impacts of urbanisation in the catchments on regional water quantity and quality.
- Waterways within the structure plan area should be constructed to manage the flooding from the 100-year average recurrence interval flood event within their channels and floodplains without allowing flooding from the upstream catchment to enter adjacent residential areas.
- New drainage corridors should be designed with consideration of the current practice in water sensitive urban design by incorporating water quality management controls and riparian vegetation.

5.2 Surface water quantity management

As a result of the identified constraints on widening certain sections of the main drainage system (Section 3.1), it will not be possible to directly convey the entire post-development 100-year average recurrence interval event peak flow. It is therefore necessary to attenuate the peak discharge by providing the equivalent storage to that which currently exists naturally within the catchment. Some storage is provided within the drain, which is hydraulically controlled by existing culverts that restrict downstream flow. However, it is necessary to also provide some additional storage within the system, especially to allow for the potential loss of floodplains identified in the *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001).

Two options were approved by the technical working group for investigation:

Option A (adopted)

- widening of Forrestdale main drain and Baileys branch drain in all areas except within environmentally sensitive areas i.e. Bush Forever sites, conservation category wetlands etc
- continued use of wetland areas for storage of floodwaters and allowance for additional floodwater volumes to pass through wetland areas during infrequent storm events.

This option uses existing overland flood routes into wetland areas. In some cases this may involve lowering sections of the levee bank through wetland areas to provide more defined flood routes.

Option B

- widening of Forrestdale main drain and Baileys branch drain along some of their length and construction of flood storage areas outside wetlands
- prevention of any additional flooding of wetland areas.

This option with limited wetland inundation provides the additional storage required by increasing storage on the main drainage system in the form of constructed flood storage areas requiring additional land for drainage purposes. Such provision has not been allowed for in the *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001).

Adopted strategy

The adopted strategy was endorsed on the basis that the changes to the periodic inundation of the wetlands from drainage overflows during major storm events is insignificant when compared to the impact due to the variability in the annual groundwater regime under existing land development conditions.

The environmental impacts from the adopted strategy were supported 'in principle' by the Department of Environment and Conservation. Changes to the hydrologic regimes of the wetlands due to surface flows during storm events (<0.3 m) are insignificant compared to the seasonal fluctuations in water level due to groundwater (1.0–2.0 m), the annual variability in maximum water levels (0.25 m) and long-term decline in water level due to drying climate (0.2–0.5 m).

The adopted strategy also offers the opportunity to manage the hydrology of the wetlands during dry periods by diverting surface flows from the drainage system. In addition, by using existing wetlands to store surface water during infrequent storm events, it minimises the construction of additional flood storage areas, reducing the land required for drainage purposes. Figure 3 shows details of the adopted *Arterial drainage strategy*.

Figures 14a to 14j show the long section of the main drains and some of the precinct drains under the preferred option.

The key assumption in developing the adopted strategy is that existing overland flood paths into wetland areas continue to be used during infrequent events, allowing increased use of the available storage within these areas. This strategy makes no change to the drains that pass through or adjacent to wetland areas other than to allow more extensive inundation at these points in the system by forming defined (and therefore controllable) flow paths out of the low flow channel. The adopted strategy allows the partial removal or lowering of levee banks and the incorporation of flow control devices.

The use of existing wetlands for storage of drainage flows from infrequent major rainfall events will not significantly affect the hydrologic regime of these wetlands. As described in Section 4, water level changes due to seasonal and annual fluctuations in groundwater are far greater than the water level changes that will result from the diversion of surface flows from infrequent major rainfall events.

Engineered hydraulic control structures will be installed, only where necessary, to regulate flows to and from the drainage system, controlling the depth and duration of inundation of wetlands due to diversion of surface flows. In the case of prolonged dry periods, these structures would allow the diversion of flows from the drainage system to maintain the hydrologic regime of significant wetlands if requested by environmental regulators.

The Forrestdale main drain and Baileys branch drain both require widening as shown on Figure 3. This has been achieved in areas where increasing the size of the drainage reserve has little impact on proposed development and provides opportunities for improving the aesthetics of the immediate surroundings.

Widening of the main drain should be located within linear public open space as shown in the typical cross-sections of Figures 14a-14j. The design includes a main drainage waterway within the linear public open space, incorporating a one-year low flow channel, sized to convey all flows up to and including the critical 10-year average recurrence interval event. More extreme events are then allowed to flow out of this waterway channel and use a broad shallow gradient floodplain area. Because it is infrequently inundated, the flood plain area may be landscaped in keeping with its primary purpose of flood storage and conveyance. This will improve the aesthetic nature of the drain reserve, and provide a valuable area of open space area for public amenity usage.

Minimise changes in hydrology to prevent impacts on receiving environments

Urbanisation results in increased impervious area. Increased rates and volumes of stormwater runoff should be managed to protect infrastructure and assets from flooding and inundation, whilst both water quantity and quality should be managed to protect wetlands and waterways from risk of increased inundation and contaminant loads. Surface water management should ensure that urban development does not increase the peak flows discharging to receiving environments.

Surface water quantity management is not restricted to preventing runoff from increasing due to development, but should also manage the maintenance or even restoration of desirable environmental flows and/or hydrological cycles where potential impacts on significant ecosystems such as wetlands are identified.

Design objectives

- For the critical one-year average recurrence interval event, the post-development discharge volume and peak flow rates shall be maintained relative to pre-development conditions in all parts of the catchment. Where there are identified impacts on significant ecosystems, desirable environmental flows and/or hydrological cycles shall be maintained or restored as outlined in this report and approved by the Department of Water.
- The catchment runoff shall be managed for all average recurrence interval events up to and including the 100-year average recurrence interval event within the development area to pre-development peak flow rates. Pre-development critical 10 and 100-year average recurrence interval event peak flow rates are specified in Table 2 of this report.
- Water sensitive urban design and best management practices promoting on-site retention of events up to the one-year average recurrence interval shall form the basis of the surface water quantity management strategy for minor events.

Increase in the post development peak flow rates from 5- to100-year average recurrence interval events may be considered, where it can be demonstrated (at district or local water management strategy stage) that the pre-development hydrologic, hydraulic, geomorphic and ecological characteristics of the downstream catchment and receiving environment can be protected and maintained.

Manage surface water flows from major events to protect infrastructure and assets

Hydrologic and hydraulic modelling of the study area using InfoWorks CS has determined indicative subcatchment scale peak discharge flows and volumes, detention volumes required to manage surface water flows from major events, and hydraulic grade lines within the main waterways.

Detention volumes required to meet specified 10 and 100-year average recurrence interval peak flow criteria are also presented in Table 2 of this report.

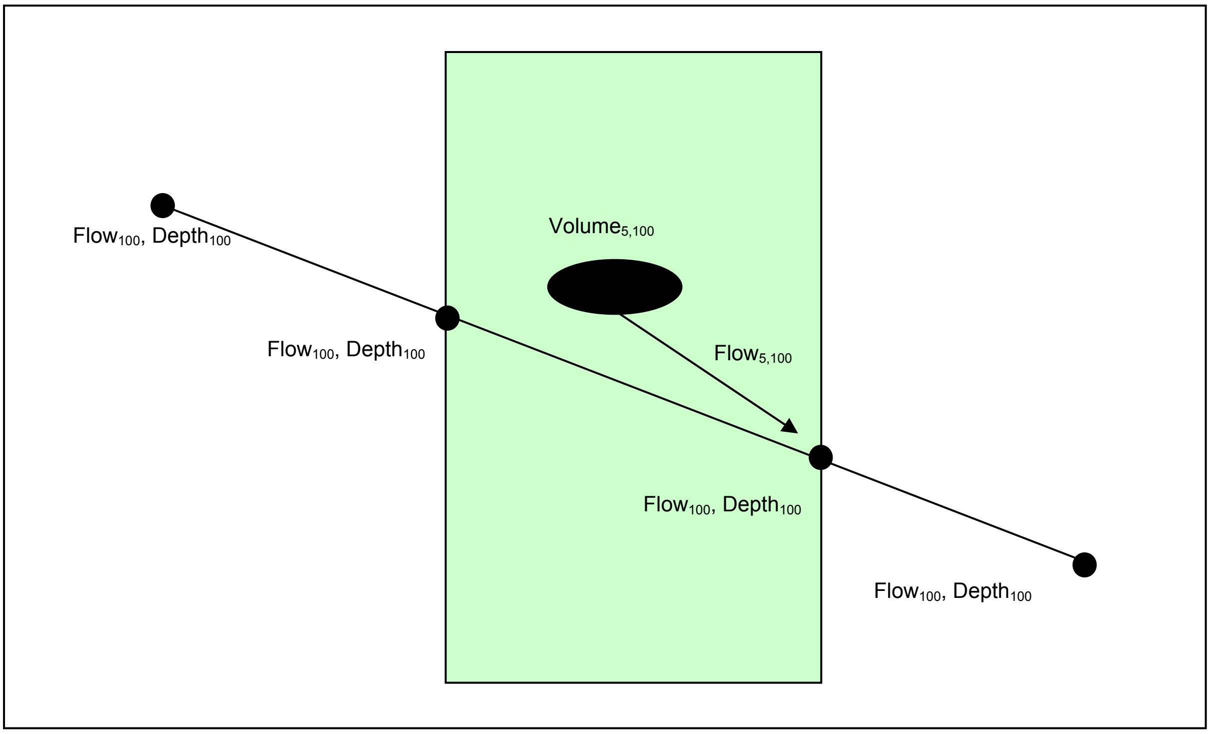
Figure 3 and Table 2 below present the proposed surface water management strategy for the Forrestdale main drain catchment. Indicative 100-year flood levels, subcatchment delineation (Figure 3), and discharge flows, discharge volumes and detention volumes (Table 2) are provided as a guide to developers. These should be refined and located during local structure planning via the local water management strategy, and finalised during subdivision scale planning via the urban water management plan.

For each subcatchment, the critical 10 and 100-year average recurrence interval event pre-development discharge flow rates are presented in Table 2 along with an indicative post-development storage volume required to maintain that flow rate. It is important to note that the *Arterial drainage strategy* model assumes that the one-year one-hour average recurrence interval event (from allotments and also from the road network) is retained at source, so this volume is not included in the indicative flood detention volumes provided in Table 2. Flows from the road network in a one-year average recurrence interval event should be retained (or detained for the duration of the one-year event) within the road reserve network in a manner that mitigates pollutant export.

Discharge flow rates quoted in Table 2 are not within main waterways, and do not include flows generated by upstream subcatchments. Discharge criteria are set for whole subcatchments at the point at which they connect to main waterways as indicated by Figure 15 below.

For each modelled node (Figure 15) along the main waterways, the critical 100-year average recurrence interval event hydraulic grade line with associated peak flow rates are presented on longitudinal sections (Figures 10a-10j and 14a – 14j).

Figure 15 Schematic presentation of information provided for subcatchments and main waterways



Where a proposed development forms a part of one or more of the subcatchments presented in Figure 3, the storage volume to be provided by that development should be calculated based on the subcatchment surface area as a percentage of the total subcatchment surface area.

Table 2 Subcatchment drainage planning criteria – ultimate development

Subcatchment identification	Catchment	Peak discharge flow (m^3/s)		Detention volume (m^3)	
Subdivisional storage basins	**area (ha)**	**10-year**	**100-year**	**10-year**	**100-year**
CATL5B 11.3		0.0	0.3	1400	1730
CATL6 30.72		0.1	0.4	10470	12910

Subcatchment identification	Catchment	Peak discharge flow (m^3/s)		Detention volume (m^3)	
Subdivisional storage basins	**area (ha)**	**10-year**	**100-year**	**10-year**	**100-year**
CATL5C 28.33		0.2	0.1	3590	4190
CATF11C 13.64		0.2	0.2	1420	1920
CATF11B 24.81		0.1	0.2	4340	4830
CATF11D 18.76		0.0	0.3	2480	2890
P4A 18.65		0.1	0.2	2350	2750
P4B 38.53		0.1	0.7	4940	5180
P4C 30.64		0.1	0.2	4680	6390
P4D 34.18		0.0	0.2	3810	4440
P4E 34.01		0.1	0.4	7410	8640
P4F 35.1		0.1	0.4	7420	8690
CATT3A 31.9		0.1	0.3	17700	20720
CATT3B 28.24		0.3	1.1	8970	9760
CATT4 21.54		0.1	0.1	3230	4300
BA8B 9.26		0.1	0.1	1100	1330
cat_lot152 9.29		0.0	0.4	1770	2150
BA8A 21.32		0.1	0.1	4010	5620
SC10 4.69		0.0	0.4	1760	2140
BA14B 68.42		0.1	0.2	17960	23600
BA13A 23.86		0.1	0.2	8730	10700
BA17 38.46		0.1	0.1	5550	7630
BA14C 21.3		0.1	0.3	2400	2990
BA11A 42.7		0.1	0.1	11070	15730
BA14a 41.39		0.1	0.3	6950	8220
BA11B 10.63		0.1	0.1	1570	2070
CATK1 9.13		0.1	0.1	1500	1900
CATB1 58.45		0.9	1.2	2910	4770
CATB2B 30.13		0.1	0.2	5750	7380
CATB2A 26.06		0.1	0.4	2910	3540
CATB3 50.55		0.1	0.4	5520	7630
CATF7C 29		0.1	0.2	3640	4330
CATF2a 24.9		0.1	0.2	5050	6450
CATF5 46.1		0.1	0.2	10340	13200
CATF3b 30.7		0.1	0.3	5580	7670
CATF8a 33.41		0.2	0.4	10510	11580
CATF7A 31.5		0.1	0.5	12440	14740
BA2 84.2		0.1	0.3	24570	32010
BA5B 36.7		0.0	0.2	7900	8960

A summary of peak flows and levels at critical locations along Forrestdale main drain and associated drains (Figure 3) are presented in Table 3 below.

Table 3 Flows and levels at critical locations – ultimate development (see Figure 3)

Location	Peak flows (m^3/s)		Peak levels (m AHD)	
Number (Figure 3) and description	10-Year ARI	100-Year ARI	10-Year ARI	100-Year ARI
1. Forrestdale main drain at Armadale Rd	1.6	2.3	22.3	23.0
2. Forrestdale main drain at Anstey Rd	2.4	3.4	22.2	22.7
3. Forrestdale main drain at Ranford Rd	3.8	4.7	21.9	22.3
4. Forrestdale main drain at Holmes St	6.4	7.8	20.9	21.2
5. Baileys branch drain at Keane Rd	0.7	0.8	22.3	22.7
6. Baileys branch drain at discharge to Forrestdale main drain	1.3 1.8		22.0	22.3
7. Keane Rd branch drain at discharge to Forrestdale main drain	0.8 1.1		22.4	23.0
8. Murphys drain at discharge to Forrestdale main drain	1.9 2.8		22.3	22.9
9. Balannup drain at Nicholson Rd	0.9	1.0	24.4	24.5
10. Balannup drain at discharge to Baileys branch drain	0.9 0.9		22.2	22.6
11. Balannup Lake drain at Southern River Rd	0.4	0.5	21.1	21.4
12. Balannup Lake drain at Matison Rd	0.9	0.9	21.1	21.4
13. Precinct 4 north drain at Passmore St	0.4	0.6	19.9	20.5
14. Precinct 4 south drain at Passmore St	0.4	0.7	21.7	22.0
15. James drain at Armadale Rd	0.9	1.1	25.4	25.6
16. James drain at discharge to Forrestdale Lake	0.2 0.3		22.9	23.1

Average recurrence interval (ARI)

The following specific main drainage upgrades are proposed by this *Arterial drainage strategy:*

Forrestdale townsite

- Baileys drain requires widening within a linear public open space of approximately 50 m width for a length north of Armadale Road (see Figure 3 section 2).
- The *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) shows the corridor required for drainage purposes and this is approximately the area required under the *Arterial drainage strategy.*
- Immediately downstream of Anstey Road there is a short length of drain to Keane Road that runs through land that remains rural but that should be widened.
- To maintain the existing hydrologic regime of the Baileys wetland (Bush Forever site no. 342) it will be necessary to reinstall the 600 mm connection from the Balannup drain into Baileys branch drain which was removed as part of the existing development of the North Forrestdale area.

Adjacent to Tonkin Highway (Armadale Road to Allen Road)

- Forrestdale main drain requires widening within a linear public open space of approximately 50 m width along the length adjacent to Tonkin Highway (see Figure 3, section 1).
- The *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) shows an area required for drainage at the southern end of the required drainage corridor, immediately north of Armadale Road. The area of land required for drainage is similar but now in a different location, although on the same landholding. The widened drain should be located in linear public open space (see linear public open space inserts on Figure 3). Its location adjacent to the Tonkin Highway provides a buffer between that road and the urban area, as well as providing a potential wildlife corridor between areas of remnant bushland.

Tonkin Highway (at Allen Road) to Anstey Road

- Forrestdale main drain requires widening within a linear public open space of approximately 50 m width for a length from the Tonkin Highway (at Allen Road) to Anstey Road (see Figure 3, section 1).
- Along this length of drain the land to the west of the drain will remain zoned rural and the land to the east of the drain is shown on the district structure plan as potential light industrial.
- The current district structure plan shows some land required for drainage within this light industrial area and this area is approximately equivalent to the land required for widening the drain under the *Arterial drainage strategy*.

Anstey Road to Ranford Road

- Forrestdale main drain requires widening within a linear public open space of approximately 70–100 m width for a length from the Anstey Road to Ranford Road (see Figure 14, section 3). This is regional drainage infrastructure and land acquisition will be required.
- Along this length of drain the land is already zoned light industrial and the district structure plan shows a wide drainage corridor. However, the corridor is bounded to the north-west by conservation category wetlands and to the south-west by a Bush Forever site, which may place significant environmental constraints on any drainage works.
- In order to fully utilise the proposed storage upstream of Ranford Road and provide protection to the existing properties within the kennels zone, it will be necessary to block one 900 mm diameter barrel of the Ranford Road culvert.

Kennels to Phoebe Road

- Forrestdale main drain requires widening within a linear public open space to create online flood storage area between the kennels zone and Phoebe Road (see Figure 3, section 4).
- The current district structure plan shows the corridor required for drainage purposes and this is approximately the area required under the *Arterial drainage strategy.*

Phoebe Road to Holmes Street

- Forrestdale main drain requires widening within a linear public open space to create online flood storage areas between Phoebe Road and Holmes Street (see Figure 3, section S4).
- The current district structure plan shows the corridor required for drainage purposes and this is approximately the area required under the *Arterial drainage strategy.*

Precinct 4

- The *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) currently indicates a drainage corridor running along the eastern boundary of Precinct 4, adjacent to the Tonkin Highway. This *Arterial drainage strategy* recommends the retention of existing drainage routes, as shown on Figure A3c.

In all locations where a widened drain within linear public open space is proposed, a low flow channel to convey baseflow and minor events (< one-year average recurrence interval) will be incorporated into the base of the main drainage channel. With appropriate planting and treatment, the low flow channel may be modified to improve water quality by providing opportunities for biofiltration as well as provide habitat, provided that the hydraulic capacity is not reduced.

5.3 Surface water quality management

The environmental values of downstream waterways within, and surrounding, the study area should be upheld.

Maintaining pre-development discharge rates and volumes from developed catchments is expected to prevent the majority of contaminants from reaching the waterways by ensuring that the majority of flows from high frequency events are detained or infiltrated on site.

Provided that the initial flow of more significant events is subject to the same detention and treatment received by high frequency events, surface runoff that occurs during more significant events represents a lower risk to downstream water quality. This is because nutrients and other contaminants that represent a threat to downstream water quality are typically transported within the ‘first flush’ of an event.

To meet the objective of no deterioration in water quality, the MOU group has developed a water quality management strategy as part of the *Southern River integrated land and water management plan* (Department of Water 2009).

To meet the objective of no deterioration in water quality, water quality will be monitored in the arterial drainage system, particularly the Forrestdale main drain. Should water quality monitoring in the Forrestdale main drain indicate deterioration, the Department of Water will seek to determine the cause and take corrective action.

In addressing any observed deterioration in water quality in the Forrestdale main drain, the Department of Water may recommend that treatment measures be included in the arterial drainage system. Where any treatment systems are installed, they should not reduce the hydraulic capacity of the arterial drainage system and should be compatible with the land uses of any multiple use corridors. It is critical that the design and construction of any treatment systems be undertaken in close collaboration with the drainage asset managers of the service providers (local authority or the Water Corporation).

5.4 Key design criteria

Surface water quantity

- The one-year one-hour average recurrence interval event shall be detained at source for the duration of the event through the use of retention (soakage) or storage devices. Refer to Chapter 9 of the *Stormwater management manual for Western Australia* (Department of Water 2004-2007) for devices suited to the soil types for this catchment. The *Stormwater management manual for Western Australia* (Department of Water 2004-2007) contains guidance for the appropriate design of retention and detention systems.
- The post-development critical one-year average recurrence interval peak flow and volume and the 100-year average recurrence interval peak flow shall be consistent with pre-development flows at:
    - the discharge points of all subdivisions into waterways
    - the discharge points from the structure plan area
    - the discharge points of each subcatchment.
- Flows from developed areas should be attenuated, in accordance with Table 2 which protects the regional system, in flood detention/storage areas incorporated into public open space within the subdivision and located outside floodways.
- Post-development flows for all average recurrence interval events should be discharged at flow rates which are consistent with pre-development flow rates for those same events.
- Developments outside the floodway should ensure finished floor levels at a minimum of 0.5 m above the 100-year flood level.
- The existing cross-sectional area of waterways should be maintained. Restoration of waterways is encouraged and in some cases channel realignments and

channel profile modifications may be carried out, provided it is demonstrated that the pre-development cross-sectional area has been preserved.

- Public open space and retention basins should operate as dry basins with a minimum clearance of 0.3 m between the groundwater level endorsed by the Department of Water and the invert of the basin.
- Defined major arterial roads should remain passable in the 100-year average recurrence interval event. The local authority should be contacted to identify roads where this criteria applies.
- Minor roads should remain passable in the five-year average recurrence interval event.
- Emergency evacuation areas should be defined at least 2.0 m above the 100-year average recurrence interval event level.
- Water quality treatment systems and water sensitive urban design structures should be designed in accordance with the *Stormwater management manual for Western Australia* (Department of Water 2004-2007) and *Australian runoff quality* (Institute of Engineers Australia 2006).

Surface water quality

Designs for infrastructure and management measures to achieve ecological protection and water quality outcomes should be based on the methodologies established in the *Stormwater management manual for Western Australia* (Department of Water 2004–07).

Targets are to be achieved through adopting a treatment train approach including:

- non-structural measures to reduce applied nutrient loads
- on-site retention of the one-year one-hour average recurrence interval event
- bioretention structures/systems, (also referred to as rain gardens) to be sized at two per cent of connected constructed impervious areas.

If it is proposed to use a computer stormwater modelling tool to assess a proposed water quality management strategy, the following design targets are recommended:

As compared with a development that does not actively managed water quality, developments should achieve:

- at least 80 per cent reduction of total suspended solids
- at least 60 per cent reduction of total phosphorus
- at least 45 per cent reduction of total nitrogen.
- at least 70 per cent reduction of gross pollutants

Proponents shall develop and present the strategies for water quantity and quality management in the local water management strategy and urban water management plans to support the planning approvals required for the development to proceed.

Engineering drawings submitted to council for approval should be supported by clear and auditable documentation, providing details of proposed staging and implementation of the surface and groundwater quantity and quality management strategy.

It is strongly recommended that consultants meet with the local authority to discuss proposed surface and groundwater management strategies and to gain further guidance on site-specific requirements of the local authority at commencement of any local water management strategy or urban water management plan.

Further details on water quality management strategies appropriate to this catchment are provided in the *Southern River integrated land and water management plan* (Department of Water 2009).

6 Groundwater management strategy

The key objectives for groundwater management are:

- protection of infrastructure and assets from flooding and inundation by high seasonal groundwater levels, perching and/or soil moisture
- protection of groundwater-dependent ecosystems from the impacts of urban runoff
- management and minimisation of changes in groundwater levels and groundwater quality following development/redevelopment

6.1 Groundwater modelling

Manage groundwater levels to protect infrastructure and assets

Groundwater modelling (Rockwater 2005) investigated a range of potential development scenarios. The groundwater model was designed to predict maximum groundwater levels for a range of climate scenarios with the conclusion that filling and/or drainage will be required over substantial areas of the catchment to prevent periodic inundation of the development areas.

The modelling also considered the use of subsoil drains to control groundwater levels within developed areas and the impact of those drains on the lakes and wetlands in the catchment. Subsoil drains are necessary to control peak groundwater levels in substantial areas of the catchment. Without them groundwater levels in the catchment would rise up to 0.2 m higher in winter as a result of urban development, and increase the groundwater flux, thereby impacting on environmentally-sensitive wetlands.

The results of the regional groundwater model have been incorporated into the InfoWorks surface water model by the application of winter peak starting water levels in wetlands and inflows to key sections of the drainage system. These starting water levels and inflows provide an assessment of the drainage systems' ability to manage significant rainfall events at times of peak groundwater, as well as an indication of the base flow within the drain at these times. Subsoil drainage flows predicted by this scenario of the groundwater model have also been incorporated into the InfoWorks surface water model used in this study.

Further information regarding the selection of pre- and post-development model scenarios and the construction and calibration of the groundwater model may be gained by requesting a copy of the *Southern River development area groundwater model* (Rockwater 2005) report from the Water Corporation.

Figure 11 presents the modelled Rockwater (2005) maximum groundwater level (788 mm annual rainfall scenario) and provides a guide to regional groundwater levels in the study area. However, groundwater levels should be determined in consultation with the Department of Water and presented in local water management strategies.

Further investigations will be required to determine local scale predicted maximum groundwater level for individual developments to determine whether subsurface drainage is required for protection of urban infrastructure. This drainage should always be located at or above a groundwater level endorsed by the Department of Water and presented in the local water management strategy.

Additional groundwater management strategies and design criteria are presented in the *Southern River integrated land and water management plan* (Department of Water 2009).

6.2 Groundwater quality management

The environmental values of groundwater within, and surrounding, the study area should be upheld.

Maintain groundwater quality at pre-development levels (median winter concentrations) and, if possible, improve the quality of water leaving the development area to maintain and restore ecological systems in the (sub) catchment in which the development is located.

Water sensitive urban design and best management practices should not only promote infiltration to aid in prevention of possible local flooding from increased runoff due to urbanisation, but they should also treat the water prior to its discharge to waterways, wetlands and to groundwater. This is particularly important given the high variability in phosphorus retention capacity of the soils in the study area and the anticipated increase in nutrient load due to urbanisation.

Where subsoil drainage is installed for groundwater level or soil moisture control, a 'treatment system' (swale/ bioretention etc) at each subsoil drain outlet point will be required. The *Stormwater management manual for Western Australia* (Department of Water 2004-07) contains guidance for the design of subsoil drainage, appropriate to calculated flow rates.

Where appropriate, field investigations should be undertaken to identify acid sulfate soils. Any reduction in groundwater level should not expose acid sulfate soils to the air, as this may cause groundwater contamination. If field investigations identify acid sulfate soils, further advice should be sought from the Department of Environment and Conservation.

Contaminated sites must be managed in accordance with the *Contaminated Sites Act 2003*.

6.3 Key design criteria

- The importation of clean fill and/or the provision of subsurface drainage will be required to ensure that adequate separation of building floor slabs from groundwater is achieved. In such instances, the subsurface drainage will need to be placed at or above a groundwater level endorsed by the Department of Water.

Guidelines on determining the groundwater drainage level are in preparation by the Department

- The bio-retention system and drainage inverts are to be set at or above the a groundwater level endorsed by the Department, although existing drainage inverts can remain.
- Subsurface drainage should be designed with free-draining outlets.
- Fill imported onto the site is to incorporate a band of material that will reduce phosphorus export via soil leaching, whilst also meeting soil permeability and soil compaction criteria specified by the local government authority.
- Where development is associated with any new or existing waterway or open drain that intersects the shallow water table, and that may discharge pollutants from the shallow groundwater to receiving environments, the following interim targets will be adopted until such time as appropriate site-specific targets are developed:

As compared with a development that does not actively manage water quality, the following should be achieved:

- at least 60 per cent reduction of total phosphorous
- at least 45 per cent reduction of total nitrogen.

Where development is associated with an ecosystem that is dependent on a particular hydrologic regime for survival, the water quality discharged to the groundwater should be in accordance with the requirements of the Department of Environment and Conservation.

Engineering drawings submitted to council for approval should be supported by clear and auditable documentation, providing details of proposed staging and implementation of the surface and groundwater quantity and quality management strategy.

It is strongly recommended that consultants meet with the local authority to discuss proposed surface and groundwater management strategies and to gain further guidance on site-specific requirements of the local authority at commencement of any local water management strategy or urban water management plan.

Further details of groundwater quality management strategies and design criteria are presented in the *Southern River integrated land and water management plan* (Department of Water 2009).

7 Commitment to best management practice

Best management practices suitable for use in the Forrestdale main drain catchment and supported by the Department of Water are presented in the *Southern River integrated land and water management plan* (Department of Water 2009).

In order to meet the design criteria of reductions in total phosphorus, total nitrogen, total suspended solids and gross pollutants as compared to developments in which water treatment is not undertaken, it is necessary to use a combination of best management practice strategies.

In addition, best management practice strategies reduce risks of flooding on housing and infrastructure while maximising the potential for stormwater to be treated as a resource.

8 Implementation

8.1 Requirements for following stages

State planning policy 2.9: water resources (Western Australian Planning Commission 2004) requires that planning should contribute to the protection and wise management of water resources through local and regional planning strategies, structure plans, schemes, subdivisions, strata subdivisions and development applications. *Better urban water management* (Department of Planning and Infrastructure, Department of Water, Western Australian Local Government Authority and Department of Environment, Water, Heritage and the Arts 2008), provides guidance on implementation of *State planning policy 2.9.* It identifies the requirements for water management strategies and plans that should be developed to accompany the land use planning and approvals process in the *Southern River integrated land and water management plan* (Department of Water 2009) area at each stage of the planning process

In summary, all local structure planning should incorporate a local water management strategy consistent with the strategies and objectives of the *Southern River integrated land and water management plan* (Department of Water 2009) and this *Arterial drainage strategy*. Subsequent subdivision applications should be accompanied by an urban water management plan where required by the Department of Water and the City of Armadale or the City of Gosnells, and/or should be consistent with an approved local water management strategy and with the strategies and objectives of the *Southern River integrated land and water management plan* (Department of Water 2009) and this *Arterial drainage strategy.*

Guidelines for *Developing a local water management strategy* are currently in preparation by the Department of Water.

Urban water management plans: guidelines for preparing plans and for complying with subdivision conditions (Department of Water 2008) are available of the Department of Water's website.

Developers are encouraged to contact the Department of Water (Swan Avon regional office) and the City of Armadale or the City of Gosnells early in the planning process to discuss specific water management requirements for proposals.

8.2 Review of integrated land and water management plan and *Arterial drainage strategy*

It is intended that the *Southern River integrated land and water management plan* (Department of Water 2009) and this *Arterial drainage strategy* be reviewed within ten years or earlier if deemed necessary until development has occurred consistent with the *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001).

The review should be undertaken by the Department of Water, with agreement from the Environmental Protection Authority, Western Australian Planning Commission, the City of Armadale, the City of Gosnells and the Water Corporation. The review should cover, but not be limited to the following:

- assessment of impacts of development
- design objectives
- requirements for local water management strategies and urban water management plans
- cost-recovery mechanisms.

Monitoring requirements and an implementation action plan for the Forrestdale main drain catchment is presented in the *Southern River integrated land and water management plan* (Department of Water 2009).

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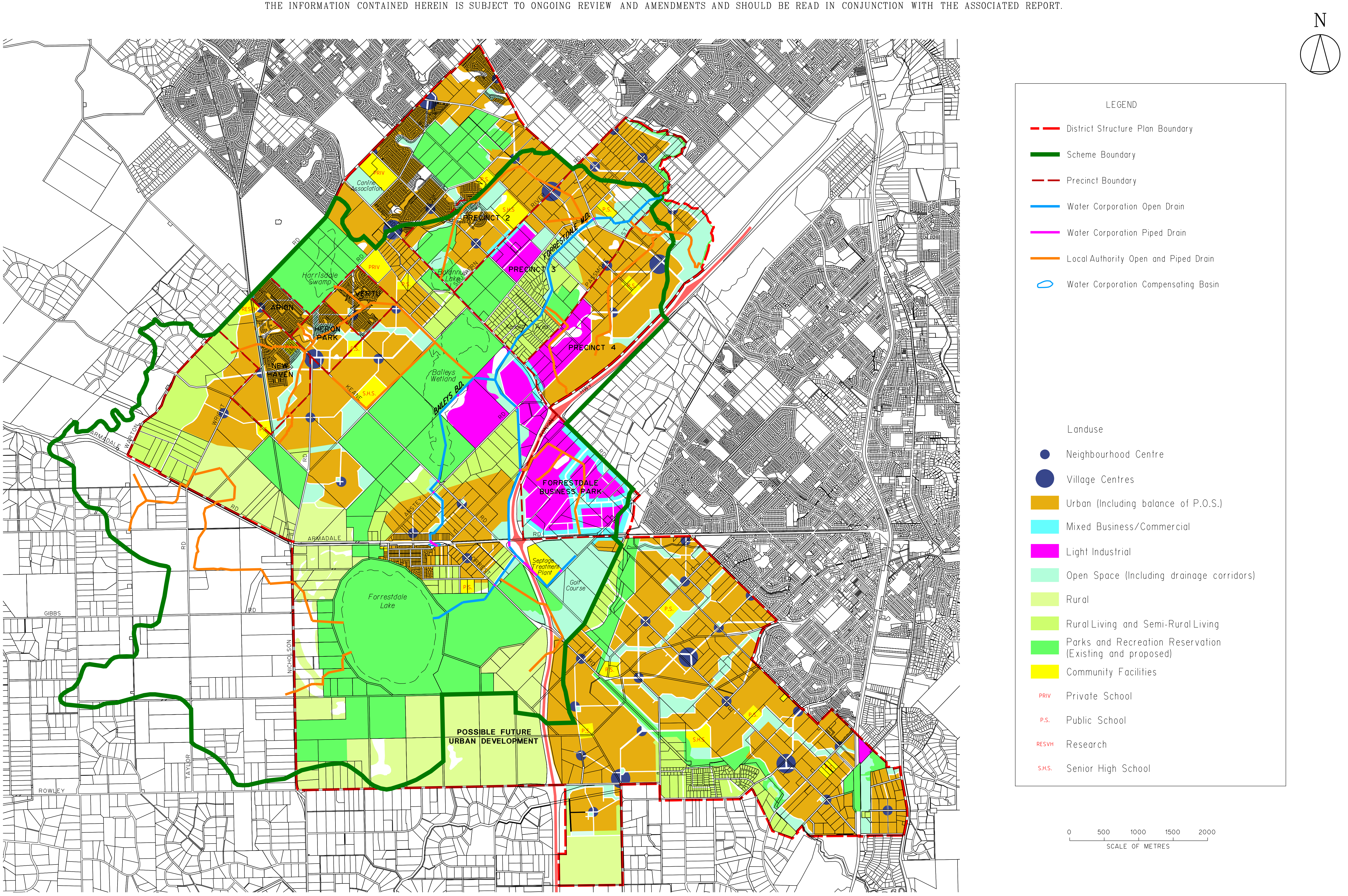

DESIGN FILE: Fig 1 ProposedLandUse.dgn

AUTHOR: SLee

WATER CORPORATION

SOUTHERN RIVER-FORRESTDALE-BROOKDALE-WUNGONG DISTRICT STRUCTURE PLAN: PROPOSED LAND USE

Figure 1

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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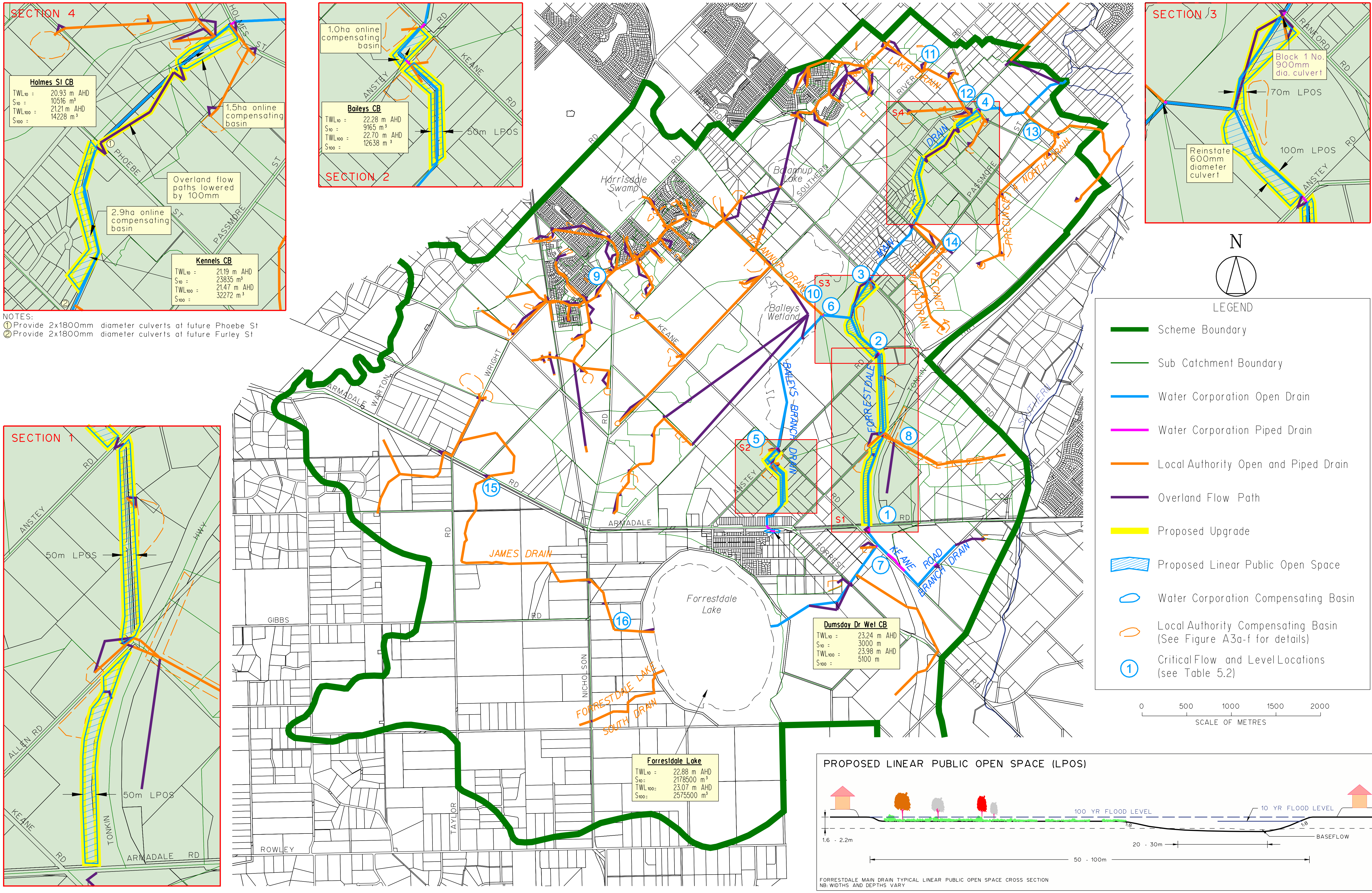


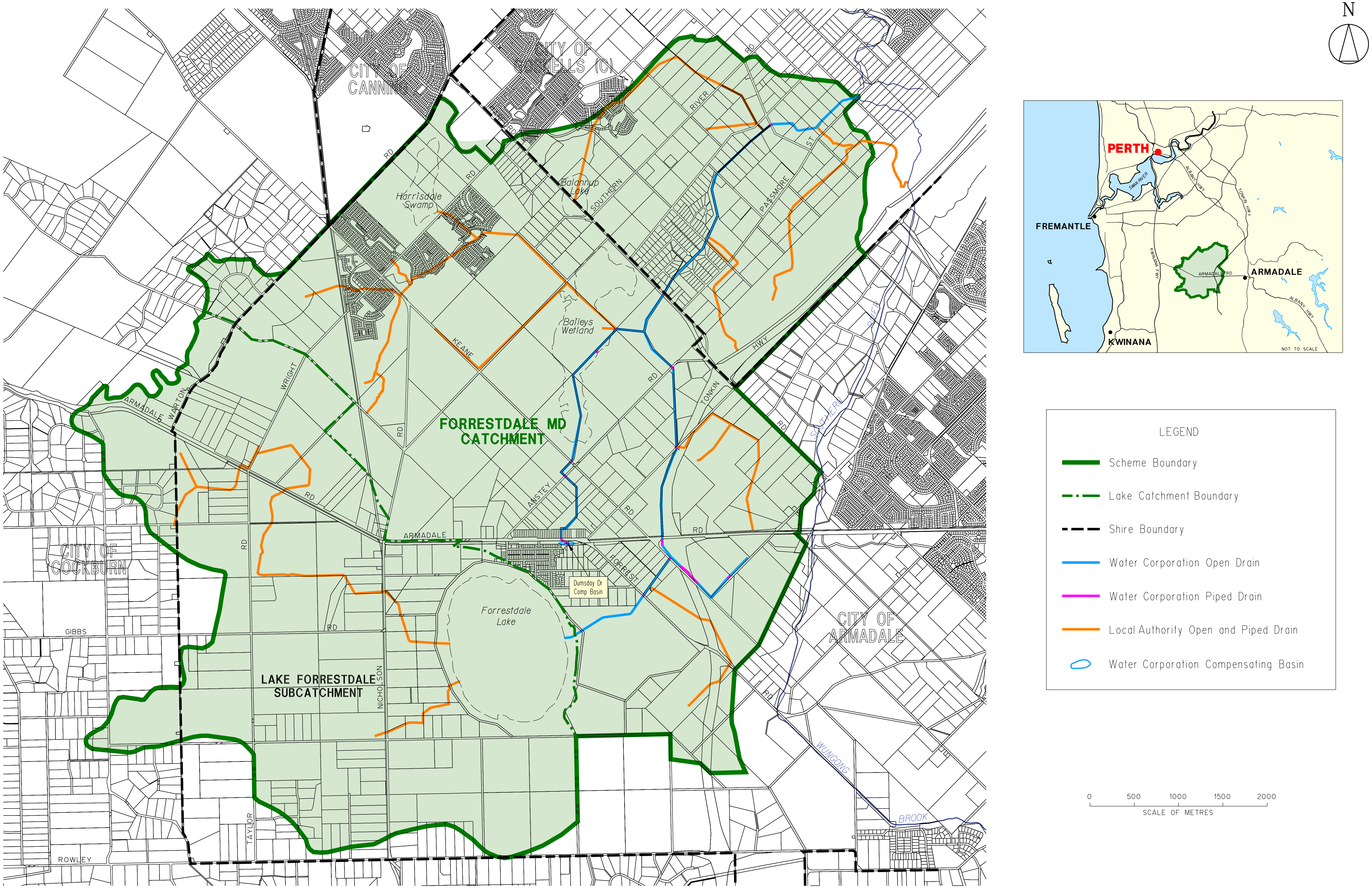
AUTHOR: P Haywood DESIGN FILE: Fig 3 Strategy.dgn

WATER CORPORATION

FORRESTDALE MAIN DRAIN CATCHMENT ARTERIAL DRAINAGE STRATEGY

Figure 3

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50



AUTHOR: SLee
DESIGN FILE: Fig 4 Locality.dgn

WATER CORPORATION

LOCALITY

Figure 4

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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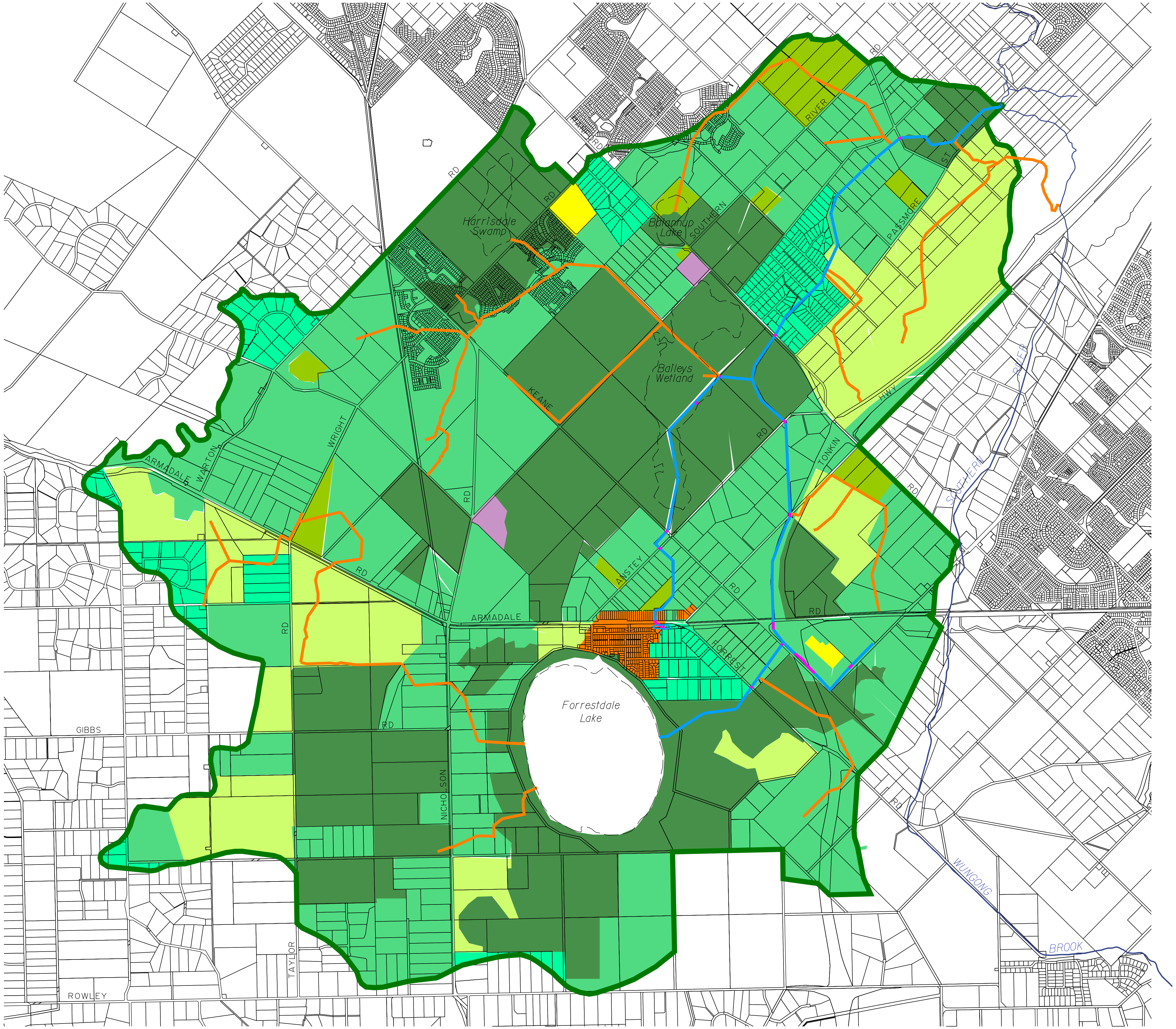

LEGEND

- Scheme Boundary
- Water Corporation Open Drain
- Water Corporation Piped Drain
- Local Authority Open and Piped Drain
- Water Corporation Compensating Basin

Landuse

- Farming
- Light Industrial
- Public Open Space
- Public Purposes
- Regional Open Space
- Residential
- Rural
- Rural Residential

0 500 1000 1500 2000
SCALE OF METRES

DESIGN FILE: Fig 5 ExistingLandUse.dgn

AUTHOR: SLee

WATER CORPORATION

EXISTING LAND USE

Figure 5

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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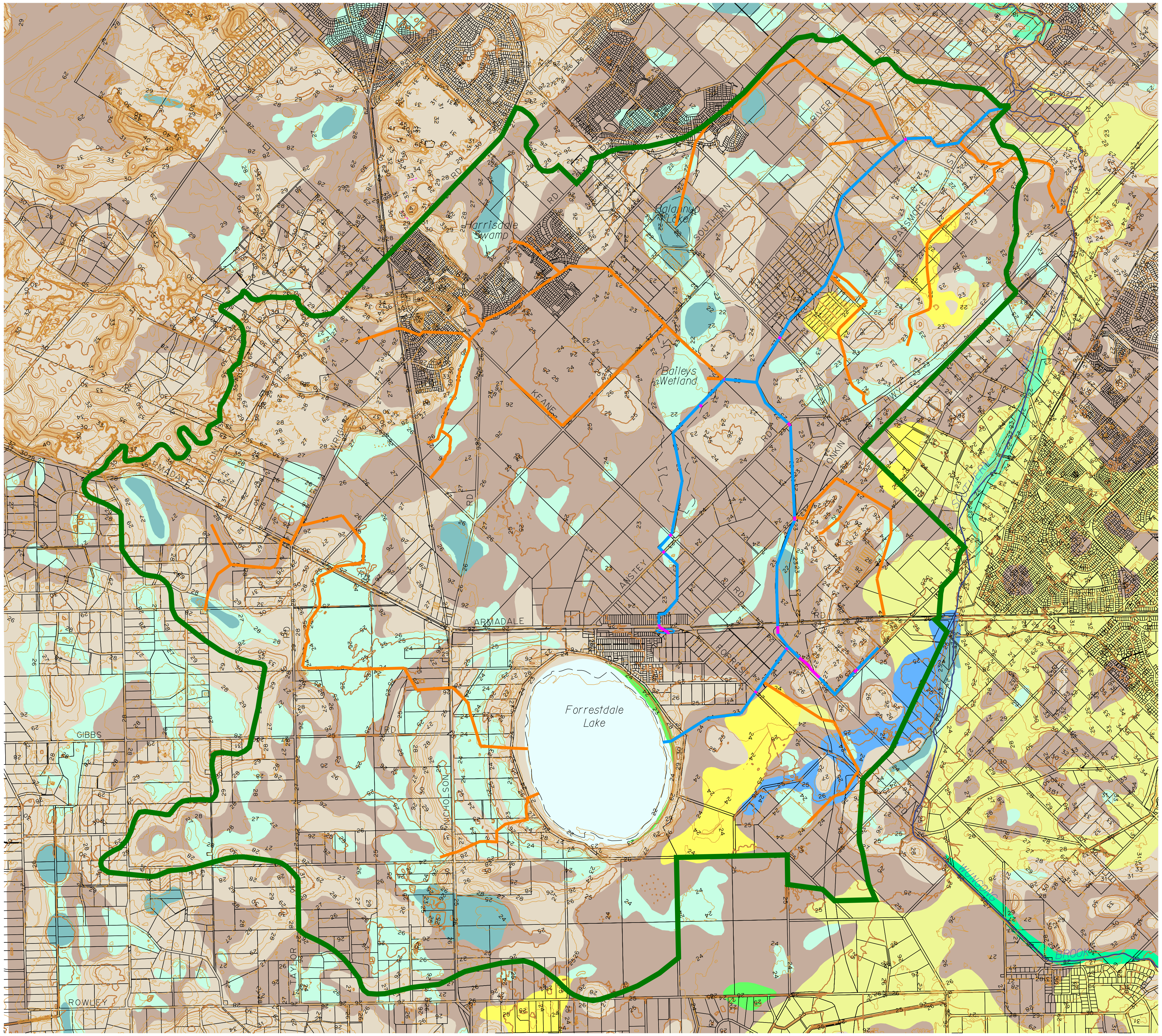


N

LEGEND

- Scheme Boundary
- Lake Catchment Boundary
- Water Corporation Open Drain
- Water Corporation Piped Drain
- Local Authority Open and Piped Drain
- Contours
- Water Corporation Compensating Basin

Geology

- Peaty Sand
- Peat-Rich Sand
- Sandy Silt
- Clayey Sandy Silt
- Sand - white to pale brown
- Limestone
- Sand - white to pale grey at surface, yellow at depth
- Sand - over sandy clay to clayey sand
- Clayey Sand
- Sandy Clay
- Water

0 500 1000 1500 2000
SCALE OF METRES

DESIGN FILE: Fig 6 TopographyGeology.dgn

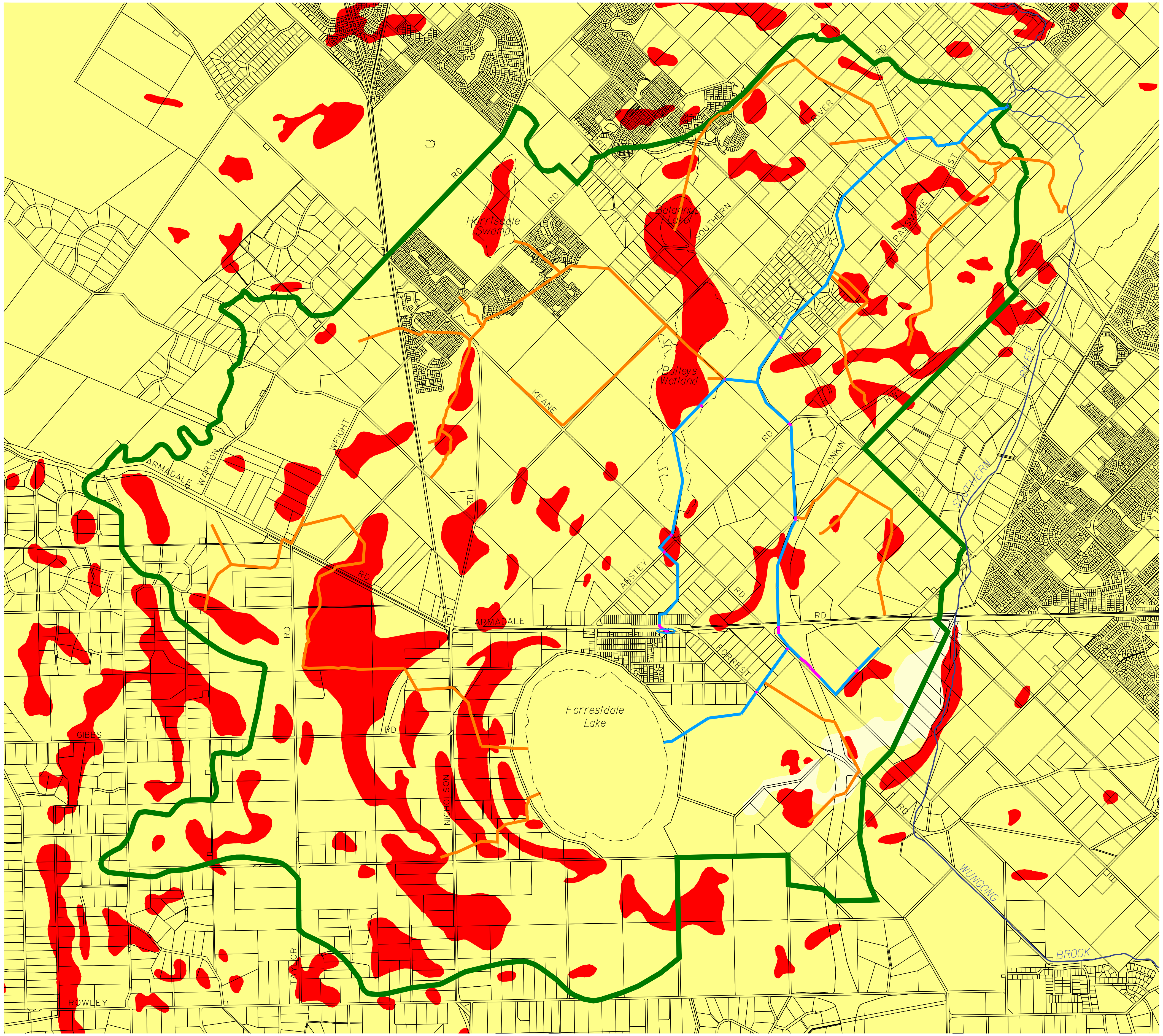
AUTHOR: SLee

WATER CORPORATION

TOPOGRAPHY AND GEOLOGY

Figure 6

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50



N

LEGEND

- Scheme Boundary
- Water Corporation Open Drain
- Water Corporation Piped Drain
- Local Authority Open and Piped Drain
- Water Corporation Compensating Basin

Acid Sulfate Soils Risk (ASS)

- Class 1 - High risk of ASS <3 m from soil surface
- Class 2 - Moderate to low risk of ASS occuring <3 m from soil
- Class 3 - Low to no risk of ASS occuring at depths of <3 m

0 500 1000 1500 2000
SCALE OF METRES

DESIGN FILE: Fig 7 AcidSulphateSoils.dgn

AUTHOR: SLee

WATER CORPORATION

PROJECT N°: DP215 DATE: 17/09/2009 COORDINATE SYSTEM: MGA94 - Zone 50

ACID SULPHATE SOILS

Figure 7

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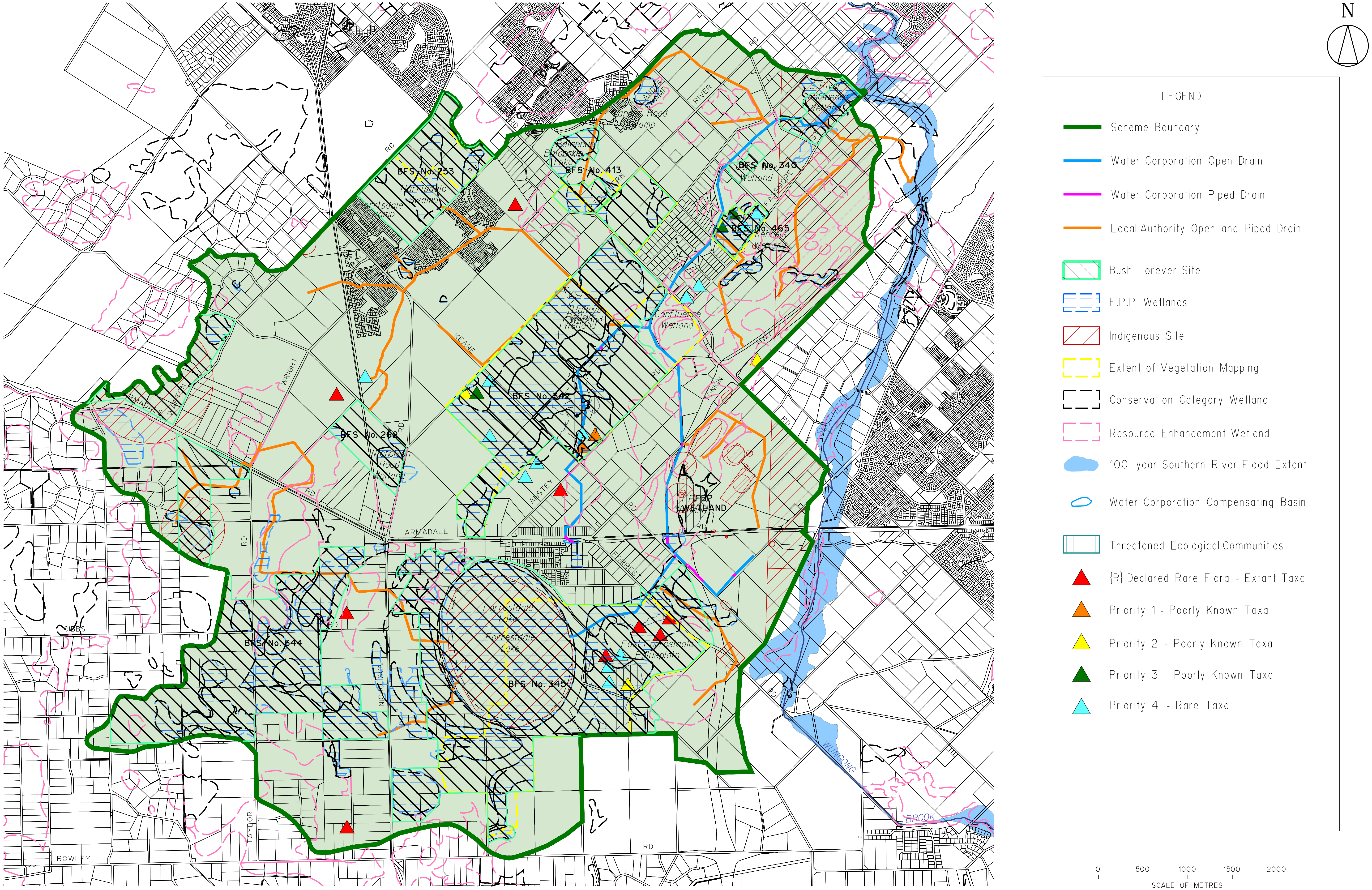

AUTHOR: P Haywood DESIGN FILE: Fig 8 EnvironmentSocial.dgn

WATER CORPORATION

ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

Figure 8

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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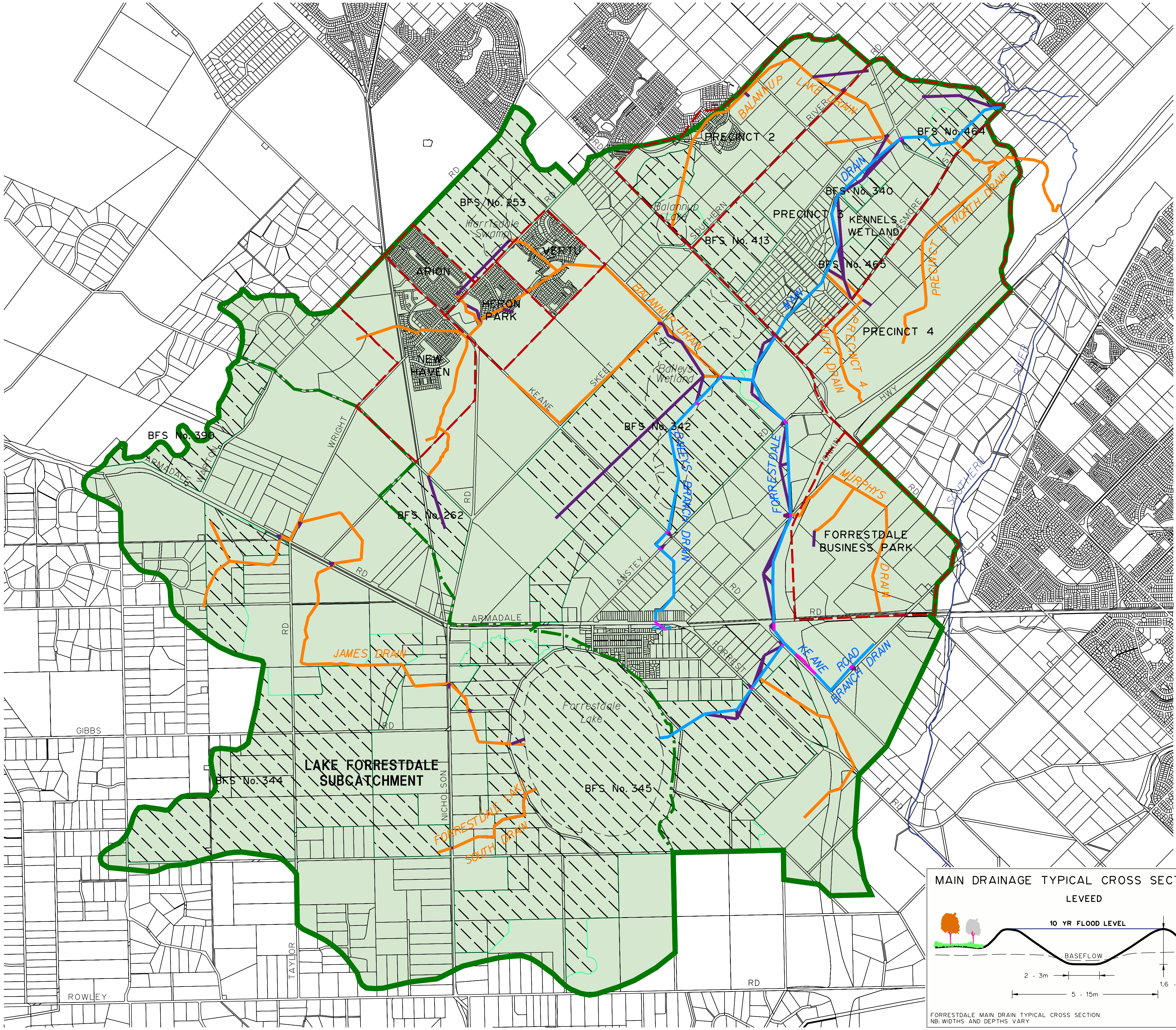
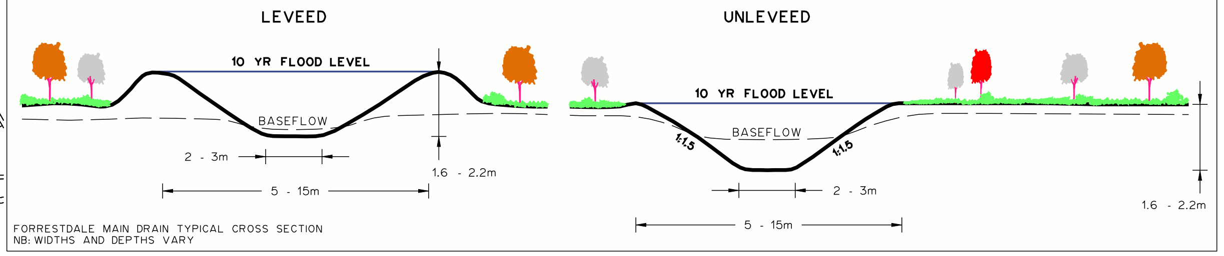


LEGEND

- Scheme Boundary
- Lake Catchment Boundary
- Precinct Boundary
- Water Corporation Open Drain
- Water Corporation Piped Drain
- Local Authority Open and Piped Drains
- Overland Flow Paths
- Bush Forever Site
- Water Corporation Compensating Basin

0 500 1000 1500 2000
SCALE OF METRES

MAIN DRAINAGE TYPICAL CROSS SECTIONS



DESIGN FILE: Fig 9 ExistingSystem.dgn

AUTHOR: SLee

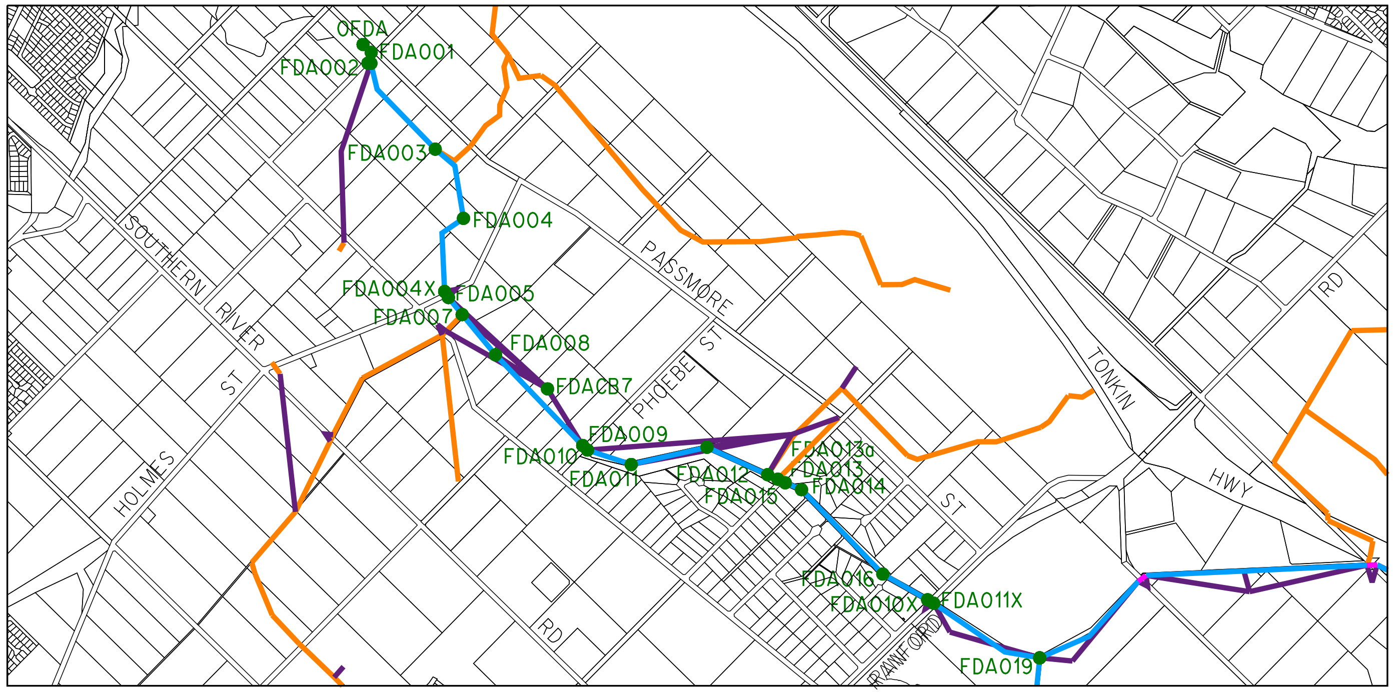
WATER CORPORATION

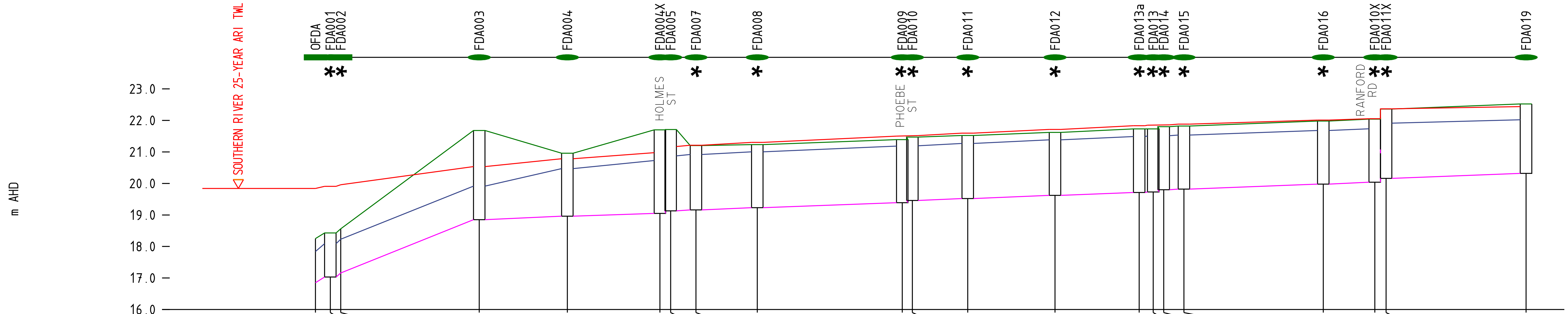
EXISTING SYSTEM DETAILS

Figure 9

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

N





Structure	Flooding (100 yr ARI)	Chainage (m)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD) in	Invert level (m AHD) out
OFDA		0	18.25	17.84	19.84	-	16.85
FDA001	*	50	18.43	18.09	19.91	17.03	17.03
FDA002	*	85	18.56	18.23	19.96	17.16	17.16
FDA003		550	21.68	19.91	20.54	18.85	18.85
FDA004		846	20.96	20.47	20.78	18.96	18.96
FDA004X		1157	21.70	20.73	20.97	19.05	19.05
FDA005		1193	21.71	20.87	21.17	19.13	19.13
FDA007	*	1278	21.20	20.92	21.21	19.16	19.16
FDA008	*	1484	21.23	21.00	21.30	19.23	19.23
FDA009	*	1971	21.39	21.18	21.50	19.39	19.39
FDA010	*	2005	21.47	21.20	21.52	19.46	19.46
FDA011	*	2191	21.52	21.27	21.59	19.52	19.52
FDA012	*	2484	21.62	21.38	21.71	19.62	19.62
FDA013a	*	2766	21.73	21.49	21.83	19.71	19.71
FDA013	*	2814	21.73	21.50	21.85	19.73	19.73
FDA014	*	2849	21.80	21.51	21.86	19.80	19.80
FDA015	*	2917	21.82	21.54	21.88	19.82	19.82
FDA016	*	3385	21.98	21.68	22.01	19.98	19.98
FDA010X	*	3558	22.04	21.73	22.05	20.04	20.04
FDA011X	*	3596	22.36	21.91	22.37	20.16	20.16
FDA019		4066	22.52	22.02	22.44	20.32	-

Reach	Size (mm)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
OFDA – FDA001	14800 x1400	6.95	8.91
FDA001 – FDA002	14800 x1400	6.95	8.91
FDA002 – FDA003	14800x1400	6.66	8.55
FDA003 – FDA004	8000x2000	6.13	7.53
FDA004 – FDA004X	8000x2000	6.13	7.54
FDA004X – FDA005	2x 1791	3.06	3.77
FDA005 – FDA007	8000 x2000	5.93	7.29
FDA007 – FDA008	8000 x2000	5.51	7.36
FDA008 – FDA009	8000x2000	5.27	7.08
FDA009 – FDA010	8000 x2000	5.28	7.15
FDA010 – FDA011	8000 x2000	5.19	7.01
FDA011 – FDA012	8000x2000	5.19	7.02
FDA012 – FDA013a	8000x2000	5.19	7.04
FDA013a – FDA013	8000 x2000	4.68	6.20
FDA013 – FDA014	8000 x2000	4.61	6.10
FDA014 – FDA015	8000 x2000	4.47	5.89
FDA015 – FDA016	8000x2000	4.37	5.79
FDA016 – FDA010X	8000x2000	4.23	5.65
FDA010X – FDA011X	5x915	0.85	1.13
FDA011X – FDA019	8600x2200	3.89	5.07

* INDICATES FLOODING DURING 100 YR ARI STORM EVENT

Forrestdale Main Drain Part 1 of 2

LONGITUDINAL SECTION

HGLs And Flows Existing System

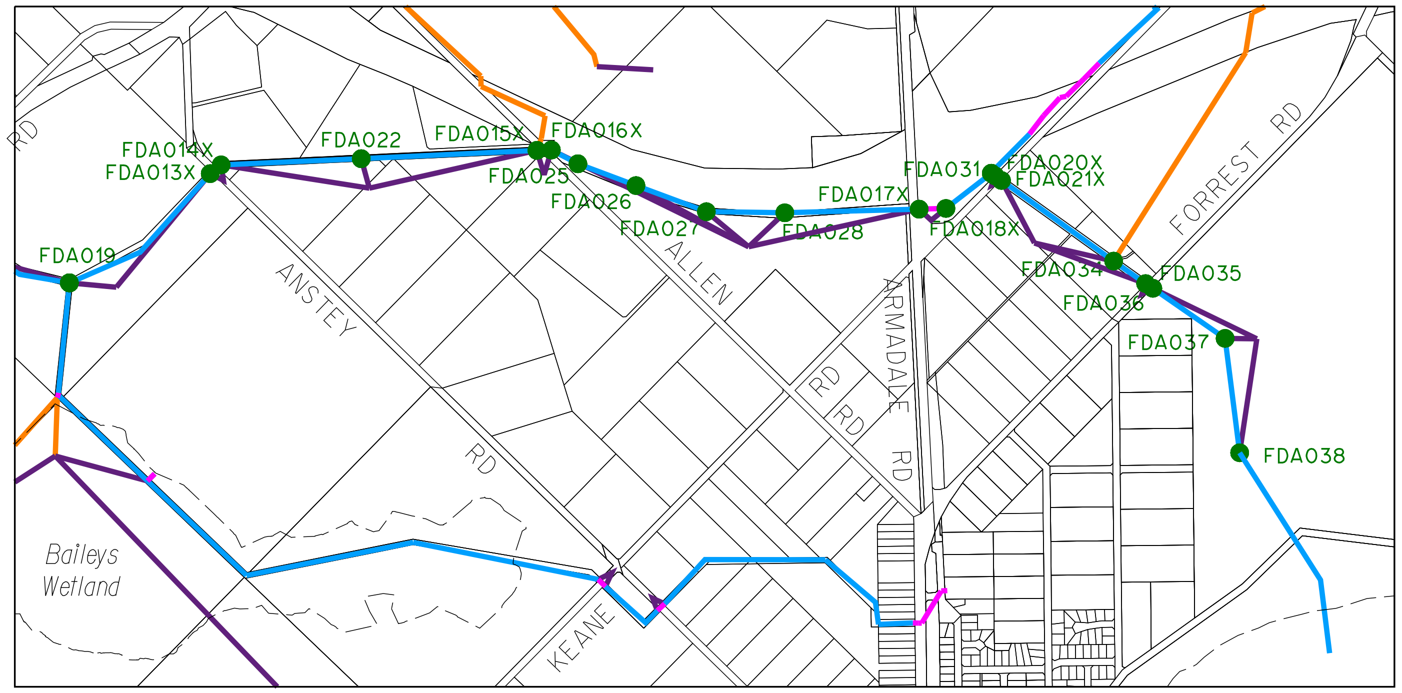
Figure 10a

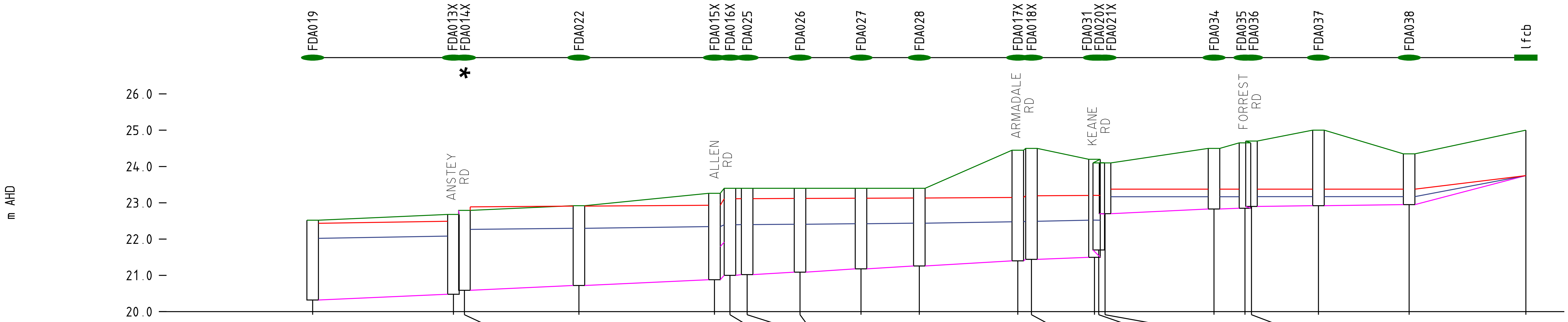
WATER CORPORATION

AUTHOR: P Haywood DESIGN FILE: Fig 10a LS ForrestdaleMD 1of2 pre.dgn

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

N





Chainage (m)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD) (upstream side)	Invert level (m AHD) (downstream side)
4066	22.52	22.02	22.44	-	20.32
4558	22.68	22.08	22.49	20.48	22.68
4596	22.79	22.27	22.89	22.79	20.59
4996	22.92	22.30	22.91	20.72	20.72
5470	23.26	22.34	22.93	20.88	20.88
5524	23.40	22.39	23.11	21.00	21.00
5584	23.40	22.40	23.11	21.02	21.02
5769	23.40	22.41	23.12	21.09	21.09
5982	23.40	22.42	23.13	21.18	21.18
6186	23.40	22.44	23.13	21.26	21.26
6530	24.45	22.48	23.15	21.40	21.40
6578	24.50	22.49	23.19	21.44	21.44
6798	24.20	22.52	23.20	21.50	21.50
6813	24.10	22.52	23.20	21.70	22.69
6835	24.10	23.17	23.38	22.70	22.70
7216	24.50	23.17	23.38	22.83	22.83
7324	24.65	23.17	23.38	22.85	22.85
7347	24.70	23.17	23.38	22.90	22.90
7581	25.00	23.17	23.38	22.92	22.92
7898	24.35	23.17	23.38	22.95	22.95
8306	25.00	22.79	22.98	23.75	-

Chainage (m)	Size (mm)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
4066–4558	8600x2200	2.56	3.94
4558–4596	3x915	0.85	1.26
4596–4996	8600x2200	1.96	2.92
4996–5470	8600x2200	1.92	2.86
5470–5524	2x915	0.47	0.80
5524–5584	8000 x2000	1.41	2.39
5584–5769	8000 x2000	1.11	1.88
5769–5982	8000x2000	1.12	1.88
5982–6186	8000x2000	1.14	1.88
6186–6530	8000x2000	1.17	1.88
6530–6578	4x1200 x600	0.30	0.47
6578–6798	8000 x2000	1.12	1.80
6798–6813	8000 x2000	0.50	0.90
6813–6835	2x750	0.25	0.45
6835–7216	5700x1400	-0.09	-0.19
7216–7324	5700 x1400	-0.04	-0.10
7324–7347	1280 x1200	-0.01	-0.04
7347–7581	3000 x1000	-0.03	-0.08
7581–7898	3000x1000	-0.02	-0.06
7898–8306	2500x250	-0.1	-0.2

* INDICATES FLOODING DURING 100 YR ARI STORM EVENT

Forrestdale Main Drain Part 2 of 2

LONGITUDINAL SECTION

HGLs And Flows Existing System

Figure 10b

AUTHOR: P Haywood DESIGN FILE: Fig 10b LS ForrestdaleMD 2of2 pre.dgn

WATER CORPORATION

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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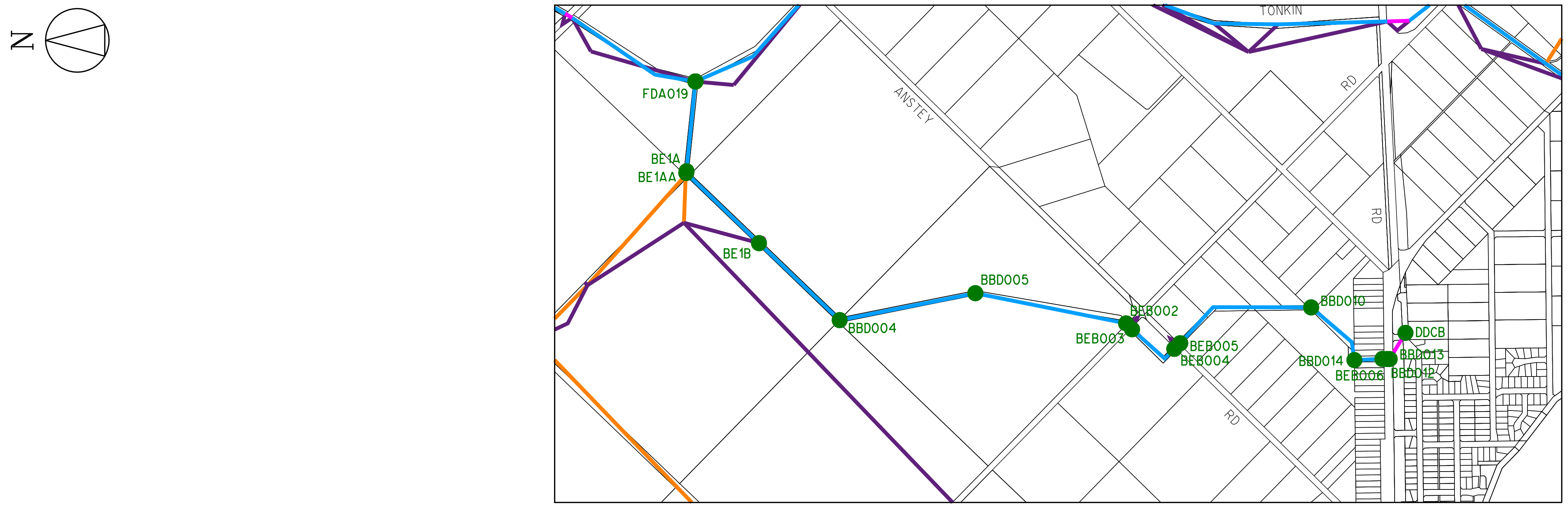
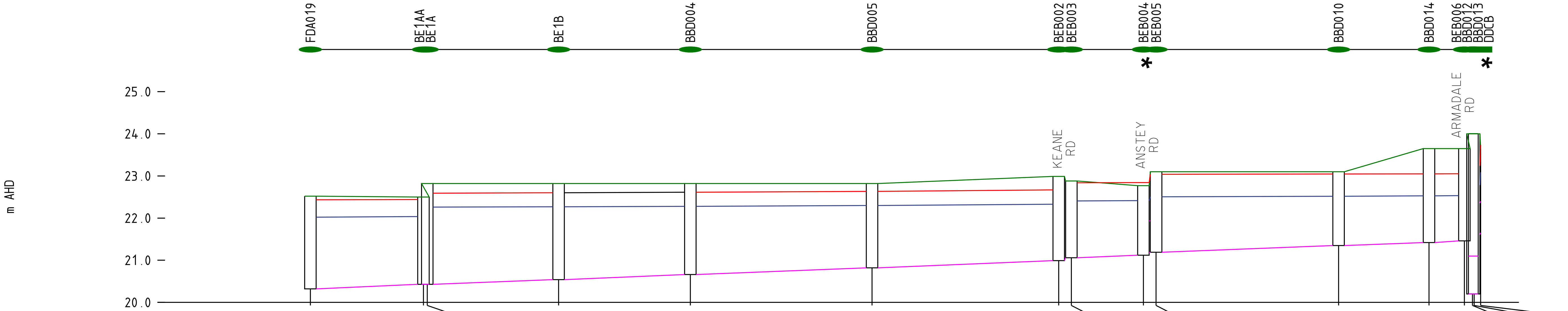




Chainage (m)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)	
0	22.52	22.02	22.44	-	20.32
303	22.50	22.04	22.44	20.43	20.43
313	22.82	22.26	22.59	20.43	20.43
665	22.82	22.27	22.60	20.54	20.54
1018	22.82	22.28	22.61	20.66	20.66
1505	22.82	22.30	22.64	20.82	20.82
2005	22.99	22.33	22.67	20.99	20.99
2039	22.88	22.41	22.84	21.06	21.06
2232	22.77	22.41	22.84	21.12	21.18
2266	23.10	22.50	23.04	21.19	21.19
2755	23.10	22.52	23.05	21.35	21.35
2997	23.65	22.53	23.05	21.42	21.42
3092	23.65	22.53	23.05	21.46	21.57
3113	24.00	22.78	23.23	21.60	20.20
3118	24.00	22.79	23.24	20.20	21.61
3135	23.65	23.09	23.74	21.65	-

Segment (Chainage m)	Size (mm)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
0 – 303	7000x2000	1.31	2.05
303 – 313	2x675	0.65	1.02
313 – 665	7000x2000	0.96	1.55
665 – 1018	7000x2000	1.06	1.65
1018 – 1505	7000x2000	1.11	1.71
1505 – 2005	7000x2000	1.22	1.80
2005 – 2039	2x750	0.50	0.65
2039 – 2232	7000x1600	1.00	1.29
2232 – 2266	2x750	0.49	0.65
2266 – 2755	5500x1500	0.65	0.75
2755 – 2997	5500x1500	0.81	0.98
2997 – 3092	5500 x1500	0.86	1.11
3092 – 3113	750	0.81	1.08
3113 – 3118	900	0.81	1.08
3118 – 3135	750	0.81	1.08

* INDICATES FLOODING DURING 100 YR ARI STORM EVENT

Baileys Branch Drain

LONGITUDINAL SECTION

HGLs And Flows Existing System

Figure 10c

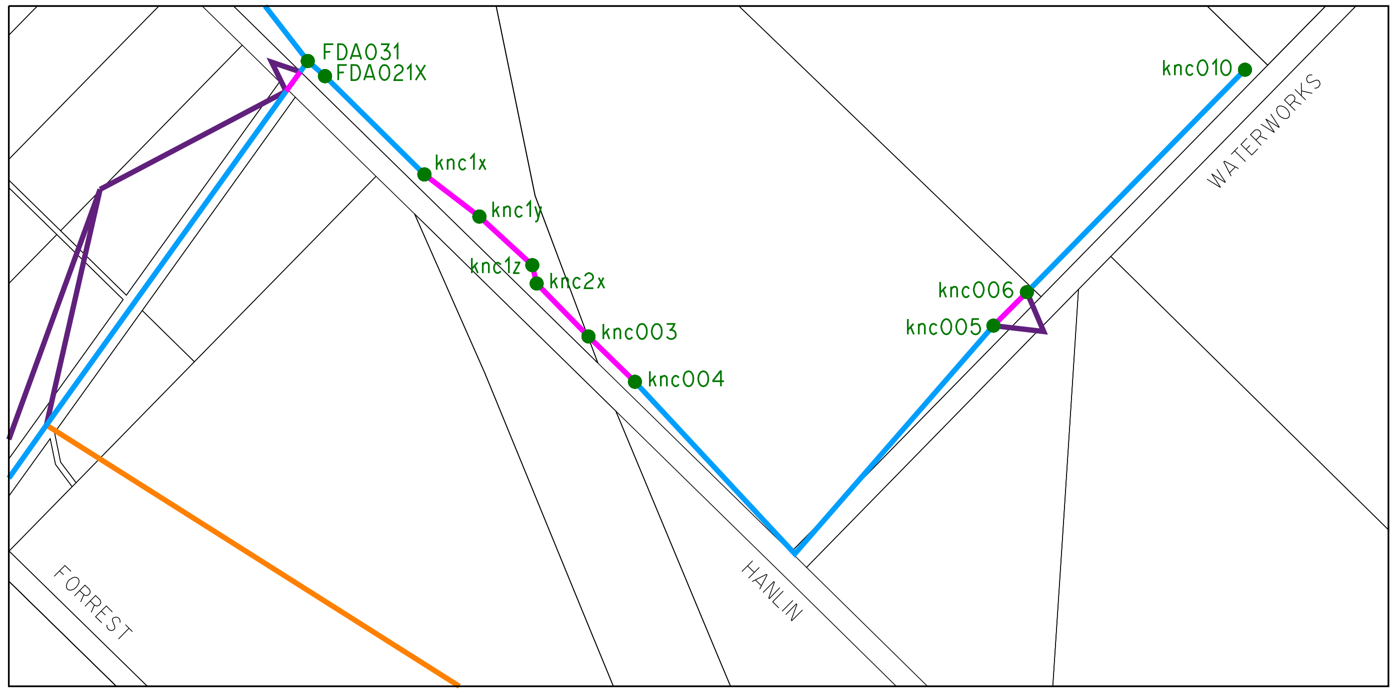
AUTHOR: P Haywood DESIGN FILE: Fig 10c LS BaileysBD pre.dgn

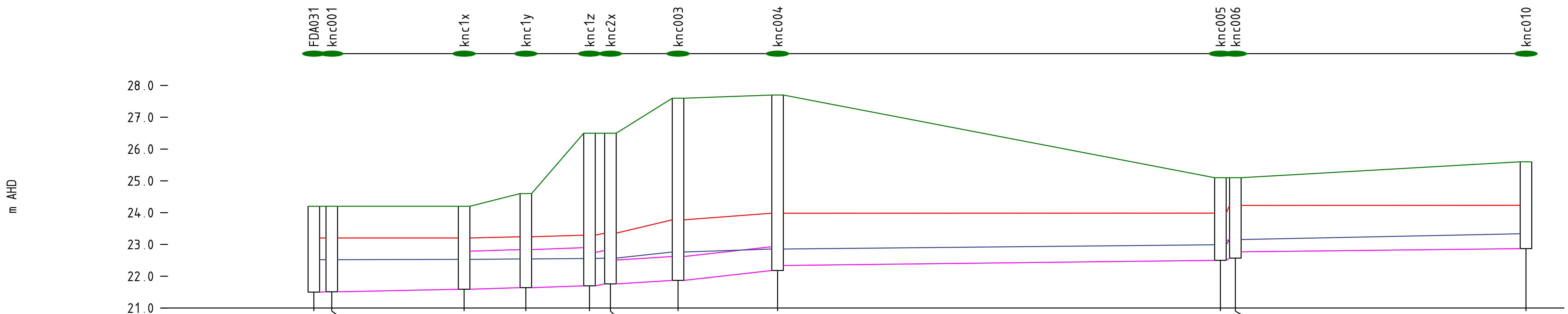
WATER CORPORATION

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.

N





Node	Chainage (m)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)
FDA031	0	24.20	22.52	23.20	- / 21.50
knc001	18	24.20	22.52	23.20	21.51 / 21.51
knc1x	151	24.20	22.53	23.21	21.59 / 21.59
knc1y	213	24.60	22.54	23.24	21.64 / 21.64
knc1z	277	26.50	22.56	23.29	21.70 / 21.70
knc2x	298	26.50	22.57	23.36	21.76 / 21.76
knc003	366	27.60	22.76	23.77	21.87 / 21.87
knc004	466	27.70	22.86	23.98	22.18 / 22.34
knc005	911	25.10	22.99	23.99	22.50 / 22.50
knc006	926	25.10	23.15	24.23	22.57 / 22.77
knc010	1218	25.60	23.33	24.23	22.87 / -

Segment	Size (mm)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
FDA031 – knc001	7500 x2000	0.68	0.98
knc001 – knc1x	7500x2000	0.68	0.99
knc1x – knc1y	1200	0.69	1.03
knc1y – knc1z	1200	0.70	1.03
knc1z – knc2x	1050	0.70	1.03
knc2x – knc003	750	0.70	1.03
knc003 – knc004	750	0.31	0.52
knc004 – knc005	7500x2000	0.30	0.51
knc005 – knc006	597	0.30	0.48
knc006 – knc010	5700x2000	0.30	0.48

AUTHOR: P Haywood DESIGN FILE: Fig 10d LS KeaneBD pre.dgn

WATER CORPORATION

Keane Road Branch Drain

LONGITUDINAL SECTION

HGLs And Flows Existing System

Figure 10d

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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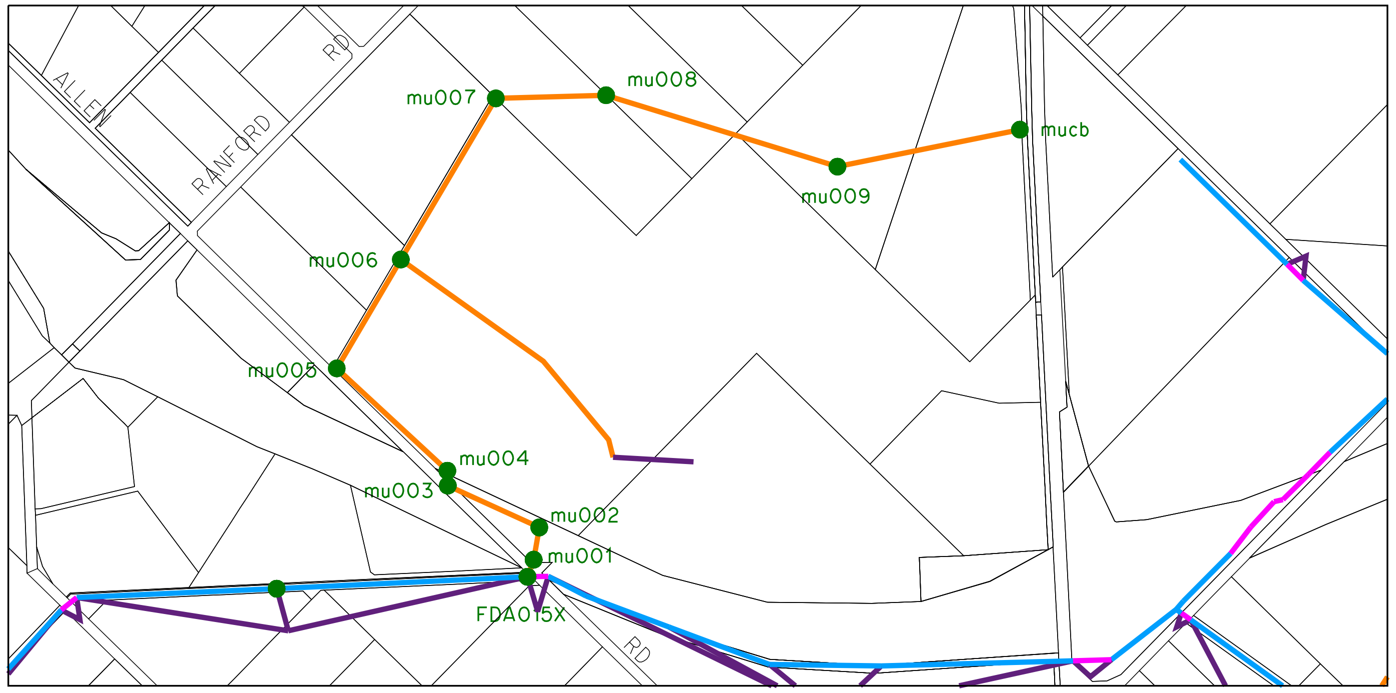

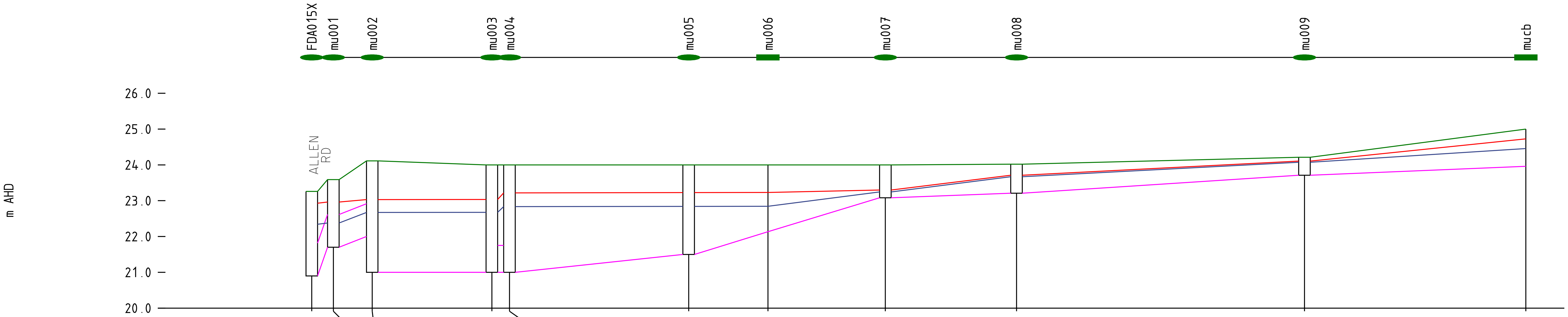

Node	Chainage (m)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)
FDA015X	0	23.26	22.34	22.93	- / 20.90
mu001	35	23.59	22.38	22.96	21.70 / 21.70
mu002	98	24.11	22.67	23.03	22.00 / 21.00
mu003	292	24.00	22.68	23.03	21.00 / 21.00
mu004	320	24.00	22.84	23.22	21.00 / 21.00
mu005	611	24.00	22.84	23.23	21.50 / 21.50
mu006	740	24.00	22.84	23.23	22.13 / 22.13
mu007	930	24.00	23.24	23.30	23.08 / 23.08
mu008	1143	24.02	23.67	23.71	23.21 / 23.21
mu009	1611	24.21	24.07	24.11	23.71 / 23.71
mucb	1970	25.00	24.46	24.73	23.96 / -

Segment	Size (mm)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
FDA015X – mu001	915	0.55	0.80
mu001 – mu002	915	0.55	0.80
mu002 – mu003	5500x2000	0.55	0.80
mu003 – mu004	750	0.55	0.79
mu004 – mu005	5500x1450	0.55	0.79
mu005 – mu006	10000x800	0.55	0.79
mu006 – mu007	10000x800	0.38	0.48
mu007 – mu008	8000x800	0.38	0.48
mu008 – mu009	8000x500	0.38	0.48
mu009 – mucb	8000x300	0.38	0.48

AUTHOR: P Haywood DESIGN FILE: Fig 10e LS ForrestdaleBusPk pre.dgn

WATER CORPORATION

Forrestdale Business Park Drain

LONGITUDINAL SECTION

HGLs And Flows Existing System

Figure 10e

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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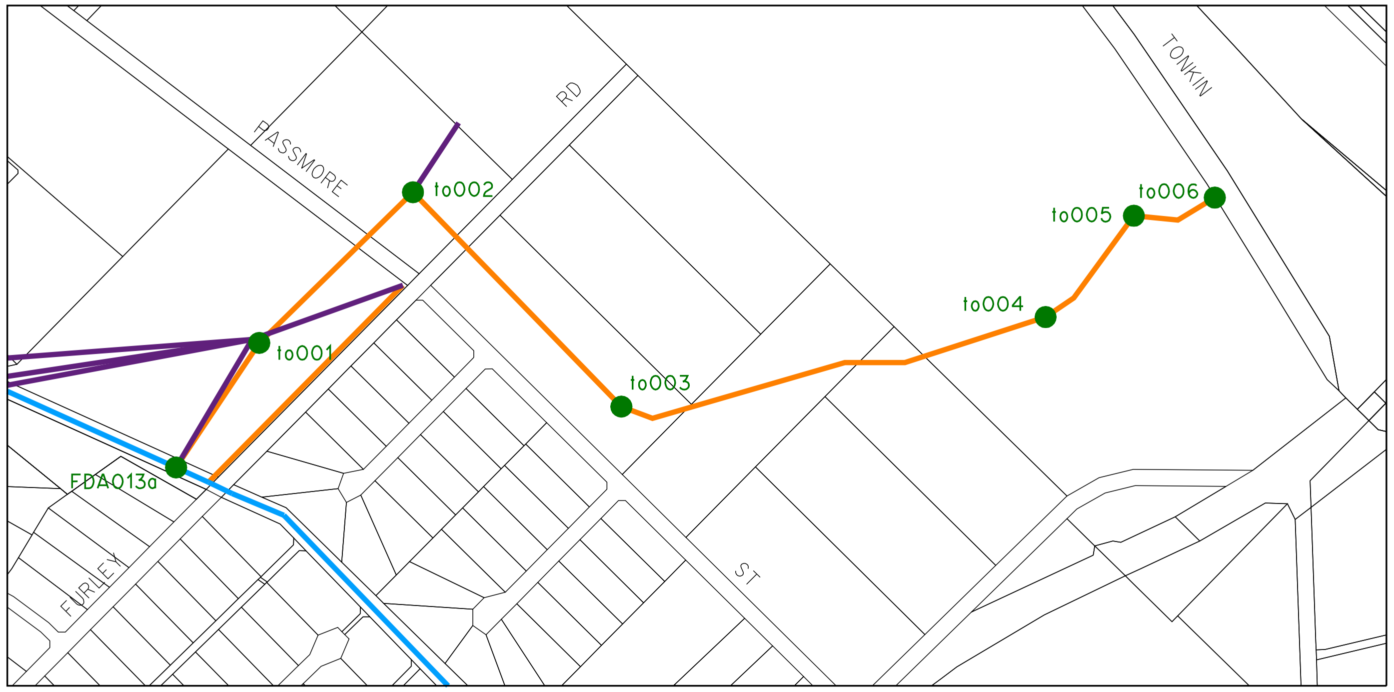
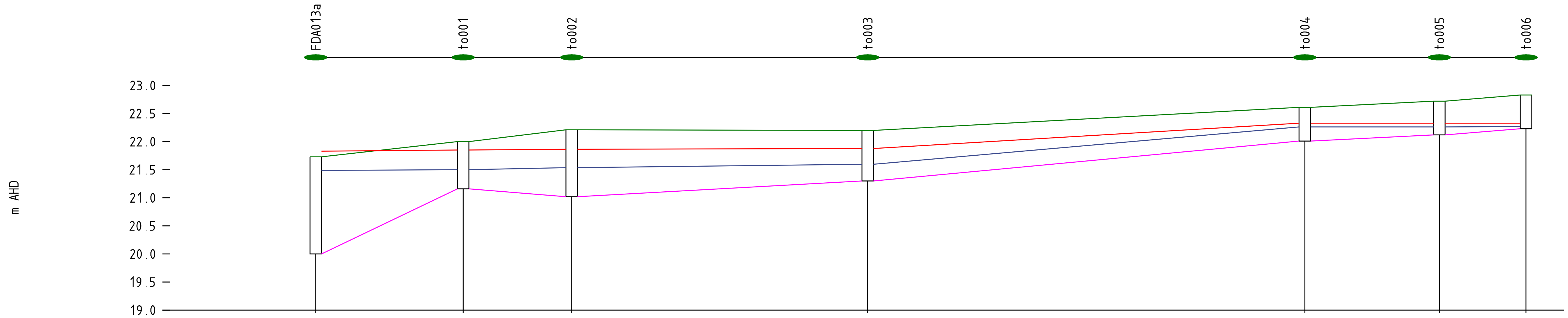
N





Node	Chainage (m)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)
FDA013a	0	21.73	21.49	21.83	- / 20.00
to001	183	22.00	21.50	21.85	21.16 / 21.16
to002	319	22.21	21.54	21.86	21.02 / 21.02
to003	688	22.20	21.60	21.88	21.30 / 21.30
to004	1233	22.61	22.26	22.33	22.01 / 22.01
to005	1401	22.72	22.26	22.33	22.12 / 22.12
to006	1509	22.83	22.27	22.33	22.23 / -

Segment	Size (mm)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
FDA013a – to001	18000x600	0.53	0.88
to001 – to002	18000x600	0.60	1.02
to002 – to003	18000x600	0.32	0.53
to003 – to004	18000x600	0.32	0.59
to004 – to005	18000x600	-0.03	-0.07
to005 – to006	18000x600	-0.01	-0.01

AUTHOR: P Haywood DESIGN FILE: Fig 10f LS Precinct4Sth pre.dgn

WATER CORPORATION

Precinct 4 South Drain

LONGITUDINAL SECTION

HGLs And Flows Existing System

Figure 10f

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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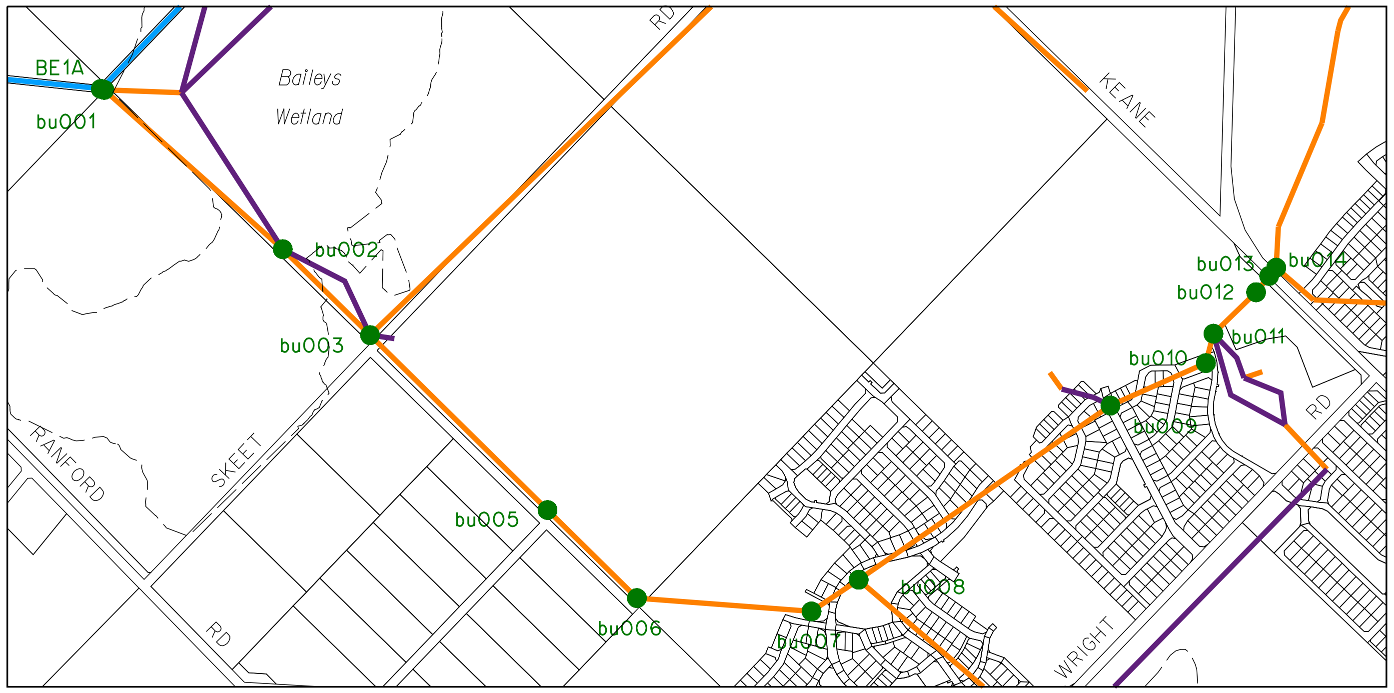

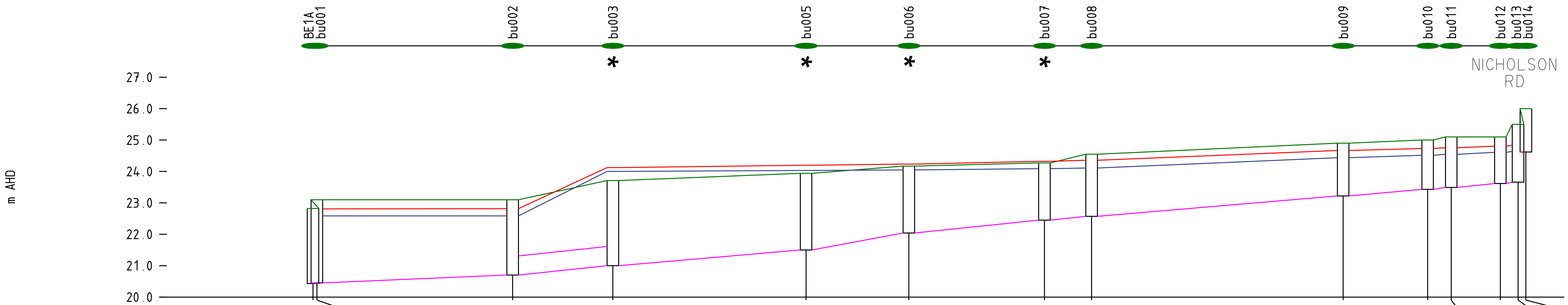

Size (mm)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
600	0.92	0.93
4000x2000	2.16	2.17
611	0.51	0.52
5500x2400	2.41	3.27
5500x2100	2.70	3.66
5250x1800	2.83	3.89
5250x1750	2.90	4.03
5040x1680	2.82	3.97
4710x1570	1.52	1.89
4710 x1570	1.50	1.90
4455 x1485	1.35	1.77
4455 x1485	1.35	1.79
3x600	0.35	0.51

Chainage (m) / Ground level (m AHD)	10 year ARI HGL level (m AHD) / 100 year ARI HGL level (m AHD)	Invert level (m AHD)
0	22.26	-
22.82	22.59	20.43
10	22.58	20.45
23.10	22.81	20.45
508	22.59	20.70
23.10	22.82	20.70
763	24.00	21.00
23.71	24.12	21.00
1254	24.03	21.50
23.94	24.20	21.50
1516	24.05	22.04
24.17	24.23	22.04
1861	24.09	22.45
24.27	24.32	22.45
1981	24.11	22.57
24.55	24.36	22.57
2621	24.44	23.22
24.90	24.67	23.22
2836	24.52	23.43
25.00	24.73	23.43
2896	24.55	23.49
25.10	24.75	23.49
3021	24.61	23.61
25.10	24.81	23.61
3066	24.64	23.66
25.50	24.83	24.60
3086	25.25	24.62
26.00	25.47	-

* INDICATES FLOODING DURING 100 YR ARI STORM EVENT

AUTHOR: P Haywood DESIGN FILE: Fig 10g LS NorthForrestdale pre.dgn

WATER CORPORATION

North Forrestdale Drain

LONGITUDINAL SECTION

HGLs And Flows Existing System

Figure 10g

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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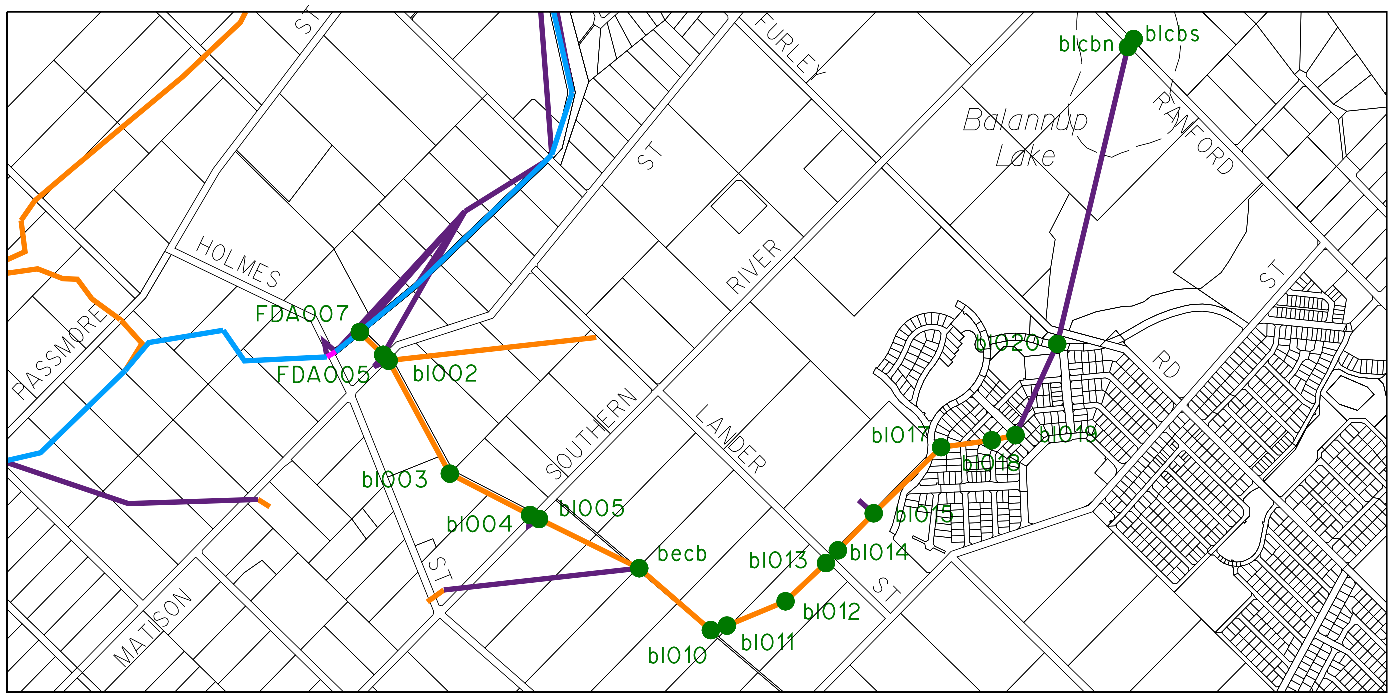
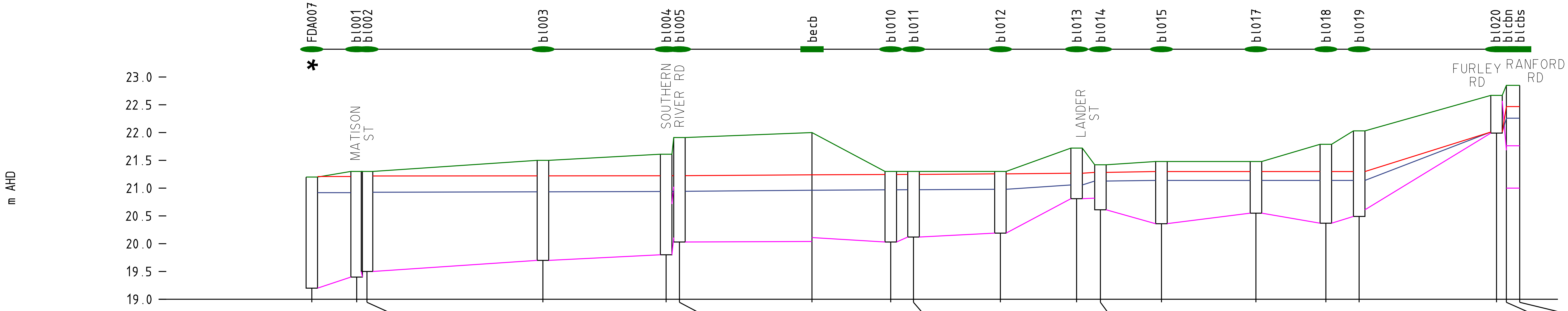
N





Chainage (m)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)
0	21.20	20.92	21.21	- / 19.20
91	21.30	20.92	21.21	19.40 / 19.40
112	21.30	20.93	21.22	19.50 / 19.50
469	21.50	20.93	21.22	19.70 / 19.70
719	21.61	20.94	21.22	19.80 / 19.80
746	21.91	20.94	21.23	20.11 / 20.03
1015	22.00	20.96	21.24	20.04 / 20.11
1174	21.30	20.97	21.25	20.03 / 20.03
1221	21.30	20.97	21.25	20.12 / 20.12
1397	21.30	20.98	21.26	20.19 / 20.19
1551	21.72	21.06	21.27	20.81 / 20.81
1600	21.42	21.13	21.28	20.82 / 20.61
1724	21.48	21.14	21.30	20.36 / 20.36
1915	21.48	21.14	21.30	20.55 / 20.55
2057	21.79	21.14	21.30	20.37 / 20.37
2125	22.03	21.14	21.30	20.49 / 20.61
2403	22.67	22.01	22.01	21.99 / 22.57
2423	22.85	22.26	22.47	21.68 / 21.00
2450	22.85	22.26	22.47	21.00 / -

Chainage (m)	Size (mm)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
0–91	6400 x1800	0.95	1.25
91–112	2x915	0.47	0.62
112–469	6400x1800	0.90	1.21
469–719	5500x1500	0.84	1.18
719–746	2x915	0.40	0.57
746–1015	6000x700	0.79	1.13
1015–1174	6000x700	0.37	0.57
1174–1221	6000 x700	0.36	0.58
1221–1397	6000x700	0.36	0.58
1397–1551	6000x700	0.36	0.60
1551–1600	6000 x600	0.37	0.61
1600–1724	6000x580	0.37	0.61
1724–1915	6000x700	-0.00	-0.04
1915–2057	6000x700	-0.00	-0.03
2057–2125	6000 x700	-0.00	-0.02
2125–2403	21100x300	-0.00	-0.02
2403–2423	21100 x300	-	-
2423–2450	762	-0.09	-0.19

* INDICATES FLOODING DURING 100 YR ARI STORM EVENT

Precinct 2-3 Drain

LONGITUDINAL SECTION

HGLs And Flows Existing System

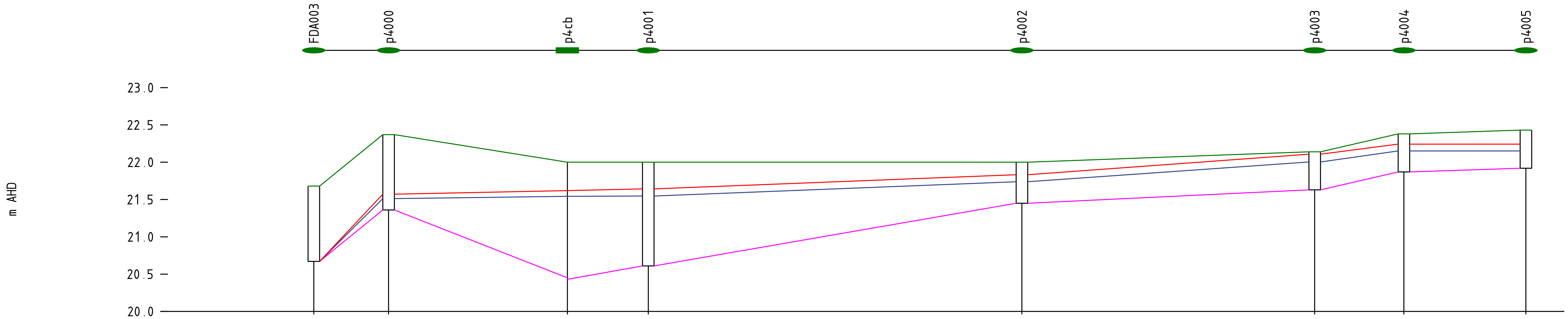
Figure 10h

WATER CORPORATION

PROJECT N°: DP215   DATE: 21/08/2009   COORDINATE SYSTEM: MGA94 - Zone 50

AUTHOR: P Haywood   DESIGN FILE: Fig 10h LS Precinct2-3 pre.dgn

N



Node	Chainage (m)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD) (left)	Invert level (m AHD) (right)
FDA003	0	21.68	19.91	20.54	-	20.67
p4000	173	22.37	21.51	21.57	21.36	21.36
p4cb	589	22.00	21.54	21.62	20.45	20.43
p4001	777	22.00	21.55	21.64	20.61	20.61
p4002	1644	22.00	21.74	21.83	21.45	21.45
p4003	2325	22.14	22.00	22.11	21.63	21.63
p4004	2532	22.38	22.15	22.24	21.87	21.87
p4005	2815	22.43	22.15	22.24	21.92	-

Segment	Size (mm)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
FDA003 – p4000	60000x1000	0.44	0.92
p4000 – p4cb	60000x1000	0.44	0.92
p4cb – p4001	8000x500	0.24	0.42
p4001 – p4002	8000x500	0.25	0.43
p4002 – p4003	8000x500	0.27	0.49
p4003 – p4004	8000x500	0.27	0.50
p4004 – p4005	8000x500	-0.04	-0.09

AUTHOR: P Haywood DESIGN FILE: Fig 10i LS Precinct4Nth pre.dgn

WATER CORPORATION

Precinct 4 North Drain

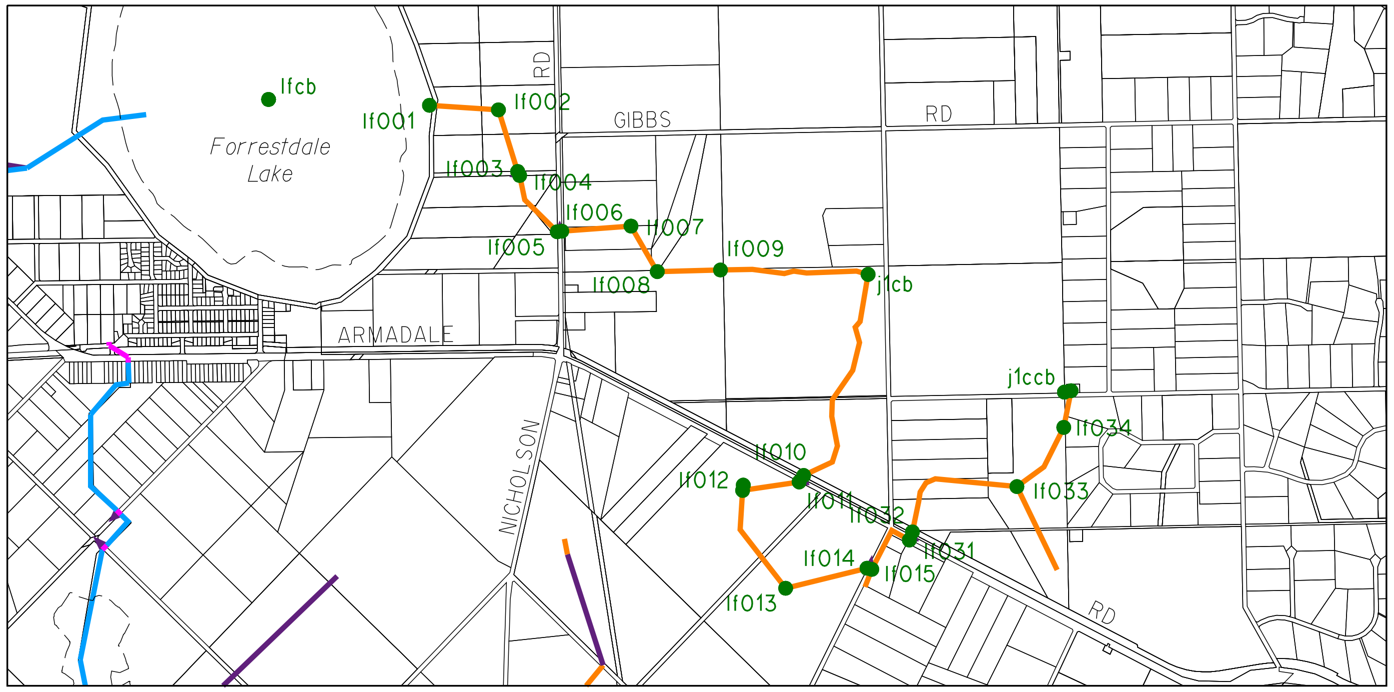
LONGITUDINAL SECTION

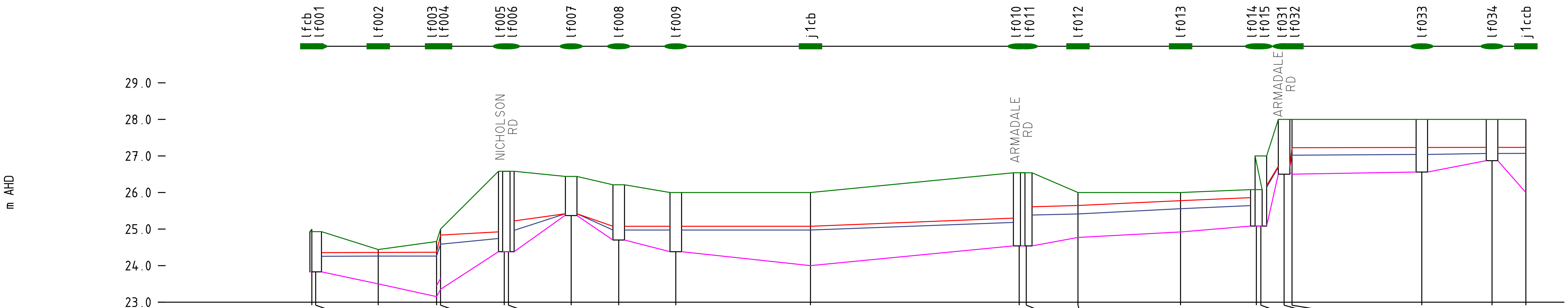
HGLs And Flows Existing System

Figure 10i

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

N





Size (mm)	Ground level (m AHD)	Chainage (m)	100 year ARI HGL level (m AHD)	10 year ARI HGL level (m AHD)	Invert level (m AHD)	Invert level (m AHD)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
		0		22.79	-			
600	25.00	20	22.98	24.25	23.83	23.83	0.18	0.26
13000 x600	24.93	340	24.36	24.26	23.83	23.50	0.18	0.26
13000x600	24.44	639	24.36	24.26	23.50	23.15	0.31	0.79
3x300	24.66	659	24.37	24.59	23.15	23.35	0.11	0.14
13000 x600	25.00	985	24.84	24.74	23.35	24.38	0.92	1.76
2x1050	26.58	1006	24.92	24.96	24.38	24.38	0.47	0.91
20000 x1000	26.58	1328	25.22	25.42	24.38	25.38	-0.04	-0.11
20000 x1000	26.44	1571	25.42	24.97	25.37	24.70	-	-
20000x1500	26.21	1864	25.08	24.97	24.70	24.38	-	-
20000x1500	26.00	2554	25.08	24.97	24.38	24.00	0.00	0.00
20000x2000	26.00	3623	25.08	25.18	24.00	24.54	0.82	1.25
1050	26.54	3659	25.30	25.38	24.54	24.54	0.83	1.26
8000 x1000	26.54	3924	25.61	25.41	24.54	24.77	0.66	1.12
8000x1000	26.00	4450	25.65	25.56	24.77	24.92	0.60	1.14
8000x1000	26.00	4838	25.78	25.64	24.92	25.08	0.45	0.89
300	26.08	4861	25.86	26.14	25.08	25.08	0.13	0.13
2400 x800	27.00	4980	26.19	26.69	25.08	26.50	0.15	0.19
2x300	28.00	5020	26.72	27.02	26.53	26.53	0.07	0.09
20000x1400	28.00	5686	27.23	27.04	26.50	26.56	0.23	0.39
20000x1000	28.00	6045	27.23	27.07	26.56	26.87	0.07	0.13
20000 x1000	28.00	6218	27.23	27.07	26.87	26.00	0.07	0.14
	28.00		27.23		-			

AUTHOR: P Haywood DESIGN FILE: Fig 10j LS James pre.dgn

WATER CORPORATION

James Drain

LONGITUDINAL SECTION

HGLs And Flows Existing System

Figure 10j

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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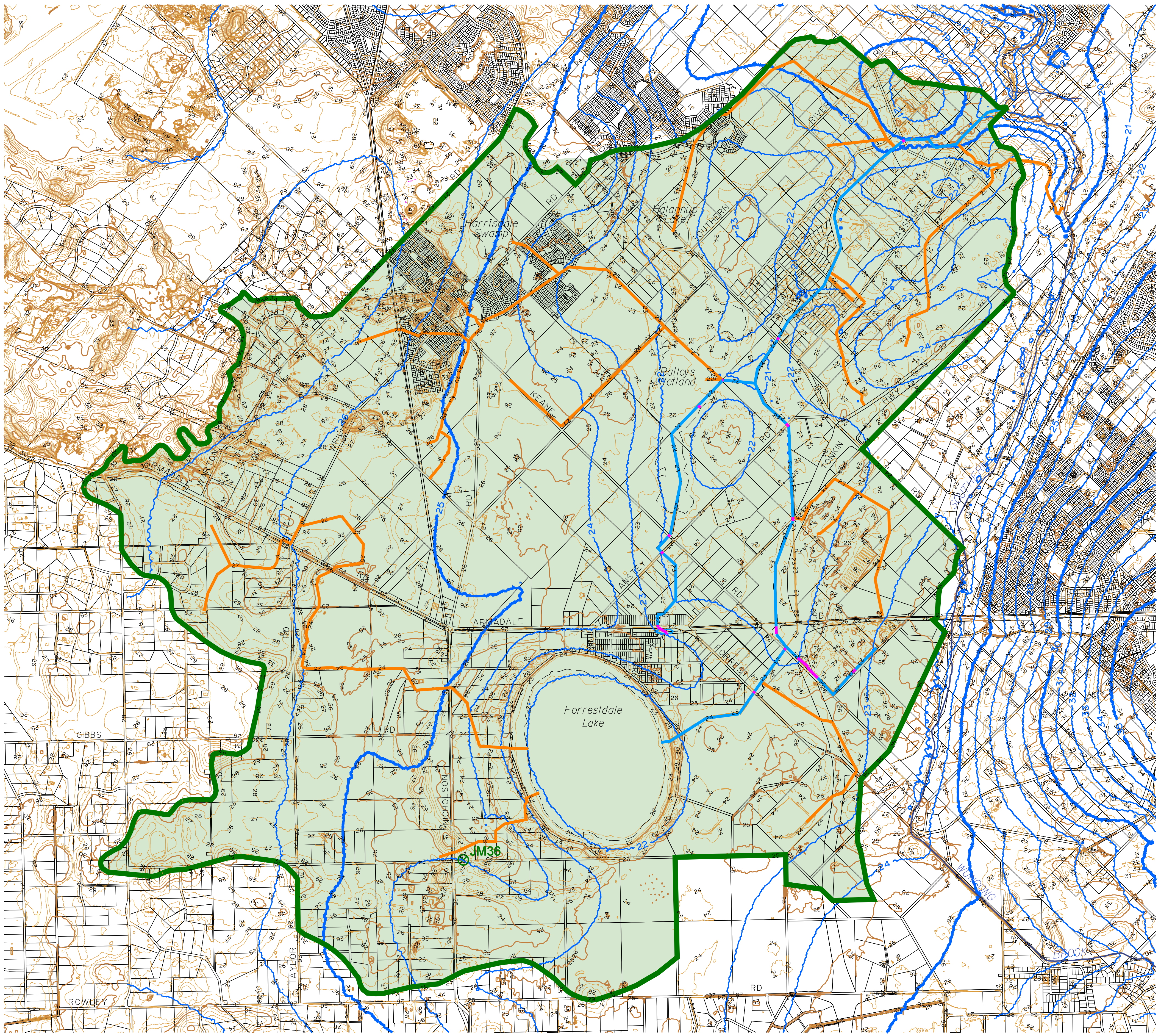

N

LEGEND

- Scheme Boundary
- Water Corporation Open Drain
- Water Corporation Piped Drain
- Local Authority Open and Piped Drain
- Pre Development Modelled Maximum Groundwater Level - 788mm Annual Rainfall Scenario (Rockwater, 2005)
- Water Corporation Compensating Basin
- Surface Contour (m)
- Groundwater Monitoring Bore

0 500 1000 1500 2000
SCALE OF METRES

DESIGN FILE: Fig 11 PreDevMaxGW 788mmAnnualRain.dgn

AUTHOR: SLee

WATER CORPORATION

PRE DEVELOPMENT CONTROLLED GROUNDWATER LEVEL - 788mm ANNUAL RAINFALL SCENARIO (ROCKWATER, 2005)

Figure 11

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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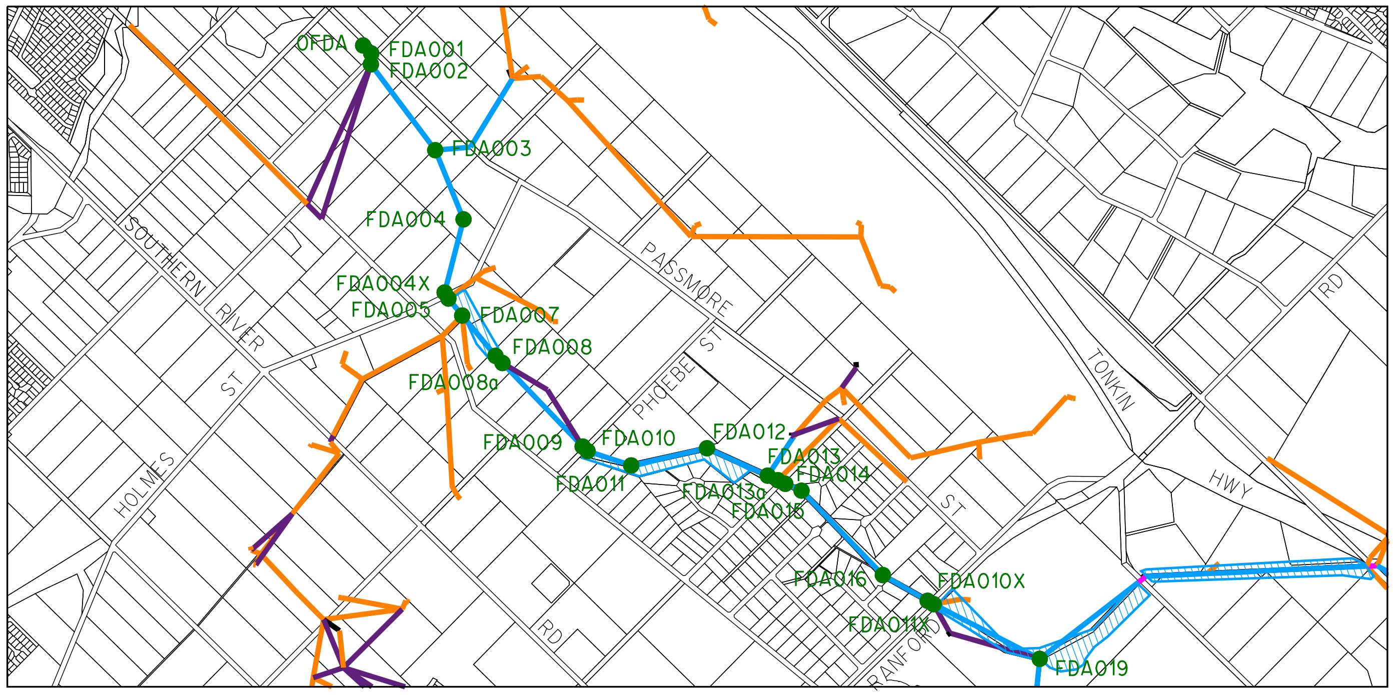
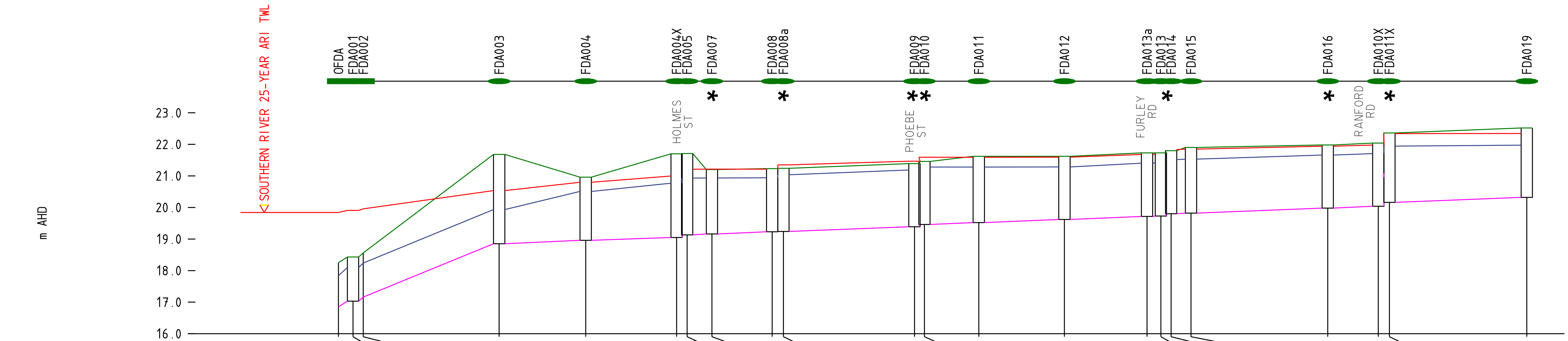




Chainage (m)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)	Invert level (m AHD)
0	18.25	17.84	19.84	-	16.85
50	18.43	18.10	19.91	17.03	17.03
85	18.56	18.24	19.96	17.16	17.16
550	21.68	19.93	20.53	18.85	18.85
846	20.96	20.51	20.80	18.96	18.96
1157	21.70	20.77	21.00	19.05	19.05
1193	21.71	20.93	21.21	19.13	19.13
1278	21.20	20.93	21.21	19.16	19.16
1484	21.23	20.94	21.22	19.23	19.23
1522	21.24	21.04	21.35	19.24	19.24
1971	21.39	21.19	21.47	19.39	19.39
2005	21.46	21.28	21.59	19.46	19.46
2191	21.62	21.28	21.59	19.52	19.52
2484	21.62	21.29	21.59	19.62	19.62
2766	21.73	21.40	21.68	19.71	19.71
2814	21.73	21.42	21.69	19.73	19.73
2849	21.80	21.52	21.84	19.80	19.80
2917	21.90	21.53	21.85	19.82	19.82
3385	21.98	21.66	21.94	19.98	19.98
3558	22.04	21.70	21.98	20.04	20.04
3596	22.36	21.94	22.34	20.16	20.16
4066	22.52	21.98	22.34	20.32	-

Size (mm)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
14800 x1400	7.26	8.87
14800 x1400	7.26	8.87
14800x1400	7.02	8.57
8000x2000	6.54	7.91
8000x2000	6.54	7.91
2x 1800	3.27	3.95
50000 x2000	6.42	7.76
50000 x2000	5.29	6.62
2x 1800	2.55	3.16
8000x2000	5.10	5.91
2x 1791	2.55	3.16
60000 x2000	4.89	6.09
60000x2000	4.86	6.09
8000x2000	4.86	6.12
8000 x2000	4.51	5.53
8000 x2000	1.47	1.81
8000 x2000	4.17	5.18
8000x2000	4.07	5.07
8000x2000	3.91	4.91
5x915	0.98	1.23
70000x2200	3.77	4.68

* INDICATES FLOODING DURING 100 YR ARI STORM EVENT

Forrestdale Main Drain Part 1 of 2

LONGITUDINAL SECTION

HGLs And Flows For Option A Adopted Strategy

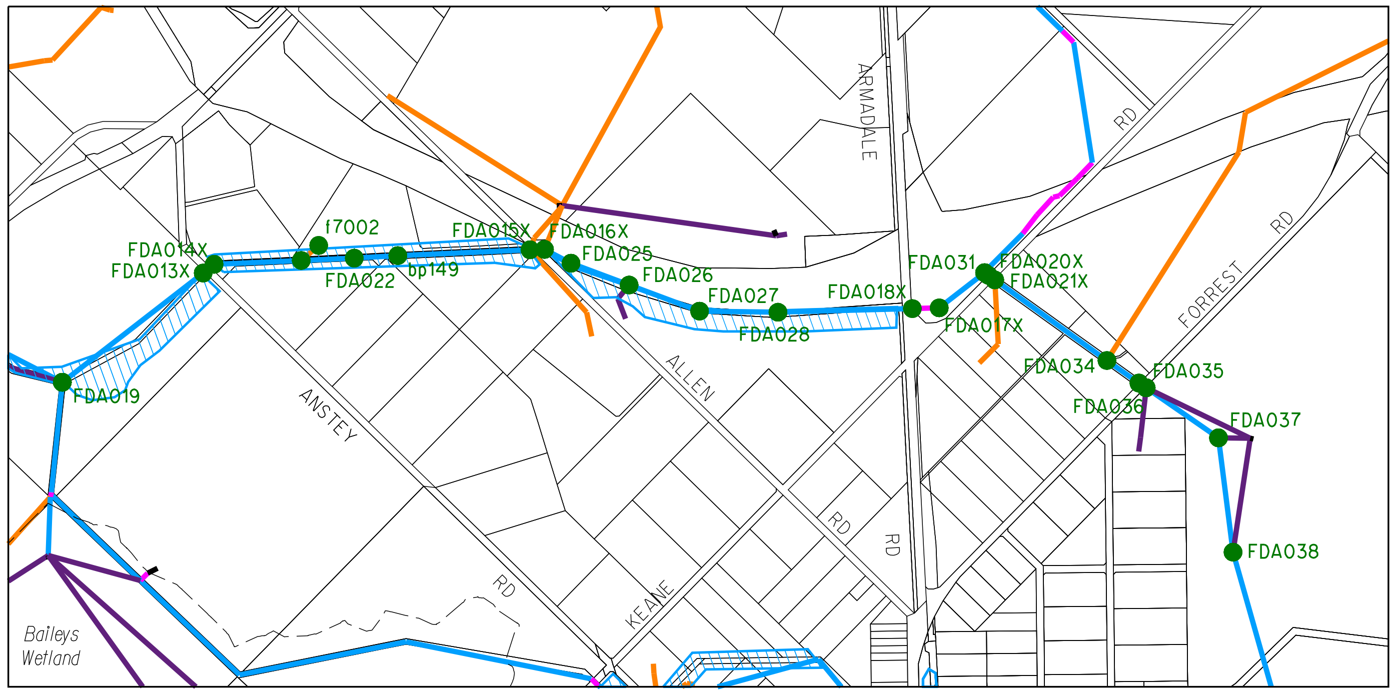
Figure 14a

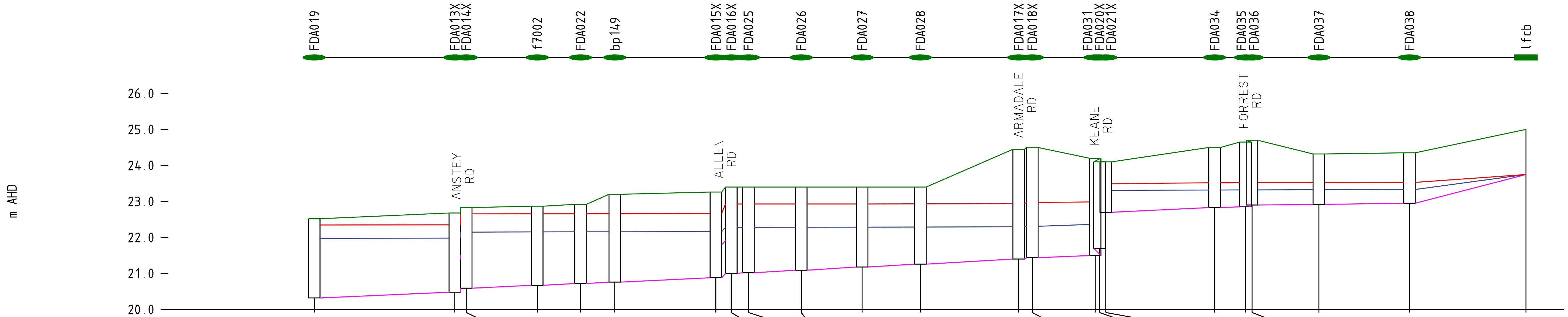
AUTHOR: P Haywood DESIGN FILE: Fig 14a LS ForrestdaleMD 1of2 post.dgn

WATER CORPORATION

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

N





Chainage (m) / Ground level (m AHD) / 10 year ARI HGL level (m AHD) / 100 year ARI HGL level (m AHD) / Invert level (m AHD)

Chainage (m)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)
4066	22.52	21.98	22.34	- / 20.32
4558	22.68	21.98	22.35	20.48 / 20.48
4598	22.83	22.15	22.66	20.59 / 20.59
4846	22.87	22.15	22.66	20.67 / 20.67
4998	22.92	22.16	22.66	20.72 / 20.72
5118	23.20	22.16	22.66	20.76 / 20.76
5472	23.26	22.16	22.67	20.88 / 20.88
5526	23.40	22.28	22.93	21.00 / 21.00
5586	23.40	22.28	22.93	21.02 / 21.02
5771	23.40	22.28	22.93	21.09 / 21.09
5984	23.40	22.29	22.93	21.18 / 21.18
6188	23.40	22.29	22.93	21.26 / 21.26
6532	24.45	22.30	22.94	21.40 / 21.40
6580	24.50	22.31	22.97	21.44 / 21.44
6800	24.20	22.36	22.99	21.50 / 21.50
6580	24.10	22.37	22.99	21.70 / 22.69
6837	24.10	23.31	23.50	22.70 / 22.70
7218	24.50	23.32	23.52	22.83 / 22.83
7326	24.65	23.32	23.53	22.85 / 22.85
7349	24.70	23.32	23.53	22.90 / 22.90
7583	24.32	23.33	23.53	22.92 / 22.92
7900	24.35	23.33	23.53	22.95 / 22.95
8308	25.00	22.88	23.07	23.75 / -

Size (mm)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
100000x2200	2.41	3.26
3x915	0.81	1.13
50000 x2200	2.42	3.39
50000 x2200	1.98	2.83
50000 x2200	1.90	2.77
50000x2200	1.90	2.79
2x915	0.86	1.05
50000 x2000	1.66	2.09
50000 x2000	1.67	2.13
50000x2000	1.68	2.19
50000x2000	1.75	2.36
50000x2000	1.84	2.50
4x1200 x600	0.47	0.67
8000 x2000	1.55	2.30
8000 x2000	0.80	1.24
2x750	0.40	0.62
5700x1400	-0.44	-0.85
5700 x1400	0.15	0.27
1280 x1200	0.07	0.13
3000 x1000	-0.07	-0.18
3000x1000	0.04	-0.12
2500x250	-0.03	-0.07

AUTHOR: P Haywood DESIGN FILE: Fig 14b LS ForrestdaleMD 2of2 post.dgn

WATER CORPORATION

Forrestdale Main Drain Part 2 of 2

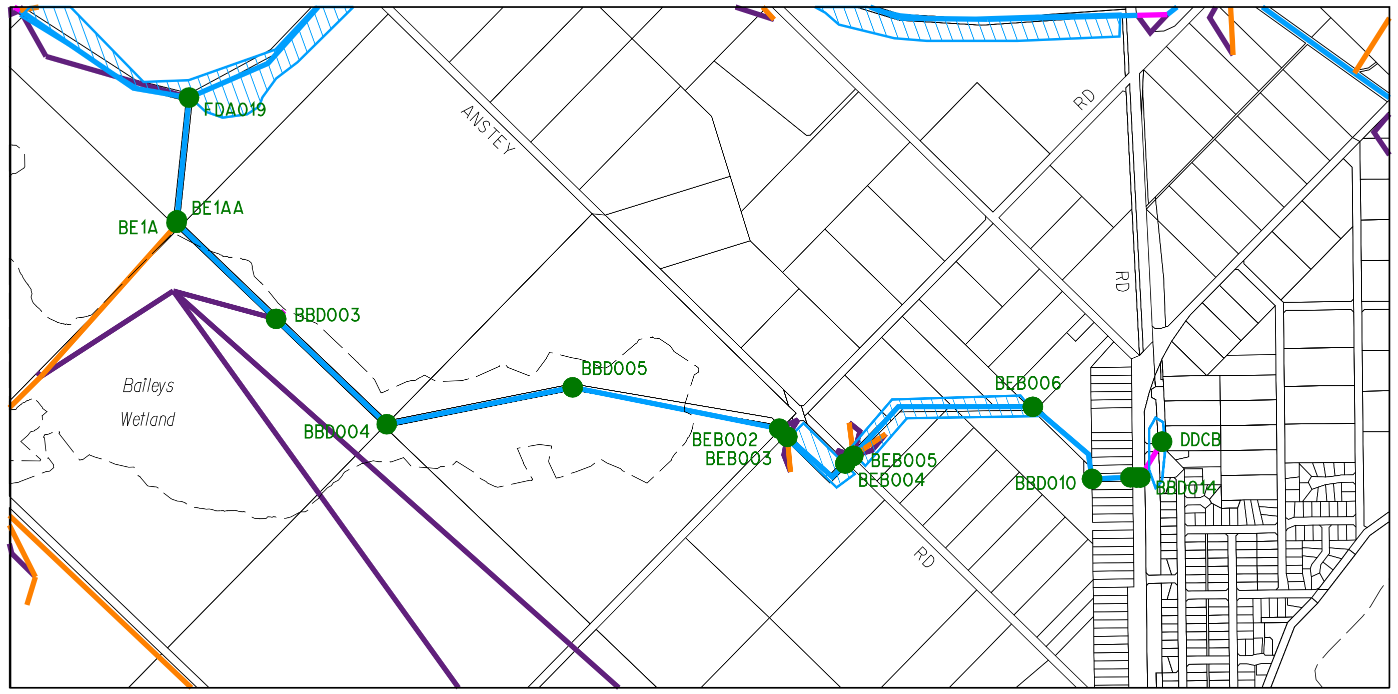
LONGITUDINAL SECTION

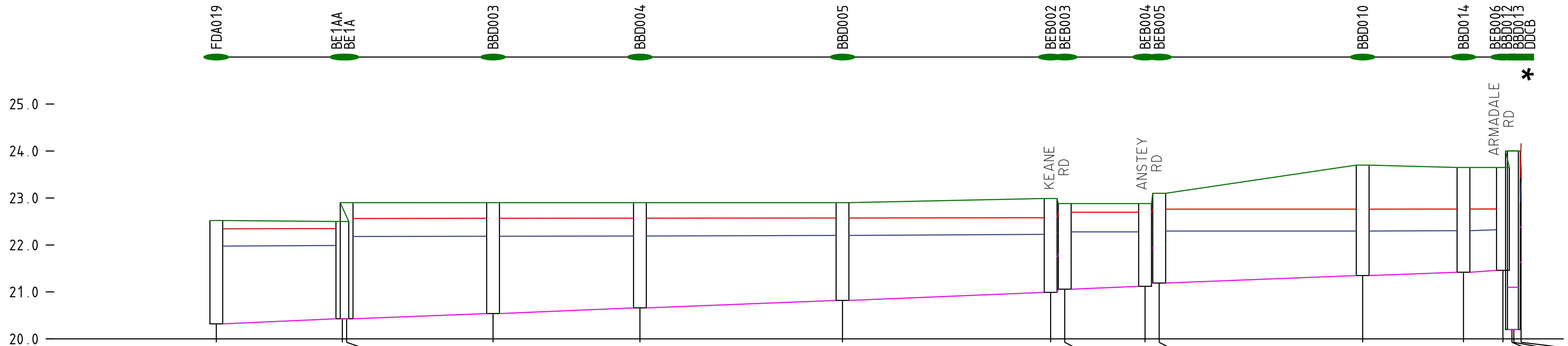
HGLs And Flows For Option A Adopted Strategy

Figure 14b

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

N





Chainage (m)	Size (mm)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
0		22.52	21.98	22.34	- / 20.32		
	7000x2000					1.30	1.82
303		22.50	21.99	22.35	20.43 / 20.43		
	2x675					0.65	0.91
313		22.90	22.18	22.56	20.43 / 20.43		
	7000x2000					0.76	1.23
665		22.90	22.18	22.57	20.54 / 20.54		
	7000x2000					0.70	1.15
1018		22.90	22.19	22.57	20.66 / 20.66		
	7000x2000					0.71	1.17
1505		22.90	22.20	22.57	20.82 / 20.82		
	7000x2000					0.72	1.18
2005		22.99	22.23	22.58	20.99 / 20.99		
	2x750					0.38	0.60
2039		22.88	22.28	22.70	21.06 / 21.06		
	50000x1600					0.65	0.81
2232		22.88	22.28	22.70	21.12 / 21.18		
	2x750					0.48	0.61
2266		23.10	22.30	22.76	21.19 / 21.19		
	50000x1900					0.81	1.02
2755		23.70	22.30	22.76	21.35 / 21.35		
	5500x1500					0.99	1.31
2997		23.65	22.31	22.77	21.42 / 21.42		
	5500 x1500					1.00	1.34
3092		23.65	22.32	22.77	21.46 / 21.57		
	750					0.94	1.27
3113		24.00	22.90	23.40	21.60 / 20.20		
	900					0.94	1.27
3118		24.00	22.91	23.42	20.20 / 21.61		
	750					0.94	1.27
3135		23.65	23.32	24.16	21.65 / -		

* INDICATES FLOODING DURING 100 YR ARI STORM EVENT

Baileys Branch Drain

LONGITUDINAL SECTION

HGLs And Flows For Option A Adopted Strategy

Figure 14c

AUTHOR: P Haywood DESIGN FILE: Fig 14c LS BaileysBD post.dgn

WATER CORPORATION

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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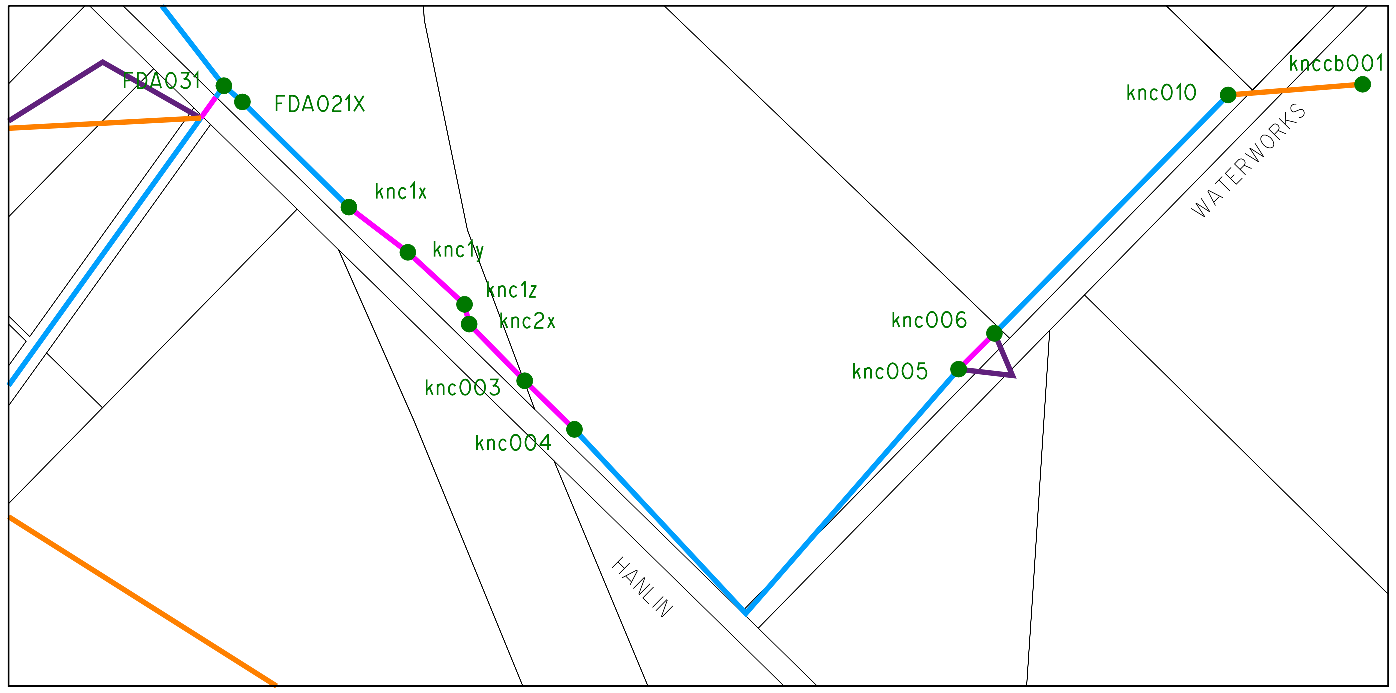
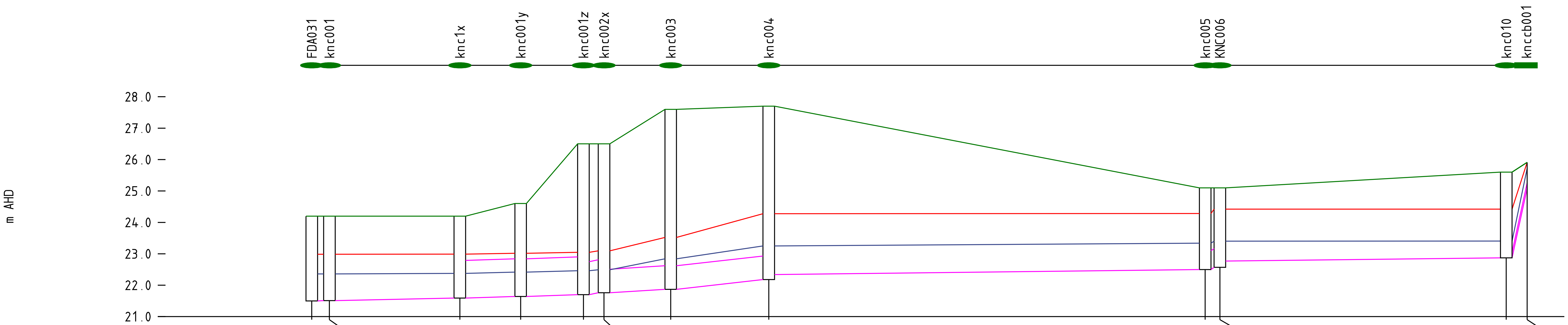
N





Chainage (m)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)
0	24.20	22.36	22.99	- / 21.50
18	24.20	22.36	22.99	21.51 / 21.51
151	24.20	22.38	22.99	21.59 / 21.59
213	24.60	22.42	23.02	21.64 / 21.64
277	26.50	22.46	23.05	21.70 / 21.70
298	26.50	22.49	23.09	21.76 / 21.76
366	27.60	22.84	23.52	21.87 / 21.87
466	27.70	23.25	24.28	22.18 / 22.34
911	25.10	23.34	24.28	22.50 / 22.50
926	25.10	23.40	24.42	22.57 / 22.77
1218	25.60	23.41	24.42	22.87 / 22.87
1238	25.90	25.70	25.88	24.70 / -

Segment (chainage m)	Size (mm)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
0–18	7500 x2000	0.67	1.10
18–151	7500x2000	0.67	1.11
151–213	1200	0.67	1.11
213–277	1200	0.67	1.11
277–298	1050	0.61	1.11
298–366	750	0.61	1.11
366–466	750	0.61	1.04
466–911	7500x2000	0.36	0.72
911–926	600	0.35	0.69
926–1218	5700x2000	0.35	0.65
1218–1238	225	0.06	0.13

AUTHOR: P Haywood DESIGN FILE: Fig 14d LS Keane BD post.dgn

WATER CORPORATION

Keane Road Branch Drain

LONGITUDINAL SECTION

HGLs And Flows For Option A Adopted Strategy

Figure 14d

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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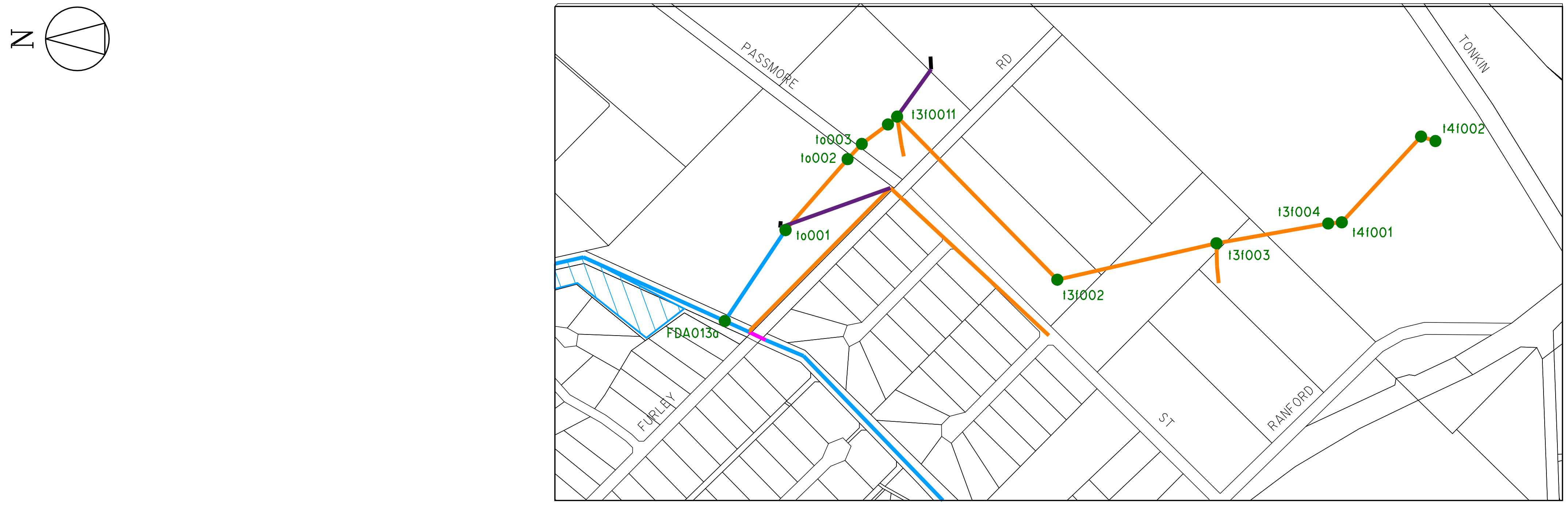
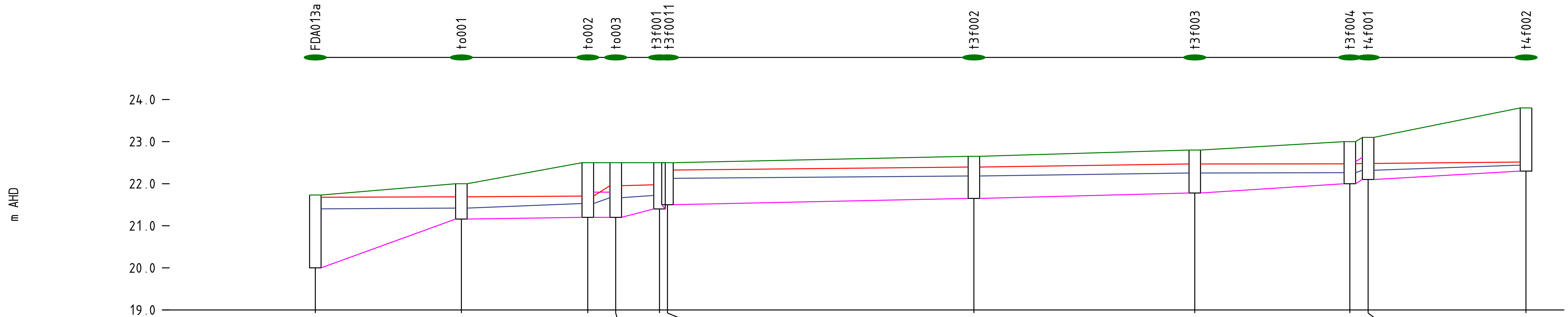




Chainage (m)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)	Invert level (m AHD)
0	21.73	21.40	21.68	-	20.00
183	22.00	21.42	21.69	21.16	21.16
343	22.50	21.53	21.70	21.20	21.20
378	22.50	21.67	21.95	21.20	21.20
433	22.50	21.72	21.97	21.40	21.40
443	22.50	22.13	22.32	21.50	21.50
829	22.65	22.18	22.40	21.65	21.65
1107	22.80	22.25	22.47	21.78	21.78
1303	23.00	22.26	22.47	22.00	22.00
1326	23.10	22.32	22.48	22.10	22.10
1525	23.80	22.44	22.51	22.30	-

Segment (chainage)	Size (mm)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
0–183	18000x600	0.36	0.71
183–343	18000x600	0.38	0.73
343–378	2x600	0.19	0.37
378–433	5000 x1000	0.38	0.73
433–443	900	0.38	0.74
443–829	5000x1000	0.31	0.65
829–1107	5000x1000	0.32	0.66
1107–1303	5000x1000	0.06	0.11
1303–1326	525	0.06	0.10
1326–1525	5000x1000	0.06	0.10

Precinct 4 South Drain

LONGITUDINAL SECTION

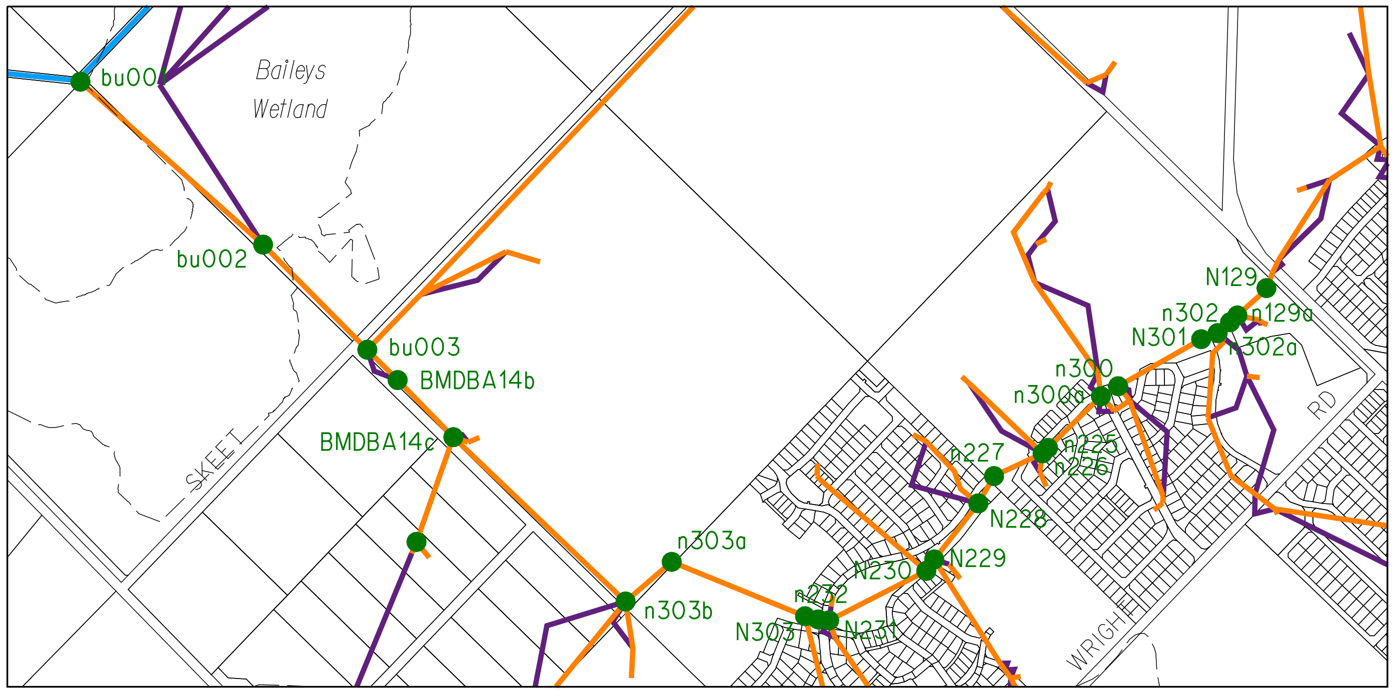
HGLs And Flows For Option A Adopted Strategy

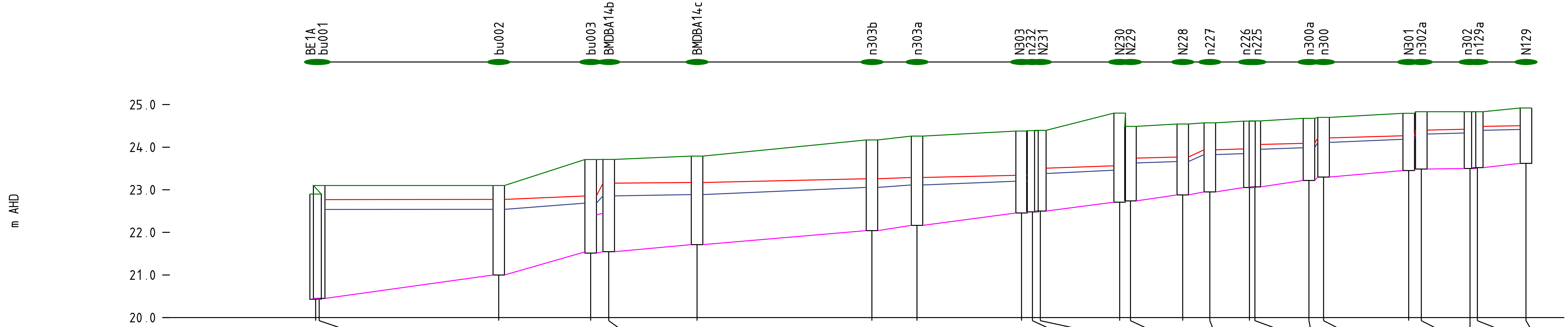
Figure 14e

AUTHOR: P Haywood DESIGN FILE: Fig 14e LS Precinct4Sth post.dgn

WATER CORPORATION
PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

N





Size (mm)
Chainage (m)
Ground level (m AHD)
10 year ARI HGL level (m AHD)
100 year ARI HGL level (m AHD)
Invert level (m AHD)
Max 10 year ARI flow (m3/s)
Max 100 year ARI flow (m3/s)

Chainage (m)	10 year ARI HGL level (m AHD)	Invert level (m AHD) (in)	Ground level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD) (out)
0	22.18	-	22.90	22.56	20.43
10	22.54	20.45	23.10	22.77	20.45
508	22.54	21.00	23.10	22.77	21.00
763	22.69	21.54	23.71	22.86	21.51
813	22.86	21.55	23.71	23.16	21.55
1058	22.89	21.71	23.79	23.17	21.71
1543	23.06	22.04	24.17	23.26	22.04
1668	23.11	22.16	24.26	23.29	22.16
1958	23.20	22.45	24.38	23.34	22.45
1988	23.21	22.48	24.39	23.35	22.48
2010	23.38	22.50	24.40	23.51	22.50
2230	23.46	22.71	24.80	23.56	22.71
2260	23.63	22.74	24.49	23.74	22.74
2405	23.66	22.88	24.54	23.77	22.88
2480	23.82	22.95	24.57	23.94	22.95
2590	23.85	23.05	24.61	23.96	23.05
2605	23.95	23.07	24.62	24.07	23.07
2755	23.99	23.22	24.68	24.09	23.22
2795	24.11	23.30	24.70	24.22	23.30
3031	24.18	23.45	24.80	24.27	23.45
3066	24.31	23.49	24.83	24.40	23.49
3201	24.33	23.50	24.83	24.42	23.50
3222	24.40	23.52	24.83	24.49	23.52
3357	24.42	23.62	24.92	24.50	-

Size (mm)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
600	0.89	0.93
4000x2000	1.90	2.10
4800x2000	2.02	2.86
2x900	0.75	1.00
19822x2050	1.51	1.99
15857x2050	1.41	1.77
15857 x2060	1.29	1.55
25973x1900	1.23	1.48
25973 x1900	1.20	1.45
1200	1.20	1.45
23239 x1700	1.20	1.45
1200	1.19	1.41
21872 x1600	1.06	1.27
1200	1.04	1.24
20505 x1500	1.04	1.24
1200	1.02	1.20
19138 x1400	1.02	1.20
1200	0.96	1.12
18318x1340	0.96	1.11
1200	0.96	1.12
17771 x1300	0.90	1.03
1200	0.87	1.00
17771 x1300	0.87	0.99

AUTHOR: P Haywood DESIGN FILE: Fig 14f LS NorthForrestdale post.dgn

WATER CORPORATION

North Forrestdale Drain

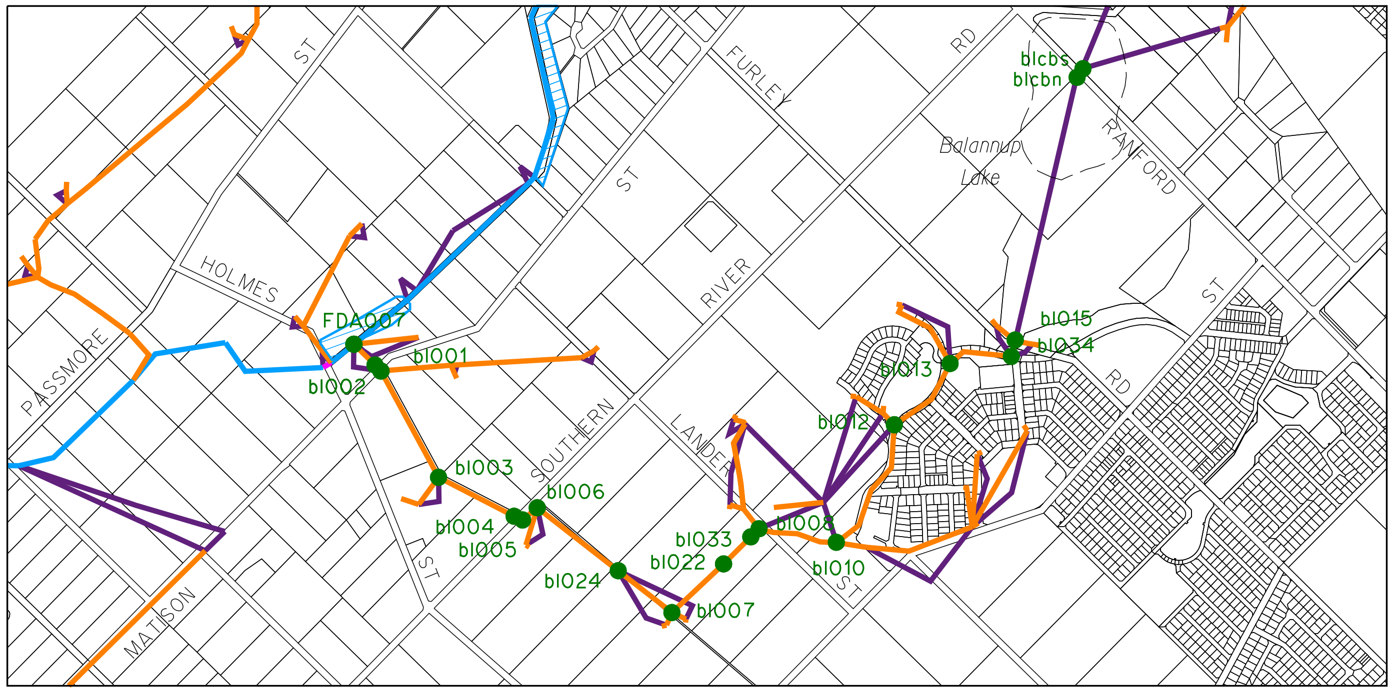
LONGITUDINAL SECTION

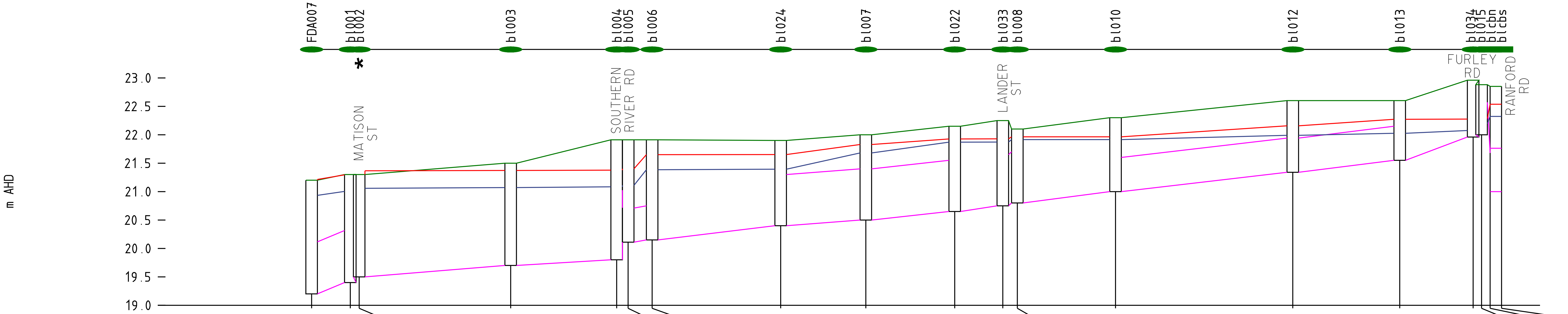
HGLs And Flows For Option A Adopted Strategy

Figure 14f

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.





Size (mm)	Start ground level (m AHD)	Start 100 year ARI HGL level (m AHD)	Start invert level (m AHD)	End chainage (m)	End 10 year ARI HGL level (m AHD)	End invert level (m AHD)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
				0	20.93	-		
2x915	21.20	21.21	19.20	91	21.00	19.40	0.61	0.71
2x915	21.30	21.30	19.40	112	21.06	19.50	0.61	0.71
6400x1800	21.30	21.36	19.50	469	21.07	19.70	0.88	0.93
5500x1500	21.50	21.37	19.70	719	21.08	19.80	0.83	0.91
2x915	21.91	21.38	19.80	746	21.11	20.11	0.43	0.48
2x600	21.91	21.40	20.11	802	21.39	20.15	0.43	0.48
8000x1500	21.91	21.65	20.15	1105	21.39	20.40	0.71	0.76
900	21.90	21.65	20.40	1306	21.68	20.50	0.70	0.71
900	22.00	21.83	20.50	1515	21.87	20.65	0.67	0.68
8000x1500	22.15	21.93	20.65	1629	21.87	20.75	0.67	0.68
900	22.25	21.93	20.75	1663	21.91	20.80	0.67	0.68
27600x1300	22.10	21.96	20.80	1894	21.91	21.00	0.40	0.58
2x600	22.30	21.96	21.00	2312	21.99	21.34	0.09	0.15
2x600	22.60	22.16	21.34	2564	22.03	21.55	0.08	0.14
18800x1000	22.60	22.27	21.55	2737	22.07	21.96	0.08	0.17
750	22.96	22.28	21.96	2757	22.20	22.00	0.07	0.07
21100 x300	22.88	22.29	22.57	2777	22.32	21.68	-	-
762	22.85	22.54	21.00	2804	22.32	21.00	-0.10	-0.15
	22.85	22.54	-					

* INDICATES FLOODING DURING 100 YR ARI STORM EVENT

Precinct 2-3 Drain

LONGITUDINAL SECTION

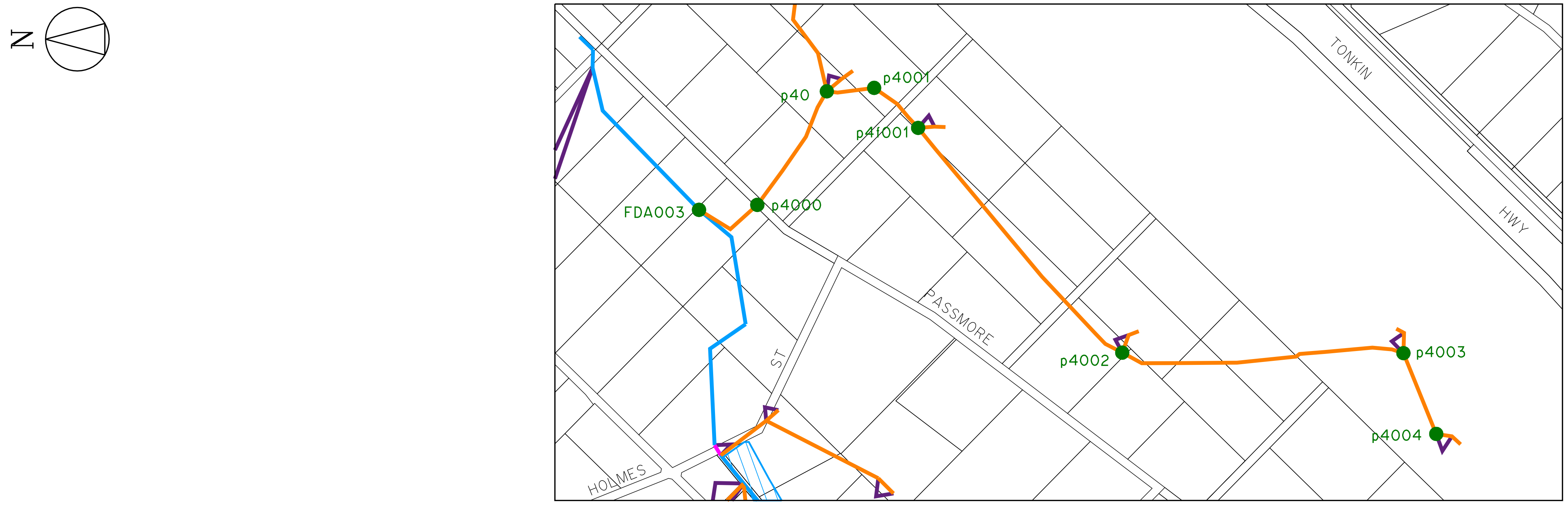
HGLs And Flows For Option A Adopted Strategy

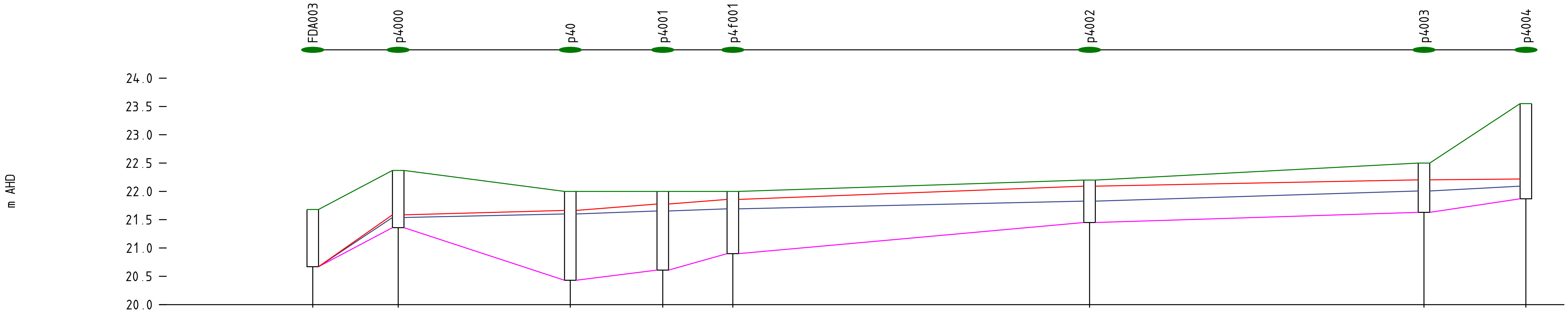
Figure 14g

WATER CORPORATION

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

AUTHOR: P Haywood DESIGN FILE: Fig 14g LS Precinct2-3 post.dgn





	FDA003	p4000	p40	p4001	p4f001	p4002	p4003	p4004
Chainage (m)	0	173	523	711	854	1579	2259	2467
Ground level (m AHD)	21.68	22.37	22.00	22.00	22.00	22.20	22.50	23.55
10 year ARI HGL level (m AHD)	19.93	21.54	21.60	21.65	21.69	21.83	22.01	22.09
100 year ARI HGL level (m AHD)	20.53	21.59	21.66	21.78	21.86	22.09	22.20	22.22
Invert level (m AHD)	- / 20.67	21.36 / 21.36	20.43 / 20.43	20.61 / 20.61	20.90 / 20.90	21.45 / 21.45	21.63 / 21.63	21.87 / -

	FDA003–p4000	p4000–p40	p40–p4001	p4001–p4f001	p4f001–p4002	p4002–p4003	p4003–p4004
Size (mm)	10000x1000	20000x1000	8000x500	8000x500	8000x500	8000x500	8000x500
Max 10 year ARI flow (m3/s)	0.37	0.37	0.54	0.52	0.37	0.27	0.15
Max 100 year ARI flow (m3/s)	0.59	0.59	0.79	0.77	0.58	-0.71	0.31

AUTHOR: P Haywood DESIGN FILE: Fig 14h LS Precinct4Nth post.dgn

WATER CORPORATION

Precinct 4 North Drain

LONGITUDINAL SECTION

HGLs And Flows For Option A Adopted Strategy

Figure 14h

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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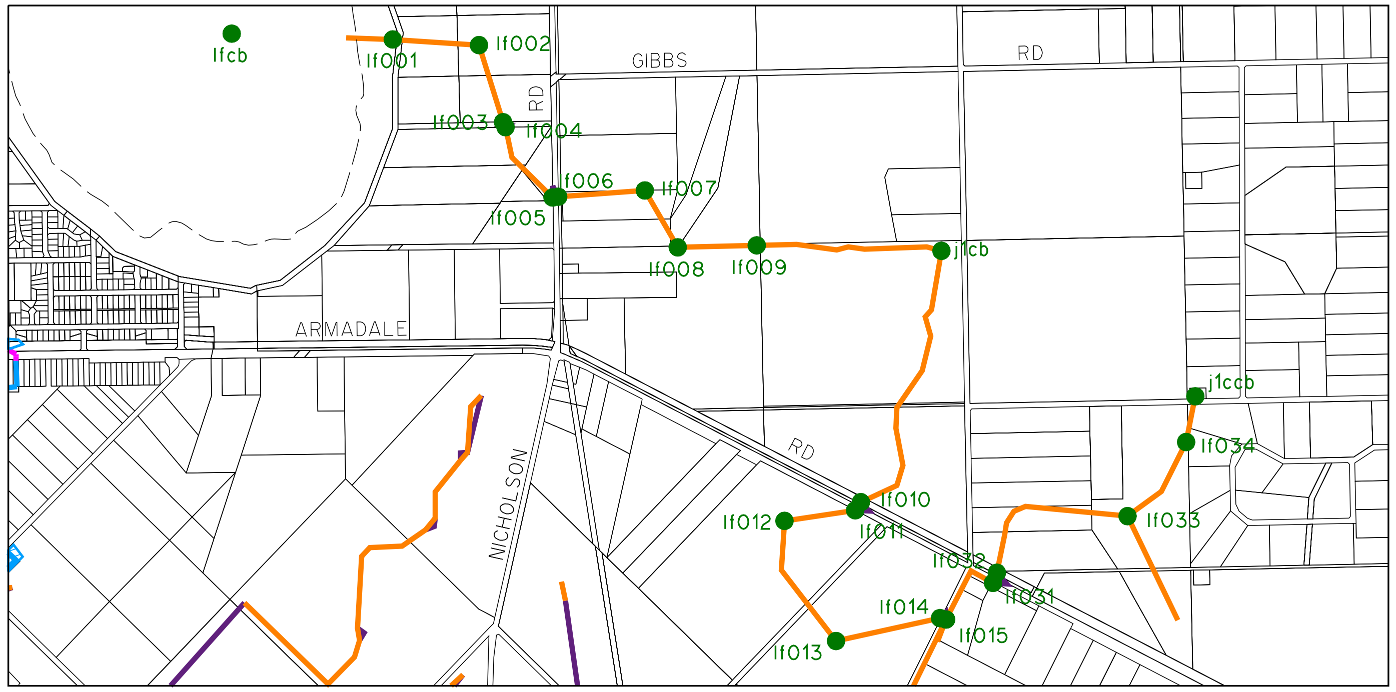
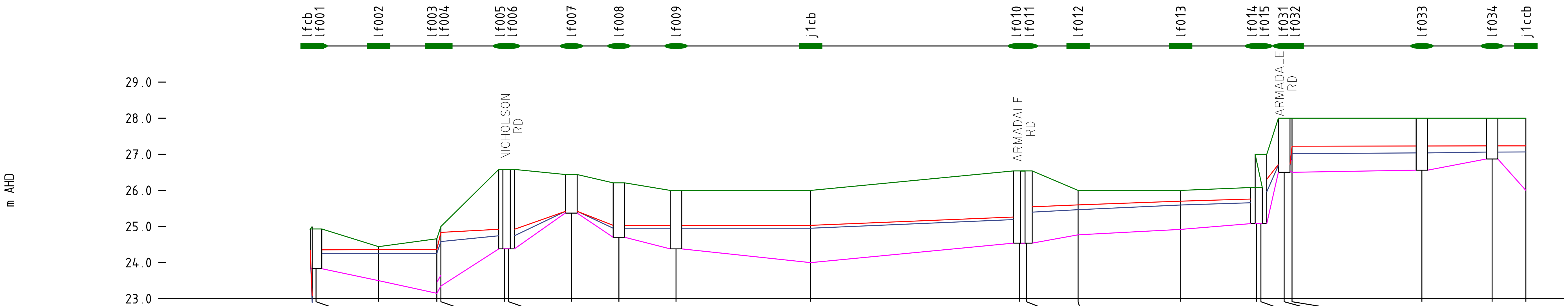




Chainage (m)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)
0	25.00	22.88	23.07	- / 23.83
20	24.93	24.25	24.35	23.83 / 23.83
340	24.44	24.25	24.36	23.50 / 23.50
639	24.66	24.26	24.36	23.15 / 23.15
659	25.00	24.58	24.84	23.35 / 23.35
985	26.58	24.74	24.92	24.38 / 24.38
1006	26.58	24.74	24.92	24.38 / 24.38
1328	26.44	25.42	25.42	25.38 / 25.37
1571	26.21	24.95	25.00	24.70 / 24.70
1864	26.00	24.95	25.00	24.38 / 24.38
2554	26.00	24.95	25.00	24.00 / 24.00
3623	26.54	25.19	25.26	24.54 / 24.54
3659	26.54	25.40	25.55	24.54 / 24.54
3924	26.00	25.47	25.60	24.77 / 24.77
4450	26.00	25.59	25.70	24.92 / 24.92
4838	26.08	25.66	25.76	25.08 / 25.08
4861	27.00	25.96	26.31	25.08 / 25.08
4980	28.00	26.69	26.72	26.50 / 26.53
5020	28.00	27.02	27.23	26.53 / 26.50
5686	28.00	27.04	27.23	26.56 / 26.56
6045	28.00	27.06	27.23	26.87 / 26.87
6218	28.00	27.06	27.23	26.00 / -

Chainage (m)	Size (mm)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
0–20	600	0.17	0.25
20–340	13000 x600	0.17	0.25
340–639	13000x600	0.31	0.79
639–659	3x300	0.11	0.14
659–985	13000 x600	0.93	1.78
985–1006	2x1050	-0.01	-0.02
1006–1328	20000 x1000	-0.01	-0.03
1328–1571	20000 x1000	-	-
1571–1864	20000x1500	-	-
1864–2554	20000x1500	0.00	0.00
2554–3623	20000x2000	0.85	1.13
3623–3659	1050	0.85	1.14
3659–3924	8000 x1000	0.85	1.14
3924–4450	8000x1000	0.70	0.93
4450–4838	8000x1000	0.46	0.63
4838–4861	600	0.46	0.63
4861–4980	2400 x800	0.15	0.19
4980–5020	2x300	0.07	0.09
5020–5686	20000x1400	0.23	0.39
5686–6045	20000x1000	0.06	0.12
6045–6218	20000 x1000	0.06	0.13

AUTHOR: P Haywood DESIGN FILE: Fig 14i LS James post.dgn

WATER CORPORATION

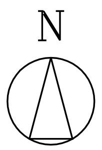
James Drain

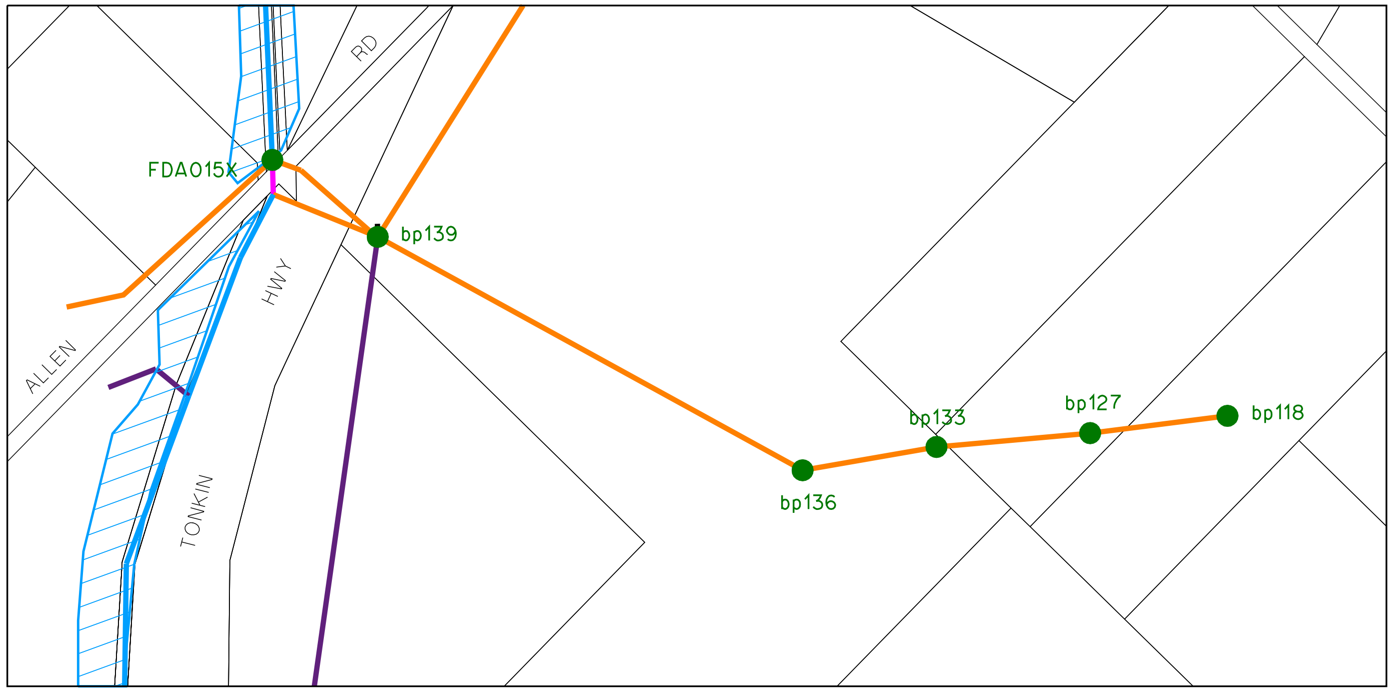
LONGITUDINAL SECTION

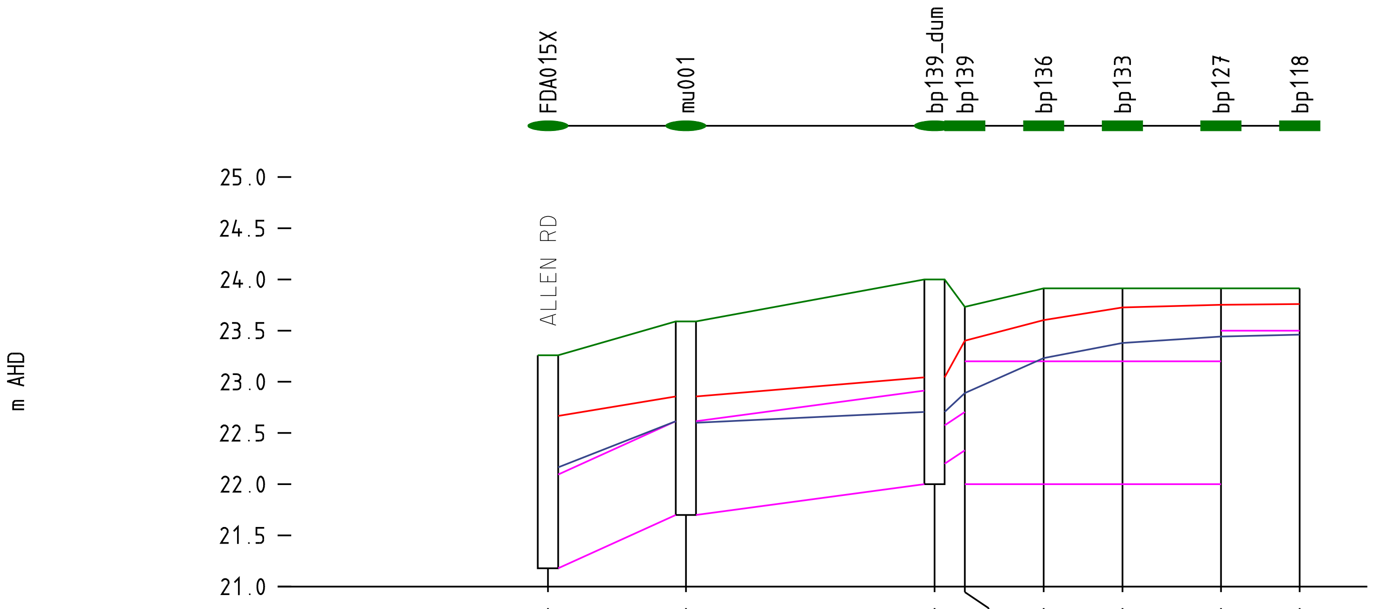
HGLs And Flows For Option A Adopted Strategy

Figure 14i

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50







Chainage (m)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD) (left)	Invert level (m AHD) (right)
0	23.26	22.16	22.67	-	21.18
35	23.59	22.60	22.86	21.70	21.70
98	24.00	22.71	23.04	22.00	22.20
105	23.70	22.89	23.40	22.33	22.00
125	24.03	23.23	23.60	22.00	22.00
145	24.03	23.38	23.73	22.00	22.00
170	24.05	23.44	23.75	22.00	23.50
190	24.06	23.46	23.76	23.50	-

Chainage (m)	Size (mm)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
0–35	915	0.58	0.82
35–98	915	0.58	0.82
98–105	375	0.29	0.41
105–125	1200	1.91	2.82
125–145	1200	1.46	1.76
145–170	1200	1.02	1.10
170–190	21100 x300	-	0.74

Forrestdale Business Park Drain

LONGITUDINAL SECTION

HGLs And Flows For Option A Adopted Strategy

Figure 14j

AUTHOR: P Haywood DESIGN FILE: Fig 14j LS ForrestdaleBusPk post.dgn

WATER CORPORATION

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

Appendices

Appendix A – Stormwater modelling in InfoWorks CS

Contents

Figures

Tables

A.1 Hydraulic modelling in InfoWorks CS

InfoWorks CS is a hydraulic modelling package used to simulate stormwater drainage systems. The software package is capable of hydrological modelling of the complete urban water cycle, including stormwater drainage master planning or studies, assessments of flooding in urban drainage systems and hydraulic response of the stormwater network infrastructure to the changes in the land use. The hydraulic software component can resolve open channel and closed conduit flows and model the effect of backwater and reverse flow. The model is used predominantly for calculations of event-based simulations; therefore the initial conditions are usually set to the worst-case scenario.

Time-varying surface runoff generated by the runoff routing model discharges into the hydraulic network. The hydraulic network consists of interconnected nodes (manholes, outfalls and storage basins) and links (weirs, pipes, culverts and open channels).

Mannings roughness coefficients applied to the conduits are summarised in Table A1.

Table A1 Culverts roughness coefficients (Mannings n)

Drain type	Manning's coefficient of roughness
Reinforced concrete pipe	0.012
Concrete box culvert	0.013
Over road flood route	0.015
Maintained open drain	0.030
Over land flood route	0.035

Nodes and manholes in the hydraulic network are modelled by standard units offered in InfoWorks CS. Most commonly, the flood level for nodes was set to a ground level. The exceptions were the basins connected to the main drain by an overland flow path; in this case flood level was elevated by 0.3 m to allow utilisation of the flow path. The default values used for nodes are summarised in Table A2.

Table A2 Default fields for nodes and manholes

Node field	Unit	Value
Shaft area bottom	m^2 1.2	
Shaft area top	m^2 1.2	
Floodable area	m^3 1.0	

Regional flood storage areas were designed according to the principles outlined in Chapter 6. First, the InfoWorks CS model is run for pre-development land use to determine maximum discharge from the catchment for a critical 100-year average recurrence interval rainfall event. The discharge of the catchment is to be maintained in the post-development scenario.

The catchment drains into a detention basin. A sealed dummy node is connected to the invert of the detention basin by a nominal 100 mm pipe to prevent the detention basin from filling by water in the initialisation of the model. The outflow pipe is connected at the invert level of the storage. The diameter of the outflow pipe will depend on storage size, pre-development discharge and storage elevation relative to the main drain, but rarely exceeds 450-600 mm.

The detention storage design is tested by running a critical 100-year average recurrence interval rainfall event for a post-development scenario. The discharge from the detention basin should not exceed the pre-development level and the storage volume should also be fully utilised. If the storage volume is inadequate, the basin is resized to achieve required volume utilisation, discharge out of the basin and the shape of the hydrograph.

Groundwater levels in drains and basins were modelled by the application of water levels and inflows directly into the drain or basin via dummy outfall nodes with reversed flap valves to prevent drain flows from discharging out of the model. Inflows were used to represent subsurface drainage flows estimated from the *Southern River development area groundwater model* (Rockwater 2005) and were applied at several locations throughout the model. Appropriate levels to represent groundwater inflows were identified with reference to the peak winter groundwater levels determined by *Southern River development area groundwater model* (Rockwater 2005).

The modelled maximum groundwater level (788 mm annual rainfall scenario) at the proposed location of the basin has been used to determine the invert of the detention basin. The invert of detention basins should be at least 300 mm above maximum groundwater level.

A.2 Modelling assumptions

The following assumptions used for modelling of Forrestdale main drain catchment:

- maximum groundwater levels (788 mm annual rainfall scenario) applied as starting water levels in basins and as baseflows in drains
- 100-year average recurrence interval rainfall event applied to whole catchment with universal start time
- 25-year river level applied as constant tailwater in the Southern River floodplain
- no infiltration modelled within flood storage areas or other components of the drainage system
- conservative parameterisation.

In isolation, these are all reasonable design assumptions to make, but it is essential that the build-up of conservatism is not forgotten. Any one of these assumptions when considered in isolation could have significant implications for the cost of the final solution, and when combined that effect could be multiplied.

A.3 Surface runoff parameters

InfoWorks CS uses the stormwater management model routing model to generate rainfall runoff from the catchment. The flow is routed using a single non-linear reservoir; its routing coefficients depend on surface roughness, surface area, ground slope, and catchment width. The runoff model consists of three components: initial losses, runoff model and runoff rate (routing). Each sub-catchment in the study area

(Figures A1 and A2) is subdivided into surface types (Table A3). These are pervious without depression storage (runoff routing value of 0.025, fixed runoff coefficient of 10 per cent), pervious with depression storage (runoff routing value of 0.025, fixed runoff coefficient of 20 per cent) and impervious with depression storage (runoff routing value of 0.015, fixed runoff coefficient 100 per cent). In rural areas an initial loss (depression storage) of 15 mm is set for natural pervious surface to account for initial wetting of the catchment.

Table A3 InfoWorks model runoff area properties

Runoff surface ID	Surface type	Surface roughness (Mannings n)	Initial loss (mm)	Fixed runoff coefficient
1	Pervious	0.025	0	0.1
2	Impervious	0.015	1.5	1
3	Pervious (shallow water table)	0.05	15	0.4-0.5 (varies with average recurrence interval event)

Permanently wet areas within the swamps and the wetlands were modelled as 100 per cent impervious (fixed runoff coefficient 100 per cent) without any initial losses.

The land use of the existing catchments was determined from the existing cadastre; the distinct structure plan provided the land use breakdown for the ultimate development. Each land use was assigned a runoff coefficient according to the *Urban main drainage manual* (Water Corporation 1998); the coefficients are summarised in Table A4. The equivalent runoff coefficients, which can be used to convert the stormwater management model routing model coefficients to rational method parameters, are also presented.

Table A4 InfoWorks model land use surface breakdown

Land use category	Runoff area 1 (%)	Runoff area 2 (%)	Runoff area 3 (%)	Equivalent runoff coefficient
Conservation category wetland	0%	0%	100%	0.40
Community facilities	28%	72%	0%	0.75
Environmental protection policy lake	0%	0%	100%	0.40
Light industrial	22%	78%	0%	0.80
Mixed business/commercial	22%	78%	0%	0.80
Open space (including drainage corridors)	0%	0%	100%	0.40
Parks and recreation reservation	0%	0%	100%	0.40
Primary regional road	20%	80%	0%	0.82
Roads	20%	80%	0%	0.82
Rural	0%	0%	100%	0.40
Rural living and semi-rural living	0%	0%	100%	0.40
Urban (including balance of public open space)	89%	11%	0%	0.20
Village/ neighbourhood centres	28%	72%	0%	0.75

The percentage of surface types for individual catchments was calculated from the existing land use and district structure plan; the results are summarised in Table A5 (pre-development scenario) and Table A6 (post development scenario).

The design rainfall events for the one-hour, three-hour, six-hour, 12-hour, 24-hour, 48-hour and 72-hour durations were run for two-year, 10-year and 100-year average recurrence interval occurrences were generated from long-term continuous rainfall records. These were then used to design the stormwater drainage infrastructure.

Table A5 Existing catchment land use breakdown and loss model

Land use	Catchment area (ha)	Equivalent (rational method) runoff coefficient
Farming 103		0.40
Light industrial	10	0.80
Open space (including drainage corridors)	178	0.40
Community facilities	22	0.75
Conservation category wetlands, Environmental protection policy lakes, parks and recreation reservation (including proposed), and other rural areas	1886	0.40
Urban (including balance of public open space)	38 0.20	
Rural 2025		0.40
Rural living and semi-rural living	172	0.40
Total catchment	**4434**	**0.40**

Table A6 Proposed catchment land use breakdown and loss model

Land use	Catchment area (ha)	Equivalent (rational method) runoff coefficient
Light industrial	275	0.80
Open space (including drainage corridors)	301	0.40
Community facilities	90	0.75
Conservation category wetlands, Environmental protection policy lakes, parks and recreation reservation (including proposed). 1423		0.40
Urban (including balance of public open space) 1092		0.20
Rural 423		0.40
Rural living and semi-rural living	424	0.40
Village/neighbourhood centres	30	0.75
Mixed business/ commercial	58	0.80
Roads 317		0.82
Total catchment	4434	0.42

Notes:

- The high runoff coefficient for unfilled areas takes into account the high groundwater table of the catchment.
- The small increase in total catchment runoff does not reflect the increased flow into drains via subsoil drainage. This has been separately accounted for in the model and represents an increase in regional groundwater levels.

Table A7 InfoWorks model catchment properties for pre-development scenario

Subcatchment identification	Total area (ha)	Vector slope (%)	Catchment width (m)	Runoff area 1 (ha)	Runoff area 2 (ha)	Runoff area 3 (ha)	FI
B10A	103.9	0.6	575	0	12.47	91.43	0.12
B10B	53.2	0.7	412	0	6.38	46.80	0.12
B11A	204.2	0.1	806	0	0	204.22	-
B11B	32.1	0.1	320	0	0	32.11	-
B12	114.0	0.1	602	0	0	114.00	-
B13	35.4	0.5	336	0	4.25	31.20	0.12
B1A	131.2	0.1	646	0	26.23	104.92	0.20
B1B	85.6	0.1	522	0	17.13	68.51	0.20
B1C	15.4	0.1	221	0	3.07	12.28	0.20
B3A	29.5	0.3	307	0	5.31	24.21	0.18
B3B	67.5	0.5	463	0	12.14	55.32	0.18
B3C	22.4	0.5	267	0	4.04	18.40	0.18
B4	74.8	0.1	488	0	0	74.83	-
B5	187.0	0.1	772	0	0	187.03	-
B6	74.4	0.1	487	0	0	74.45	-
B7	67.7	0.1	464	0	0	67.75	-
B8	100.4	0.1	565	0	0	100.38	-
BA1D	7.9	0.1	158	0	0	7.85	-
BA6A	16.2	0.1	227	0	0	16.15	-
bu033	35.2	0.1	335	0	4.22	30.97	0.12
CATB1	58.4	0.5	431	43.84	14.61	0	0.25
CATB2	56.2	0.5	423	0	0	56.18	-
CATB3	53.7	0.2	414	0	0	53.71	-
CATB4	55.8	0.0	421	0	0	55.78	-
CATF1	671.1	0.2	1462	0	127.52	543.63	0.19
CATF10	38.5	0.2	350	32.73	5.78	0	0.15
CATF11A	11.5	0.2	191	0	0	11.51	-
CATF11B	24.6	0.2	280	0	0	24.64	-
CATF11C	14.4	0.2	214	0	0	14.44	-
CATF11D	18.8	0.2	244	0	0	18.76	-
CATF11E	2.1	0.2	82	0	0	2.09	-
CATF12A	47.3	0.0	388	0	0	47.25	-
CATF12B	10.1	0.0	180	0	0	10.14	-
CATF2	136.4	0.3	659	0	0	136.39	-
CATF3	93.9	0.1	547	0	0	93.93	-
CATF4	19.5	0.6	249	17.54	1.95	0	0.10
CATF5	54.5	0.0	417	0	0	54.54	-
CATF7	125.1	0.0	631	0	0	125.06	-
CATF8	64.0	0.3	452	0	0	64.03	-
CATF9	66.2	0.0	459	59.57	6.62	0.00	0.10
CATG1	149.0	0.0	689	0	0	148.97	-
CATJ1a	160.5	0.1	715	0	0	160.47	-
CATJ1b	214.2	0.1	826	0	0	214.23	-
CATJ1c	70.6	0.1	474	0	0	70.57	-
CATJ2	488.5	0.1	1247	0	0	488.50	-
CATK1	47.1	0.0	387	0	0	47.05	-

Subcatchment identification	Total area (ha)	Vector slope (%)	Catchment width (m)	Runoff area 1 (ha)	Runoff area 2 (ha)	Runoff area 3 (ha)	FI
CATK2	48.1	0.6	391	0	0	48.09	-
CATL1	87.7	0.3	528	0	0	87.71	-
CATL2	91.7	0.3	540	0	0	91.69	-
CATL3	65.7	0.2	458	0	0	65.74	-
CATL4	56.1	0.0	423	0	0	56.14	-
CATL5A	8.2	0.2	161	0	0	8.19	-
CATL5B	10.8	0.2	186	0	0	10.82	-
CATL5C	27.4	0.2	295	0	0	27.37	-
CATL6	30.4	0.1	311	0	0	30.36	-
CATM1	97.7	0.1	558	0	0	97.66	-
CATT1A	45.0	0.1	379	0	0	45.02	-
CATT1B	52.8	0.1	410	0	0	52.84	-
CATU4	49.1	0.7	396	0	0	49.13	-
FDACB1	13.5	0.0	208	0	0	13.53	-
MU02	40.4	0.1	359	0	0	40.42	-
MU02B	50.5	0.1	401	0	0	50.49	-
P4A	154.7	0.1	702	0	0	154.67	-
P4B	41.6	0.1	364	0	0	41.62	-
to007	24.1	0.0	277	20.26	3.86	0	0.16
tocb	33.9	0.2	328	0	0	33.87	-

Table A.8 InfoWorks model catchment properties for post-development scenario

Subcatchment identification	Total area (ha)	Vector slope (%)	Catchment width (m)	Runoff area 1 (ha)	Runoff area 2 (ha)	Runoff area 3 (ha)	FI
B12	111.4	0.1	595.5	0	0	111.42	0.00
BA1	101.3	0.1	568	1.01	4.05	96.27	0.04
BA10	63.5	0.1	449.7	43.84	11.44	8.26	0.18
BA11A	42.7	0.1	368.7	26.05	7.69	8.97	0.18
BA11B	10.6	0.1	183.8	7.21	3.39	0	0.32
BA13A	23.9	0.1	275.6	11.45	12.40	0	0.52
BA14a	41.4	0.1	363	30.63	9.52	1.24	0.23
BA14B	68.4	0.1	466.7	49.94	16.42	2.05	0.24
BA14C	21.3	0.1	260.4	14.06	4.90	2.34	0.23
BA17	38.5	0.1	349.9	26.15	12.31	0	0.32
BA2	84.1	0.1	517.4	21.02	5.89	57.19	0.07
BA3	68.4	0.1	466.6	46.51	19.83	2.74	0.29
BA5A	23.9	0.1	276.1	0	0	23.94	-
BA5B	37.0	0.1	343	26.61	9.24	0	0.25
BA5C	51.0	0.1	402.8	0	0	50.98	-
BA5d	39.3	0.1	353.6	0	0	39.27	-
BA6A	17.0	0.1	232.8	0	0	17.03	-
BA6B	27.8	0.1	297.4	0.56	3.61	23.61	0.13
BA8A	21.3	0.1	260.5	14.71	5.76	0.85	0.27
BA8B	9.3	0.1	171.6	6.11	1.94	1.20	0.21
BA9	55.2	0.1	419.1	5.52	6.07	43.59	0.11
bp119	6.5	0.1	144.1	1.96	4.57	0	0.70

Subcatchment identification	Total area (ha)	Vector slope (%)	Catchment width (m)	Runoff area 1 (ha)	Runoff area 2 (ha)	Runoff area 3 (ha)	FI
bush 5.5		0	132.1	4.00 1.48		0	0.27
cat_lot152 9.3		0.1	171.9 4.46		1.30	1.49	0.14
cat_lot153 8.1		0.1	160.9 0.31		0.09	0.11	0.01
cat_lot154 7.8		0.1	157.7 0.29		0.09	0.10	0.01
cat_lot155 10.6		0.1	183.6 9.00		1.59	0	0.15
CATB1 58.4		0.5	431.3	26.30 15.78		16.37	0.27
CATB2A 26.1		0.5	288	18.50 5.99		1.56	0.23
CATB2B 30.1		0.5	309.7 20.49		6.93	2.71	0.23
CATB3 50.6		0.2	401.1	13.65 3.03		33.87	0.06
CATB4 55.8		0	421.4	0	0	55.78	-
CATB5 208.2		0.1	814.1 0		2.08	206.13	0.01
CATB6 49.3		0.7	396.1	0.49 1.97		46.81	0.04
CATB7 32.4		0.1	321	0.65 2.59		29.13	0.08
CATF1 670.7		0.2	1461.1 0		127.43	543.24	0.19
CATF10 38.6		0.2	350.3	3.47 12.72		22.36	0.33
CATF11A 11.5		0.2	191.4 0		0	11.51	-
CATF11B 24.8		0.2	281	15.13 4.96		4.71	0.20
CATF11C 13.6		0.2	208.4 5.87		2.87	4.91	0.21
CATF11D 18.8		0.2	244.3 12.57		2.44	3.75	0.13
CATF11E 2.1		0.2	81.5 0.02		0.04	2.03	0.02
CATF12A 47.1		0	387.3	11.31 6.13		29.69	0.13
CATF12B 10.1		0	179.6 7.81		2.33	0	0.23
CATF2a 24.9		0.3	281.5	10.21 6.47		8.22	0.26
CATF2b 111.6		0.3	596	0.00 1.12		110.49	0.01
CATF3a 64.6		0.1	453.6	2.59 9.70		52.36	0.15
CATF3b 30.7		0.1	312.7	14.44 6.76		9.53	0.22
CATF4A 16.1		0.6	226.2	13.98 1.93		0.16	0.12
CATF4B 10.9		0.6	186	2.17	8.69	0	0.80
CATF5 46.1		0.1	383.3	29.07 11.08		6.00	0.24
CATF7A 31.5		0.1	316.5	5.67 20.77		5.04	0.66
CATF7B 56.1		0	422.7	0.56 1.12		54.44	0.02
CATF7C 29.0		0.1	303.6	24.61 4.05		0.29	0.14
CATF8 64.0		0.3	451.5	0	0	64.03	-
CATF9 66.1		0.1	458.8	1.32 4.63		60.17	0.07
CATG1 148.7		0	688.1	28.26 13.39		107.09	0.09
CATJ1 160.8		0.1	715.4	0	0	160.77	-
CATJ2 489.2		0.1	1247.9	0	0	489.20	-
CATJ3 216.6		0.1	830.3	0	0	216.57	-
CATJ4 70.6		0.1	474	0	0	70.60	-
CATK1 9.1		0	170.4	5.20 3.29		0.64	0.36
CATK2A 42.6		0.6	368 0		0.43	42.13	0.01
CATK2B 34.9		0.6	333.4 0		0.35	34.57	0.01
CATL1 32.0		0.3	318.9	0.64 2.88		28.44	0.09
CATL2 62.6		0.3	446.3	4.38 4.38		53.81	0.07
CATL3 12.7		0.2	200.9	0.63 1.65		10.40	0.13
CATL5A 8.2		0.2	161.4 6.30		1.88	0	0.23

Subcatchment identification	Total area (ha)	Vector slope (%)	Catchment width (m)	Runoff area 1 (ha)	Runoff area 2 (ha)	Runoff area 3 (ha)	FI
CATL5B 11.3		0.2	189.7 8.70		2.60	0	0.23
CATL5C 28.3		0.2	300.3 21.53		6.80	0	0.24
CATL6 30.7		0.1	312.7	8.29 18.43		3.99	0.60
CATT1A 18.0		0.1	239.6	0.54 1.62		15.87	0.09
CATT1B 15.7		0.1	223.6	1.41 5.18		9.11	0.33
CATT2 24.1		0.1	277.1	0.24 1.21		22.68	0.05
CATT3A 31.9		0.1	318.9	6.39 19.49		6.07	0.61
CATT3B 28.2		0.1	299.8 8.47		19.77	0	0.70
CATT4 21.5		0.1	261.9	14.43 3.23		3.88	0.15
creek 29.4		0.1	305.7	22.01 7.34		0.00	0.25
FBPw 35.5		0.1	336.1	0	0	35.49	-
FDACB1 13.5		0	207.5	0	0	13.53	-
LAC 11.8		0.2	193.9	9.33 2.13		0.35	0.18
LB 16.5		0.2	229.4	13.23 2.98		0.33	0.18
LD 9.9		0.2	177.6	7.03 2.87		0	0.29
LE1 3.9		0.2	111	3.17	0.70	0	0.18
LE2 5.9		0.2	136.6	3.46 1.41		1.00	0.24
LF1 7.3		0.2	152.3	5.68 1.09		0.51	0.15
LF2 5.3		0.2	129.5	1.32 1.11		2.85	0.21
LF3 4.7		0.2	122.6	4.16 0.57		0	0.12
LF4 6.4		0.2	67.3	2.89 1.09		2.44	0.17
LF5 2.9		0.2	96.5	1.46 1.46		0.00	0.50
LG 3.9		0.2	111.9	1.14 1.46		1.34	0.37
LH 14.6		0.2	215.4	8.45 6.12		0	0.42
LH2 2.8		0.2	94.2	0.72 2.06		0	0.74
LI 5.1		0.2	126.9	2.02 2.94		0.10	0.58
LJ 6.0		0.2	138	4.13 1.85		0	0.31
LK 2.8		0.2	94.7	2.51 0.31		0	0.11
LL 14.4		0.2	213.9	10.49 3.88		0	0.27
LM 9.4		0.2	173.4	8.12 1.32		0	0.14
LN 13.2		0.2	205.3	11.39 1.85		0	0.14
LO 19.6		0.2	221.5	14.51 5.10		0	0.26
N115 7.1		0.1	150	2.12	4.95	0	0.70
N116 5.3		0.1	129.8	1.59 3.71		0	0.70
N117 9.8		0.1	176.8	2.95 6.87		0	0.70
N120 10.6		0.1	183.9	3.19 7.44		0	0.70
N121 5.0		0.1	126.7	1.51 3.53		0	0.70
N122 3.2		0.1	100.2	0.95 2.21		0	0.70
N123 10.6		0.1	184.1	3.19 7.45		0	0.70
N124 9.0		0.1	169.4	2.70 6.31		0	0.70
N125 9.1		0.1	170.6	2.74 6.40		0	0.70
N126 6.3		0.1	141.1	1.88 4.38		0	0.70
N128 4.6		0.1	121	1.38	3.22	0	0.70
N129fbp 6.3		0.1	141.6 1.89		4.41	0	0.70
N130 4.2		0.1	115.6	1.26 2.94		0	0.70
N131 5.8		0.1	135.6	1.73 4.04		0	0.70
N132 5.7		0.1	134.8	1.71 4.00		0	0.70

Subcatchment identification	Total area (ha)	Vector slope (%)	Catchment width (m)	Runoff area 1 (ha)	Runoff area 2 (ha)	Runoff area 3 (ha)	FI
N134	7.1	0.1	150.4	2.13	4.98	0	0.70
N135	6.5	0.1	144.3	1.96	4.58	0	0.70
N137	5.6	0.1	133.1	1.67	3.89	0	0.70
N138	7.9	0.1	158.4	2.36	5.52	0	0.70
N140	10.2	0.1	179.8	3.05	7.11	0	0.70
N141	8.6	0.1	165.6	2.58	6.03	0	0.70
N142	5.2	0.1	129.1	1.57	3.67	0	0.70
N143	8.4	0.1	163.5	2.52	5.88	0	0.70
N144	7.5	0.1	154.7	2.26	5.26	0	0.70
NH1A-1	6.1	0.1	139.4	3.36	2.75	0	0.45
NH1A-2	5.7	0.1	135.2	3.39	0.92	1.44	0.16
P4	14.2	0.1	212.5	8.08	2.84	3.26	0.20
P4A	18.7	0.1	243.7	12.50	4.29	1.87	0.23
P4B	38.5	0.1	350.2	25.05	8.48	5.01	0.22
P4C	30.6	0.1	312.3	19.92	3.06	7.66	0.10
P4D	34.2	0.1	329.8	24.61	6.84	2.73	0.20
P4E	34.0	0.1	329	24.15	9.86	0	0.29
P4F	35.1	0.1	334.3	23.17	9.83	2.11	0.28
SC10	5.5	0.1	132	4.54	0.93	0	0.17
SC10a	1.3	0.1	65.3	1.11	0.23	0	0.17
SC12	9.8	0.1	176.8	6.87	2.95	0	0.30
SC12a	1.9	0.1	77	1.55	0.32	0	0.17
SC13	10.2	0.1	180.1	7.03	3.16	0	0.31
SC14	17.1	0.1	233.6	14.23	2.92	0	0.17
SC14a	3.0	0.1	98.1	2.51	0.51	0	0.17
SC15	11.0	0.1	186.8	6.90	4.05	0	0.37
SC15A	4.2	0.1	115.6	2.56	1.64	0	0.39
SC16	2.2	0.1	84.4	1.86	0.38	0	0.17
SC17	0.8	0.1	49.5	0.64	0.13	0	0.17
SC2	1.3	0.1	64.7	1.09	0.22	0	0.17
SC5	4.8	0.1	124.1	3.48	1.36	0	0.28
SC5a	1.6	0.1	70.7	1.30	0.27	0	0.17
SC6	16.8	0.1	231.1	13.93	2.85	0	0.17
SC7	10.6	0.1	184	7.66	2.98	0	0.28
SC7a	2.4	0.1	87.5	2.00	0.41	0	0.17
SC7b	6.6	0.1	144.4	4.72	1.83	0	0.28
SC8	2.8	0.1	94.9	2.04	0.79	0	0.28
SC8a	5.6	0.1	133.1	4.62	0.95	0	0.17
SC9	6.0	0.1	138	4.66	1.32	0	0.22
SCA9A	5.1	0.1	127.9	0	0	5.14	-
VER11AA	1.7	0.1	73.5	1.36	0.34	0	0.20
VER11AB	1.1	0.1	59	0.88	0.22	0.00	0.20
VER11AC	3.2	0.1	100.4	1.24	0.32	1.62	0.10
VER12A	7.1	0.1	149.8	4.23	1.06	1.76	0.15
VER14A	5.5	0.1	132.1	4.39	1.10	0	0.20
VER15A	1.7	0.1	74.2	0	0	1.73	-

Subcatchment identification	Total area (ha)	Vector slope (%)	Catchment width (m)	Runoff area 1 (ha)	Runoff area 2 (ha)	Runoff area 3 (ha)	FI
VER16A 2.4		0.1	86.5	1.27 0.31		0.78	0.13
VER1A 3.4		0.1	104.5	2.37 0.58		0.48	0.17
VER2A 1.7		0.1	73.8	1.04 0.65		0.02	0.38
VER2AA 1.8		0.1	75.7	1.44	0.36	0	0.20
VER2AB 2.6		0.1	91.8	1.85 0.45		0.34	0.17
VER2B 10.8		0.1	185.8 9.22		1.63	0	0.15
VER2C 8.6		0.1	165.3	5.32 2.92		0.34	0.34
VER2D 3.0		0.1	98.5	1.58 0.70		0.76	0.23
VER2E 7.5		0.1	154.7	5.41 1.95		0.15	0.26
VER2F 6.9		0.1	148.1 5.58		1.31	0	0.19
VER2G 7.9		0.1	158.4	6.70	1.18	0	0.15
VER2H 3.7		0.1	109.1	3.33	0.41	0	0.11
VER2J 4.9		0.1	124.6	3.90 0.83		0.15	0.17
VER2K 4.7		0.1	121.9 3.97		0.70	0	0.15
VER3A 3.0		0.1	98.2	1.49 0.36		1.18	0.12
VER4A 2.9		0.1	96.4	1.43 0.35		1.14	0.12
VER5A 1.0		0.1	57.5	0.58 0.15		0.31	0.14
VER6A 4.9		0.1	124.4	0	0	4.86	-
VER7A 3.2		0.1	101.5	2.59 0.65		0.00	0.20
VER8A 0.9		0.1	53.3	0.72 0.18		0.00	0.20
VER9A 3.8		0.1	109.7	2.27 0.57		0.95	0.15

A.4 Model calibration

The lack of flow measurements on Forrestdale main drain did not allow calibration of model flows. This factor led to the adoption of conservative model parameterisation and the use of design storm events only.

A.5 Local arterial drainage – conceptual design

Local arterial drainage conceptual designs are presented in Figures A3a to A3f

The local arterial drainage designs presented in this *Arterial drainage strategy* for individual precincts are conceptual designs only. Whilst they may be developed directly into detailed designs, it is the preference of the Department of Water that they be used to provide an initial set of drainage characteristics for a development from which drainage designs following water sensitive urban design principles are developed.

Conceptual designs include:

- proposed arterial drainage alignments, designed to provide optimum performance for the subcatchment
- detention basins, designed to compensate the 100-year average recurrence interval event to not exceed its pre-development peak flow.

The conceptual design of a dry basin is presented in Figure A4. Imported fill will be required in some locations to ensure that residential lots are constructed with a finished floor level at a minimum of 500 mm above the 100-year flood level both in the drain and within the basin.

The Department of Water does not generally support the construction of wet basins, ornamental lakes, irrigation lakes or open water bodies. Further information on this may be found in *Interim position statement: constructed lakes* (Department of Water 2007).

A.6 City of Gosnells – Precinct 2 (Bletchley Park)

A conceptual design for the drainage in this catchment has been prepared by consultants (GHD) working on behalf of developers. The drainage, as described in the *Bletchley Park local water management strategy* (GHD 2005) has been incorporated into the InfoWorks model. Figure A3a shows the layout of the proposed drainage network and the locations of planned compensating basins.

Total catchment area	= 166 ha
Estimated pre-development 100-year peak discharge	= 1.2 m^3/s
Estimated 100-year tailwater condition	= 21.3 m AHD

It is important to note that the catchment includes two school sites, which the local water management strategy designs intend not to contribute to the local arterial drains. Therefore the total contributing area has been reduced by 9 ha. It is essential therefore that the building conditions for these two sites stipulate on-site detention of all flows up to and including the critical 100-year average recurrence interval event.

The *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) did not fully address the drainage corridors required for this precinct. The *Bletchley Park local water management strategy* (GHD 2005) proposes to maintain the existing path of Balannup Lake drain.

The local water management strategy was designed with a higher indicated 100-year tailwater condition and as a result will require additional throttling to meet the peak discharge criteria. InfoWorks modelling suggests that twin 600 mm culverts immediately upstream of Southern River Road will be sufficient. These replace twin 915 mm culverts indicated in the local water management strategy.

A.7 City of Gosnells– Precinct 3

Figure A2 provides details of compensating basins proposed within Precinct 3 as well as showing proposed arterial drainage routes that in general follow the routes of existing agricultural drains.

Precinct 3 to Balannup Lake drain

100-year flood storage parameters		Holmes St North	Lander St	Stirling St North
100-year peak discharge	m^3/s	0.3	0.4	0.1

100-year peak downstream tailwater	m	21.4 21.9		21.8
Contributing area	ha	11.3	30.7	28.3
100-year surface area	ha	0.2	1.3	0.5

The existing route of the Balannup Lake drain is not included in the *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001); it is proposed to maintain its existing course serving both Precincts 2 and 3.

Precinct 3 to Forrestdale main drain

100-year flood storage parameters		Matison Rd	Holmes St south	Stirling St south
100-year peak discharge	m^3/s	0.2	0.2	0.3
100-year peak downstream tailwater	m	21.3 21.2		21.2
Contributing area	ha	13.6	24.8	18.8
100-year surface area	ha	0.2	0.6	0.4

Precinct 3 to Southern River

Conceptual designs for the small section of Precinct 3 known as Subprecinct 3A are in the early stages of development by consultants (ENV Australia Ltd) on behalf of developers.

Total catchment area = 18 ha

Estimated pre-development 100-year peak discharge

(to Southern River floodplain and Forrestdale main drain) = 0.1 m^3/s

At present, drainage of the subprecinct ponds occurs in two locations: along the north side of Matison Street, and at the corner of Holmes Street and Southern River Road. During major storm events these roads can be overflowed and drainage then flows overland into the Precinct 2 floodplain north of Southern River Road, and the Southern River floodplain conservation category wetland and Forrestdale main drain in the south.

With the development of Subprecinct 3A, the drainage design should be such that overflows to the conservation category wetland and Forrestdale main drain are maintained at pre-development levels.

For the purposes of this study, the existing natural storage to the south has been retained, as shown in the *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001). Overflows into the conservation category wetland post-development remain the same as pre-development. It is assumed that additional flows are diverted downstream to the Leslie Street local authority outlet via the Matison Street drain.

With the development of Precinct 2, overflows into the Precinct 2 floodplain can no longer occur, and for the purposes of this study it has been assumed that this area will also be diverted to the Leslie Street local authority outlet.

A.8 City of Gosnells – Precinct 4

The proposed arterial drainage routes and compensating basin details for Precinct 4 are shown in Figure A3c. This catchment is divided into two subprecincts, each discharging directly into the Forrestdale main drain, although Precinct 4 North also makes use of an existing drainage path directly into the Southern River.

The *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission, 2002) indicates a drainage corridor running along the entire eastern boundary of the Precinct 4 north drain catchment adjacent to the Tonkin Highway before turning west into the Forrestdale main drain at the northern end. During the development of the *Arterial drainage strategy* it was found that excessive fill would be required to drain this precinct to the proposed corridor. It is therefore proposed that the existing drainage routes are retained and in general the routes of existing agricultural drains have been followed.

Precinct 4 north drain

100-year flood storage parameters		Dallen St west	Holmes St	Stirling St	Furle y Rd	Gert y St	Dalle n St east
100-year peak discharge	m^3/s	0.2 0.7 0.		2 0.2		0.4	0.4
100-year peak downstream tailwater	m	21.7 21.9 22.1			22.2	22.2	21.9
Contributing area	ha	18.7	38.5 30.6		34.2	34.0	35.1
100-year surface area	ha	0.3 0.5 0.8			0.4	1.0	1.0

Precinct 4 south drain

100-year flood storage parameters		Passmore St	Ranford Rd	Tonkin Hwy
100-year peak discharge	m^3/s	0.3 1.1 0.1		
100-year peak downstream tailwater	m	22.4 22.5 22.5		
Contributing area	ha	31.9 28.2 21.5		
100-year surface area	ha	2.4	1.1	0.5

A.9 City of Armadale – North Forrestdale

North Forrestdale encompasses all of the land connected to the Balannup drain, which passes through Bush Forever site no. 342 and connects to Baileys branch drain via a single 600 mm diameter culvert. Baileys branch drain then continues through twin 675 mm diameter culverts and joins the Forrestdale main drain some 300 m upstream of Ranford Road.

The drainage corridors indicated in the *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) have already been modified in the *North Forrestdale urban water management strategy* (Parsons Brinkerhoff 2005) and in general are proposed to follow the existing Balannup drain and agricultural drainage routes.

Figure A3d shows the proposed arterial drainage routes through North Forrestdale and provides details of proposed flood storage areas. Where conceptual drainage designs have been developed by others, they have been incorporated into the InfoWorks model. The general layout of these designs is indicated in Figure A3d.

Nicholson Road West

100 year flood storage parameters		Nicholson Rd west	Wright Rd west	Mason Rd
100-year peak discharge	m^3/s 0.1		0.4	0.1
100-year peak downstream tailwater	m	25.9 26.9		25.9
Contributing area	ha	9.3	9.2	21.3
100-year surface area	ha	0.2	0.2	0.7

Balannup Lake

100 year flood storage parameters		Reilly Rd south	Reilly Rd north	Lakeside	Southern River Rd
100-year peak discharge	m^3/s	0.2 0.2 0.1			0.3
100-year peak downstream tailwater	m	23.4 23.5 23.5			23.4
Contributing area	ha	68.4 23.9 38.5			21.3
100-year surface area	ha	3.0	1.2	0.8	0.3

The *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) proposes development of areas that are currently inundated in significant storm events forming a part of the Balannup Lake floodplain. This not only reduces the floodable area of the lake but also reduces its natural catchment. Some stormwater runoff is directed to Balannup Lake to maintain pre-development top water levels. The remainder is diverted to the Balannup drain upstream of Bush Forever site no. 342 and provision for this is made within the downstream flood storage areas.

In developing drainage proposals for this catchment, this complex hydrological change has been considered and short-term flood levels for various significant events within the lake remain unchanged. The longer-term seasonal and inter-annual effects of the reduced lake catchment as a result of development are unknown.

Nicholson Road east

100-year flood storage parameters		Skeet Rd	Skeet Rd north	Keane Rd
100-year peak discharge	m^3/s 0.1		0.3	0.1
100-year peak downstream tailwater	m	23.4 23		23.5
Contributing area	ha	42.7	41.4	10.6
100-year surface area	ha	2.0	0.9	0.2

Much of this catchment is currently undrained with a gradual slope towards the wetland within Bush Forever site no. 342. This wetland is then linked to the Balannup drain and Baileys branch drain close to their confluence. Similar to the Balannup Lake subcatchment, the contribution that this area makes to the inundation of the wetland in major events has been maintained by ensuring that any additional flows are diverted around the wetland. In addition, the existing drain serving this area, running adjacent to Bush Forever site no. 342 and joining Balannup drain at Skeet Road, will be retained.

Newhaven

Consultants (Parsons Brinkerhoff) on behalf of the developers have prepared a conceptual design of stormwater drainage system for Newhaven and this has been incorporated into the model.

Total catchment area	= 142 ha
Estimated pre-development 100-year peak discharge	= 0.8 m^3/s
Estimated 100-year tailwater condition	= 25.5 m AHD

Generally the design of this area ensures that post development flows are similar to pre-development flows.

Lot 49 – Heron Park

Consultants (Parsons Brinkerhoff) on behalf of the developers have prepared a conceptual design of stormwater drainage system for Heron Park.

Total catchment area	= 49 ha
Estimated pre-development 100-year peak discharge	= 0.3 m^3/s
Estimated 100-year tailwater condition	= 24.7m AHD

There is currently some uncertainty regarding the existing hydrological regime of the conservation category wetland within this development. Control levels for the wetlands will need to be set ensuring that any change between the pre- and post-development 100-year average recurrence interval levels are acceptable to the relevant environmental regulators.

Generally the design of this area ensures that post-development flows are similar to pre-development flows.

Lot 50 – Vertu

Consultants (Parsons Brinkerhoff) on behalf of the developers have prepared a conceptual design of stormwater drainage system for Vertu.

Total catchment area	= 60 ha
Estimated pre-development 100-year peak discharge	= 0.3 m^3/s
Estimated 100-year tailwater condition	= 24.3 m AHD

Generally the design of this area ensures that post development flows are similar to pre-development flows.

Lot 388 – Arion

Consultants (JDA Consultant Hydrologists) on behalf of the developers have prepared a conceptual design of stormwater drainage system for Arion.

Total catchment area	= 35 ha

Estimated pre-development 100-year peak discharge = 0.1 m^3/s

Estimated 100-year tailwater condition = 26.1 m AHD

Generally the design of this area ensures that post-development flows are similar to pre-development flows.

Lot 153 and 154 – Burtonia Gardens

Consultants (JDA Consultant Hydrologists) on behalf of the developers have prepared a conceptual design of stormwater drainage system for Burtonia Gardens.

Total catchment area = 27 ha

(includes 11 ha upstream undeveloped catchment)

Estimated pre-development 100-year peak discharge = 0.06 m^3/s

Estimated 100-year tailwater condition = 26.5 m AHD

Generally the design of this area ensures that post development flows are similar to pre-development flows.

A.10 City of Armadale – Keane Road branch drain and Forrestdale townsite and business park

Apart from the Forrestdale main drain and Baileys branch drain, drainage corridors have not been identified in the *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) for these precincts. Figure A3e shows the proposed drainage routes for each of these precincts and provides details of proposed flood storage areas.

Keane Rd branch drain

100-year flood storage parameters		Armadale Rd
100-year peak discharge	m^3/s 0.1	
100 year peak downstream tailwater	m	24.3
Contributing area	ha	9.1
100-year surface area	ha	0.2

Only a very small part of this precinct is proposed for development and the existing drainage will be maintained with the addition of a single compensating basin.

Forrestdale townsite to Baileys branch drain

100-year flood storage parameters		Dumsday Dr	Anstey Rd	Keane Rd Sth	Keane Rd Nth
100-year peak discharge	m^3/s	1.2 0.2 0.4			0.4
100-year peak downstream tailwater	m	23.1 23		23	22.9
Contributing area	ha	58.4 30.1 26.1			50.6
100-year surface area	ha	0.4	0.9	0.4	1.1

The existing Dumsday Drive compensating basin was relocated by the City of Armadale as part of converting Armadale Road into a dual carriageway through the existing Forrestdale townsite. The volume of the basin was reduced as a result of these works, but modelling has determined that the shortfall in storage can be accommodated in the proposed upgrade of the Baileys branch drain upstream of Anstey Road.

Forrestdale townsite to main drain

100-year flood storage parameters		Allen Rd north	Forrest Rd	Allen Rd south	Tonkin Hwy
100-year peak discharge	m^3/s 0.2		0.2	0.2	0.3
100-year peak downstream tailwater	m	23.1 24.1		23.4	24
Contributing area	ha	29.0 24.9		46.1	30.7
100-year surface area	ha	0.5	0.8	1.7	1.1

Forrestdale business park

A conceptual design of the catchment has been prepared by consultants (Parsons Brinkerhoff) and incorporated into the InfoWorks model.

Total catchment area	= 176 ha
Estimated pre-development 100-year peak discharge	= 1.0 m^3/s
Estimated 100-year tailwater condition	= 23.1 m AHD

An additional 375 mm diameter connection has been made from this precinct to the Forrestdale main drain with an upstream invert level of 21.5 m AHD which is approximately 0.5 m below the modelled regional maximum groundwater level (788 mm annual rainfall scenario).

An opportunity exists to reduce the fill and/or storage volume requirements for this catchment by the use of the existing conservation category wetland to store some flooding from significant events. Following the development of this catchment, the natural catchment of the wetland will be reduced and therefore periodic surface flows into the wetland will be lower.

In order to mitigate this reduction in surface water flows, it may be possible to divert some of the major event flows out of the constructed flood storage areas and into the wetland. Control levels for flow into the wetland would need to be set to ensure that any change between the pre- and post-development 100-year average recurrence interval levels are acceptable to the relevant environmental regulators.

Industrial area (Allen Road to Ranford Road)

100-year flood storage parameters		Anstey Rd
100-year peak discharge	m^3/s 0.5	
100-year peak downstream tailwater	m	23
Contributing area	ha	31.5
100-year surface area	ha	1.8

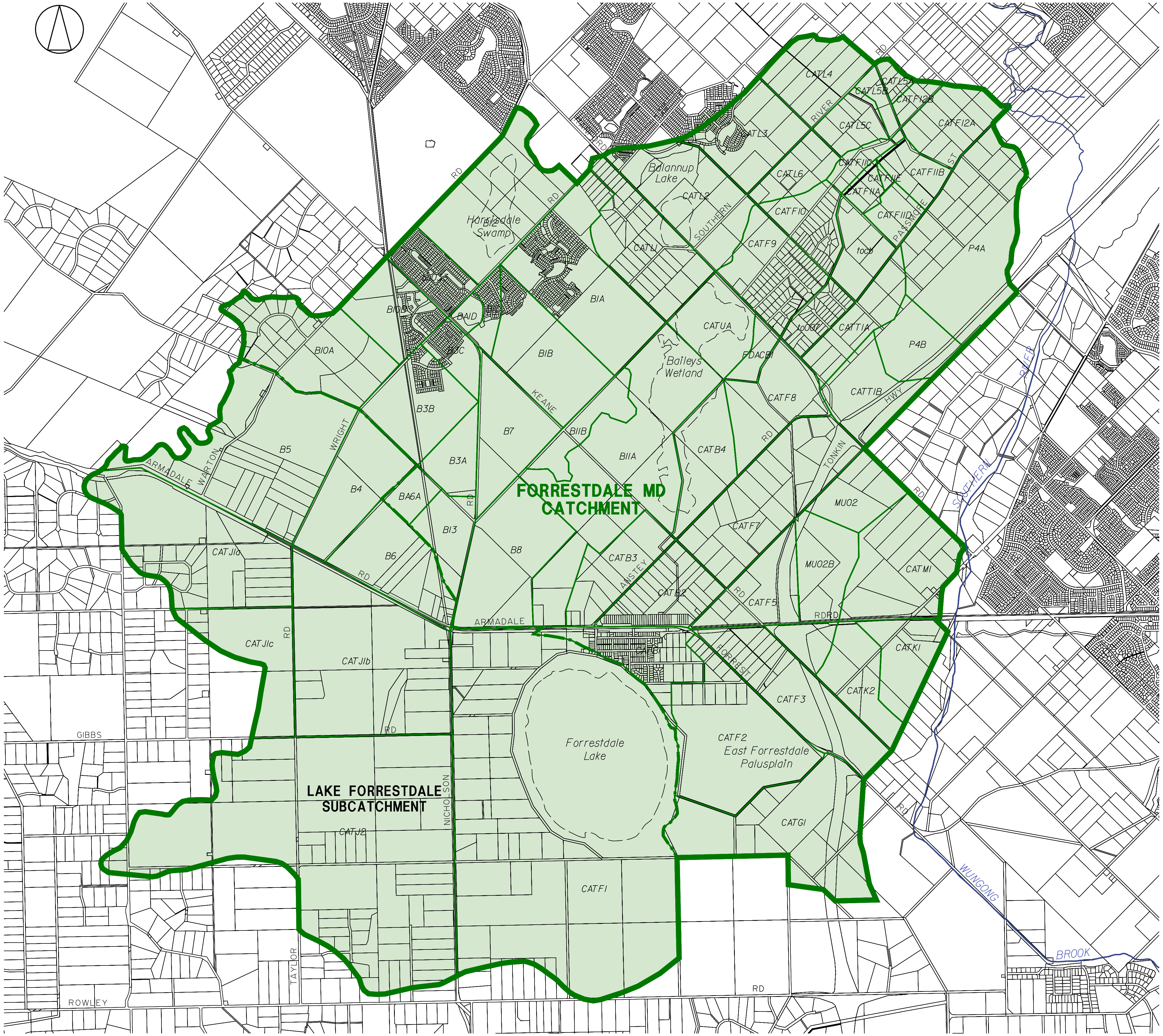
The existing land use between Anstey Road and Ranford Road has been retained at present, as there is some doubt about the rezoning of this land to industrial being investigated. It is believed that the land within Bush Forever site no. 342 between Anstey Road and the Forrestdale main drain will remain rural.

A.11 City of Armadale – upper Forrestdale Lake

100-year flood storage parameters		**Wright Rd west**	**Wright Rd east**
100-year peak discharge	m^3/s	0.3	0.2
100-year peak downstream tailwater	m	26.2	26.2
Contributing area	ha	84.2	36.7
100-year surface area	ha	4.0	1.0

A large part of the Forrestdale Lake catchment is contained within Bush Forever site no. 344 and 345 and most of it lies outside of the *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) area. The only area where there is some development planned is the upper catchment, to the north of Armadale Road at Mason Road. The *Southern River/Forrestdale/Brookdale/Wungong district structure plan urban water management strategy* (JDA 2002) recommended that the section of this catchment to the north of Armadale Road be diverted into the Balannup drain via North Forrestdale. However, it has since been determined that this loss of catchment area has the potential to have a significant negative impact on Lake Forrestdale. Current proposals therefore maintain the existing catchment boundaries with discharge to Lake Forrestdale.

THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.



N

LEGEND

- Scheme Boundary
- Lake Catchment Boundary
- InfoWorks SubCatchment
- CATF2 InfoWorks SubCatchment Number

0 500 1000 1500 2000
SCALE OF METRES

DESIGN FILE: Fig_A1_ModelledSubcatchments_pre.dgn

AUTHOR: SLee

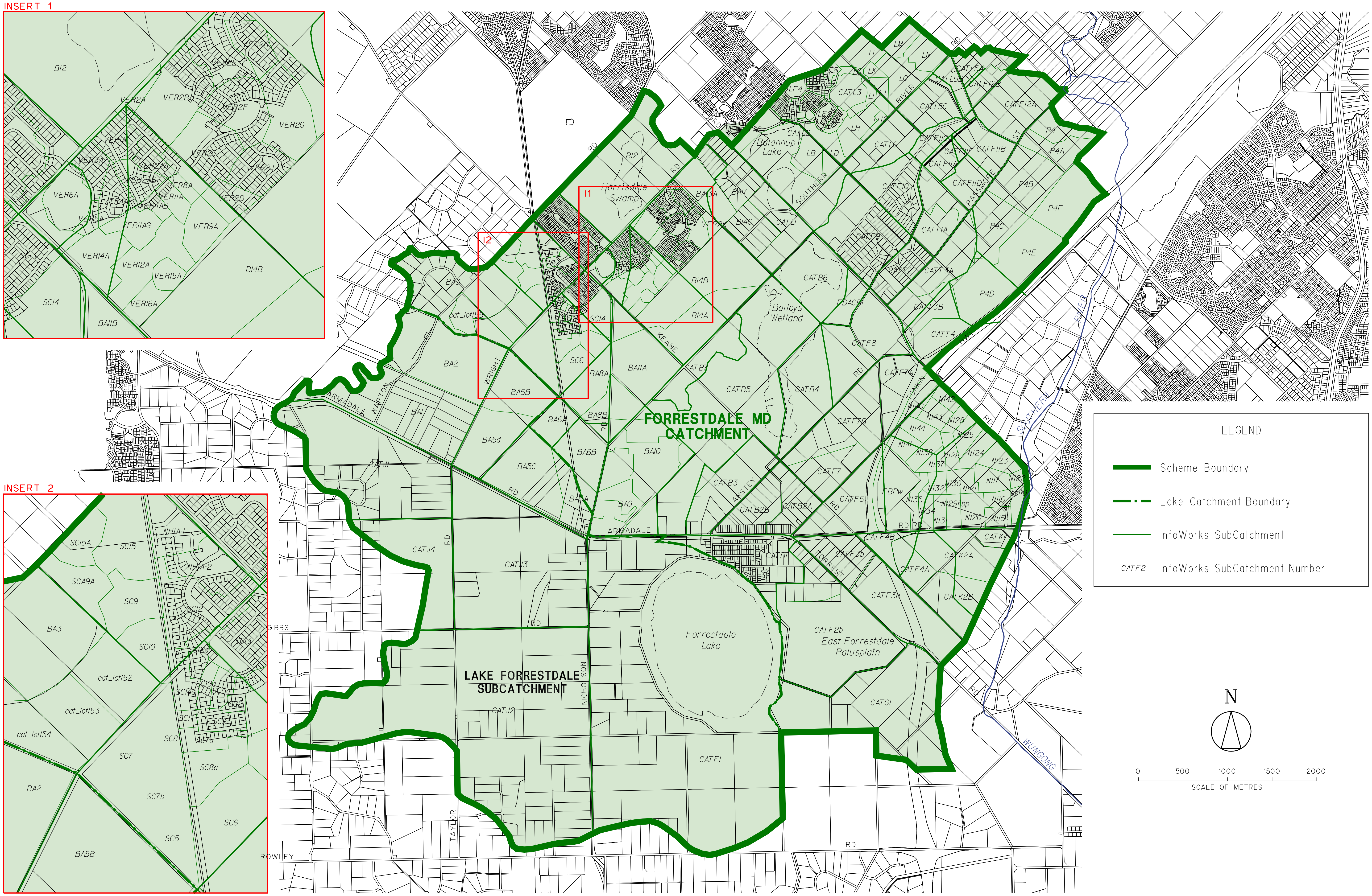
WATER CORPORATION

MODELLED SUBCATCHMENTS PRE-DEVELOPMENT

Figure A1

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.



WATER CORPORATION

MODELLED SUBCATCHMENTS POST-DEVELOPMENT

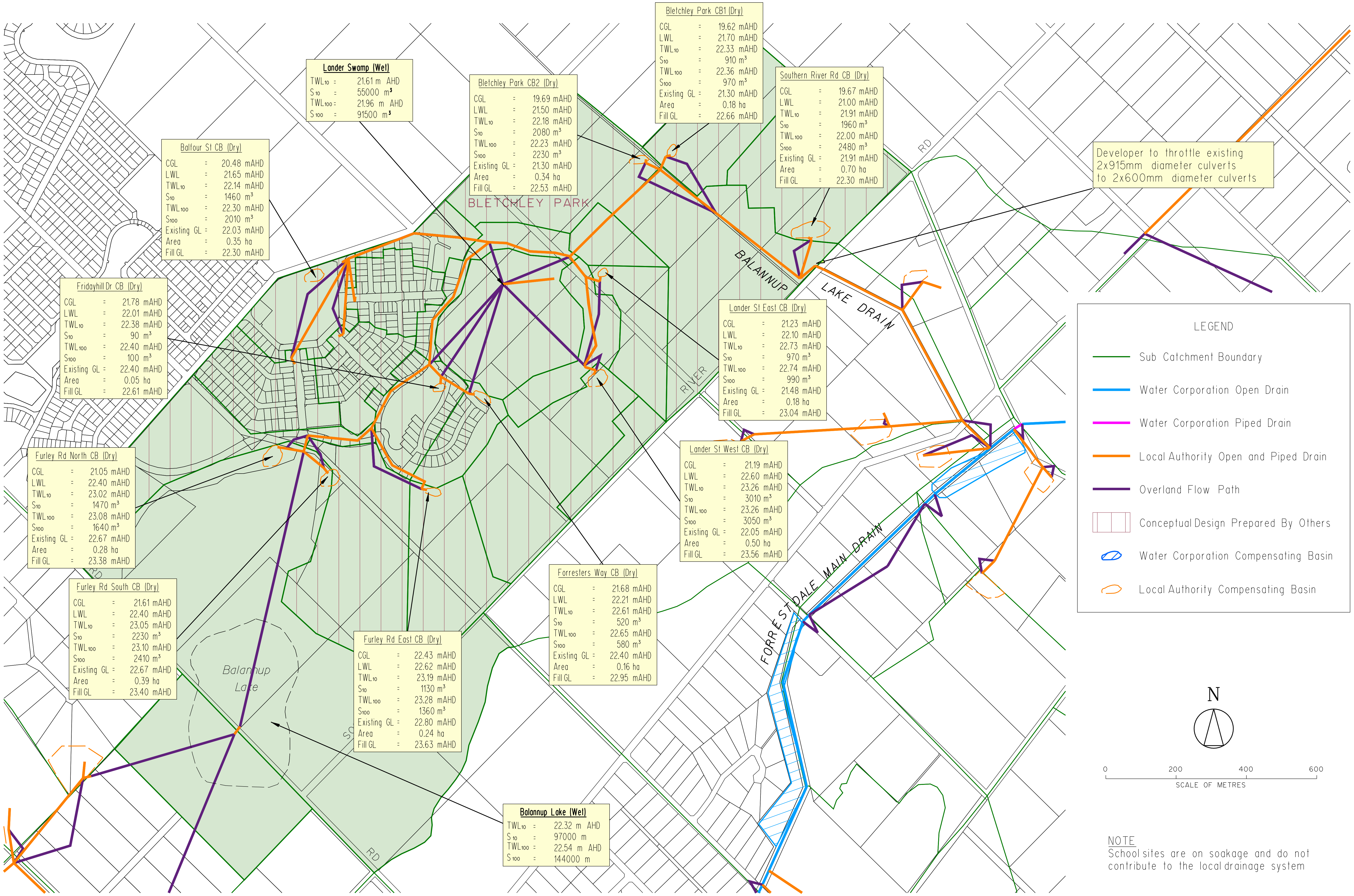
Figure A2

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

AUTHOR: SLee

DESIGN FILE: Fig_A2_ModelledSubcatchments_post.dgn

THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.



AUTHOR: P Haywood DESIGN FILE: Fig_A3a_ArterialDrainagePrecinct2.dgn

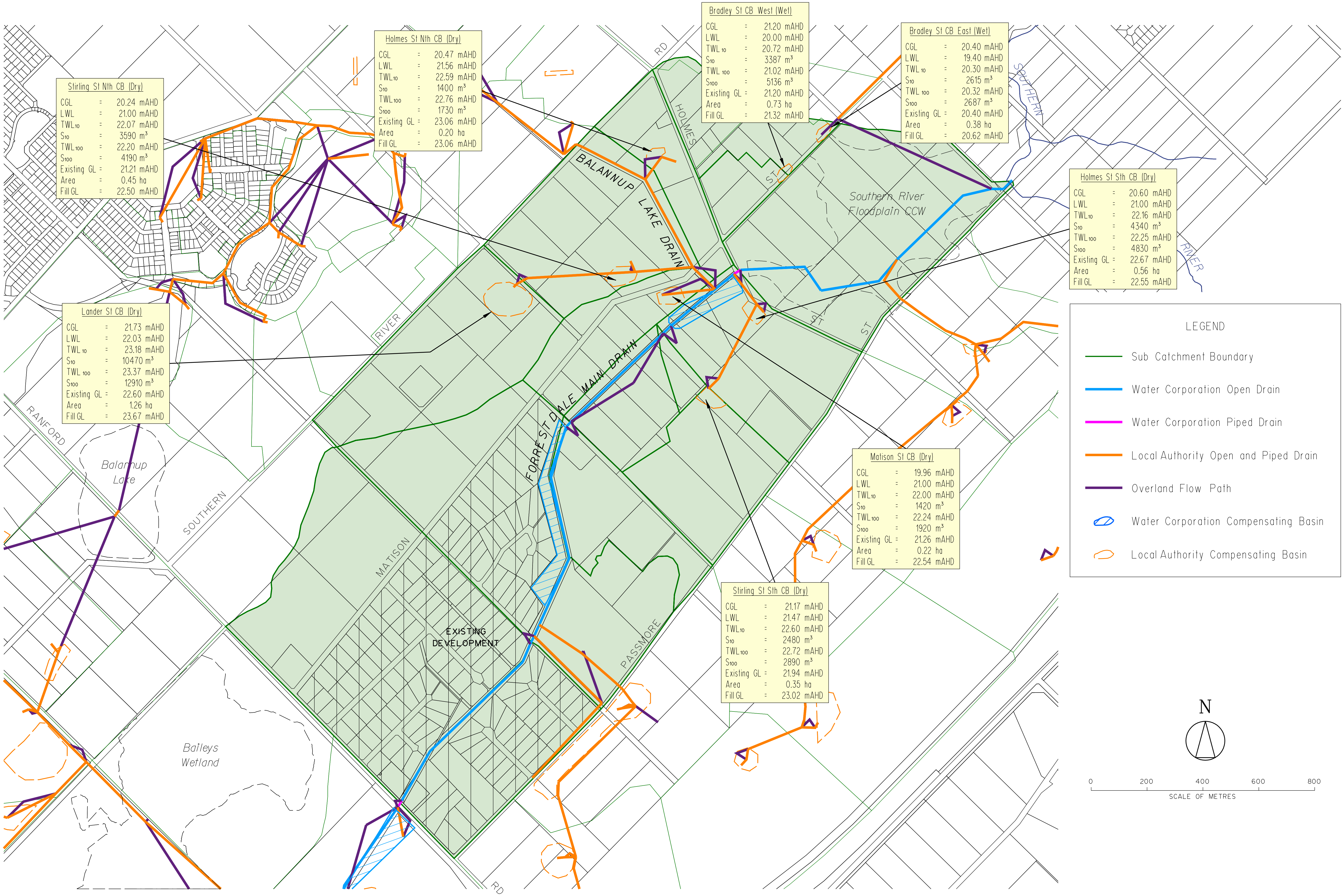
WATER CORPORATION

LOCAL ARTERIAL DRAINAGE CONCEPTUAL DESIGN (PRECINCT 2)

Figure A3a

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.



DESIGN FILE: Fig_A3b_ArterialDrainagePrecinct3.dgn

AUTHOR: SLee

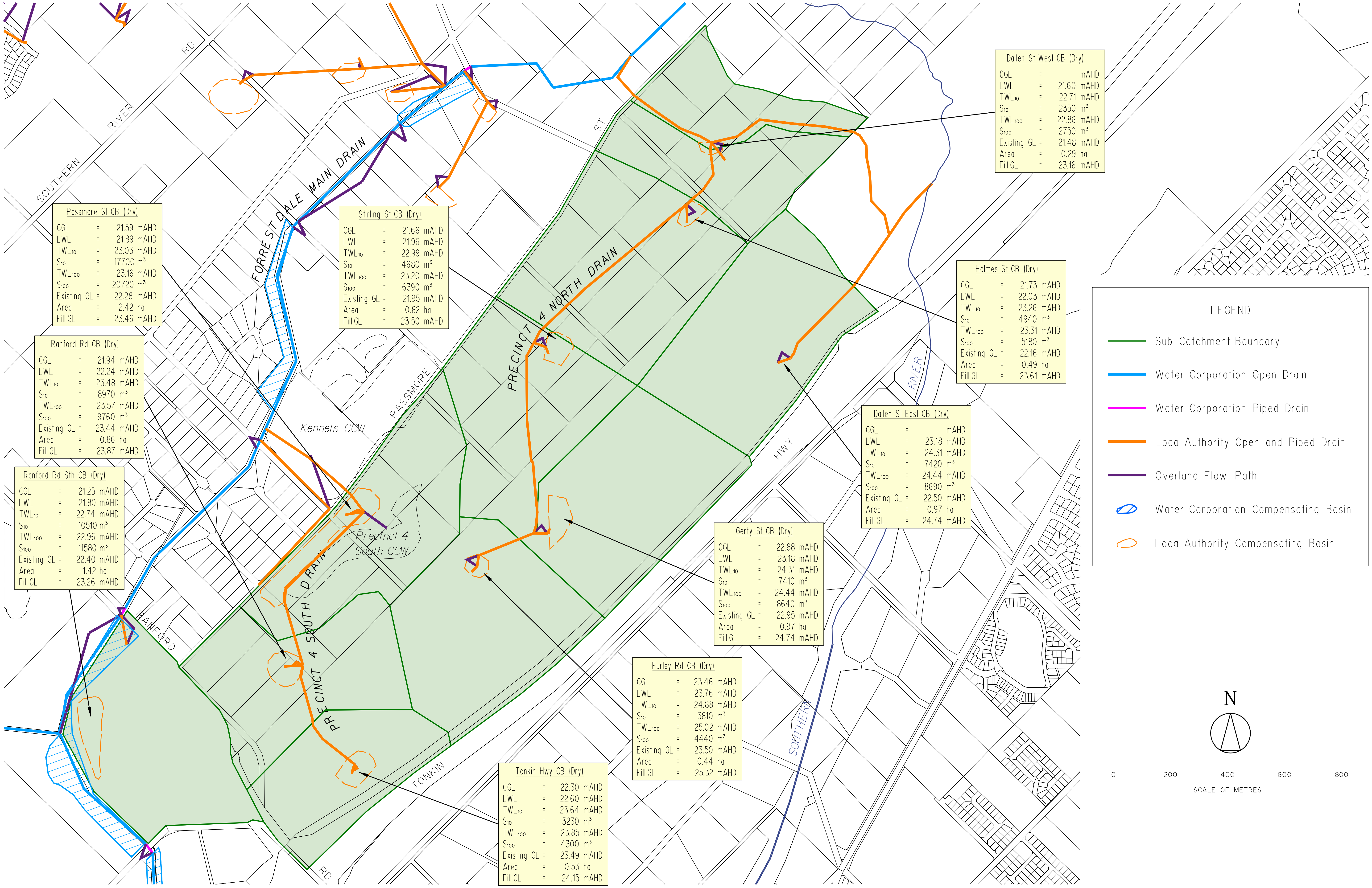
WATER CORPORATION

LOCAL ARTERIAL DRAINAGE CONCEPTUAL DESIGN (PRECINCT 3)

Figure A3b

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.



DESIGN FILE: Fig_A3c_ArterialDrainagePrecinct4.dgn

AUTHOR: SLee

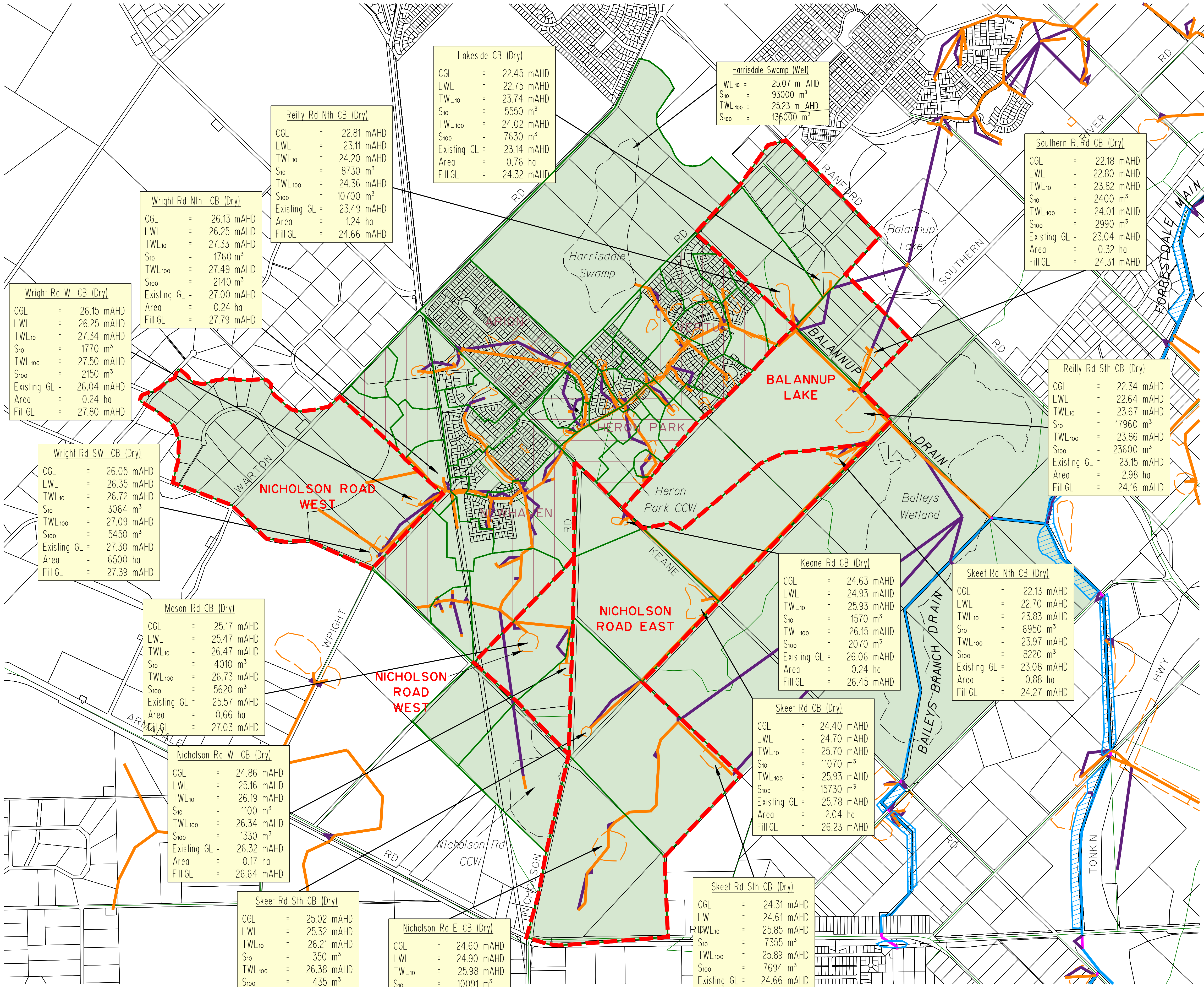
WATER CORPORATION

LOCAL ARTERIAL DRAINAGE CONCEPTUAL DESIGN (PRECINCT 4)

Figure A3c

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.



AUTHOR: P Haywood DESIGN FILE: Fig_A3d_ArterialDrainageNthForrestdale.dgn

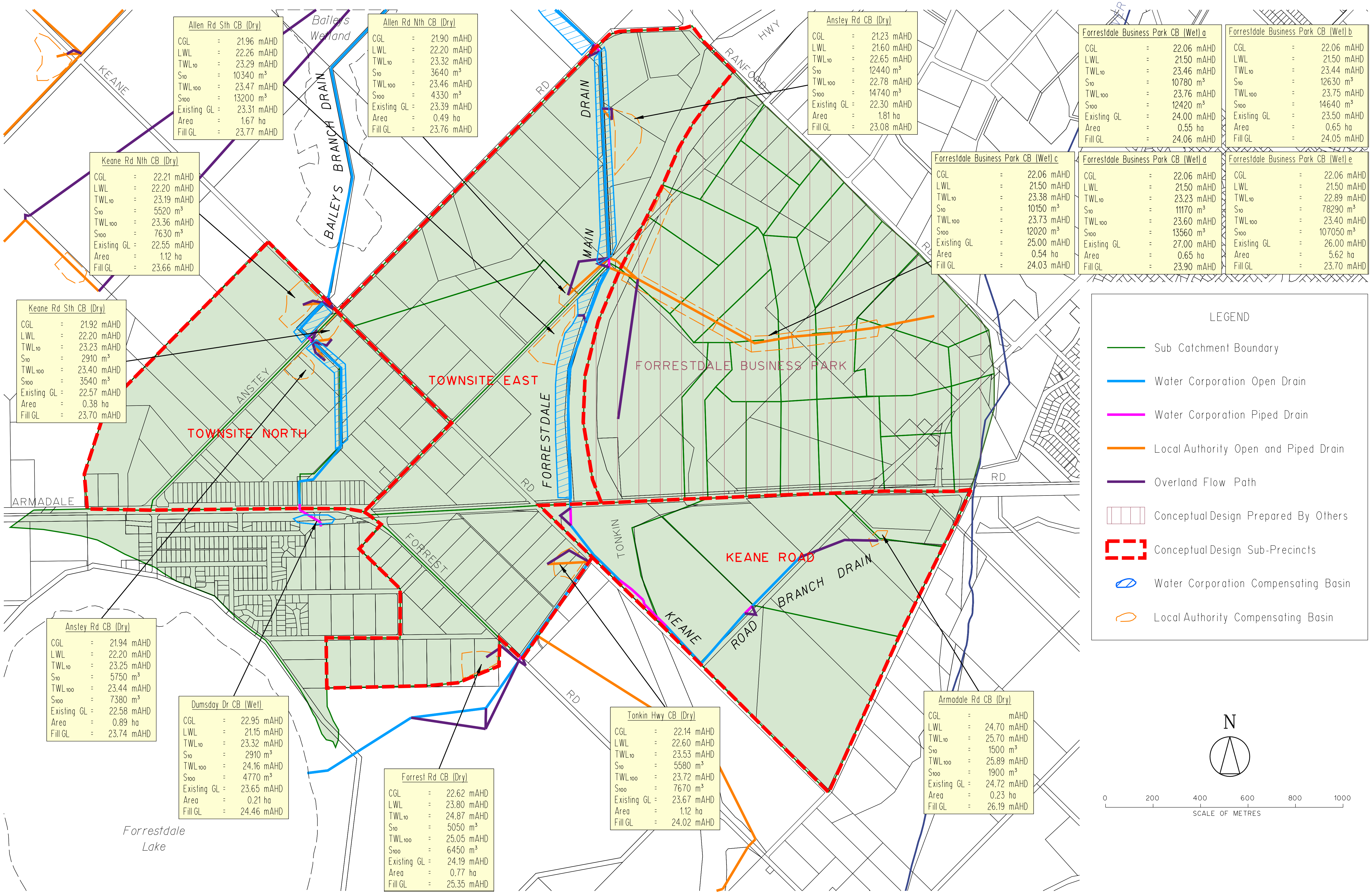
WATER CORPORATION

LOCAL ARTERIAL DRAINAGE CONCEPTUAL DESIGN (NORTH FORRESTDALE)

Figure A3d

PROJECT Nº: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.



DESIGN FILE: Fig_A3e_ArterialDrainageKeaneForrestdale.dgn

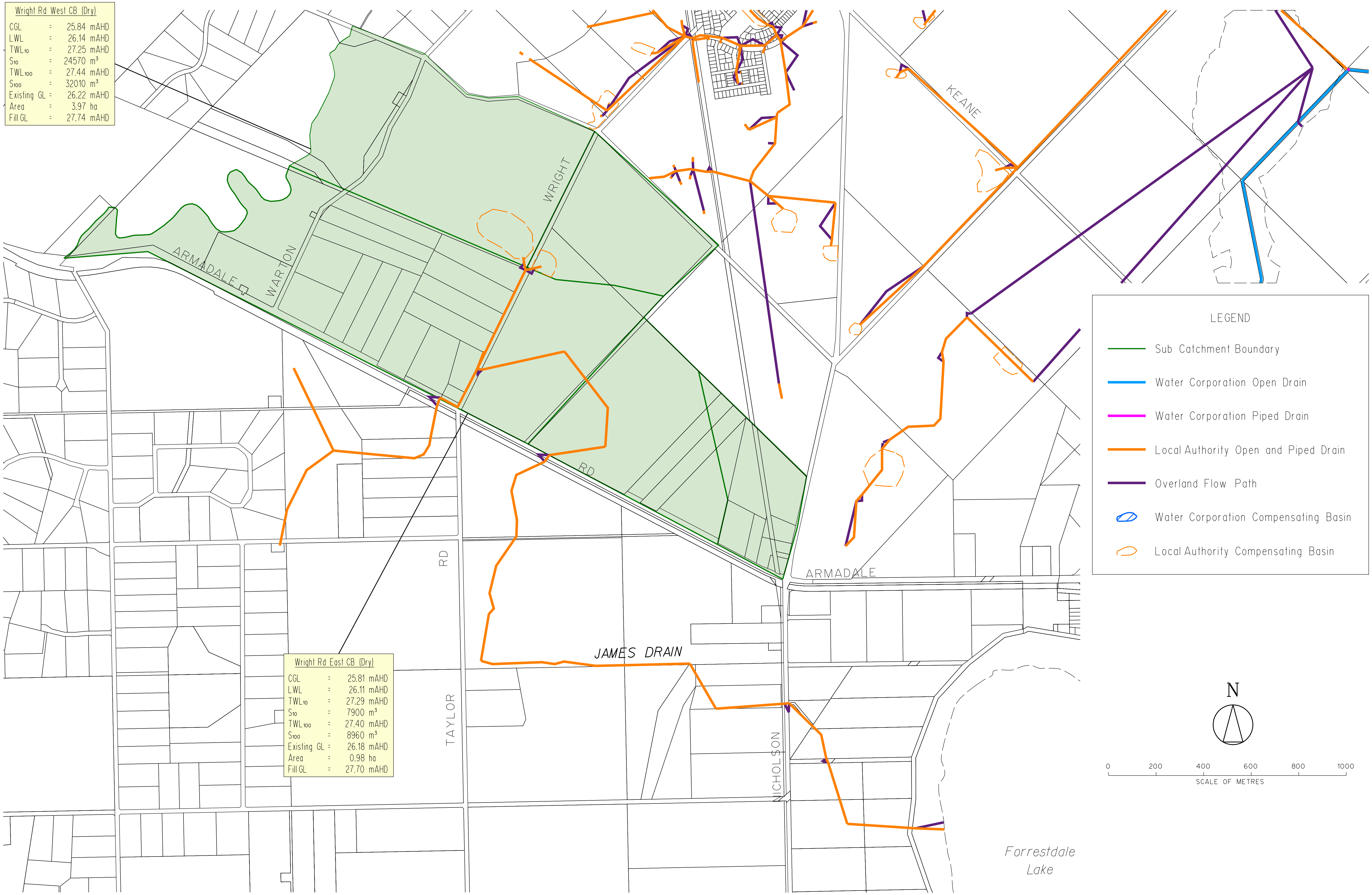
AUTHOR: SLee

WATER CORPORATION

LOCAL ARTERIAL DRAINAGE CONCEPTUAL DESIGN
KEANE RD BD, FORRESTDALE TOWNSITE & BUSINESS PARK

Figure A3e

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50



DESIGN FILE: Fig_A3f_ArterialDrainageForrestdaleLake.dgn

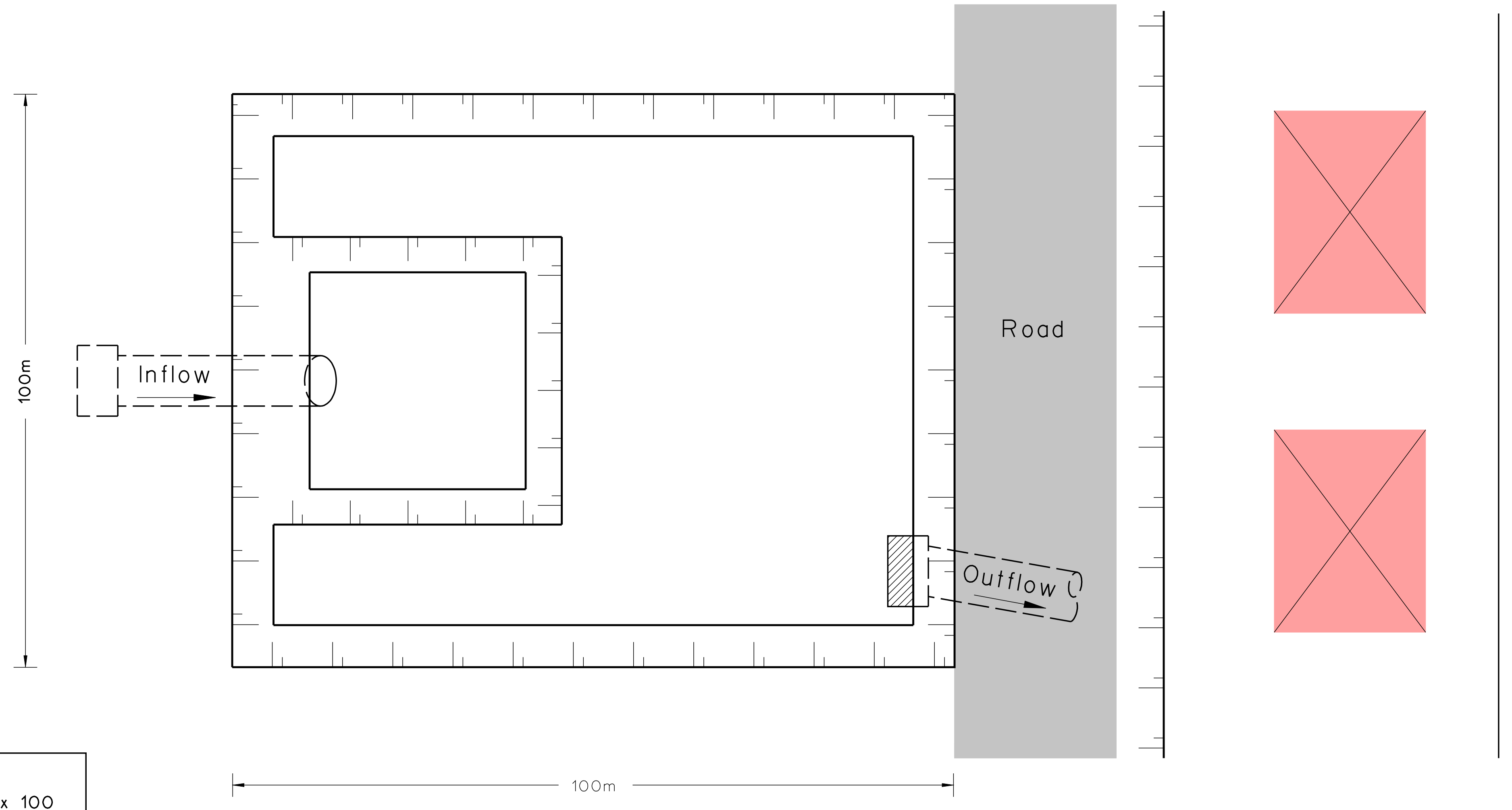
AUTHOR: SLee

WATER CORPORATION

LOCAL ARTERIAL DRAINAGE CONCEPTUAL DESIGN (UPPER FORRESTDALE LAKE)

Figure A3f

PROJECT N°: DP215 DATE: 26/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50



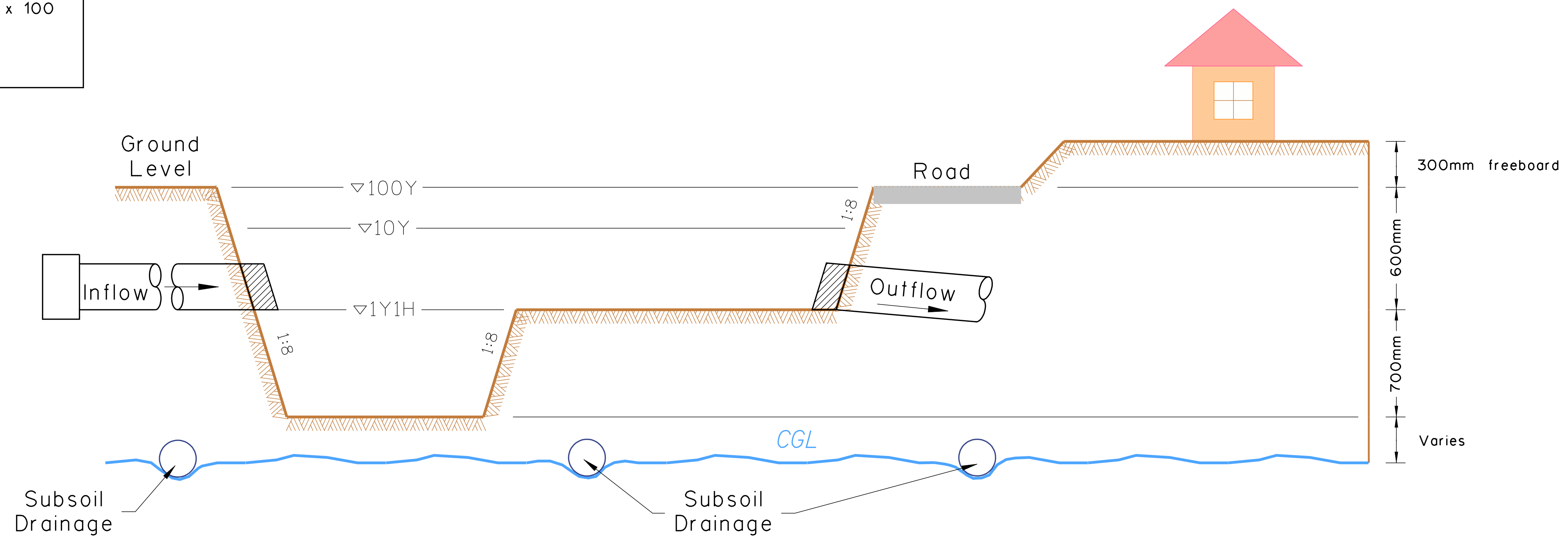
Land Requirement:

$$\frac{\text{CB Area}}{\text{POS Area}} = \frac{100 \times 100}{50{,}000} \times 100$$

$$= 20\%$$

$$\frac{\text{CB Area}}{\text{S/C Area}} = \frac{100 \times 100}{500{,}000} \times 100$$

$$= 2\%$$



DESIGN FILE: Fig_A4_ConceptualDryDetentionBasins.dgn

AUTHOR: vlchong

WATER CORPORATION

CONCEPTUAL DESIGN OF LOCAL DRY DETENTION BASINS

Figure A.4

PROJECT N°: DP215 DATE: 21/08/2009 COORDINATE SYSTEM: MGA94 - Zone 50

List of shortened forms

AHD	Australian height datum
ARI	Average recurrence interval
ASS	Acid Sulfate Soil
BMP	Best management practice
HGL	Hydraulic grade line
MGL	Maximum groundwater level
PASS	Potential acid sulfate soils
POS	Public open space
TWL	Top water level

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