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

Swan urban growth corridor drainage and water management plan

Including Albion, Caversham, West Swan and Whiteman Park south

Looking after all our water needs

Department of Water

Drainage and water management plan no. 2

June 2009

Department of Water
168 St Georges Terrace
Perth Western Australia 6000
Telephone +61 8 6364 7600
Facsimile +61 8 6364 7601
www.water.wa.gov.au

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Revised edition

This is a revised June 2009 edition from the previous January 2009 edition

Please note the data in Tables 6.1, 6.2 and 6.3 and the flood levels within long sections have been updated and modified

Acknowledgements

This report was prepared by Helen Brookes and associates at GHD for Department of Water.

For more information about this report, contact Urban Drainage Planning, Drainage and Waterways Branch, Department of Water.

Contents

Appendices

Figures

Tables

Summary

This drainage and water management plan forms a key part of the Department of Water's urban drainage initiative. The focus of this initiative is the preparation of drainage and water management plans to help address water issues in proposed development areas.

The plan offers guidance on water management issues to the City of Swan, the Western Australian Planning Commission, land developers and other state agencies in order to facilitate development within the Swan urban growth corridor.

The plan also assists in integrating land and water planning as required by *Statement of planning policy 2.9 Water resources* (Western Australian Planning Commission 2004) and outlined in *Better urban water management* (Western Australian Planning Commission 2008a).

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

A checklist for developers is also provided to aid in the preparation of local water management plans.

Regional scale controlled groundwater levels are established and advice for developers and stakeholders for the management of groundwater quantity and quality within the Swan urban growth corridor is given.

Section 9 the implementation section of the plan, presents monitoring requirements for local water management strategies and an implementation action plan.

1 Introduction

This drainage and water management plan supports the development of the *Sub-regional structure plan for the Swan urban growth corridor* (Department for Planning and Infrastructure in press). The sub-regional plan provides a guide to subdivision and development/redevelopment of the Swan urban growth corridor while addressing the social and environmental constraints within the area and reflecting the area's expedient location within the north-eastern metropolitan growth sector of Perth. The Albion, Caversham, West Swan east and West Swan west cells make up the Swan urban growth corridor. Whiteman Park south is also included for the purposes of this plan.

A number of key investigations have been undertaken in the Swan urban growth corridor both at a regional scale, and a local scale during the preparation of draft Local water management strategies for Albion, West Swan east and Caversham. It is the aim of this drainage and water management plan to incorporate information from the draft local water management strategies associated investigations and present design criteria and management strategies. The drainage and water management plan will then enable the Department of Water to facilitate the future planning for development by providing a framework of site specific water management criteria for development within the Swan urban growth corridor, supporting the implementation of development plans in the area. Proposed local water management strategies will be reviewed for their consistency with the strategies, objectives and key design criteria presented in this plan.

Total water cycle management, also referred to as integrated water cycle management, "recognises that water supply, stormwater and sewage services are interrelated components of catchment systems, and therefore must be dealt with using a holistic water management approach that reflects the principles of ecological sustainability" (Department of Environment 2004 Ch. 2, p. 14).

The scope of the drainage and water management plan is to cover all aspects of total water cycle management, including:

- protection of significant environmental assets within the structure plan area, including meeting their 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 both peak event (flood) management and water sensitive urban design principles to be applied to frequent events
- groundwater, including the impact of urbanisation, variation in climate, installation of drainage to manage maximum annual 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 sulphate soil management, control of contaminated discharges from industrial areas and management of nutrient exports from surface runoff and groundwater through structural measures

The position of the drainage and water management plan within the state government planning framework is defined in *Better urban water management* (Western Australian Planning Commission 2008a) and *Planning bulletin 92 Urban water management* (Western Australian Planning Commission 2008c) and is outlined in Figure 1-1, below. This drainage and water management plan is part of the department's water planning framework, with State and regional water plans setting the strategic context and more detailed water management plans such as allocation plans, water source protection plans and drainage and water management plans providing more specific direction.

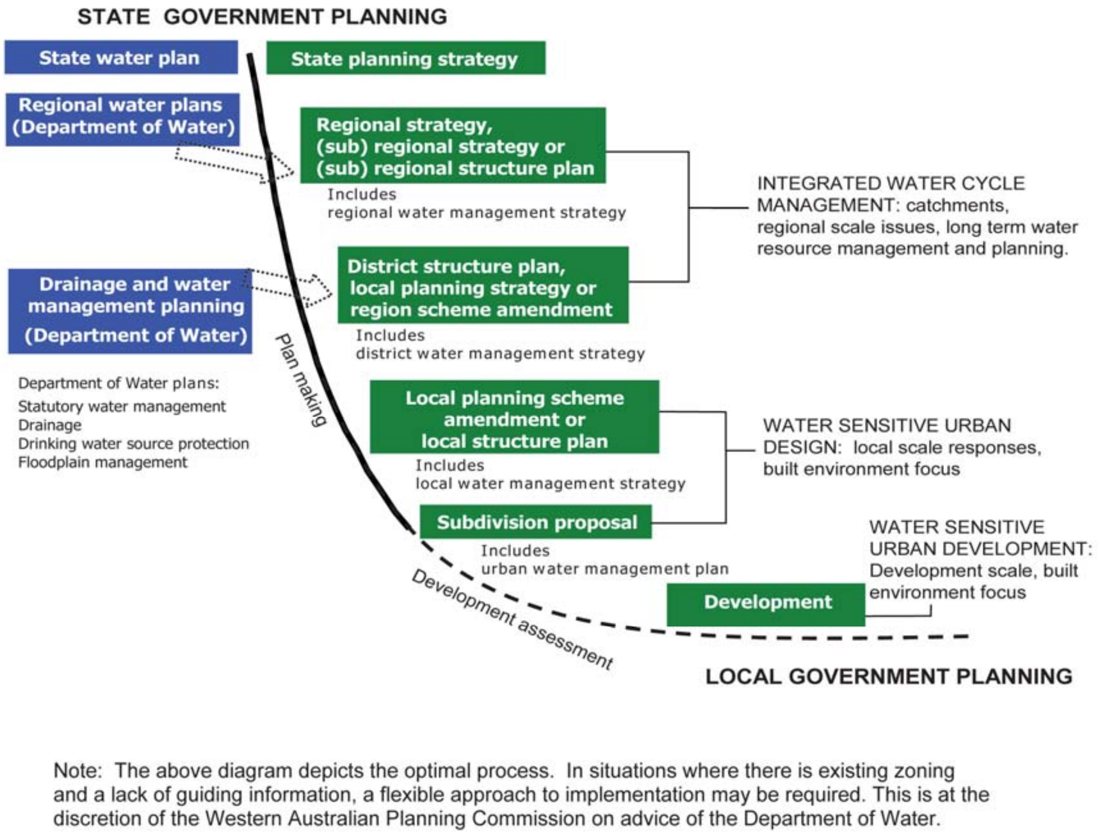


Figure 1-1 Planning framework integrating drainage planning with the land planning process.

While the proposed structure identified in Figure 1-1 is supported by the City of Swan, *Local planning scheme no. 17* was written and adopted by the City of Swan in absence of a district water management strategy. Consequently *Local planning scheme no. 17* requires water management documents to be prepared at different stages throughout the planning and development framework, depending on the zoning of each urban cell. Specifically, water planning in Albion and West Swan east is brought forward within the planning framework to ensure adequate consideration is given to water management in these more constrained areas.

For land zoned “special use” under *Local planning scheme no. 17* (currently Albion and West Swan east), a local water management strategy is required to accompany the district structure plan for each area. This local water management strategy will be supplemented with an urban water management plan to accompany local structure plans within those precincts.

Where land is zoned for residential development under *Local planning scheme no. 17* (currently Caversham), there is only one tier of strategic planning and water management planning will thus be consistent with Figure 1-1. Specifically, a local water management strategy will be required to accompany a local structure plan for the precinct and urban water management plans will be required to accompany application for subdivision.

1.1 Planning background

In addition to *Better urban water management* (Western Australian Planning Commission 2008a) and *Planning bulletin 92 Urban water management* (Western Australian Planning Commission 2008c) the drainage and water management plan uses the following documents to define its key principles and objectives:

- *North east corridor urban water management strategy* (GHD for Department of Water 2007)
- *Gnangara land use and water management strategy* (Western Australian Planning Commission 2001)
- *Liveable Neighbourhoods Edition 4* (Western Australian Planning Commission 2008b)
- *Statement of planning policy 2.7 Public drinking water source* (Western Australian Planning Commission 2003b)
- *Statement of planning policy 2.9 Water resources* (Western Australian Planning Commission 2004)
- *Urban growth policy no. POL-C-102* (City of Swan 2006a)
- *Environmental planning policy no. POL-C-104* (City of Swan 2006b)
- *Local planning scheme no. 17* (City of Swan 2008).

1.2 Previous studies

A number of key investigations have been undertaken in the Swan Urban Growth Corridor. It is the aim of this drainage and water management plan to incorporate information from all of these studies and present design criteria and management strategies that will enable the City of Swan and Department of Water to inform the review of future water management documents for developments within the study area.

Draft *Local water management strategies* have been produced for Albion (JDA Consultant Hydrologists 2006), West Swan east (JDA Consultant Hydrologists 2007) and Caversham (Cardno BSD 2007). These draft strategies have not been endorsed by any of the relevant regulatory authorities. The preparation of these strategies included performing drainage hydraulic modelling using XPStorm for Albion and West Swan East, and preliminary post-development peak flow analysis for Caversham. Post-development nutrient input modelling has also been conducted for Albion and West Swan East, with the results presented in the respective draft *Local water management strategies*.

Preparations of draft *Local water management strategies* in Albion, West Swan east and Caversham have also included conducting local scale groundwater investigations in these areas. Monitoring bores have been installed, with the resulting water levels used to determine current climate (1974–2007) maximum groundwater levels for the three areas.

The entire study area has been assessed at a regional scale for acid sulphate soil risk. The results are presented in the Western Australian Planning Commission *Planning bulletin no. 64 acid sulphate soils* (2003). More local scale acid sulphate soil risk investigations have been undertaken in Albion (Douglas Partners 2006), Caversham (Douglas Partners 2005), and West Swan east (RPS BBG).

Investigations into environmental water requirements of groundwater dependent ecosystems have commenced.

2 Pre-development environment

Documents referred to for background information include

- *North East corridor urban water management strategy* (GHD 2007)
- *Swan urban growth corridor sub regional plan* (Department for Planning and Infrastructure in press)
- *Planning bulletin no. 64 Acid sulphate soils* (Western Australian Planning Commission 2003a)
- *Swan Coastal Plain geomorphic wetland mapping*
- *draft Albion local water management strategy* (JDA Consultant Hydrologists 2006)
- *draft Caversham district structure plan – Local water management strategy* (Cardno BSD 2007)
- *draft West Swan east local water management strategy* (JDA Consultant Hydrologists 2007)
- *Aboriginal Heritage Act 1972* (Department of Indigenous Affairs)
- *Register of Aboriginal sites* (Department of Indigenous Affairs).

2.1 Study area

The study area of this *Drainage and water management plan* is the area referred to by the Department for Planning and Infrastructure and the City of Swan as the Swan urban growth corridor (Figure 10-1). The study area includes the cells of Albion, West Swan west, West Swan east and Caversham as covered by the *Swan urban growth corridor sub regional plan* (Department for Planning and Infrastructure in press) as well as the area known as Whiteman Park south which includes some existing developed areas to the south of Marshall Road and a large area of Whiteman Park to the north of Marshall Road.

The 1960 ha study area is located approximately 15 km northeast of the Perth CBD, within the City of Swan. Whiteman Park lies within and to the northwest of the study area, the Swan River is located to the east and south, and Bennet Brook runs north to south through the western extent of the study area.

The existing catchment land use is predominantly rural or rural residential, with the majority of rural land consisting of open grassland. The southern extent of Whiteman Park and the forested Caversham Airbase site also lie within the study area. A more detailed discussion of these sites is in Section 2.5.

The site location plan is presented in Figure 10-1.

2.2 Topography

According to Landgate one metre contour digital topographic data, the general topographic trend is a decrease in elevation from the north to the south of the study area. At the northern extent of the study area at Park Street the elevation is approximately 34m AHD whilst at the southern extent of the study area at Benara Road the elevation is approximately 12m AHD. Whiteman Park south, west of Bennett Brook, has a general trend of decreasing elevation from west to east, ranging from roughly 34 m AHD to 12 m AHD. There are some localised elevated areas across the study area, most noticeably those running across the Albion cell from the south-west to the north-east, and through the north of the West Swan cells from the west to the east. Localised regions of depression are generally restricted to the existing open drainage channels located through the study site. Figure 10-2 includes the topography of the study area.

2.3 Soils and geology

The Perth 1:50 000 *Environmental Geology map* (Gozzard 1986) indicates that the study area is made up of a variable thickness of Bassendean sand of aeolian origin overlying Guildford formation of alluvial origin (Figure 10-2).

The geological map legend indicates that the Bassendean sand consists of a white to pale grey sand at surface, grading yellow with depth, fine to medium grained, sub-rounded quartz. This is the dominant surface soil type in the mid to northern extent of the study area, and the area west of Bennett Brook.

The underlying Guildford formation consists of yellow brown to strong brown, fine to coarse grained, pebbly silt and clayey silt with variable clay and sand content. Pebbly silt is particularly dominant in the southern extent of the study area.

Pockets of peaty clay, with variable sand content, and of lacustrine origin, are associated with wetlands and lower lying areas within the study area.

A strategic acid sulphate soil (ASS) investigation within the Albion cell (Douglas Partners 2006) confirmed that for the majority of the area (102 of 114 boreholes) the Bassendean Sand layer is 2.0 to 2.4 m deep.

A more detailed geotechnical investigation has also been undertaken within the Caversham cell (Douglas Partners 2005), as reported in the draft *Caversham local water management strategy* (Cardno BSD 2007) This investigation indicated that the overlying sand layer in the majority of the Caversham cell is less than 0.8 m, and often is not present at all in areas adjacent to existing surface drainage features.

2.4 Acid sulphate soils

Areas with acid generation risk are mapped in Figure 10-3.

The Western Australian Planning Commission *Planning bulletin no. 64 acid sulphate soils* (2003), which is based upon a review of existing geomorphological, geological and hydrological information, indicates that the soils in the north and west of the study are largely at moderate to low risk of actual acid sulphate soils or potential acid sulphate soils occurring within 3 m of natural soil surface. Soils in the southeast of the study area are generally at no known risk of actual acid sulphate soils or potential acid sulphate soils occurring within 3 m of natural soil surface (or deeper).

There are also regions of high risk of actual acid sulphate soils and potential acid sulphate soils occurring within 3m of the natural soil surface within the study area as shown in Figure 10-3. These high risk regions generally correspond with existing drainage routes and wetlands.

More detailed, site specific actual acid sulphate soils investigations have been conducted within the Albion and Caversham cells.

Douglas Partners (2006) concluded that acid sulphate soils conditions within Albion would not prevent its development, nor place unreasonable requirements on the development. They do however state that it would be appropriate to undertake detailed planning for management of acid sulphate soil issues at the development stage when the locations and extent of ground and groundwater disturbing activities are known.

Results of the testing of soil samples from Caversham showed that there was no strong indication of actual acid sulphate soils or potential acid sulphate soils at up to 3 m depth at any of the test pit locations. Douglas Partners (2005) therefore concluded that the risk of actual acid sulphate soils or potential acid sulphate soils at depths of up to 3 m below the existing ground surface is considered to be low for the three geological units in the area, and there are therefore no implications for the progression of the draft *Local water management strategy*. They do recognise however that more detailed investigations may be required prior to subdivision approval.

2.5 Environmental assets and water dependent ecosystems

Australian White Ibis

Image from: John Gould (1804-81) *The birds of Australia 1840-48*. 7 vols. 600 plates Artists: J. Gould and E. Gould; Lithographer: E. Gould.

Environmental Assets and Water Dependent Ecosystems are presented in Figure 10-4.

The Department of Environment and Conservation Swan coastal geomorphic wetland mapping indicates there are wetlands classified as resource enhancement throughout the study area. There are also a number of conservation category wetlands within and adjacent to the study area. These wetlands are under the protection of the *Revised draft environmental* *protection (Swan Coastal Plain wetlands) policy* (Environmental Protection Authority 2004) with high conservation and environmental values.

Horse Swamp is located at the northern border of the West Swan west cell (Figure 10-4). It is located within Whiteman Park, is 18.7 hectares and is used as an annual breeding ground by endemic water bird species such as the Australian White Ibis (*Threskiornis molucca*) and the Black Swan (*Cygnus atratus*).

Bennet Brook is an outflow of the superficial aquifer and originates in Whiteman Park, running through Mussel Pool and south to join the Swan River at Guildford. It provides habitat for numerous flora and fauna including the freshwater crayfish Gilgie (*Cherax quinquecarinatus*) and the flooded gum (*Eucalyptus rudis*). On average Bennett Brook flows from early August until early November, depending on the magnitude and timing of precipitation.

There are two Conservation Category wetlands, Orchid Park and Victoria Road Swamp, within the developed areas in the south of Whiteman Park South. A tributary of Bennett Brook and two associated upstream wetlands are also located within Whiteman Park South.

A portion of Bush Forever Site 200, Caversham Airbase bushland, is also located within the Albion cell of the study area. This 97 ha bushland contains significant flora *Kunzea aff. recurva* and *Burchardia bairdiae*. It is unknown whether this site provides habitat for any significant fauna.

The majority of Whiteman Park south (Figure 10-1) currently lies within Whiteman Park. Although this area was initially included within the Whiteman Park bush forever site 304, as shown in Figure 10-4, the areas of Whiteman Park south now classified as bush forever are limited to the Bennett Brook region, bush forever sites 304 and 305. Bush forever site 480, associated with Victoria Road Swamp, also abuts the southwest extent of Whiteman Park south.

There are two declared rare and priority flora species within the study area, specifically *Drosera occidentalis* subsp. *Occidentalis* and *Epiblema grandiflorum* var. *Cyaneum*, both located within Whiteman Park south. *Drosera occidentalis* subsp. *occidentalis* is found within Orchid Park, whilst *Epiblema grandiflorum* var. *cyaneum* is found in the road reserve near the Beechboro Road North and Marshall Road intersection.

The potential impacts of development on existing known surface and groundwater dependent ecosystems within the study area have been considered in the preparation of the water management strategies and objectives presented in this drainage and water management plan. Further studies to identify and manage any localised impacts on these and any ecosystems as yet unidentified must be carried out during the development of Local water management strategies.

2.6 Social considerations

The *Aboriginal Heritage Act* was introduced in Western Australia in 1972. The Act recognises Aboriginal peoples' strong relationships with the land, which goes 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 known 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, must 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 Department of Indigenous Affairs register of Aboriginal sites identifies extensive areas of indigenous significance in the Swan urban growth corridor associated with the floodplains of the Swan River and its tributaries. There are also some additional sites outside of the floodplain that relate to indigenous artefacts, ceremonial, mythological or other significance.

The locations of these sites (as current from Department of Indigenous Affairs December 2007) are identified in Figure 10-4.

Any government agency, organisation or individual who is the proponent for strategic or statutory planning documents or construction of individual developments or engaged in any ground disturbing activities should seek advice from the Department of Indigenous Affairs regarding requirements and obligations under the *Aboriginal Heritage Act 1972*, and any other investigations that may be required. This may include, but not be limited to consultation with relevant Aboriginal people about the proposal in general, consultation about areas that may be subject to physical alteration, the undertaking by a qualified consultant of an Aboriginal Heritage survey or investigation or predictive modelling for any specific location to identify unregistered sites, and/or the development of a full inventory of heritage values.

In the proximity of some indigenous sites, this *drainage and water management plan* is consistent with the concept presented in developer proposals to date in suggesting minor alterations to existing areas of shallow, ill-defined overland flow paths to direct flow into a more refined channel, requiring earthworks. In subsequent land and water planning this concept will need to be considered by proponents in designing or refining their own proposals for flow through the area, and, if it is to be proposed, proponents must ensure that they undertake the appropriate actions in regard to sites of Aboriginal significance in accordance with sections 17 and 18 of the Act.

Water and waterways (including rivers, pools, wells, soaks and estuaries) hold an important place in the spiritual and mythological realm for Aboriginal people. Water is also significant to Aboriginal people as a crucial survival factor for people living traditional lifestyles. Proponents should ideally consider opportunities to address and include heritage management principles in their proposals that go beyond the scope of the Act.

2.7 Groundwater

There are four distinct aquifers underlying the study area, each being assigned the name of the major geological unit contributing to it. From natural surface level in descending order they are:

- Superficial aquifer (unconfined)
- Mirrabooka aquifer (semi-confined)
- Leederville aquifer (confined)
- Yarragadee aquifer (confined).

Groundwater modelling to assess effects of climate change and planned development (GHD 2008) presents a calibrated model of the Superficial and Mirrabooka aquifers and considers the potential impacts of development within the Swan urban growth corridor. The deep Leederville and Yarragadee aquifers have not been modelled for this study.

This groundwater modelling study includes consideration of the impact of extensive use of subsurface drainage in the area and in particular provides an assessment of changes in maximum and minimum groundwater levels in the study area. Specific modelling scenarios, their results and implications for development are described in more detail in 7 Groundwater management strategy.

Protection of public drinking water supply

The north-east portion of the Albion cell is located within the Gnangara underground water pollution control area. The relevant area of Albion is classified as a Priority 3 (P3) area.

In addition to constraints on land use permitted within such protected areas, each groundwater production well within the underground water pollution control area has a well head protection zone which is a 300m circular buffer extending around the well head in a P3 area. Special conditions, such as restrictions on storage and use of chemicals apply in these zones. Further information may be sought in *Water quality protection note: land use compatibility in public drinking water supply areas* (Department of Water 2004).

There are three Water Corporation production wells with well head protection zones that affect the Albion cell, specifically bore M182 on Woollcott Ave and bores M282 and M285 on the north side of Park Street (Figure 10-5). Water Corporation production wells M50, M55 and M40 are also located within Whiteman Park south, although these bores are not within the Gnangara underground water pollution control area.

Residential development within the P3 area of Albion is already zoned urban deferred in the *Metropolitan regional scheme* and is restricted only by a requirement for sewerage connection. Development within the well head protection zone buffer is restricted, which has been taken into account in the preparation of the proposed structure plan for the Albion cell. Additional restrictions within the well head protection zones are a requirement for sewerage connection and a ban on storage of chemicals. Further information may be sought in *Water quality protection note: land use compatibility in public drinking water supply areas* (Department of Water 2004).

The *Gnangara land use and water management strategy* (Western Australian Planning Commission 2001) recommends urban land use within Whiteman Park south.

Groundwater resources

The study area extends over two groundwater management areas – the Swan groundwater area and the Mirrabooka groundwater area. Within the Swan groundwater management areas the study area falls in the South Swan sub area for the superficial aquifer, whilst in the Mirrabooka groundwater management areas the sub area is Whiteman Park.

Both the Superficial and Mirrabooka aquifers in the Whiteman Park sub area and the South Swan sub area are extensively allocated. Consideration of new applications for groundwater abstraction will depend on the state of groundwater allocations at the time of application. The department's draft *Gnangara groundwater areas allocation plan* (2008) provides information on groundwater resources in the area. The Department of Water should be contacted for up to date details of groundwater allocations.

Groundwater levels

There are numerous Department of Water monitoring bores located in and around the study area. A number of bores have also been installed in the study area for the purposes of developing local water management strategies.

Current climate (1974–2007) maximum groundwater levels have been determined for Albion, West Swan east and Caversham by using the installed monitoring bores, adjusted to the closest reference bore sites exhibiting long-term data.

Groundwater flow through the catchment is generally eastwards from the Gnangara mound to the Swan River. Current climate maximum groundwater levels range from approximately 40 m AHD in the north-west of the study area to less than 5 m AHD along the eastern boundary adjacent to the Swan River.

Groundwater quality

Groundwater quality data is only available within the Albion, West Swan east and Caversham cells, due to a lack of monitoring bores within West Swan west.

Total nitrogen and total phosphorous data collected in Caversham over the period March 2006 to August 2007 has median values across the bores of 0.465 mg/L to 1.3 mg/L total nitrogen, and 0.04 mg/L to 0.195 mg/L total phosphorous over the period (Cardno BSD 2007).

As presented by JDA CONSULTANT HYDROLOGISTS (2006) the median values of total nitrogen and total phosphorous across the monitoring bores within Albion over September 2001–December 2004 are total nitrogen-1.9 mg/L and total phosphorous-0.06 mg/L .

Total nitrogen levels recorded during the period July 2005 to December 2006 across West Swan east were highly variable, though the median level was 5.1 mg/L. total phosphorous levels were found to be generally below 1 mg/L, with a median value of 0.19 mg/L.

The Swan River Trust *Healthy rivers program* provides targets of 0.1 mg/L total phosphorous and 1.0 mg/L total nitrogen. However, these are end of catchment targets and therefore not directly applicable to these local monitoring results. Continued work is being undertaken to translate these targets into usable mid-catchment targets.

2.8 Infrastructure

Water Corporation and private drainage networks, water and wastewater infrastructure are shown in Figure 10-5.

Other notable features within the Swan urban growth corridor include the presence of the Parmelia and Dampier gas pipelines traversing the Albion cell north to south and the RAAF Caversham Airbase and Caversham Raceway that are to the south of Youle-dean Road in the Albion cell.

2.9 Surface water

The existing drainage network (Figure 10-5) within the study area is a combination of natural drainage lines and excavated drains, extended or deepened to enhance drainage from the area. The main natural drainage channels within and adjacent to the study area are Bennett Brook, St Leonards Creek and Wandoo Creek, all of which drain to the Swan River.

Albion

The general drainage of Albion is south-east towards the Swan River. There are three main subcatchments within this cell, discharging to St Leonards Creek, Wandoo Creek and Horse Swamp respectively. The *Albion local water management strategy* presents the GB Hill & Partners (1995) arterial drainage scheme as the pre-development drainage network, although it is recognised that Lord Street has been constructed on fill since the GB Hill & Partners (1995) report. This has created an artificial catchment boundary between Horse Swamp, Wandoo Creek and St Leonards Creek. Pre-development modelling shows extensive flooding in this area and suggests that culverts under Lord Street will be required to re-establish former flow paths. Proposals for new and revised culverts are discussed in more detail in Section 6.

West Swan east

The existing drainage network within West Swan east is a combination of natural drainage lines and local authority and private excavated drains. The cell consists of three catchments. Wandoo Creek and West Swan catchments discharge east to the Swan River, whilst the Bennett Street catchment discharges west to Bennett Brook.

Caversham

There are two surface drainage pathways running through the Caversham cell. These pathways convey surface water from the West Swan east cell and upstream agricultural land as well as from within the Caversham area. A previously developed subdivision to the west of Caversham also discharges to a swale within the Caversham cell.

West Swan west

West Swan west consists of three catchments. The largest, central catchment drains south into the Bennet Brook and the two smaller catchments discharge west to the Bennett Brook a little further upstream and north to Horse Swamp respectively.

Whiteman Park south

Whiteman Park south is part of the Emu Swamp main drain catchment. A significant part of this cell is already developed and served by an established local drainage network. The area to the north of Marshall Road remains undeveloped and is divided into four main catchments of which one drains east directly into the Bennett Brook. The remaining three catchments drain to the south and contribute minor flows to the Emu Swamp main drain via three culverts under Marshall Road.

Current advice from the Water Corporation is that the Emu Swamp main drain does not have sufficient capacity to accommodate additional stormwater. The department will need to provide advice as to whether any proposals for future development should include redirection of all flows to the easternmost culvert under Marshall Road to connect to the main drain downstream of the Freshwater Promenade compensating basin. Any connection to the main drain will require approval by the Water Corporation based on agreed criteria with the department.

Surface water quality

The Swan Rivers Trust *Healthy rivers program* is a key instrument for the implementation of the *Swan and Canning Rivers management Act 2006*. This legislation protects waterways such as St Leonards Creek and Bennett Brook, as well as the Swan and Canning Rivers, for their significance as important ecosystems and valuable recreational waterways. The Swan Rivers Trust have developed short- and long-term end of catchment water quality targets for nutrient concentrations in tributaries of the Swan-Canning river system. Recommendations from the Healthy rivers program have been incorporated into the water quality management strategies presented in Section 6.3.

The *Nutrient report card for Bennett Brook* (Swan River Trust and Department of Water 2006) provides an assessment of nitrogen and phosphorus discharge rates for the Bennett Brook catchment for the period 1996–2006. The catchment is classified in the study as passing its short-term but failing its long-term target (median concentration 0.8–1.2 mg/L) for total nitrogen and passing both short and long-term target (median concentration less than 0.1 mg/L) for total phosphorous.

A national pollutant inventory (Acacia Springs Environmental 2000) report extrapolated export rates from 14 gauging stations across the Swan-Canning catchment, deriving annual export rates for Bennett Brook and St Leonards Creek. The rates are 1.4 kg/ha/yr total nitrogen and 0.37 kg/ha/yr total phosphorous for Bennett Brook and 1.61 kg/ha/yr and 0.78 kg/ha/yr total phosphorous for St Leonards Creek, and have been adopted by JDA CONSULTANT HYDROLOGISTS (2006) as the design objectives for stormwater discharge in the *Albion local water management strategy*.

Surface water quality in West Swan east has been monitored since 2005 by JDA Consultant Hydrologists (2007) at three sites, all within the Bennett Street catchment which drains to Bennett Brook. In the roughly two years between the start of the monitoring and the completion of the *West Swan east local water management strategy* the median total nitrogen concentration was 4.7 mg/L whilst the median total phosphorous concentration was 0.44 mg/L. Nutrient input loadings within West Swan east were also modelled using NiDSS (JDA Consultant Hydrologists 2007), with pre-development land use estimated to have input loadings of greater than 19 kg/ha/yr for total phosphorous and 59 kg/ha/yr of total nitrogen.

Monitoring of surface water quality in Caversham is currently being undertaken by RPS BBG. The draft *Caversham local water management strategy* does not have specific water quality targets.

3 Proposed development

Existing land use in the study area, as indicated by cadastral data, is a combination of bushland, rural and higher density residential, with the bulk of the land currently rural. The north west of the study area is located within Whiteman Park and as such is currently, and will continue to be, bushland. Existing land use within the north-east of the study area consists of broad acre grazing, rural residential, bushland and a small area in the north that is already developed residential land. The south of the study area is currently used for agricultural, commercial, rural and higher density residential purposes, with the majority of the land currently used for rural purposes.

There is a network of sealed and unsealed roads in the study area. Road density is highest in the urban areas. Reid Highway crosses through the south of the study area, Lord Street runs from the north of the study area and West Swan Road runs through the eastern reaches of the study area. The proposed Perth Darwin Highway route runs through the western reaches of the study area. The Dampier to Bunbury natural gas pipeline corridor runs north to south through the length of the study area.

The *Metropolitan region scheme* (Western Australian Planning commission 2006) specifies urban zoning for the Albion cell (except Bush forever site 200), urban zoning for West Swan east, urban deferred for West Swan west, a mixture of urban, urban deferred and rural for Caversham, and a mixture of rural and parks & recreation for the undeveloped part of Whiteman Park south that is to the north of Marshall Road. The area to the south of Marshall Road is zoned urban and has already been developed.

The *Swan urban growth corridor sub regional plan* (Department for Planning and Infrastructure in press), shown in Figure 10-8, presents the proposed development in the study area, with the exclusion of Whiteman Park south. This plan is further defined in proposed district structure plans presented in each of the draft local water management strategies.

Proposed development is predominantly residential throughout the study area. Bush forever site 200 in the Albion cell and some existing drainage routes are maintained, though others are not. Residential densities are not presented in the context plan, though densities ranging from R5 to R60 are presented within the three district structure plans. The R5 lots form a buffer between the study area and adjacent rural lots to the east and south, whilst the R60 lots are located within the Albion town centre. There has been general agreement with the City of Swan for an overall density target of 22 dwellings per hectare.

The department acknowledges the decision of Parliament (June 2007) to disallow the urbanisation of Whiteman Park south (MRS amendment 1027/33).

4 Protection of environmental assets

The following strategies have been developed to protect and enhance the value of environmental assets in the study 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 4-1). 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.

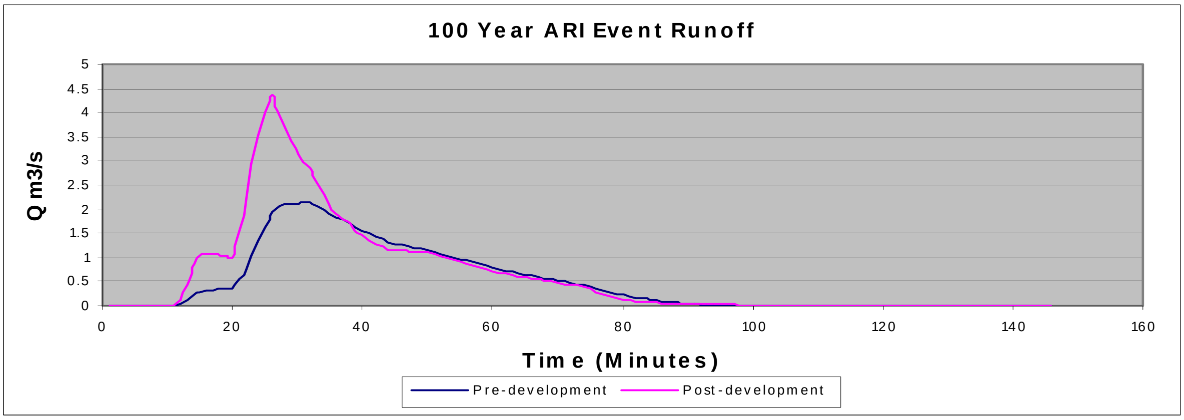


Figure 4-1 Typical pre- and post-development urban runoff hydrograph comparison, with directly connected constructed impervious surfaces, without detention storage.

Surface water management must ensure that urban development does not increase the peak flows discharging to receiving environments although there may be increases in total runoff volumes (Figure 4-2). Development must also ensure that watercourses and wetlands do not dry out due to over abstraction of water resources or lowering of groundwater levels.

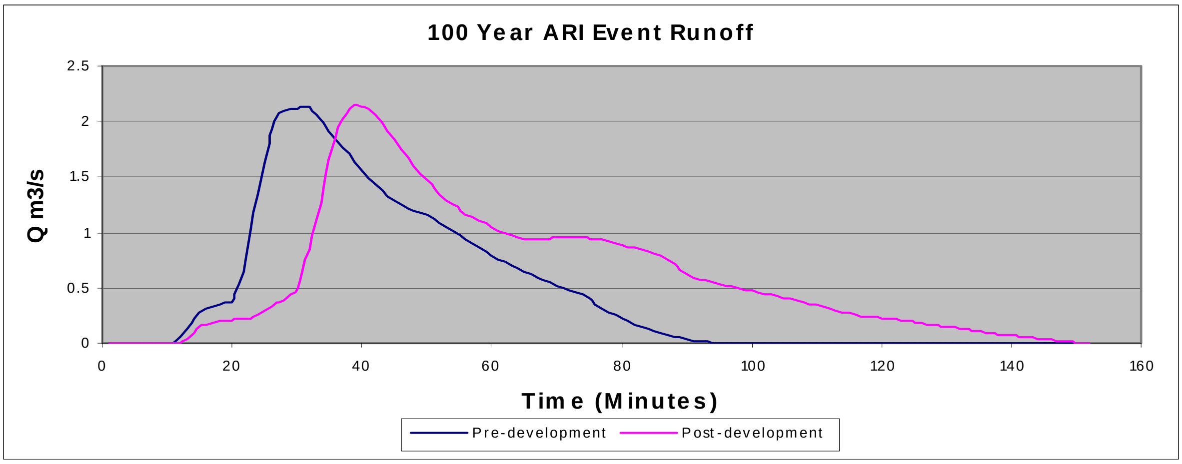


Figure 4-2 A typical pre- and post-development urban runoff hydrograph comparison, with WSUD best practice' and retention/detention of post-development flows.

Manage and restore watercourses and wetlands

There are wetlands classified as conservation category adjacent to the study area, and wetlands classified as resource enhancement both adjacent to and within the study area. The Environment Protection Authority requires all conservation category wetlands to be protected and managed for conservation purposes. The Environment Protection Authority also recommends the consideration of existing watercourses and inclusion of requirements for restoration, revegetation and reservation of an appropriate corridor width. Various guidelines are available for all aspects of wetland and watercourse protection and restoration and are published by the Department of Water and the Department of Environment and Conservation. Specific information relevant to the management of watercourses and wetlands within this study area is contained in 6 Stormwater management strategy.

Assess and manage impacts on native flora and fauna

There are two declared rare and priority flora species within the study area, specifically *Drosera occidentalis* subsp. *Occidentalis* and *Epiblema grandiflorum* var. *cyaneum* (Figure 4-3). Detailed flora and fauna assessments are required to be undertaken as part of more detailed levels of planning to ensure that development and subdivision is cognisant and sensitive to the protection of native flora and fauna.

Figure 4-3 Epiblema grandiflora var. cyaneum, photograph by Robson, J.L.

5 Water use efficiency

Water conservation and efficiency are about reducing water consumption, making it available for higher value purposes and/or achieving greater productivity from the same amount of water.

In new developments, water use efficiency requires the urban form to minimise use and to achieve the highest value use of fit-for-purpose water. This means that water should be of a quality suitable for its intended final use. For example in areas identified as suitable, garden bores provide a fit for purpose alternative to scheme water for garden use.

In the average household, 47 per cent of water is used outside the home. Gardens (private and public) and public open space areas should be waterwise to minimise irrigation requirements. This includes the use of low water requirement plants and minimal turf areas. The use of scheme water for non drinking purposes should be minimised.

Non-scheme water is often used in applications outside buildings, commonly for maintenance of public open space and passive and active recreation areas. Demand has traditionally been met by groundwater resources.

Efficient water use can be achieved through approaches such as raising community awareness, regulation, market mechanisms, and financial incentives or assistance to facilitate change. The State Government has identified demand reduction and efficient use of potable water as a priority (Government of Western Australia 2007).

New developments should aim to achieve a target of:

- less than 100 kilolitres per person per year (kL/person/year) for consumers within Perth.

In addition there is an aspirational target of:

- Not more than 40–60 kL/person/yr scheme water.

The *State water recycling strategy* (Department of the Premier and Cabinet and Department of Water 2008) further identified the need for new housing developments to consider the use of alternative, fit-for-purpose, water supplies.

5.1 Water efficiency tools

Water efficiency standards and labelling

Products that use water in the home are sold with a star rating similar to that used for energy products. The higher the star rating, the more water efficient the product is.

5 star plus: water use in houses

The Water use in houses code stage one applies to new homes approved for construction after 1 September 2007 (Department of Housing and Works 2007). This provides for:

- limiting water use through efficient 3 or 4 star taps, shower and toilet fittings
- new swimming pools to be fitted with a pool blanket
- reducing energy waste by limiting the distance of taps from a hot water source.

Waterwise rebate

The Waterwise rebate program aims to achieve more efficient water use by promoting water efficient appliances in households. Since being introduced in February 2003 as a state water strategy initiative, the program has been extremely successful in saving water. It has been extended and rebates are now available for swimming pool covers, rain sensors, subsurface irrigation systems, waterwise garden assessments, flow regulators, greywater re-use systems, washing machines, rainwater tanks, garden bores and waterwise irrigation systems.

Waterwise communities toolkit

To integrate and further develop options for household scale water conservation and recycling, an online Waterwise communities toolkit is being developed.

This toolkit will promote water conservation and recycling to local government, developers and other users. It will provide access to information on both recycling and wise water use, including:

- the availability of shallow groundwater
- the availability of sources for recycled water
- key land planning considerations
- alternative water solutions including rainwater tanks, community bores, greywater and landscaping
- streamlined application and approval processes.

The toolkit is currently under development led by the Department of Water, and will be finalised by 2010.

H2Options

H2Options (Water Corporation 2008) is a seven-step guide for developers for considering alternative water supplies, in addition to the existing processes for securing water supply, wastewater and drainage services within a development.

Water conservation/efficiency plans

The *State water strategy* (Government of Western Australia 2003) introduced the concept of water users developing and implementing water conservation/efficiency plans as part of the water licensing process undertaken by the Department of Water and integrating water use efficiency measures into water users' daily operations.

Water conservation/efficiency plans enable licensees to obtain a thorough knowledge of their water use and provide details of a water efficiency implementation program to achieve improved water use efficiency. *Statewide policy no 16 – Policy on water conservation/efficiency plans: Achieving water use efficiency through water licensing* (Department of Water 2008a) further discusses the plans.

In the Perth region, Water conservation plans are required for local governments to:

- develop and implement climate change adaption strategies
- ensure that water use remains within licensed allocations
- demonstrate efficient groundwater use
- address decreasing groundwater availability while maintaining amenity, sport and recreation and biodiversity outcomes
- promote a culture of continuous improvement.

Developers should liaise with the relevant Local Government Authority to ensure that any development will align with the requirements of their Water conservation plan.

Other documents that may also provide guidance are:

- *Interim position statement: constructed lakes* (Department of Water 2007)
- *Interim position statement: third pipe (community bores)* (Department of Water in press)
- *Stormwater management manual for Western Australia* (Department of Water 2004–2007).

6 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.

6.1 Floodplain management strategy

Investigation of and recommendations for floodplain management are presented in the *Swan urban growth corridor flood management strategy* (GHD in press(b)).

This study developed flood modelling and mapping of the Swan urban growth corridor and resulted in the identification of floodway and flood fringe areas. The proposed Floodplain management plan includes structural and non-structural measures for flood mitigation focused on managing potential flooding impacts on the site and to the immediate neighbouring land and drainage infrastructure.

Flood modification

The purpose of flood modification measures is to modify the behaviour of a flood by reducing flood levels or velocities or by excluding floodwaters from areas at risk. Flood modification measures by their nature may have environmental and ecological impacts (positive or negative), so any proposal for such works must be subject to strict and detailed assessment in accordance with planning and assessment legislation.

Suggested flood modification measures in the Swan urban growth corridor are outlined below.

- Retention and/or detention of the one-year-one-hour average recurrence interval event at source.
- Maximisation of infiltration at source – use of soak wells, swales, basins, and other structures to encourage infiltration and reduce the volume of stormwater generation at the source. Infiltration is generally only an option in areas with adequate infiltration rates (i.e. sandy soils).
- Detention near source – use of detention storages (e.g. swales, constrained public open space, and wetlands) widely disbursed throughout mainly urban areas to temporarily hold back stormwater, thus reducing downstream peak flow rates and water levels. Storage volumes need to be large enough to contain a suitable amount of stormwater and need to have suitably regulated outlets to control outflow rates.
- Channel modification – extensive modification of existing waterways is not generally supported and would require prior advice to be given by Department of Water. However modifications may be proposed that will ensure the ability of streamlines to safely convey flow, particularly reducing the effects of man-

made structures in creating ponding (afflux), such as undersized culverts and constructed drains. Where such proposals are made, the impact on the regional drainage strategy must be investigated. Components of this option are revegetation maintenance and upgrade of drainage infrastructure:

- Revegetation, strategic channel stabilisation and improved land use practices for the flood plain, drainage channels and adjacent areas could also have environmental and aesthetic benefits. Works could include revegetation with native species, weed control, erosion stabilisation and land use change (e.g. reduced fertiliser and pesticide use near or on the floodplain or drainage lines). Key aims of these works could be to stabilise banks and floodplain areas against erosion, help improve water quality (e.g. by reducing nutrient export) and improve aesthetic and general environmental characteristics.
- Maintenance. Appropriate maintenance is important to prevent culvert blockage, scour, etc. which reduces channel capacity and to minimise erosion and deposition issues. Upgrade of undersized infrastructure should also be included as part of a maintenance/upgrade programme.

Property modification

Property modification involves works that make property (eg houses and roads) located within the floodplain less susceptible to flooding.

Suggested property modification options include:

- Land use zoning, planning controls and building regulations for the floodplain area.
- Design guidelines, including addressing setbacks, fencing types and drainage.
- Adequate flood protection from a 100-year average recurrence interval flood. Provided by building floor-level controls—specified finished floor levels for new buildings in flood prone areas, based on predicted flood levels plus a freeboard.
  - New dwellings in proposed and existing residential areas located within an area that is below 0.50m above the 100-year average recurrence interval (of rivers and the main drainage system), must have their floor levels elevated 0.50 m above the 100-year average recurrence interval flood level.
  - New industrial or commercial premises located within an area that is below 0.50 m above the 100-year average recurrence interval (of rivers and the main drainage system), should have their floor levels elevated 500 mm above the 100-year average recurrence interval flood level.
  - Major arterial roads with immunity to the 100-year average recurrence interval flood level that access new residential areas and can provide egress to emergency services must be identified. Other residential streets should be designed to be serviceable up to the 5-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 on regional water quantity and quality in the catchments.

Proposed development may not detrimentally impact on the existing 100-year average recurrence interval flooding regime of the general area. Where proposed developments include new or modified waterways and drainage corridors the following criteria apply:

- New and modified 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 and modified waterways should be designed with consideration of the current practice in water sensitive urban design by incorporating water quality management controls and riparian vegetation to allow the drainage paths to recover to a more natural state.

Response modification

Response modification involves modifying the response of the community to a flood threat. Unless designed for a probable maximum flood, all flood protection measures will at some time be overwhelmed by a larger flood than the design, and the implementation of appropriate flood warning, evacuation and clean-up plans can be effective in managing flood impacts. In some cases, response modification may be the only economic or socially acceptable flood management option.

Response modification measures that may be appropriate for the Swan urban growth corridor include:

- community awareness, including community involvement in floodplain management practices and education
- community preparedness, that is, the ability of the community to defend their properties and well-being from flood threat using appropriate preparatory and evacuation measures
- flood prediction and warning (warnings based on weather predictions are likely to be of most value to the catchment)
- emergency response plans, including evacuation planning and definition of tasks and responsibilities
- emergency recovery plans, including clean-up planning and definition of tasks and responsibilities
- flood insurance, including awareness of exclusions in general insurance policies relating to flood damage and potentially for locally funded speciality insurance schemes.

6.2 Surface water quantity management

Minimise changes in hydrology to prevent impacts on receiving environments

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

Surface water quantity management is not only restricted to preventing runoff from increasing due to development, but must 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-one-hour average recurrence interval event, the post-development discharge volume and peak flow rates should be maintained relative to pre-development conditions in all parts of the catchment. Where there are identified impacts on significant ecosystems, maintain or restore desirable environmental flows and/or hydrological cycles as outlined in this report.
- Manage catchment runoff within the development area to pre-development peak flow rates. Pre-development critical 5- and 100-year average recurrence interval event peak flow rates are specified in Table 6-1.
- Water sensitive urban design and best management practices which promote on-site retention of events up to the one-year-one-hour average recurrence interval form the basis of the surface water quantity management strategy for minor events.

The Department of Water may consider allowing an increase in the post development peak flow rates from 5- to100-year average recurrence interval events, 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 the computer model 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 maintain pre-development peak flow rates at 5- and 100-year average recurrence interval rainfall events are presented in Table 6-1.

Figure 10-9 and Table 6-1 present the proposed surface water management strategy for the Swan urban growth corridor. Indicative 100-year flood levels, overland flow paths, subcatchment delineation (Figure 10-9), discharge flows and detention volumes (Table 6-1) are provided as a guide to developers. They should be refined and located during district 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 5- and 100-year average recurrence interval event pre-development discharge flow rates are presented in Table 6-1 along with and indicative post -development storage volume required to maintain that flow rate. It is important to note that the drainage and water management plan model assumes that the one-year-one-hour average recurrence interval event (from allotments and also from the road network) is retained at source. This volume is not included in the indicative flood detention volumes provided in Table 6-1. Flows from the road network in a one-year average recurrence interval event should be retained within the road reserve network in a manner that mitigates pollutant export.

Discharge flow rates quoted in Table 6-1 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 (Figure 6-1).

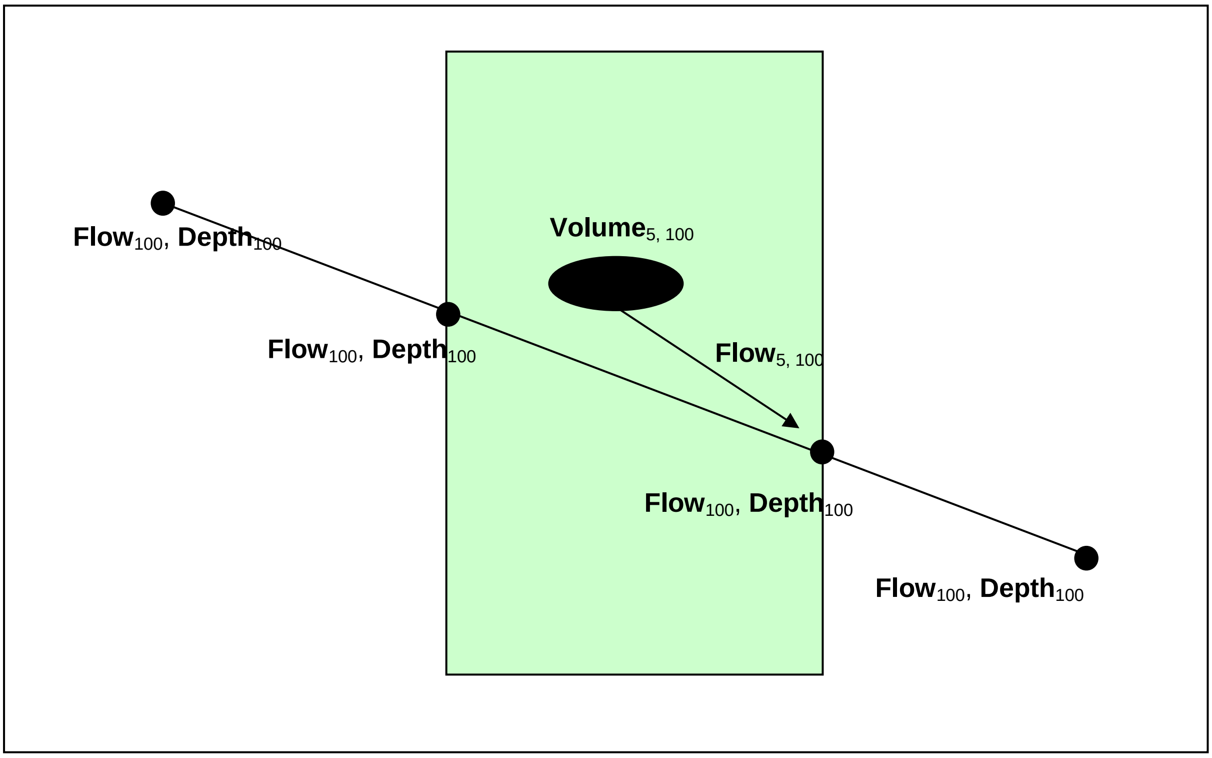


Figure 6-1 Schematic presentation of information provided for subcatchments and main waterways.

For each modelled node (Figure 6-1) 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 (Figure 10-11).

In Table 6-1, the subcatchment ID WSEschool refers to a subcatchment containing the proposed primary school site adjacent to Lord Street and a part of the road itself, in the West Swan east area. The storage volume requirement for this subcatchment could be incorporated into school recreation areas and therefore should not impact on the rest of the development area.

Where a proposed development is within one subcatchment (Figure 6-1), the storage volume to be provided by that development is to be calculated based on the development surface area as a percentage of the subcatchment surface area. Where the development spans several subcatchments, the storage volume should be calculated based on combined total surface area from those subcatchments.

Table 6-1 Subcatchment drainage planning criteria

Subcatchment ID	Subcatchment	peak discharge flow (m^3/s)		detention volume (m^3)	
Subdivisional Storage Basins:	**area (ha)**	**5-year**	**100-year**	**5-year**	**100-year**
Aa	27.4	0.1	0.6	16500	12000
Ab	67.5	0.0	0.8	3100	13800
Ac	25.5	0.1	0.6	2200	5500
Ad slc	228.5	0.1	0.9	24800	60100
Ad wc		0.3	0.6		
Af	121.8	0.2	1.4	7800	14400
Ag	103.6	0.2	1.5	12000	12900
WSEa	77.0	0.1	0.7	3700	7700
WSEb	108.9	0.1	0.8	10100	16300
WSEc	39.3	0.1	0.4	4300	9000
WSEd	43.8	0.2	0.7	8200	10700
WSEschool	14.6	0.0	0.1	3600	9400
CWa	34.9	0.1	1.2	4200	5200
CWb	36.1	0.1	1.2	2400	4600
CWc	19.4	0.1	0.4	1500	2600
CWd	25.5	0.1	0.4	2600	4700
CEa	23.3	0.1	0.8	1200	2200
CEb	22.7	0.3	2.1	1000	2700
CEc	33.3	0.2	1.3	1800	2700
WSWa	24.2	0.0	0.4	3500	6500
WSWb	72.1	0.1	1.7	5500	12600
WSWc	67.0	0.1	1.9	9500	20700
WSWd	24.0	0.1	0.3	800	2300
WPSa	49.8	0.0	0.2	Detention volumes are not presented for Whiteman Park South – development of this area is not anticipated within the next 10 years.	
WPSb	137.4	0.1	0.2		
WPSc	72.9	0.1	0.1		
WPSd	49.1	0.0	0.2		

NOTE: Flows and volumes are for each subcatchment only and are not cumulative in downstream direction.

Surveyed cross sections and culvert dimensions were built into the pre-development model. For the post-development model, unless otherwise indicated it should be assumed that existing cross sections remain unmodified and local investigations will be necessary to establish the existing cross sections for specific development areas.

The existing cross sectional area of waterways must be maintained. Restoration of waterways is essential. 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.

Typical cross-sections of modified waterways are presented in Figure 10-10. A summary of peak flows, levels and indicative floodway widths at critical locations (Figure 10-9) are presented in Table 6-2. A range for the indicative floodways is given for some locations (eg location 2. Albion – St Leonards Creek at Murray Road: 50-100 m), this represents the range of widths of the natural channel immediately up and/or downstream. To provide a single width for these locations may be misleading.

Table 6-2 Flows, levels and floodway widths at critical locations

Location	**peak flows (m3/s)**		**peak levels (m AHD)**		**indicative floodway width (m)**
Number(Fig. A-8) and description	**5 Year ARI**	**100 Year ARI**	**5 Year ARI**	**100 Year ARI**	**100 Year ARI**
1. Albion - Inflow to St Leonards Creek at Park St	0.5	1.1	30.8	30.9	16
2. Albion - St Leonards Creek at Murray Rd	0.5	1.5	23.4	23.4	50-100
3. Albion - St Leonards Creek at Woolcott Ave / Murray Rd	0.1	0.3	22.0	22.1	50
4. Albion - Inflow to Wandoo Creek at Lord St	0.2	0.6	32.8	33.0	16
5. Albion - Wandoo Creek at Henley Brook Ave	0.3	0.6	20.1	20.2	32
6. Albion - Outflow to Horse Swamp north of Lord St	0.1	0.4	24.0	24.3	-
6b. Albion - Outflow to Horse Swamp south of Lord St	0.1	0.5	24.0	24.1	-
7. Albion - Wandoo Creek via Bush Forever Site	0.2	0.5	15.1	15.4	50 - overland
8. West Swan East – Bennett Brook at Malvern St	0.1	0.2	17.9	18.0	16
9. West Swan East – Bennett Brook at Malvern St	0.3	0.5	13.9	13.4	16
10. West Swan East - Outflow to Caversham at Reid Hwy	0.3	0.4	12.5	12.6	16
11. West Swan East - Outflow to Horse Swamp	0.0	0.0	21.3	21.7	-
12. Caversham East - Inflow at West Swan Rd	0.7	1.2	10.9	10.8	16
13. Caversham East - Outflow to Bennet Brook U/S Benara Rd	0.9	1.6	8.0	9.4	16
14. Caversham West - Inflow at Reid Hwy	0.2	0.4	11.7	12.6	16
15. Caversham West - Outflow to Bennet Brook U/S Benara Rd	0.6	1.1	5.8	6.2	16
16. West Swan West - Outflow to Horse Swamp	0.0	0.1	21.4	21.7	50 - overland
17. West Swan West - Outflow to Bennet Brook at Reid Hwy	0.3	0.6	10.5	10.6	32
18. West Swan West - Outflow to Bennet Brook at Marshall Rd	0.1	0.1	16.1	16.6	35
19. Whiteman Pk S - Outflow to Local Authority System at Marshall Rd	0.0	0.2	23.5	24.6	40
20. Whiteman Pk S - Outflow to Local Authority System at Marshall Rd	0.1	0.2	19.2	19.3	100-200
21. Whiteman Pk S - Outflow to Local Authority System at Marshall Rd	0.1	0.1	18.2	19.6	100-200

The alignment of new local swale drains may be modified from those shown on Figure 10-9 in order to fit in with district structure planning requirements. Proposals to modify alignments should be discussed with the Department of Water and the City of Swan prior to the submission of local water management strategy documents and will need to be assessed for their impact on the regional drainage strategy. Details of realignment proposals should then be included in local water management strategies for final approval by the City of Swan and Department of Water.

As previously discussed in 3 Proposed development, development of the Whiteman Park south section of the Swan urban growth corridor is not anticipated and has therefore not been modelled within this study. Pre-development discharge flow rates have been provided in Table 6-1 and Table 6-2 and may be used as a guide for any proposed future development. However, it is important to note that the current Water Corporation advice suggests that approval for connection to the Emu Swamp main drain would only be granted downstream of the Freshwater Promenade compensating basin via the eastern most culvert under Marshall Road at location 21 (Table 6-2 and Figure 10-9).

In general the drainage strategies proposed by the Albion, Caversham and West Swan east draft *local water management strategies* have been adopted. However, regional scale modelling has resulted in some revisions to storage volumes & drain dimensions to ensure that the pre-development hydrology of the area is not significantly modified.

There are two resource enhancement wetlands that should be retained within the Albion area. It is a requirement of the Department of Environment and Conservation that the hydrological regime of these wetlands is not detrimentally impacted by development. It is proposed that overland flow should continue to be allowed to enter these wetlands from the surrounding developed area but that sufficient storage will be provided outside their buffers to ensure that the 1-, 5- and 100-year average recurrence interval event top water level remains consistent with the pre-development case. Proposals to incorporate development generated flood storage detention volumes (for greater than one-year average recurrence interval events) within buffers may be considered by the Department of Water, where this is part of a vegetation rehabilitation plan for the buffer area and this plan has the support of the City of Swan and the Department of Environment and Conservation. The proposal should be fully documented within the local water management strategy submitted for the relevant development area.

A similar approach has been taken to ensure that there is no detrimental impact on Horse Swamp which is a conservation category wetland within the adjacent Whiteman Park and receives discharges from a number of subcatchments within the Swan urban growth corridor. All of the discharges into this wetland have been restricted to their pre-development peak flow rates for the critical 5- and 100-year average recurrence interval events.

Table 6-3 provides the modelled top water levels for pre- and post-development scenarios. The duration of wetland inundation due to flood detention should also be considered when developing local water management strategies.

Table 6-3 Modelled top water levels for selected wetlands

Wetland Name	Pre-development Top Water Level (m AHD)			Post-development Top Water Level (m AHD)		
	1-year ARI	5-year ARI	100-year ARI	1-year ARI	5-year ARI	100-year ARI
Horse Swamp (CCW)	21.1	21.1	21.2	21.1	21.1	21.2
Albion wetland north (REW)	28.1	28.2	28.5	28.1	28.2	28.6
Albion wetland south (REW)	26.1	26.1	26.2	26	26.1	26.3

The two existing 600 mm diameter culverts under Lord Street should be upsized to 900 mm diameter culverts to re-establish the former flow path from the south western section of Albion into Horse Swamp at the flow rates indicated at location 6a and 6b (Table 6-2 and Figure 10-9) and to provide protection to Lord Street from flooding in the 100-year annual recurrence interval event. These two culverts are separated by Youle-dean Road. Modifications to culverts under Murray Road in the Albion cell will also be required to provide protection from the 100-year average recurrence interval event flooding for that road. At location 3 the culvert will require upsizing to 600 mm diameter. At location 2, four additional 600 mm culverts located 1 m above the existing culvert invert will be required to convey high level flows.

An existing waterway passes through the well head protection zone at Woolcott Avenue and the current proposals for Albion include retaining this waterway. Although the maintenance of an existing waterway at this location should not contravene the restrictions placed on development of this site there may be limitations on the restoration and/or modification of this waterway.

In order to ensure that downstream flows are maintained at pre-development rates at locations 13 and 15 (outflows from the Caversham cell) new 900 mm diameter culverts (one on each waterway) will be required to restrict downstream flows and make full use of the upstream capacity of the waterway. An alternative strategy may be to increase the subcatchment storage provided, thereby further reducing the flow into the waterway itself. Whilst this strategy may require modification to the currently proposed structure plan for this cell, it has the potential to reduce fill requirements for the downstream end of the development by lowering the 100-year average recurrence interval top water levels. Negotiation will be required with the City of Swan to determine the most appropriate design to achieve the required discharge flow rates and minimise fill requirements.

Within the West Swan West cell, in order to reduce bed velocities and maximise the use of available instream storage, a 1 m drop structure has been modelled, incorporated into the culverts under Marshall Road. It may be more appropriate to reduce the invert drop at this structure and include one or two further small riffle structures when the design of this waterway is finalised. Guidance for the design of living streams, incorporating riffle type structures, is contained in the *Stormwater management manual for Western Australia* (Department of Water 2004–07).

6.3 Surface water quality management

The environmental values of downstream waterways within, and surrounding, the study area must be maintained.

Maintaining pre-development discharge rates and volumes from developed catchments is expected to prevent the majority of contaminants from reaching the waterways. This management strategy ensures that the majority of flows from high frequency events are retained 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.

The Swan Rivers Trust *Healthy rivers program* short and long term end of catchment water quality targets for nutrient concentrations in tributaries of the Swan-Canning river system are presented in Table 6-4. Surface water discharging into wetlands, including conversation and resource enhancement category wetlands, may require separate water quality targets.

Table 6-4 Healthy rivers program water quality targets

Guideline		Total nitrogen (mg/L)	Total phosphorus (mg/L)
Tributaries	Short term	2.0	0.2
	Long term	1.0	0.1
Estuary target (Upper Swan)		1.0	0.1

In order to achieve the end of catchment targets, it is appropriate to establish site-specific design objectives for water quality. The Department of Water is currently developing these objectives. Water quality treatment systems and Water Sensitive Urban Design structures to meet these objectives must be designed, implemented and managed in accordance with the *Stormwater management manual for Western Australia* (Department of Water 2007) and *Australian runoff quality: a guide to water sensitive urban design* (Engineers Australia 2006).

6.4 Key design criteria

Surface water quantity

- The one-year-one-hour average recurrence interval event should be retained at source through the use of retention (soakage) or storage devices. The *Stormwater management manual for Western Australia* (Department of Water 2004–07) contains guidance for the appropriate design of retention systems. Refer to Chapter 9 for devices suited to the soil types for this catchment.
- The post-development critical one-year average recurrence interval peak flow and volume should be consistent with pre-development flows at:
  - the discharge points of all subdivisions into waterways
  - the discharge points from the district structure plan areas.
- Post development flood protection peak flow rates and detention volumes, based on maintenance of pre-development flows are presented in Table 6-1.
- Flood detention/storage areas shall be incorporated into public open space within the subdivision and located outside defined floodways (Figure 10-9).
- Post-development flows from 5- to100-year average recurrence interval events may be greater than pre-development flows, only 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.
- Floodways are defined in Figure 10-9 and contain the regional 100-year average recurrence interval event flow. Floodways may not be developed or obstructed in any way, and are entirely separate from the storage volumes presented in Table 6-1.
- Where the urban form is located within an area that is below 0.50 m above the 100 year ARI flood level from rivers or main drainage networks, residential development shall be located outside of the floodway with a minimum habitable floor level of 0.50 m above the 100-year average recurrence interval event flood level. In all other parts of the catchment, development shall have a minimum habitable floor level 0.30 m above the 100-year average recurrence interval event level, calculated for the local drainage systems.
- The existing cross sectional area of waterways must be maintained. Restoration of waterways is essential. 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.
- Defined major arterial roads should remain passable in the 100-year average recurrence interval event.
- Minor roads should remain passable in the 5-year average recurrence interval event.

Water quality treatment systems and water sensitive urban design structures must be designed in accordance with the *Stormwater management manual for Western Australia* (Department of Water 2004–07) and *Australian runoff quality: a guide to water sensitive urban design* (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).

Protection of catchment ecological function, geomorphic stability and water quality maintenance are to be achieved through adopting a treatment train approach including:

- non-structural measures to reduce applied nutrient loads
- onsite retention of one-year-one-hour average recurrence interval event
- swales/vegetated bioretention systems (also referred to as rain gardens) are to be sized at 2% of the constructed impervious area from which they receive runoff.

Where it is proposed to use a computer stormwater modelling tool to assess the impacts of urban development and to size structural controls for protection of downstream surface water quality, the following pollutant reduction targets are to be achieved:

- As compared with past urban development practices that did not actively manage water quality, developments must 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.

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

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

7 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
- managing and minimising changes in groundwater levels and groundwater quality following development/redevelopment.

It is important to note that groundwater levels are not the same as flood levels and should be dealt with accordingly.

7.1 Groundwater quantity management

Manage groundwater levels to protect infrastructure and assets

To protect buildings and community infrastructure from flooding and damage from groundwater, the predicted maximum groundwater levels for the current and wet climate scenarios should be determined through modelling and/or measurement. Where this information is not available local studies should be undertaken and endorsed by the Department of Water.

Where the predicted maximum groundwater level is close to the ground surface the provision of subsurface drainage will be required to protect against potential surface saturation (soil moisture control).

The regional modelled current climate maximum groundwater level for the study area is presented in Figure 10-6. This is the current climate (average of last 20 years) rainfall scenario as modelled by GHD (in press(a)).

The regional modelled wet climate maximum groundwater level adopted for the study area is presented in Figure 10-7. This is the high rainfall scenario for the 1915–1934 as modelled by GHD (in press(b)).

The modelled groundwater levels (Figure 10-6 and Figure 10-7) provide a guide to regional groundwater levels in the area. Further investigations will be required to determine local scale groundwater levels to determine wether subsurface drainage is required for protection of urban infrastructure. This drainage should always be located at a groundwater level endorsed by the Department of Water.

Maintain groundwater regimes for the protection of groundwater dependent ecosystems

To ensure protection of groundwater dependent ecosystems, local studies to model and/or measure groundwater levels and refine the regional groundwater levels should be undertaken.

Proposals to control the seasonal or long-term maximum groundwater levels should demonstrate, through adequate field investigations, how any local and regional impacts are to be managed.

Where subsoil drainage is required, the level at which it will be installed must be developed with consideration of ecological water requirements for groundwater dependent ecosystems, such as wetlands. Determination of ecological water requirements of groundwater dependent ecosystems is intended to be outlined in the Department of Water’s guidelines for determining ecological water requirements. Environmental water provisions acknowledge the water requirements in the context of land use change and the drying climate.

Once the ecological water requirements have been determined, local levels for drainage design can then be finalised in accordance with the requirements of the *Decision process for stormwater management in Western Australia* (Department of Environment and Swan River Trust 2005). These levels should always aim to meet ecological water requirements. However, if ecological water requirements cannot be met, the likely impacts on the groundwater dependent ecosystems values should be outlined.

Regional scale groundwater modelling (GHD in press(a)) indicates that the development of the Swan urban growth corridor with subsurface drainage will have limited impact on minimum and maximum groundwater levels in wetlands both within and outside the study area. However, there is potential for some increase in predicted maximum groundwater levels (up to 0.5 m in Horse Swamp) should subsurface drainage not be provided.

Manage the shallow aquifer to protect the value of groundwater resources

Groundwater in the area is currently utilised for domestic and commercial purposes and is potentially an important source of water for new development in the area.

Groundwater modelling (GHD, in press (a)) has indicated that development of the Swan urban growth corridor is likely to result in a general increase in predicted maximum groundwater levels in the study area with some areas increasing by as much as 1 m for average rainfall scenarios and 4 m for high rainfall (no groundwater drainage) scenarios. Outside of the study area the impact is much less marked and increases are less than 0.5 m with average rainfall and 1 m with high rainfall. There is generally very little to no change indicated for predicted minimum groundwater levels.

Groundwater modelling (GHD, in press(a)) also investigated the impact of subsurface drainage (located at controlled groundwater level, see Figure 10 6, within the Swan urban growth corridor. Scenarios including subsurface drainage resulted in less change to predicted maximum groundwater level. With average rainfall, there was less than 0.5 m increase within the study area and virtually zero change outside. With high rainfall the trend was reversed by the introduction of subsurface drainage and predicted maximum groundwater levels fell by up to 3 m within the study area and 1 m outside. Again very little to no change was indicated for predicted minimum groundwater levels.

7.2 Groundwater quality management

The environmental values of groundwater within and surrounding the study area must be maintained.

Maintain groundwater quality and ecological systems in the catchment

The groundwater quality should be maintained at pre-development levels (median winter concentrations) and, if possible, the quality of water leaving the development should be improved. Ecological systems in the (sub) catchment the development is located in should be maintained and restored.

Water sensitive urban design and stormwater best management practices must promote infiltration to aid in prevention of possible local flooding from increased runoff due to urbanisation. In addition, they must also treat the water prior to its discharge to waterways, wetlands and to groundwater.

Where subsoil drainage is installed for groundwater level or soil moisture control, a 'treatment system' (e.g. swale or bioretention) 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 and methods appropriate to calculated flow rates.

Where appropriate field investigations must be undertaken to identify acid sulphate soils. Any reduction in groundwater level should not expose acid sulphate soils to the air as this may cause groundwater contamination. If field investigations identify acid sulphate 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*.

7.3 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

- The bioretention system and drainage inverts are set at or above the drainage design level endorsed by the department, level although existing drainage inverts can remain.
- Subsurface drainage must be designed with free-draining outlets.
- Imported fill onto the site is to incorporate a component of soil 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 a waterway or open drain that intersects the shallow water table and may discharge pollutants from the shallow groundwater to receiving environments, the following nutrient reduction targets should apply:

As compared with a development that does not actively manage water quality, achieve:

- at least 60% reduction of total phosphorous
- at least 45% 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 must be in accordance with the requirements of the Department of Environment and Conservation.

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

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 prior to the completion of any local water management strategy or urban water management plan.

8 Commitment to best management practise

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

Best management practice strategies reduce risks of flooding on housing and infrastructure whilst maximising the potential for stormwater to be treated as a resource.

The hierarchy of best management practice principles is as follows:

- implement controls at or near the source to prevent pollutants entering the system and/or treat stormwater
- install *intransit* measures to treat stormwater and mitigate pollutants that have entered the conveyance system
- implement end-of-system controls to treat stormwater, addressing any remaining pollutants prior to discharging to receiving environments.

Structural and non-structural best management practice strategies must be used in combination to achieve the required stormwater treatment outcomes.

Recommended best management practices include:

- residential lot scale:
  - on-site soakage devices (with overflow outlets (detention), if required)
  - water-wise and nutrient-wise landscaping
  - porous pavements
  - amended topsoils
  - rainwater tanks for harvesting, detention and re-use
- commercial lot scale:
  - on-site Detention and/or Retention
  - water-wise and Nutrient-wise landscaping
  - maximised permeable surfaces
  - porous pavements
  - amended topsoils
  - landscaped infiltration structures
  - hydrocarbon management and sediment traps

Rainwater tank, GHD, 2007

  - rainwater tanks for harvesting, detention and re-use
- street scale:
  - infiltration measures
  - sediment traps
  - porous pavements (car parking)
  - conveyance bioretention systems
- estate scale:
  - retention/detention (including water quality treatment) areas integrated within public open space, in accordance with the objectives and requirements of elements 4 (public parkland) and 5 (urban water management) of *Liveable neighbourhoods edition 4*
  - using imported fill material with a high phosphorous retention capability
  - retain existing waterways and aim to restore a pre-development ecology and channel morphology in new and existing waterways
  - non-structural best management practices such as interpretive signage, garden education programs, publishing a water sensitive urban design web-page for the estate and inviting residents to engage with existing community catchment groups
- area scale:
  - non-structural best management practices such as public education campaigns support of local community catchment groups, installation of interpretive signage and web pages and the adoption of appropriate planning principles including local laws for on-site detention and retention.


Biofiltration pocket
GHD, 2007

The above practices may be limited by several factors, including: local soil and hydrological conditions, the depth and type of fill imported, public safety and public health standards, design life/reliability requirements, maintenance/management costs, legal authority and streetscape aesthetics. Advice should be sought from the local government authority on the practices most appropriate for adoption within the Swan urban growth corridor.

9 Implementation

9.1 Requirements for the following stages

State planning policy 2.9: water resources policy (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* (Western Australian Planning Commission 2008a) provides guidance on implementation of State planning policy 2.9. It identifies the requirements for water management strategies and plans that must be developed to accompany the land use planning and approvals process in the drainage and water management plan area at each stage of the planning process.

All local structure planning should incorporate a local water management strategy consistent with the strategies and objectives of this drainage and water management plan. Subsequent subdivision applications should be accompanied by urban water management plans where required by the City of Swan and the Department of Water and/or should be consistent with any approved local water management strategy and with the strategies and objectives of this drainage and water management plan. *Urban water management plans: Guidelines for preparing plans and for complying with subdivision conditions* (Department of Water 2008b) are available from the Department of Water to help with the preparation of urban water management plans. Draft guidelines for local water management strategies are being prepared and will be available by the end of 2008. Developers are encouraged to contact the City of Swan early in the planning process to discuss specific water management requirements for proposals.

It is strongly recommended that proponents 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 prior to the completion of any local water management strategy or urban water management plan.

The City of Swan is responsible for approving water management plans throughout the structure planning framework and will refer those documents to the Department of Water and Western Australian Planning Commission for guidance and comment.

It is essential that details of the proposed monitoring strategy and action plan are built into the local water management strategy and urban water management plan for each structure plan area, for approval by the City of Swan and adoption under *Local planning scheme no. 17*.

9.2 Review of drainage and water management plans

It is proposed that the drainage and water management plan be reviewed within ten years or earlier if deemed necessary until development has occurred consistent with the Albion/West Swan east/Caversham/West Swan west structure plans.

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.

9.3 Monitoring strategy

A groundwater and surface water monitoring program should be designed as part of the local water management strategy to assess the hydrological impacts of the proposed development and to establish a contingency action plan with associated trigger values for specified parameters.

The baseline monitoring program should be conducted for at least three years prior to development to characterise the sites hydrology and hydrogeology. However in some cases it may be acceptable to provide 18 months of pre-development monitoring with a minimum of two winters where it can be shown that the monitored hydrology and hydrogeology is suitably reflective of the long-term environment. The results of the baseline monitoring strategy should be presented in the final local water management strategy.

The post-development monitoring program should be tailored to the development, quantifying the development’s impact on surfaces water quality, surface water flows, groundwater levels seasonal fluctuation and quality.

The monitoring results can then provide:

- pre-development baseline data
- post-development comparison to target design objectives and criteria
- a trigger for contingency action, as per the contingency plan
- an interim internal assessment tool of the monitoring programme.

All monitoring results should be provided to the Department of Water in an agreed format. A report on these results is not usually required; however where a trigger for contingency action has been reached, it will be necessary to report on the action taken.

Standards

Monitoring sampling should follow Australian Standards AS/NZ 5667 series of *Water quality sampling guidance notes* and a National Association of Testing Authorities accredited laboratory is required to perform water quality testing.

Monitoring network

The groundwater monitoring bore network's extent and density should spatially represent the hydrogeology of the local area.

Surface water monitoring sites should capture inflows and outflows for the whole site, all detention or retention storages, and any water dependent ecosystems.

Monitoring parameters

Monitoring of groundwater levels should be initially on a monthly basis to establish water level fluctuations. Surface water monitoring requirements are site-specific and must meet the regulatory bodies' recommendations.

Samples should be analysed for at least the following water quality parameters:

- *insitu* pH, electrical conductivity and temperature
- heavy metals - arsenic, cadmium, chromium, copper, lead, nickel, zinc, mercury, aluminium
- total suspended solids
- total nitrogen and total kjeldahl nitrogen
- ammonia (NH_4)
- nitrate and nitrite (NO_x)
- total phosphorus (TP)
- orthophosphate (PO_4^{3-}).

The following additional parameters are recommended in locations where drainage intercepts shallow groundwater systems:

- total titratable acidity and total alkalinity
- major anions (chloride, bromide and sulphate)
- major cations (calcium, magnesium, sodium and potassium)
- iron and aluminium.

The effective management of urban stormwater quality typically focuses on the treatment of frequent, low-intensity stormwater events. These small but frequent flows account for the majority of nutrient loads and represent the best opportunity for water quality improvement.

The process of infiltration filters the stormwater and is effective in the removal of particulate nutrients. Dissolved nutrients cannot be filtered and are therefore more difficult to treat. Urban runoff is a combination of dissolved and particulate nutrients.

If the treatment measure is infiltration, then filtered and unfiltered samples of total nutrient concentrations should be measured to quantify the proportion of dissolved and particulate nutrients generated within the development site, and the method recorded.

A summary of an example monitoring program is presented in Table 9-1. The format and frequency of post-development reporting should be proposed within the local water management strategy and approved by the local government authority and Department of Water. Where a trigger for contingency action, as specified in the local water management strategy is reached, it will be necessary to report on the action taken.

Table 9-1 Monitoring programme summary

	Sites	Frequency	Parameters
Surface water	Developments inflow and outflow locations Detention storages inflow and outflow Water bodies	Site specific	-Flows -Water levels
		Monthly grab samples while flowing, to be reviewed after the first year of monitoring	-***Insitu*** pH, EC and temperature. -**Unfiltered sample**: pH, EC, TN, FRP, TKN, ammonia, TP, heavy metals -**Filtered sample**: nitrate/nitrite and PO4,
Groundwater	Network of monitoring bores providing a suitable spatial representation of the study area.	Monthly	Water level
		Quarterly (typically Jan, Apr, July, Oct)	-***Insitu*** pH, EC and temperature. -**Unfiltered sample**: pH, EC, TN, FRP, TKN, ammonia, TP, heavy metals -**Filtered sample**: nitrate/nitrite and PO4

A summary of monitoring requirements and responsibilities is provided in Table 9-2.

Contingency action plan

A site specific contingency action plan with associated trigger values must be developed and presented in the local water management strategy. As a minimum, the contingency action plan must include communication with the Department of Water, Swan Rivers Trust, and the City of Swan as a priority action when trigger values are breached.

Table 9-2 Assessment requirements of development proposals–monitoring.

Responsible Agency	Timing	Monitoring Requirement
Developers	Period of 3 years pre-development (minimum of 18 months with at least 2 winters with approval of Department of Water)	Monitor key criteria for maintenance of hydrologic regimes, buffers and ecological corridors/linkages of environmental assets Monitor local superficial aquifer groundwater levels Monitor flow and water quality (including nutrients, TSS, and gross pollutants) at regular intervals (monthly) Monitor peak flows (snapshots) within developments and wetlands
	Period of 3 years post-development, including at least 1 year following completion of the majority (80%) of developments	Monitor key criteria for maintenance of hydrologic regimes, buffers and ecological corridors/linkages of environmental assets Monitor local superficial aquifer groundwater levels Monitor flow and water quality (including nutrients, TSS, and gross pollutants) at regular intervals (monthly) Monitor peak flows (snapshots) within developments and wetlands Monitor behavioural patterns with respect to non-structural measures for water quality management Monitor performance of new drainage systems
Department of Water	Ongoing	Monitor efficacy of water conservation measures and achievement of water consumption targets Monitor regional surface water flows and quality Monitor confined aquifer groundwater levels and regional superficial aquifer groundwater levels and quality Monitor groundwater abstraction in the DSP area Monitor surface water quality and flows at strategic locations in main drains and waterways Monitor structural BMPs for efficacy with advice from the BMP technical reference group Monitor performance of new drainage systems across catchments and property boundaries
DEC	Ongoing	Evaluate health of significant environmental assets

9.4 Action plan

Table 9-3 presents the key actions necessary to implement the *Drainage and water management plan*, identifying the responsible agency and proposed time for completion.

Table 9-3 Actions and responsibilities for implementation of the drainage and water management

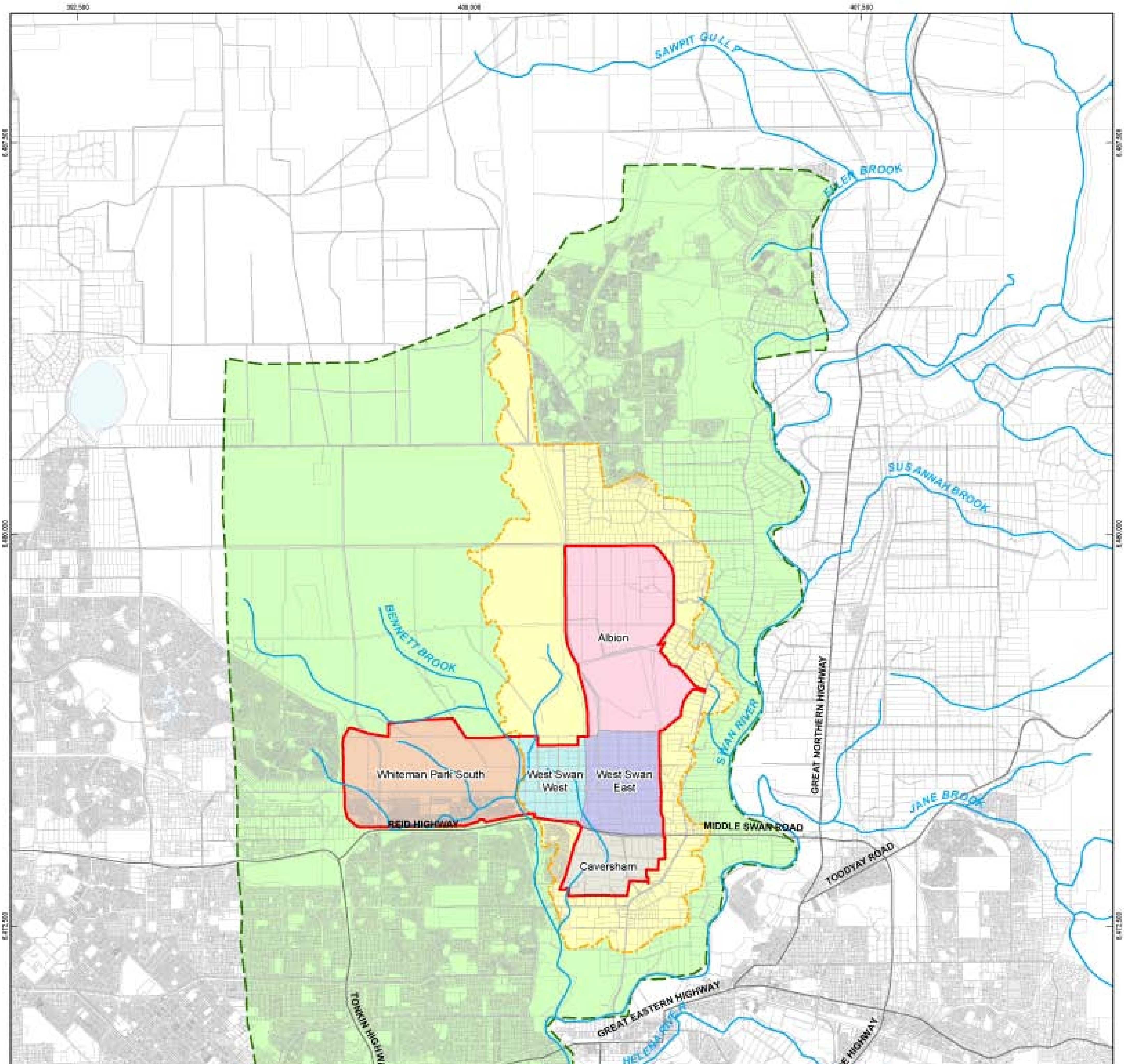
Strategy	Action	Lead Agency	Timing
Protection of environmental assets			
Minimise changes to hydrology to prevent impacts on watercourses and wetlands	Establish a process for ongoing evaluation of the impacts of development on significant environmental assets and review of the strategy	DEC	
	Identify land required for protection of environmental assets and to allow for the management of their hydrologic regimes	DEC	
	Incorporate environmental assets as a key part of community planning	DPI and City of Swan	Through assessment of planning proposals
Manage and restore watercourses and wetlands	Determine post-development hydrology for the Bennett Brook and St Leonards Creek	Department of Water	
Assess and manage impacts on native flora and fauna	Provide appropriate buffers and ecological corridors/linkages in Local Structure Plans	WAPC and City of Swan	Through assessment of planning proposals
	Establish responsibilities for ongoing management of natural areas	DEC and City of Swan	As part of the planning process
	Undertake more detailed fauna assessments at the Local Structure Plan stage, including details of management measures to deal with issues such as habitat protection, fauna relocation and non-native animal control	WAPC and City of Swan	Through assessment of planning proposals
Surface water management			
Minimise changes in hydrology to prevent impacts on receiving environments	Ensure development complies with the stormwater design objectives for flooding and ecological protection	Department of Water	Through assessment of water management strategies/ plans
Manage surface water flows from major events to protect infrastructure and assets	Ensure development in the DWMP area complies with the stormwater design criteria for flood management in this Drainage and water management plan	City of Swan, Department of Water and WAPC	Through assessment of water management strategies/ plans
	Develop and Implement flood management/response/recovery plans	City of Swan	As part of the planning process

Strategy	Action	Lead Agency	Timing
	Secure land that might be required for arterial drainage in Swan urban growth corridor	WAPC and City of Swan	Through Local Structure Planning
	Design and construct modified drainage within and associated with development cells	Developers and City of Swan where modifications on boundaries are required	Through local water management strategies
Apply the principles of Water Sensitive Urban Design	Seek opportunities to include environmental and social objectives in planning of stormwater management, such as incorporation of multiple use corridors to provide habitat values and opportunities for recreation	City of Swan	Through assessment of Local Structure Plans
	Retain existing natural waterways and drainage lines in the design of stormwater management systems for urban development	City of Swan, Department of Water and WAPC	Through assessment of water management strategies/ plans
Adopt nutrient load reduction design objectives for stormwater runoff	Ensure development in the DWMP area complies with the design objectives for stormwater quality	City of Swan, Department of Water and WAPC	Through assessment of water management strategies/ plans
Groundwater management			
Manage groundwater levels to protect infrastructure and assets	Monitor superficial aquifer groundwater levels pre and post-development at the local scale	Developers, data to be passed by City of Swan to Department of Water for collation	3 years pre- and 5 years post-development
	Monitor confined aquifer groundwater levels and regional superficial aquifer groundwater levels	Department of Water	Commencing immediately & ongoing
	Investigate potential changes to local water balance and implications for groundwater rise	Department of Water	Through assessment of water management strategies/ plans
	Manage groundwater levels within ranges reported in this DWMP via a combination of subsoil drainage, imported fill and groundwater abstraction as appropriate for management of groundwater rise, and via recharge mechanisms for falling groundwater levels	Developers for 5 years post-development, after that time responsibility of City of Swan	Commencing immediately & ongoing
Maintain groundwater regimes for groundwater dependent ecosystems	Review developers investigations of local groundwater regime to establish local groundwater management criteria near GDEs	Department of Water	Through assessment of water management strategies/ plans
Protect the value of groundwater resources	Prepare a groundwater allocation plan for the DWMP area	Department of Water	
Adopt nutrient load reduction design objectives for discharges to groundwater	Ensure development in the DWMP area complies with the design objectives for groundwater quality	Department of Water	Through assessment of water management strategies/ plans

Strategy	Action	Lead Agency	Timing
	Monitoring & implementation		
Adopt an adaptive management approach	Develop and implement contingency action plans with associated trigger values for surface and groundwater	Developers within Local water management strategies	Commencing immediately and ongoing
	Monitor water quality and flows pre- and post-development, both within developments and at strategic locations in waterways This includes both regular (monthly) sampling for flow and water quality and targeted peak flow during storm events Locations to include key outlets to waterways	At the local scale: developers then Water Corporation within main drainage areas and Department of Water; At the regional scale (subcatchment outlets): Water Corporation within main drainage areas and Department of Water	3 years pre- and 5 years post-development, then ongoing
	Collate and analyse monitoring data to establish baseline water quality data throughout DWMP area	Developer to pass data to Department of Water, Department of Water to collate and organise data, CSIRO's real-time data collection system to support data analysis	Commencing immediately and ongoing
	Assess behavioural patterns with respect to non-structural measures and the effectiveness of these measures, using a method such as Community Based Social Marketing	Developer to implement with guidance from Local Government, Department of Water to take over responsibility 5 years post-development	Ongoing
	Determine efficacy of structural best management practices (BMPs), provide feedback to developers and allow for alteration of practices if necessary	Department of Water with advice from the BMP Technical Reference Group	Ongoing
	Engage the research community in the process of evaluation and feedback	Department of Water with advice from the BMP Technical Reference Group	Ongoing
	Urban water use		
Adopt household consumption targets	Ensure that residential development complies with consumption targets: Less than 100kL/person/yr Less than 40–60kL/person/yr scheme water	Department of Water	Through assessment of water management strategies/ plans
	Ensure scheme water substitution does not lead to an overall increase in water consumption	Department of Water	Through assessment of water management strategies/ plans
Ensure that non-potable water supply systems deliver a net benefit to the community	The impact of a non-potable water supply system on the local water balance must be assessed as part of the Local water management strategy	Department of Water	Through assessment of water management strategies/ plans
	The design of a non-potable water supply system must be subject to a sustainability assessment as part of the Local water management strategy to determine the net benefit or cost of the scheme	Department of Water	Through assessment of water management strategies/ plans

Strategy	Action	Lead Agency	Timing
Ensure that non-potable water supply systems are designed as part of an integrated water supply	Non-potable water supply systems must be designed in conjunction with potable water supply systems, to ensure that fire fighting requirements can be met from one or both of the systems and that both systems are designed for efficiency (e.g. minimising pipe sizes and pumping requirements where possible)	Department of Water	Through assessment of water management strategies/ plans
	Reach agreement between the developer, LGA and licensed service provider (e.g. Water Corporation) on the design, operation and management of a non-potable water supply system, including arrangements for use in public open space and appropriate level of water quality, to ensure that all water demands are met appropriately	Department of Water	Through assessment of water management strategies/ plans

10 Figures



LEGEND

Swan Urban Growth Corridor DWMP Study Area - GHD-20080212

Groundwater Model Area - GHD - 20081801

Surface Water Model Area - GHD - 20081102

1:75,000

0 375 750 1,500 2,250 3,000

Metres (at A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 50

N

Government of Western Australia
Department of Water

Department of Water
Swan Urban Growth Corridor -
Drainage and Water Management Plan

Location Plan

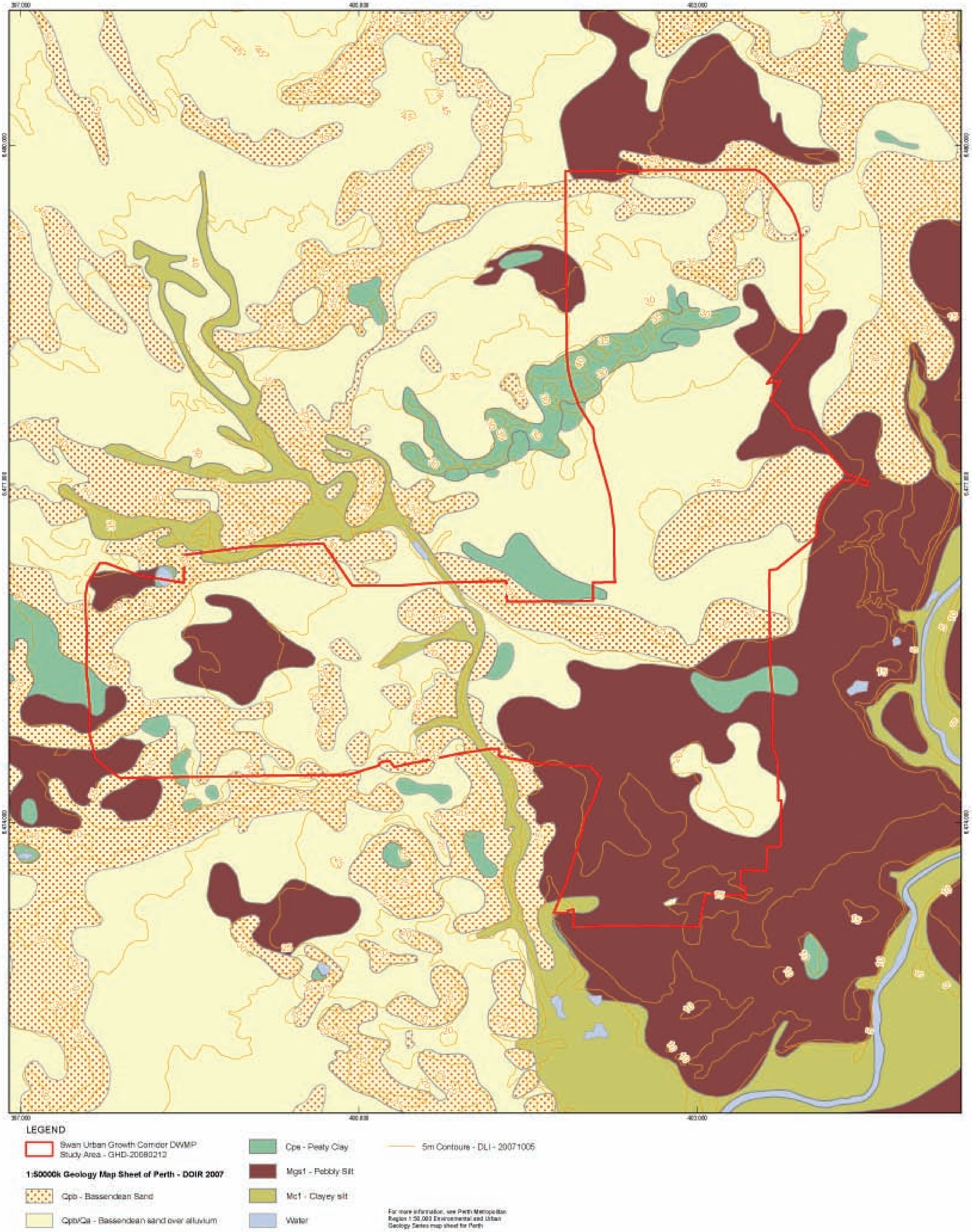
Job Number	6121416
Revision	2
Date	2 September 2008

Figure 10.1

G:\61\21416\GIS\maps\6121416-G1_rev2.mxd

239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

Note that positional errors can be > 5m in some areas. Dataset names include published date where available. Base data sourced from Geoscience Australia Topo 250k Series 3 Topographic Data, July 2004. Created by: W Davis



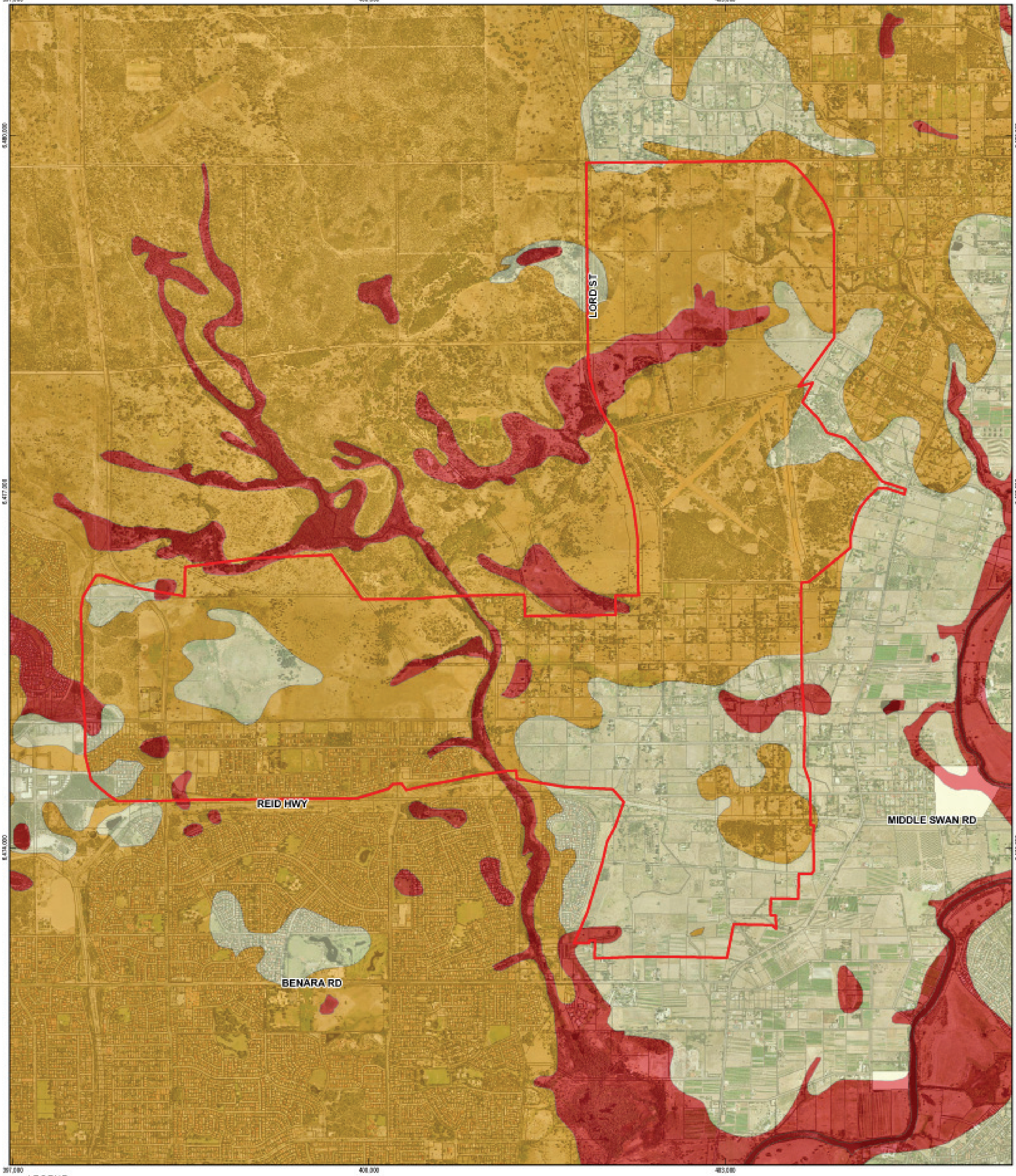
Department of Water
Swan Urban Growth Corridor -
Drainage and Water Management Plan

Topography & Geology

Job Number	6121416
Revision	1
Date	2 September 2008

Figure 10.2

239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au



LEGEND

Acid Sulfate Soil Risk - DEC - 2007

- High to moderate ASS disturbance risk (<3m from surface)
- Moderate to low ASS disturbance risk (<3m from surface)
- No known ASS disturbance risk (<3m from surface)
- Swan Urban Growth Corridor DWMP Study Area - GHD-20080212
- Cadastre - DLI 2007

1:30,000

0 150 300 600 900 1,200

Metres (at A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 50

N

Government of Western Australia
Department of Water

Department of Water
Swan Urban Growth Corridor -
Drainage and Water Management Plan

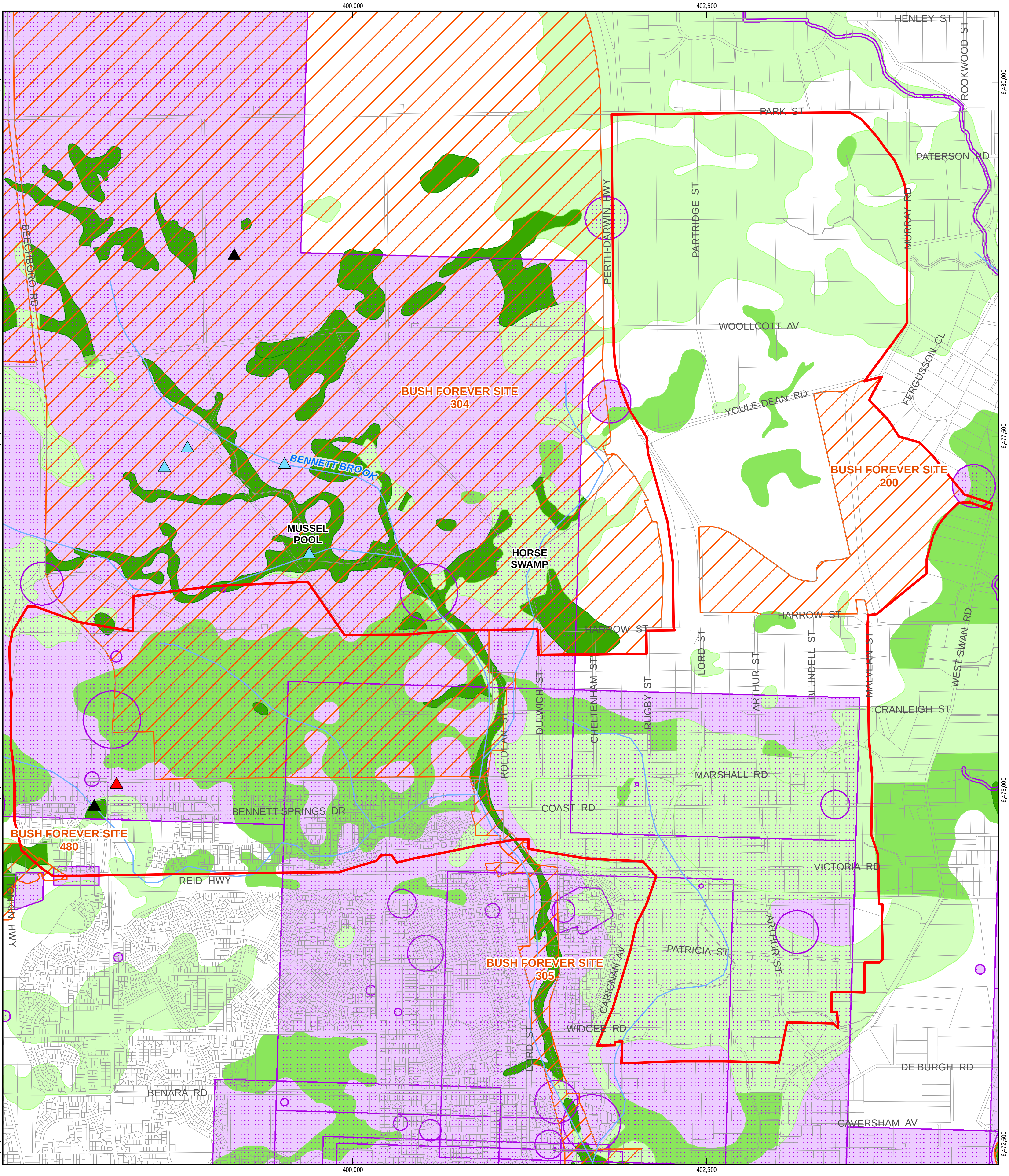
Acid Sulfate Soil Risk

Job Number	6121416
Revision	1
Date	2 September 2008

Figure 10.3

G:\61\21416\GIS\mxds\6121416-G3_rev1.mxd

239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au



LEGEND

- Swan Urban Growth Corridor DWMP Study Area - GHD-20080212
- Bush Forever Sites - DPI - 2000
- Aboriginal Heritage Sites - DIA - 200712

Declared Rare & Priority Species - DEC - 200706

- (R) Declared Rare Flora - Extant Taxa
- Priority 1 - Poorly Known Taxa
- Priority 2 - Poorly Known Taxa
- Priority 3 - Poorly Known Taxa
- Priority 4 - Rare Taxa

Geomorphic Wetlands - DEC - 200706

- Conservation
- Resource Enhancement
- Multiple Use

1:25,000

0 100 200 400 600 800 1,000

Metres (at A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 50

N

GHD

Government of Western Australia
Department of Water

Department of Water
Swan Urban Growth Corridor -
Drainage and Water Management Plan

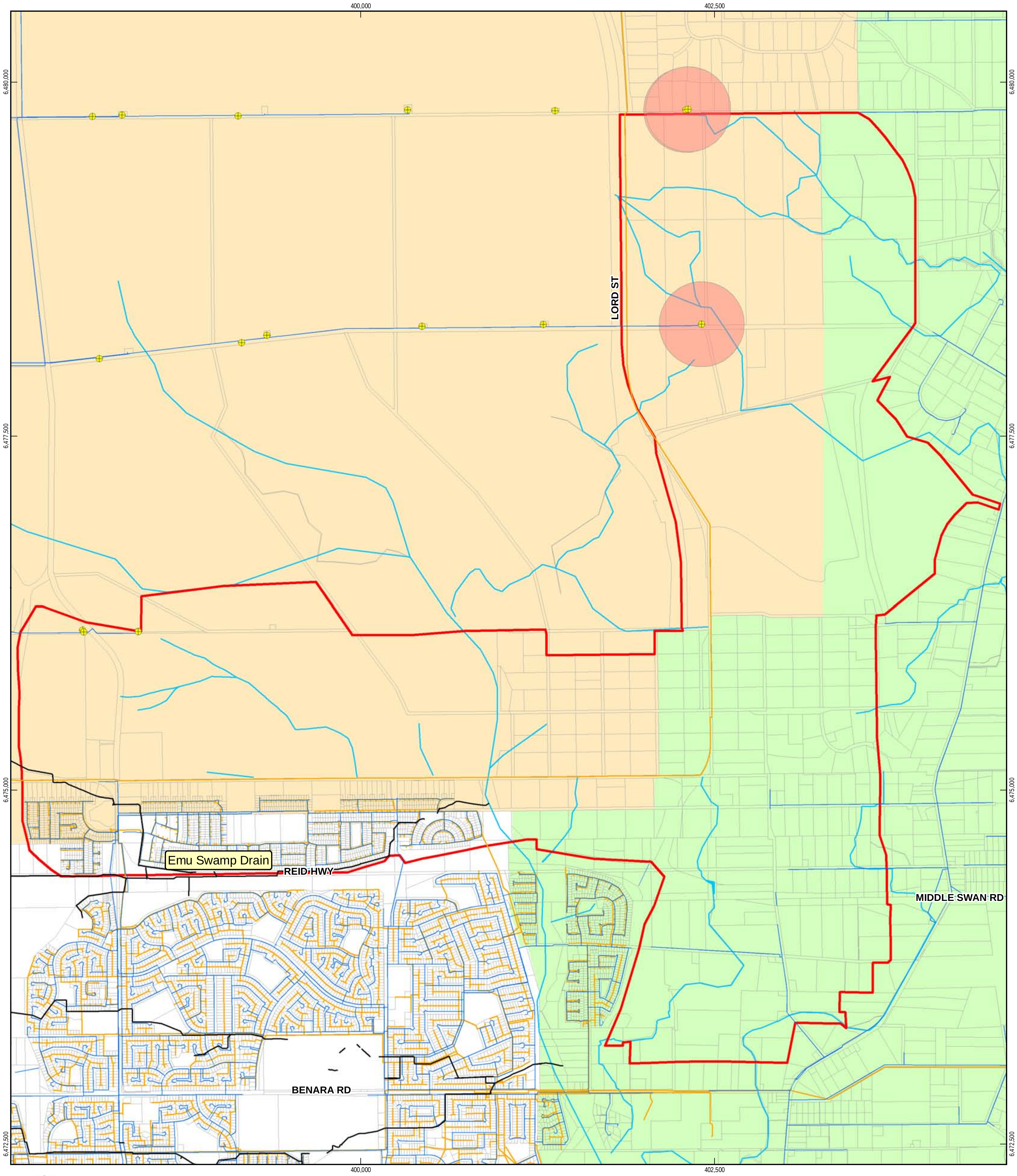
Job Number 6121416
Revision 0
Date 5 September 2008

Environmental and Social Considerations

Figure 10.4

G:\61\21416\GIS\mxds\6121416-G4_rev3.mxd

239 Adelaide Terrace Perth WA 6004 Australia **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au



LEGEND

Swan Urban Growth Corridor DWMP Study Area - GHD-20080212

Cadastre - Landgate - 2007

Watercourse Areas - GA - 2006

Water Corporation Infrastructure - WC - 2007

Water Source Location

Well Head Protection Zone

Water Main

Sewer

Drain

Groundwater Areas - DoW - 20080212

Mirrabooka

Swan

1:25,000

0 125 250 500 750 1,000 1,250

Metres (at A3)

N

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 50

Department of Water

Swan Urban Growth Corridor - Drainage and Water Management Plan

Existing Infrastructure

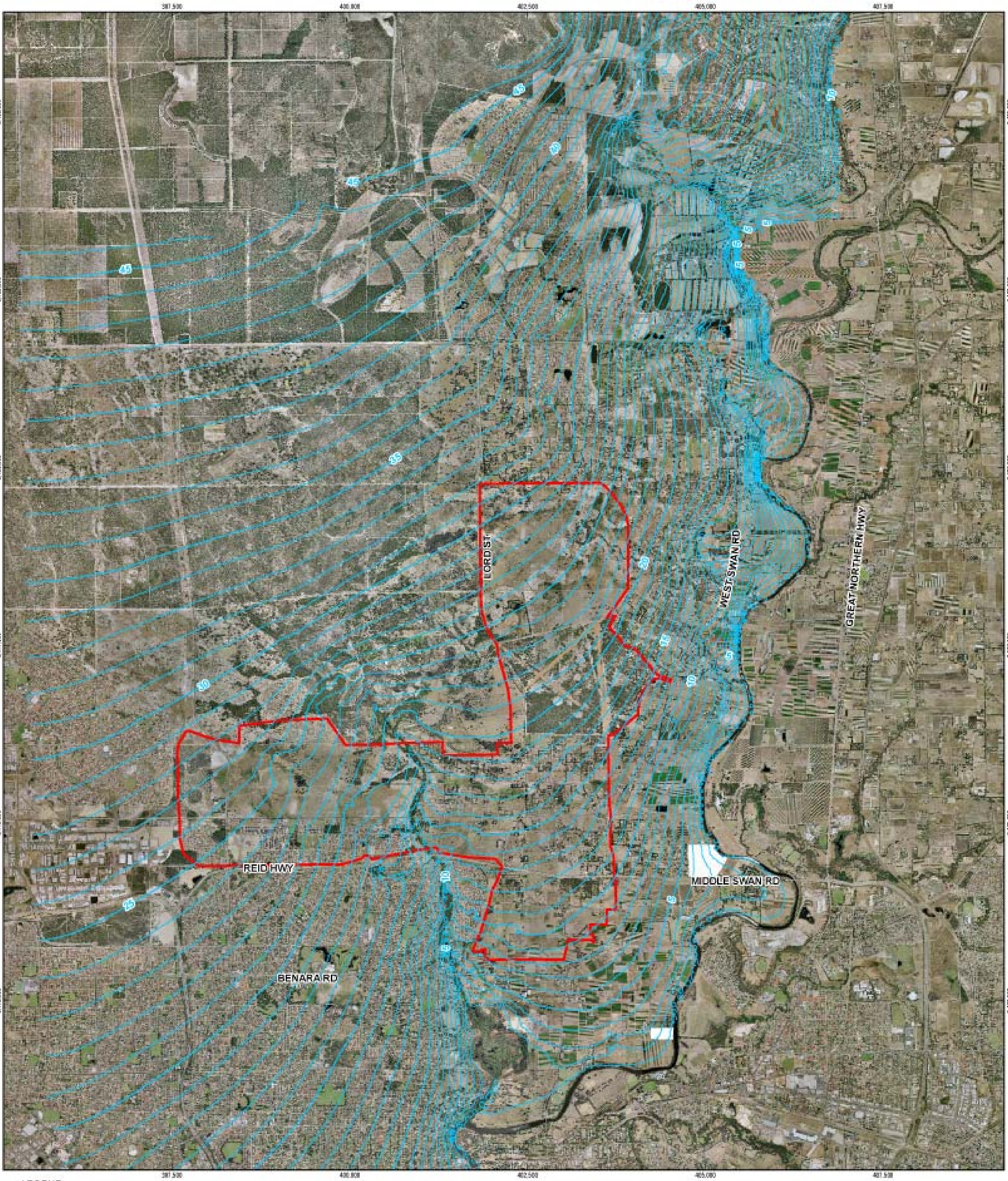
Job Number	6121416
Revision	2
Date	2 September 2008

Figure 10.5

G:\61\21416\GIS\mxds\6121416-G7_rev2.mxd

239 Adelaide Terrace Perth WA 6004 Australia **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

Note that positional errors can be > 5m in some areas Dataset names include published date where available. Created by: W Davis



LEGEND

Swan Urban Growth Corridor DWMP Study Area - GHD-20080212

Modelled Maximum Groundwater Level (AHD) - Current Climate - GHD - 1m contours - Date Unknown

1:50,000

0 250 500 1,000 1,500 2,000

Metres (at A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 50

GHD

Government of Western Australia Department of Water

Department of Water
Swan Urban Growth Corridor - Drainage and Water Management Plan

Modelled Current Climate Maximum Groundwater Level

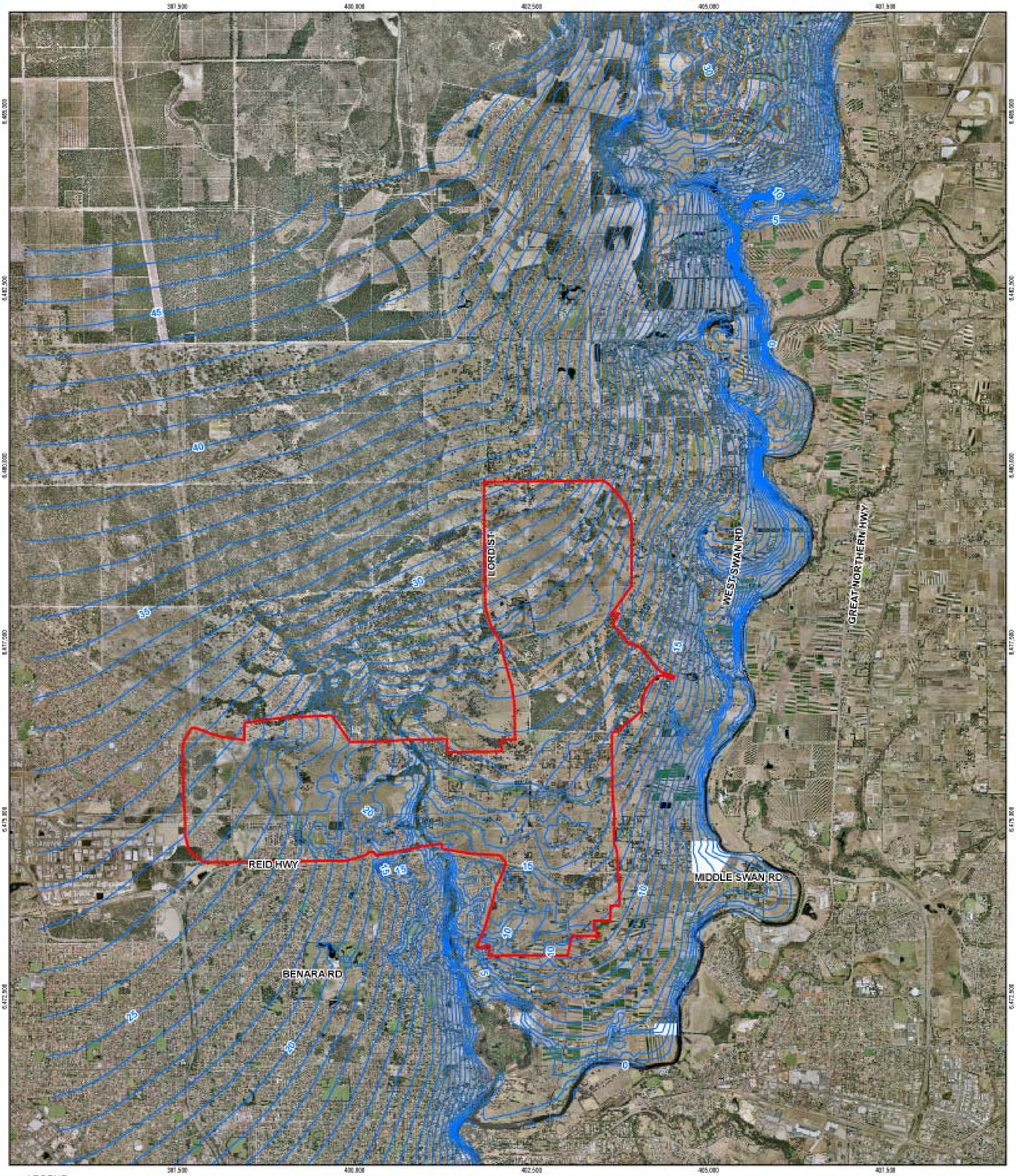
Job Number	6121416
Revision	1
Date	2 September 2008

Figure 10.6

G:\61\21416\GIS\mxds\6121416-G8_rev1.mxd

239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

Note that positional errors can be > 5m in some areas Dataset names include published date where available. Aerial Photography sourced from DoW dated 2007. Created by: W Davis



LEGEND

Swan Urban Growth Corridor DWMP
Study Area - GHD-20080212

Modelled Maximum Groundwater Level (AHD) -
Wet Climate - GHD - 1 m contours

1:50,000
0 250 500 1,000 1,500 2,000
Metres (at A3)
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 50

N

Government of Western Australia
Department of Water

Department of Water
Swan Urban Growth Corridor -
Drainage and Water Management Plan

Modelled Wet Climate Maximum Groundwater Level

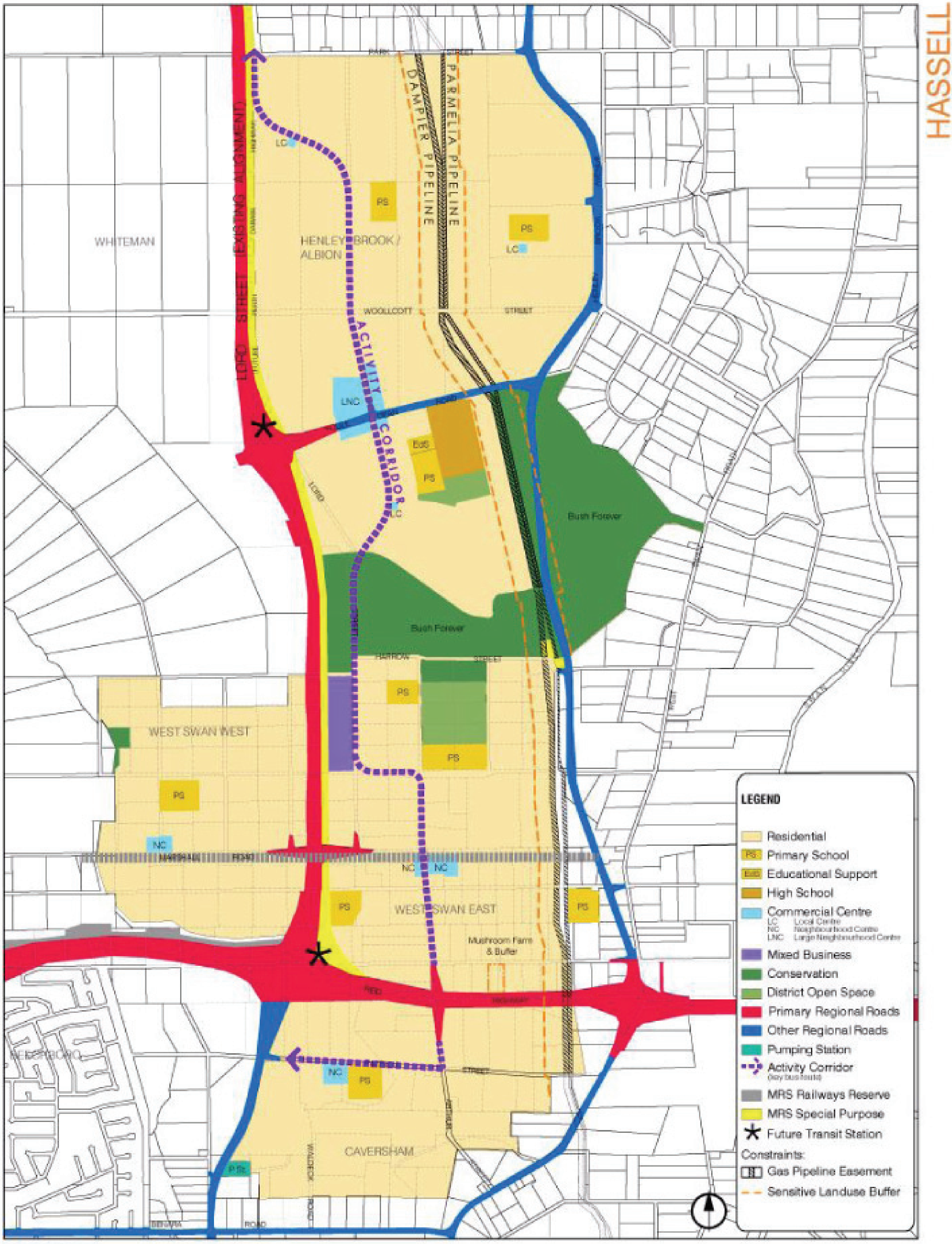
Job Number	6121416
Revision	0
Date	2 September 2008

Figure 10.7

G:\61\21416\GIS\mxds\6121416-G10_rev1.mxd

239 Adelaide Terrace Perth WA 6004 Australia **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

Note that positional errors can be > 5m in some areas Dataset names include published date where available. Aerial Photography sourced from DoW dated 2007. Created by: W Davis



NOT TO SCALE
JOB NO. PPP0167
APRIL 2008

SUB REGIONAL STRUCTURE PLAN FOR THE SWAN URBAN GROWTH CORRIDOR

HENLEY BROOK WEST SWAN CAVERSHAM

Not To Scale

Government of Western Australia
Department of Water

Department of Water
Swan Urban Growth Corridor
Drainage and Water Management Plan

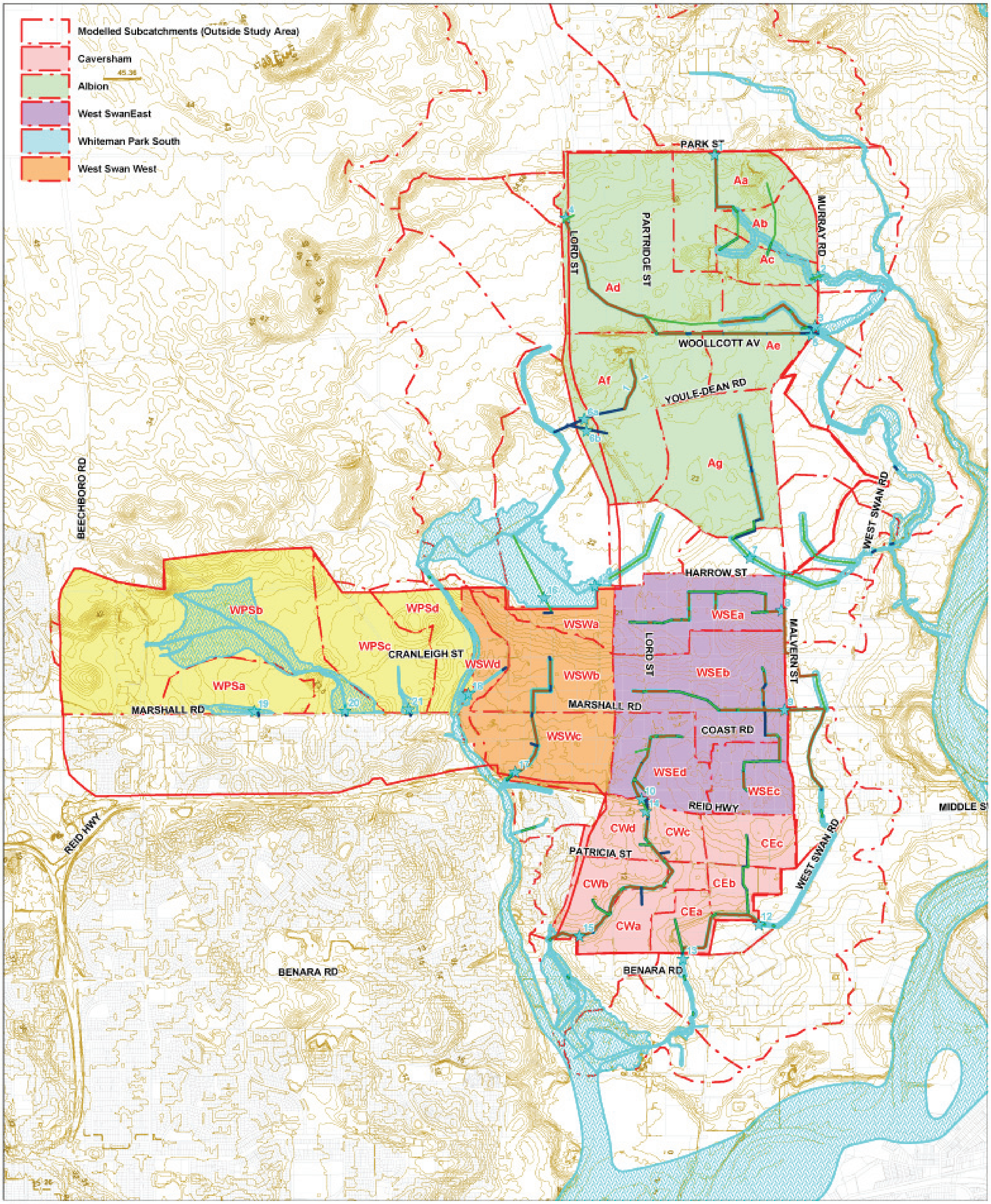
Proposed Development

Job Number	61-21416
Revision	A
Date	28 August 2008

Figure 10.8

239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

Note that positional errors can be ±5m in some areas. Data source: Sub Regional Plan sourced from WAPC 2008. Created by: H Brookes



LEGEND

- Swan Urban Growth Corridor DWMP Study Area
- Floodways (Incorporates Swan river Floodway DoW 2007)
- Modelled Main Waterways (Restored) see fig 10 for cross section
- Critical Flow and Level Locations (See Table 6.2)
- Modelled Swale Drains see fig 10 for cross section
- Modelled Piped Drains
- Modelled overland flow paths
- 1 m Contours - DLI - 20071005
- Modelled Subcatchments (see inset for colour key)

1:30,000 (at A3)

0 0.5 1

kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 50

GHD

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

Department of Water

Swan Urban Growth Corridor
Drainage and Water Management Plan

Job Number	61-21416
Revision	A
Date	28 August 2008

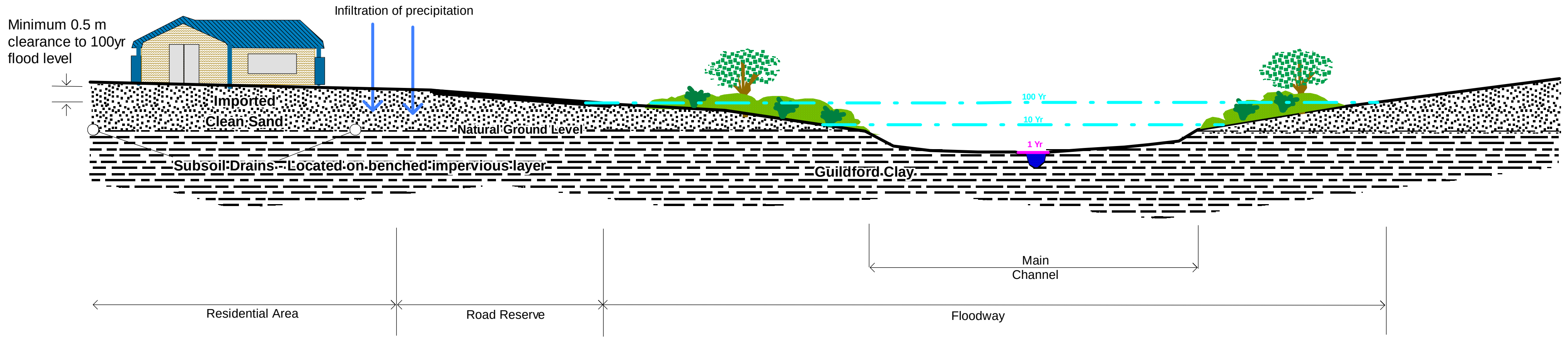
Stormwater Management Strategy

Figure 10.9

I:2\XX\XXX\GIS\MAPS\

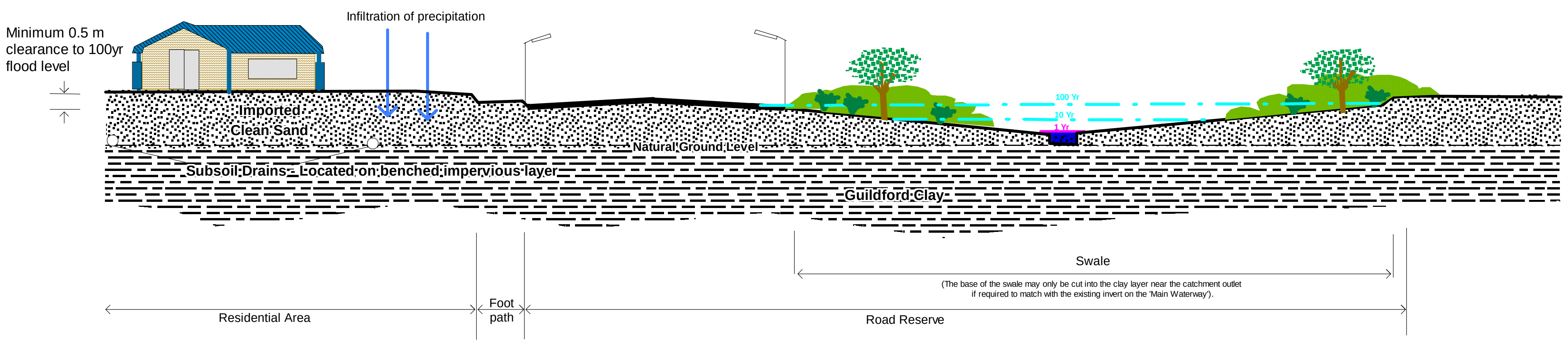
239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

Note that positional errors can be+5m in some areas. Dataset names include published date where available. Data source: Cadastre sourced from DLI 2007. Created by: H Brookes



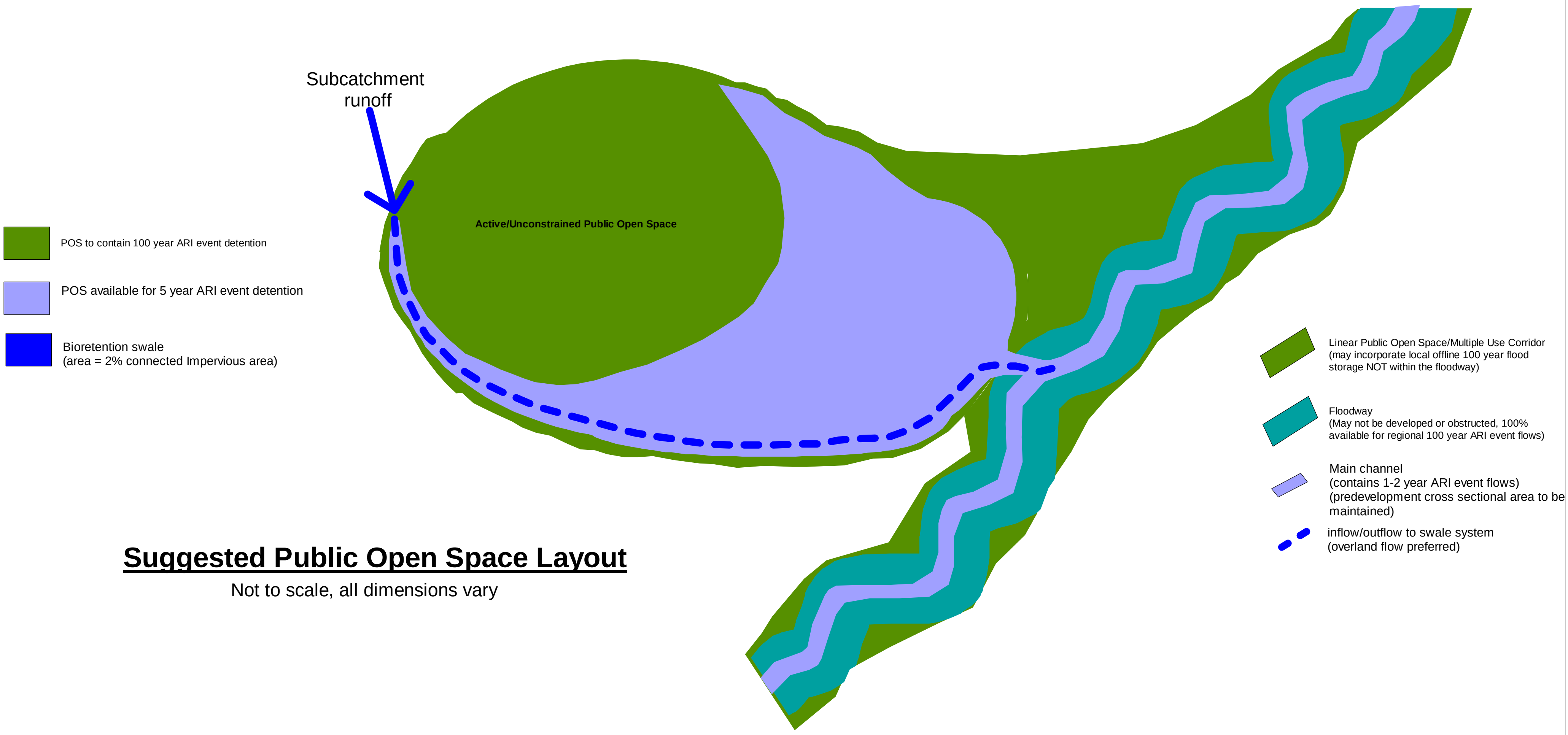
Main Waterway with Fill

Not to scale, all dimensions vary



Major Swale in Road Reserve with Fill

Not to scale, all dimensions vary



Suggested Public Open Space Layout

Not to scale, all dimensions vary

Not To Scale

Department of Water

Swan Urban Growth Corridor
Drainage and Water Management Plan

Job Number 61-21416
Revision A
Date 28 August 2008

Proposed Waterway Cross Sections

Figure 10.10

239 Adelaide Terrace Perth WA 6004 Australia **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

Created by: H Brookes

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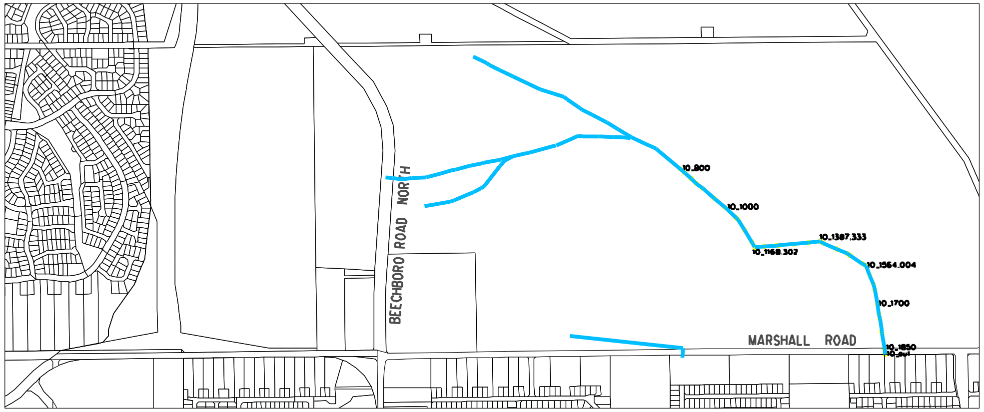
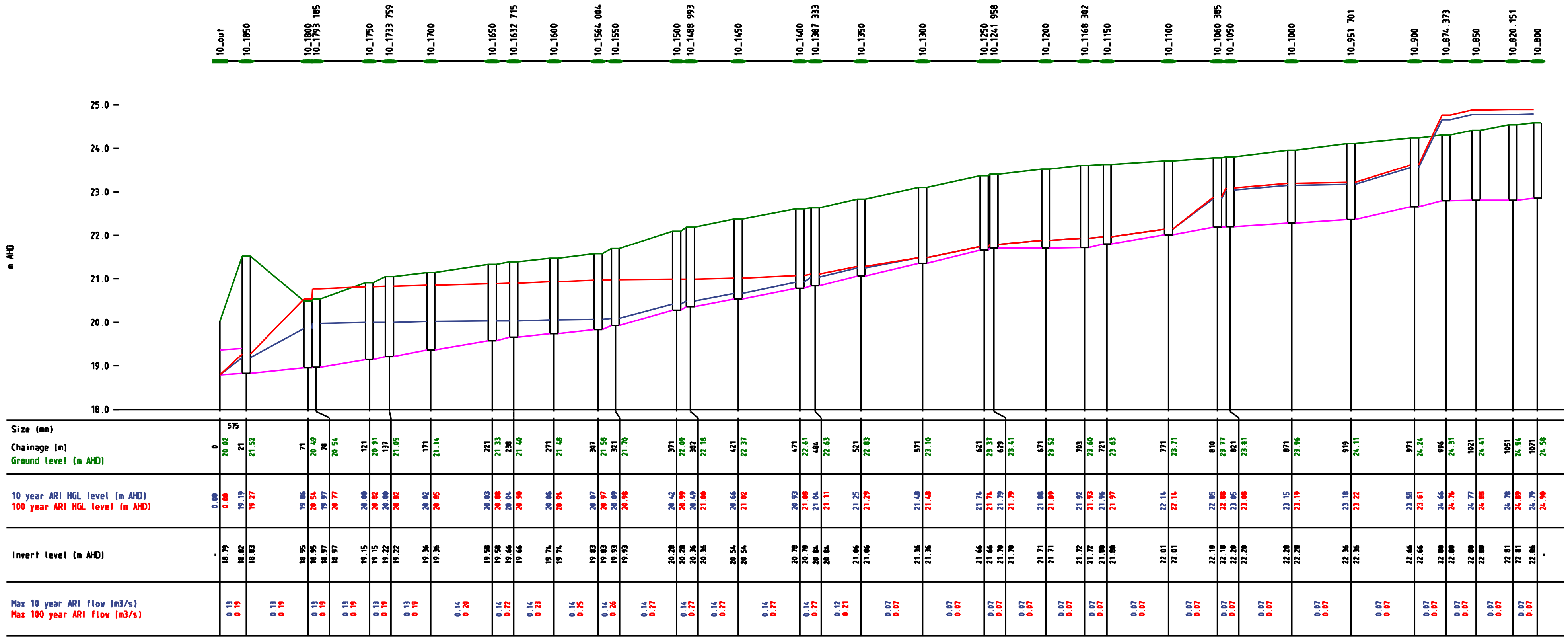




DESIGN FILE: Figure 10-11.1a Whiteman Park.dgn

AUTHOR: A Santos

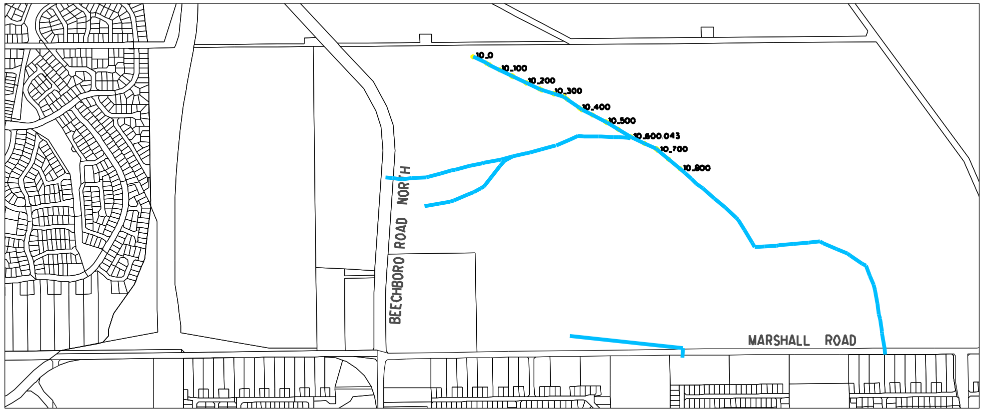
Government of Western Australia
Department of Water

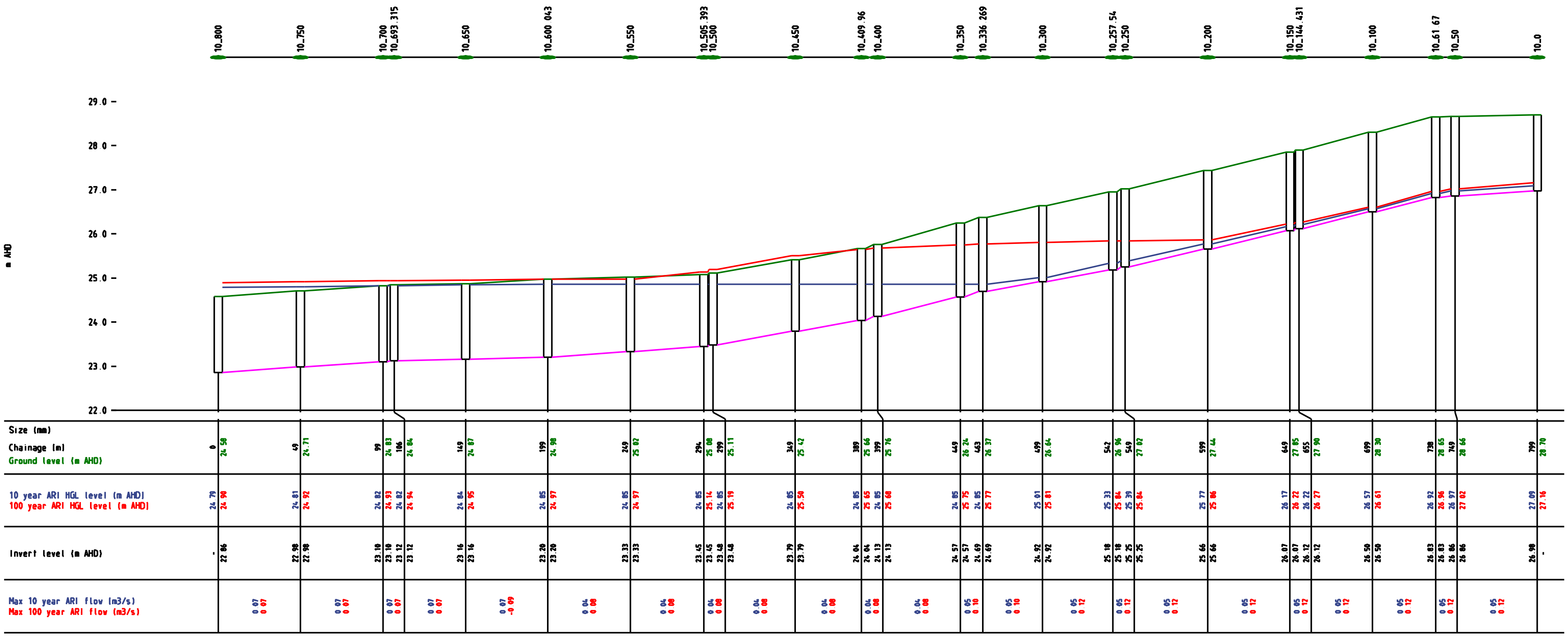
PROJECT N°: 6121416 DATE: 21/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

Whiteman Park South
Part 1 of 2

LONGITUDINAL SECTION
Existing System
Figure 10-11.1a-R

N





DESIGN FILE: Figure 10-11.1b Whiteman Park.dgn

AUTHOR: A Santos

Government of Western Australia
Department of Water

Whiteman Park South
Part 2 of 2

LONGITUDINAL SECTION
Existing System
Figure 10-11.1b-R

PROJECT N°: 6121416 DATE: 21/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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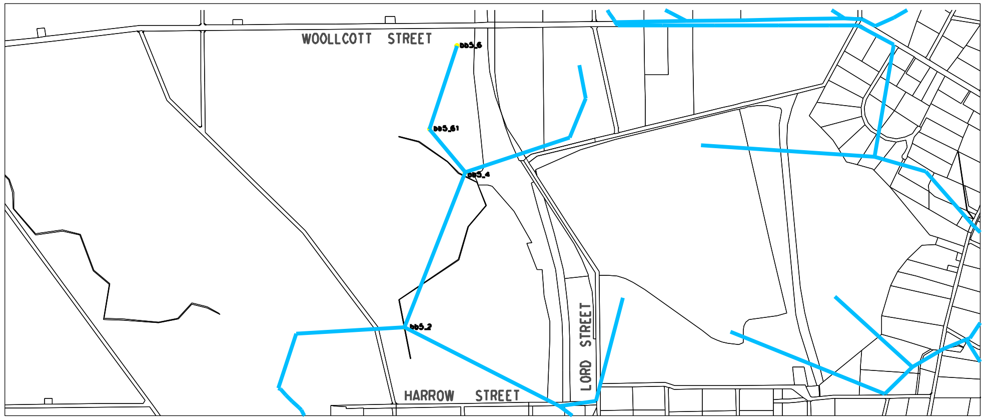
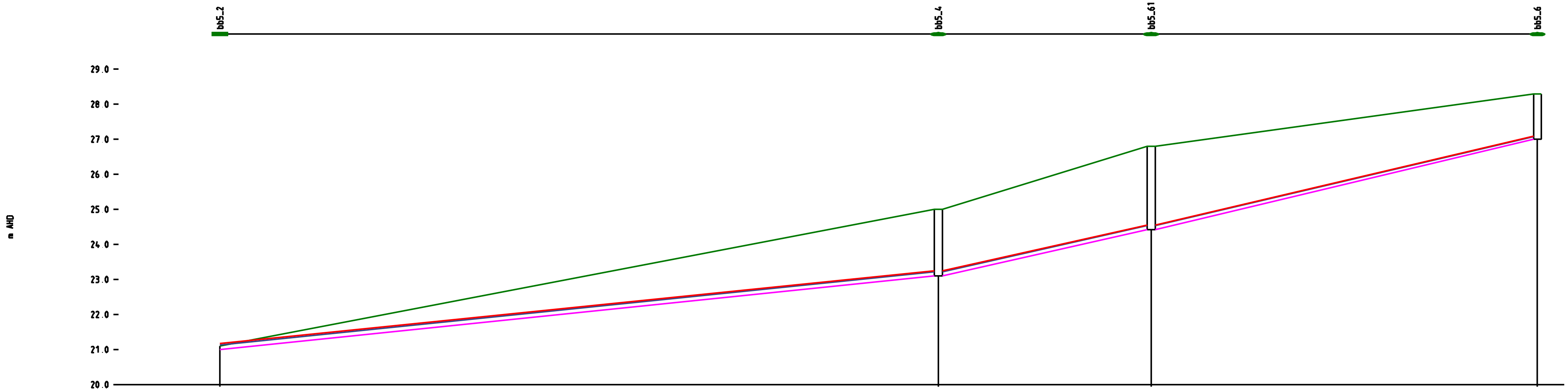
N





Size (mm)							
Chainage (m)	0		1120		1453		2056
Ground level (m AHD)	21.10		25.00		26.80		28.30
10 year ARI HGL level (m AHD)	21.13		23.22		24.53		27.07
100 year ARI HGL level (m AHD)	21.17		23.25		24.55		27.10
Invert level (m AHD)	- 21.00		23.10 23.10		24.42 24.42		27.00 -
Max 10 year ARI flow (m3/s)		0.13		0.13		0.13	
Max 100 year ARI flow (m3/s)		0.44		0.30		0.30	

DESIGN FILE: Figure 10-11.2 Horse Swamp.dgn

AUTHOR: A Santos

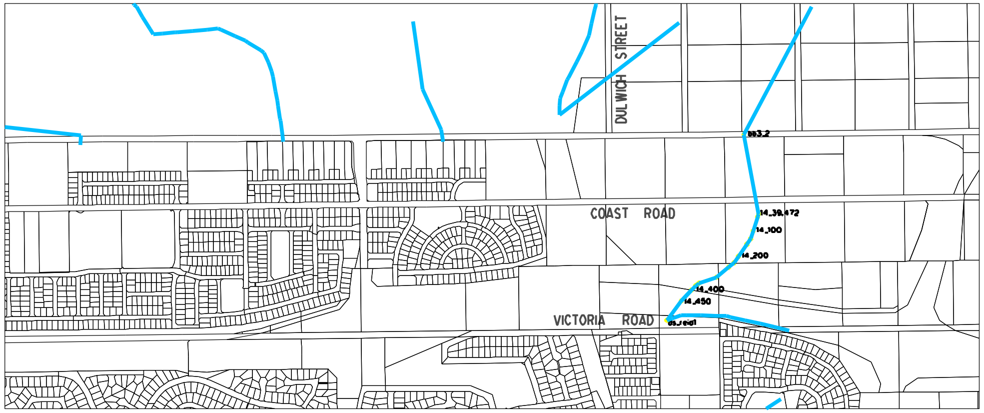
Government of Western Australia
Department of Water

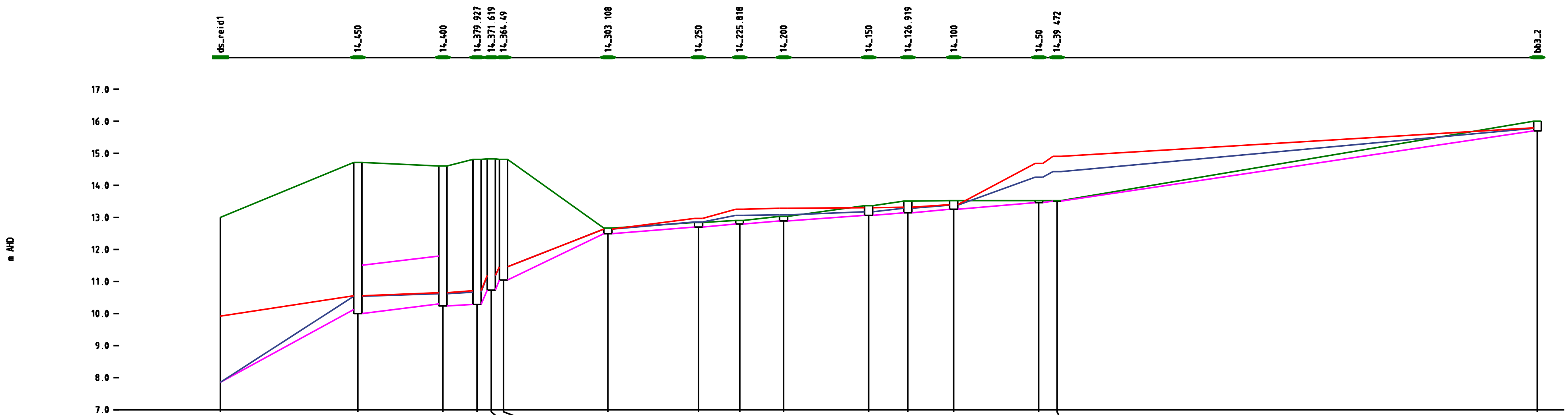
Horse Swamp
Part 1 of 1

LONGITUDINAL SECTION
Existing System
Figure 10-11.2-R

PROJECT N°: 6121416 DATE: 21/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

N





Size (mm): 1500 (14_450 to 14_400)

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)	
ds_reid1	0	13.00	0.00	9.92	-	7.86
14_450	80	14.72	10.53	10.56	10.12	10.00
14_400	130	14.60	10.62	10.65	10.30	10.23
14_379.927	150	14.81	10.67	10.71	10.28	10.28
14_371.619	159	14.82	11.18	11.18	10.73	10.73
14_364.49	166	14.82	11.45	11.46	11.05	11.05
14_303.108	277	12.67	12.63	12.64	12.50	12.50
14_250	288	12.84	12.86	12.97	12.70	12.70
14_225.818	304	12.90	13.06	13.26	12.80	12.80
14_200	330	13.03	13.08	13.30	12.89	12.89
14_150	380	13.38	13.18	13.30	13.06	13.06
14_126.919	403	13.51	13.29	13.32	13.14	13.14
14_100	430	13.53	13.38	13.40	13.26	13.26
14_50	480	13.52	14.26	14.69	13.47	13.47
14_39.472	491	13.52	14.43	14.91	13.51	13.51
bb3_2	773	16.00	15.78	15.81	15.70	-

Reach	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
ds_reid1 – 14_450	0.48	0.57
14_450 – 14_400	0.24	0.29
14_400 – 14_379.927	0.48	0.57
14_379.927 – 14_371.619	0.48	0.57
14_371.619 – 14_364.49	0.48	0.57
14_364.49 – 14_303.108	0.48	0.57
14_303.108 – 14_250	0.48	0.57
14_250 – 14_225.818	0.48	0.57
14_225.818 – 14_200	0.48	0.57
14_200 – 14_150	0.48	0.58
14_150 – 14_126.919	0.48	0.58
14_126.919 – 14_100	0.48	0.58
14_100 – 14_50	0.48	0.58
14_50 – 14_39.472	0.37	0.43
14_39.472 – bb3_2	0.36	0.42

DESIGN FILE: Figure 10-11.3 West Swan West.dgn

AUTHOR: A Santos

Government of Western Australia
Department of Water

West Swan to Bennett Brook
Part 1 of 1

LONGITUDINAL SECTION
Existing System
Figure 10-11.3-R

PROJECT N°: 6121416 DATE: 21/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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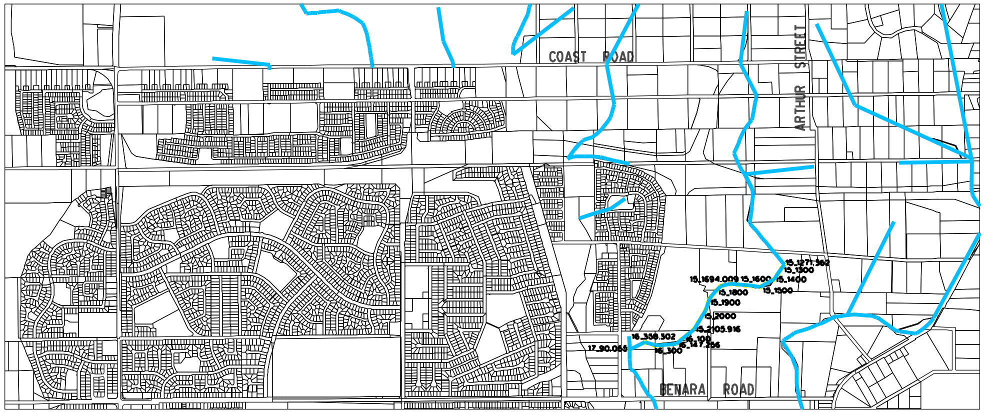
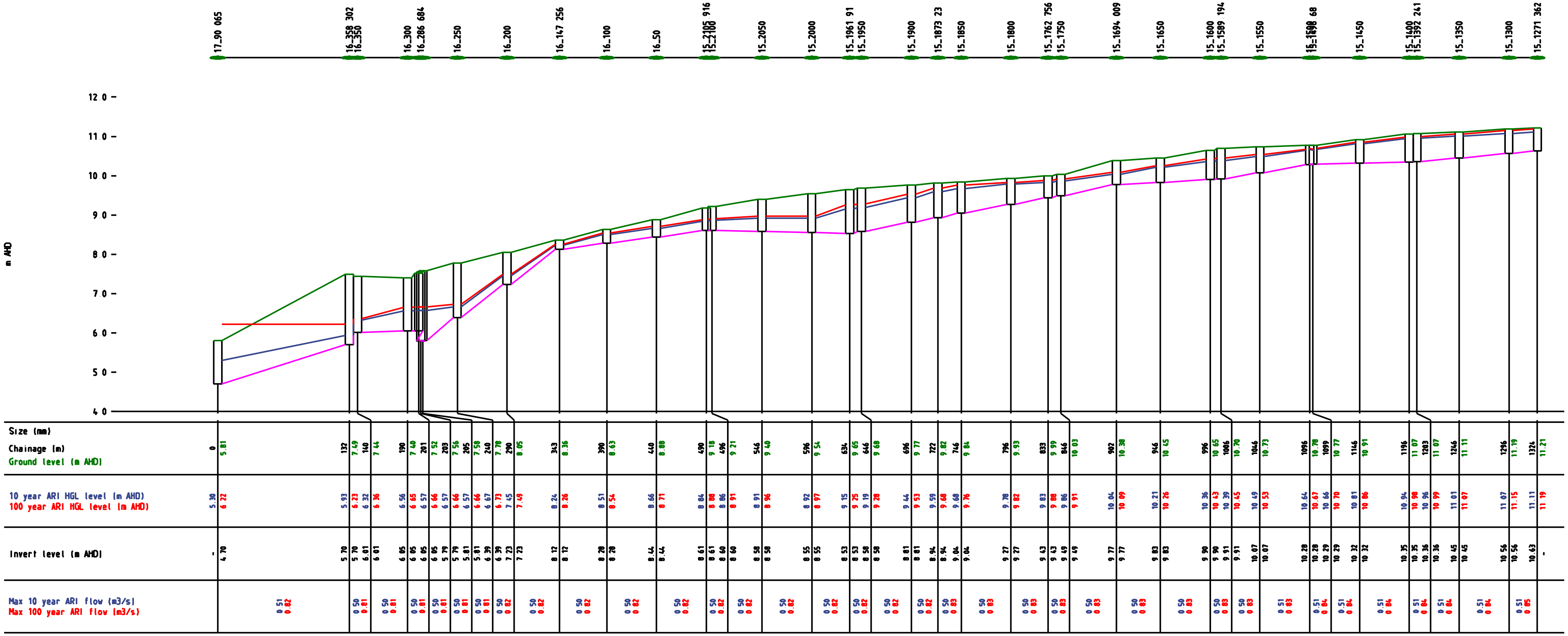
N





DESIGN FILE: Figure 10-11.4a West Swan East.dgn

AUTHOR: A Santos

Government of Western Australia
Department of Water

West Swan East and Caversham West to Bennet Brook
Part 1 of 2

LONGITUDINAL SECTION
Existing System
Figure 10-11.4a-R

PROJECT N°: 6121416 DATE: 21/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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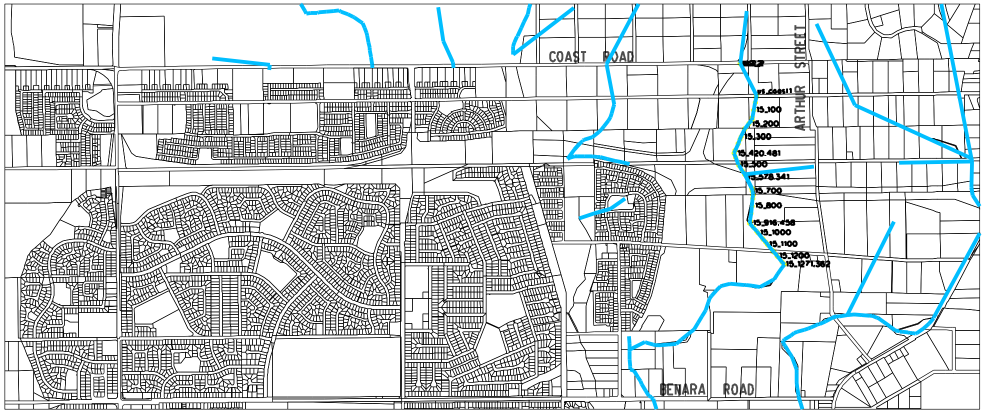

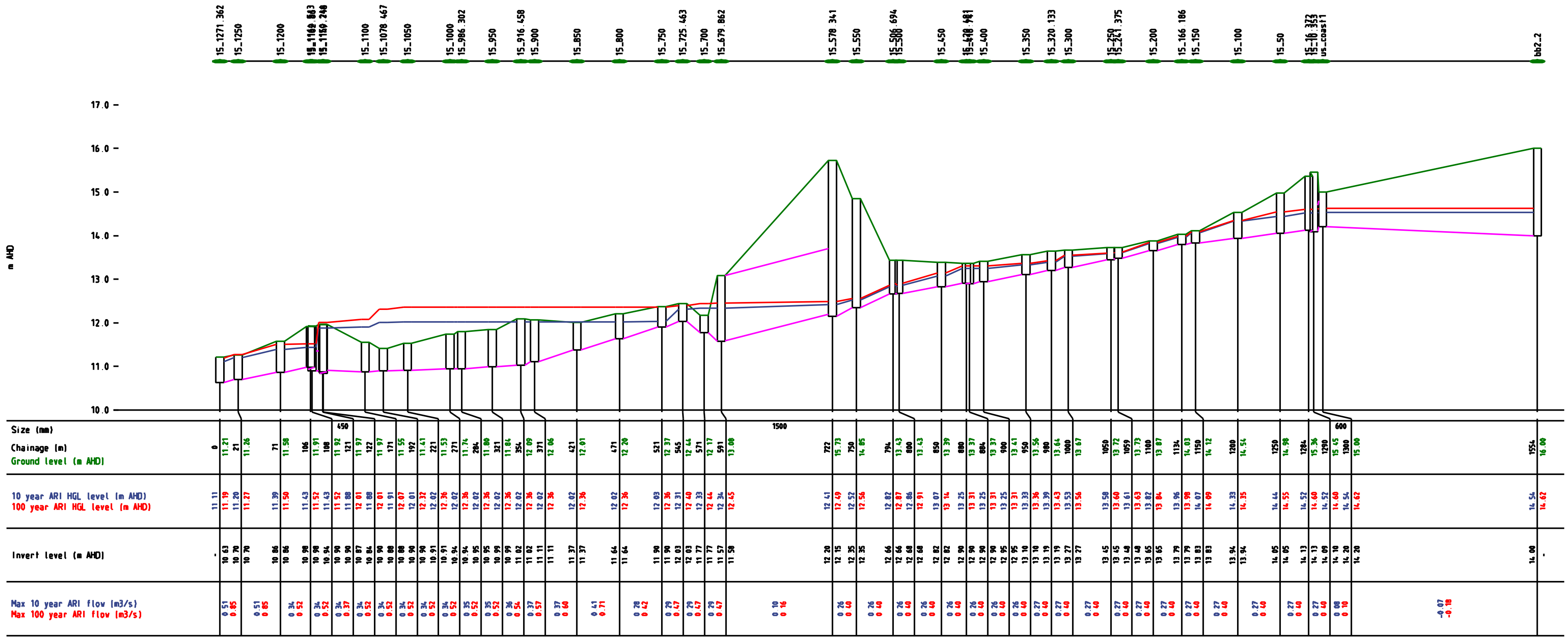

DESIGN FILE: Figure 10-11.4b West Swan East.dgn

AUTHOR: A Santos

Government of Western Australia
Department of Water

West Swan East and Caversham West to Bennet Brook
Part 2 of 2

LONGITUDINAL SECTION
Existing System
Figure 10-11.4b-R

PROJECT N°: 6121416 DATE: 21/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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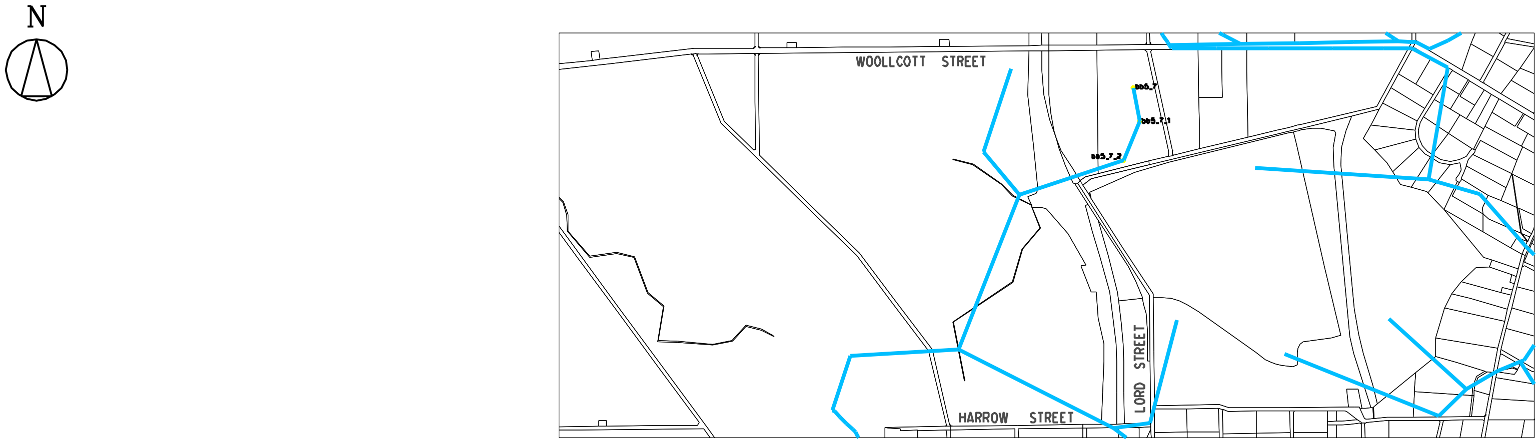

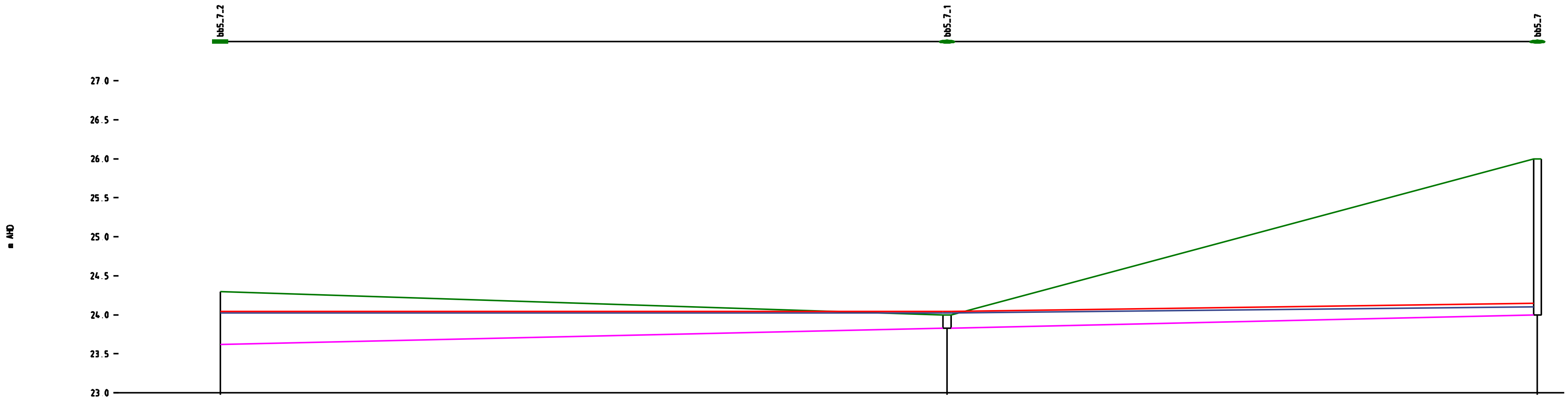

	bb5_7_2		bb5_7_1		bb5_7
Size (mm)					
Chainage (m)	0		239		434
Ground level (m AHD)	24.30		24.00		26.00
10 year ARI HGL level (m AHD)	24.02		24.03		24.10
100 year ARI HGL level (m AHD)	24.04		24.05		24.15
Invert level (m AHD)	- / 23.62		23.83 / 23.83		24.00 / -
Max 10 year ARI flow (m3/s)		0.13		0.18	
Max 100 year ARI flow (m3/s)		0.33		0.51	

DESIGN FILE: Figure 10-11.5 Albion.dgn

AUTHOR: A Santos

Government of Western Australia
Department of Water

Albion to Horse Swamp
Part 1 of 1

LONGITUDINAL SECTION
Existing System
Figure 10-11.5-R

PROJECT N°: 6121416 DATE: 21/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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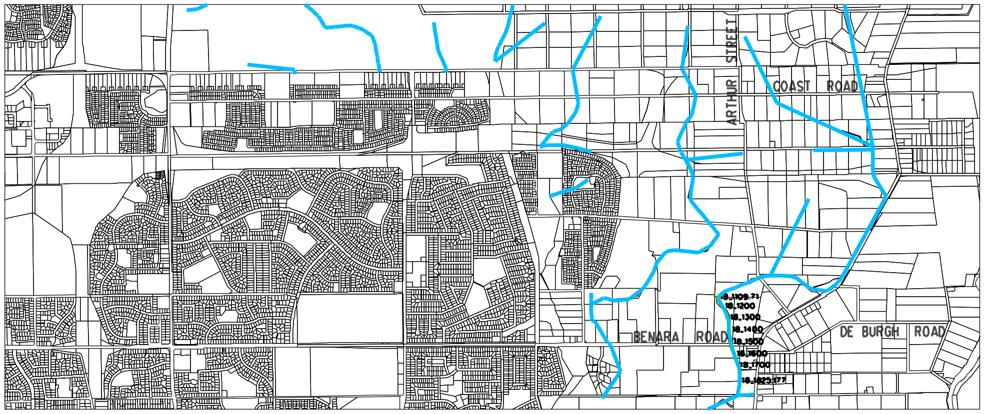
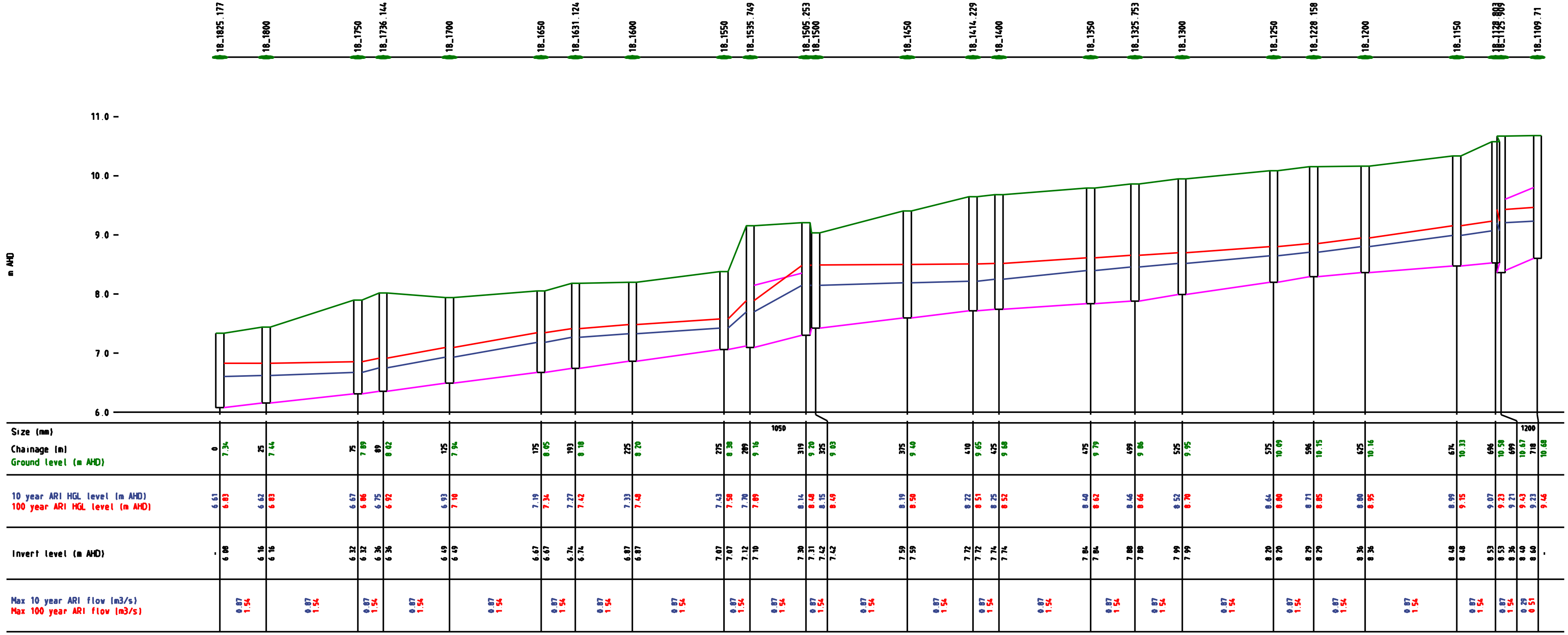
N





DESIGN FILE: Figure 10-11.6a West Swan East.dgn

AUTHOR: A Santos

Government of Western Australia
Department of Water

West Swan East and Caversham East to Bennet Brook
Part 1 of 3

LONGITUDINAL SECTION
Existing System
Figure 10-11.6a-R

PROJECT N°: 6121416 DATE: 21/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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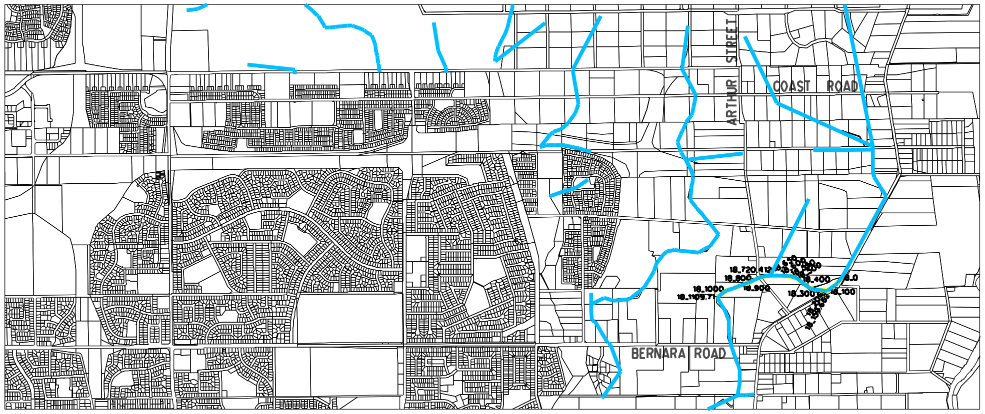
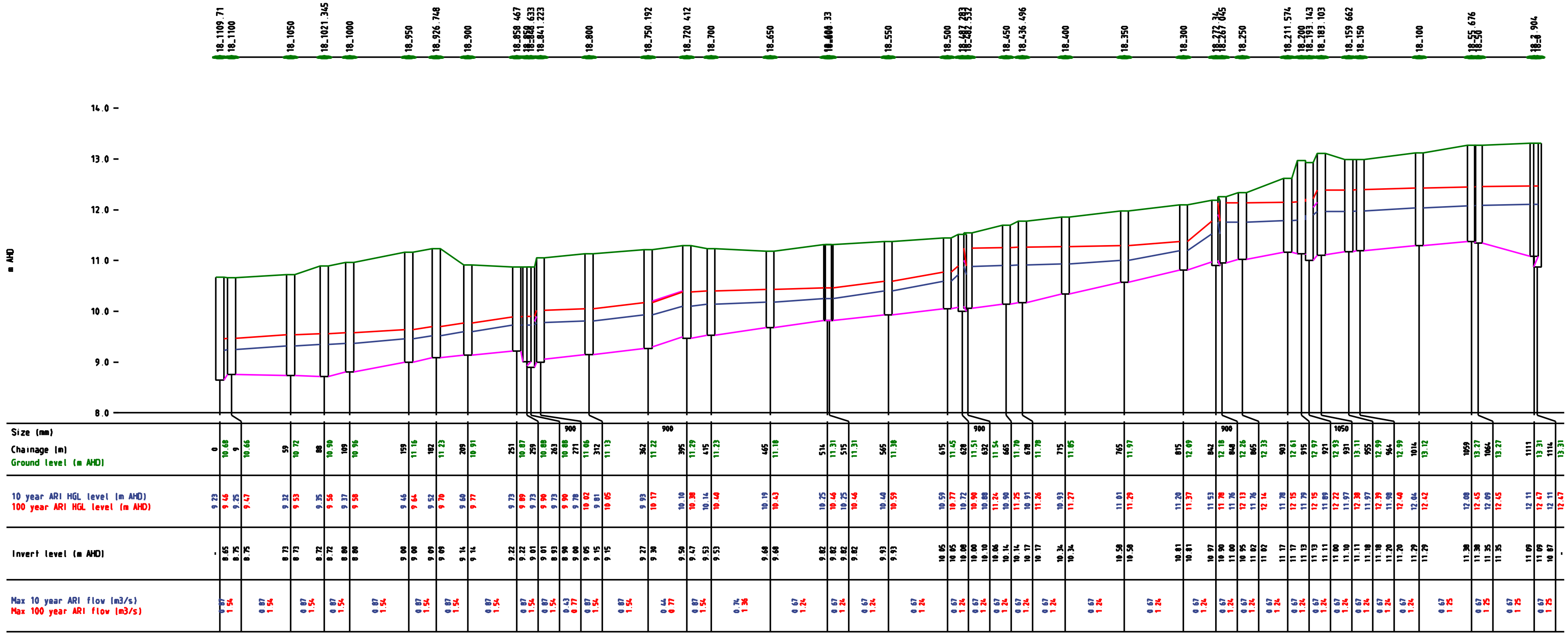
N





DESIGN FILE: Figure 10-11.6b West Swan East.dgn

AUTHOR: A Santos

Government of Western Australia
Department of Water

West Swan East and Caversham East to Bennet Brook
Part 2 of 3

LONGITUDINAL SECTION
Existing System
Figure 10-11.6b-R

6121416 DATE: 21/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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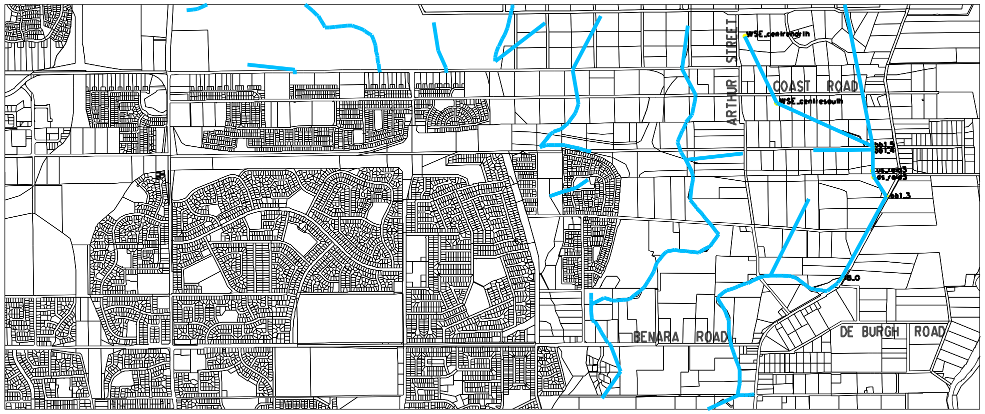
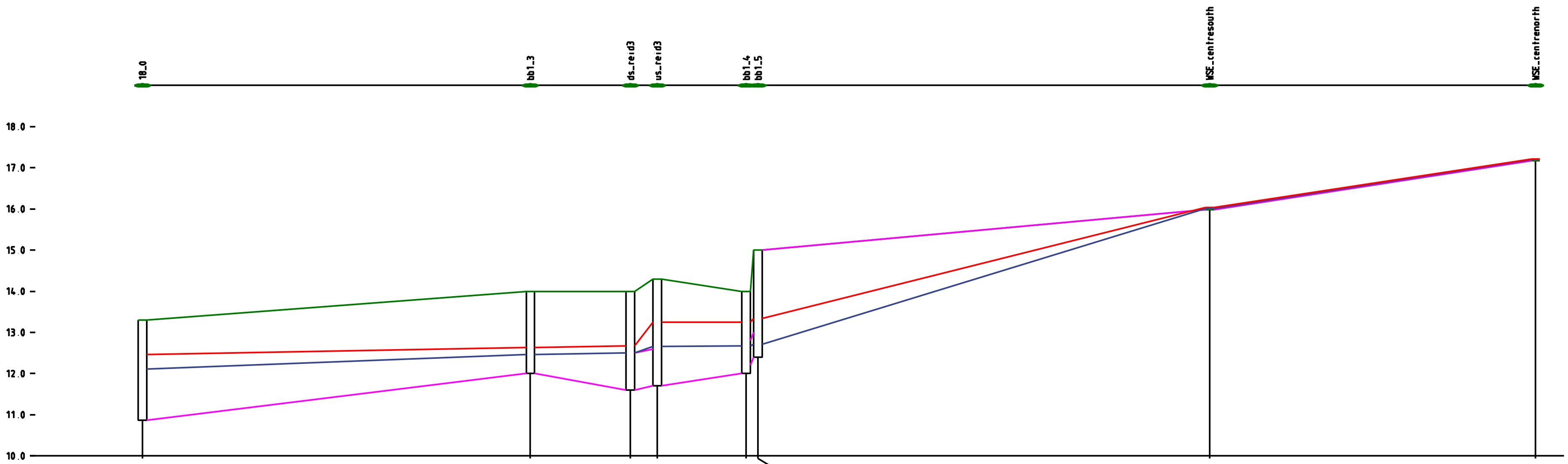




	18_0		bb1_3		ds_reid3		us_reid3		bb1_4		bb1_5		WSE_centresouth		WSE_centrenorth
Size (mm)						900				600		50000x300		50000x300	
Chainage (m)	0		753		947		999		1172		1195		2072		2706
Ground level (m AHD)	13.31		14.00		14.00		14.30		14.00		15.00		15.98		17.18
10 year ARI HGL level (m AHD)	12.11		12.47		12.50		12.65		12.67		12.71		16.02		17.20
100 year ARI HGL level (m AHD)	12.47		12.64		12.67		13.25		13.25		13.35		16.03		17.21
Invert level (m AHD)	- / 10.87		12.00 / 12.00		11.60 / 11.60		11.70 / 11.70		12.00 / 12.20		12.40 / 15.00		15.98 / 15.98		17.18 / -
Max 10 year ARI flow (m3/s)		0.60		0.64		0.64		0.50		0.18		0.13		0.04	
Max 100 year ARI flow (m3/s)		1.13		1.35		1.37		1.08		0.46		0.32		0.12	

DESIGN FILE: Figure 10-11.6c West Swan East.dgn

AUTHOR: A Santos

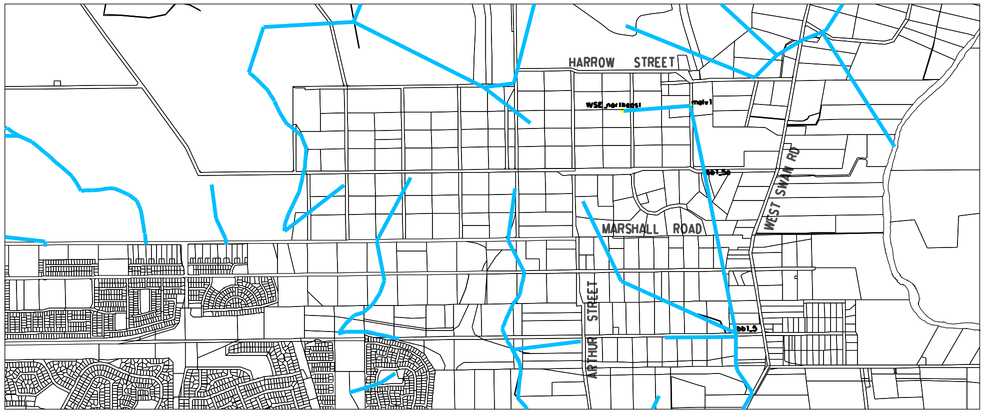
Government of Western Australia
Department of Water

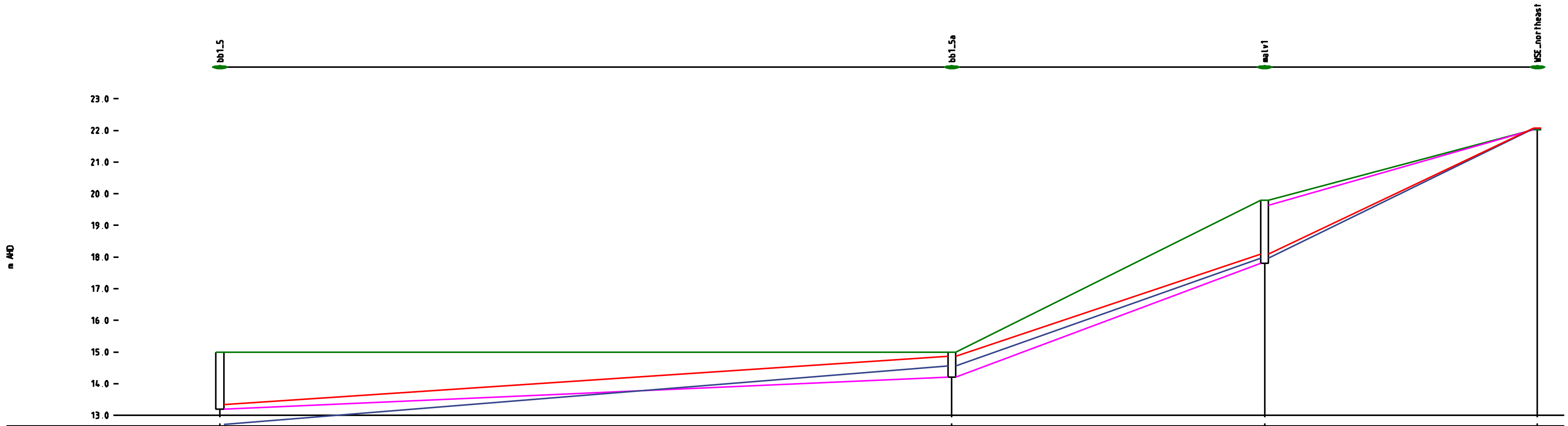
West Swan East and Caversham East to Bennet Brook
Part 3 of 3

LONGITUDINAL SECTION
Existing System
Figure 10-11.6c-R

PROJECT N°: 6121416 DATE: 21/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

N





	bb1_5		bb1_5a		malv1		WSE_northeast
Size (mm)		2000		2000		50000x300	
Chainage (m)	0		1220		1742		2197
Ground level (m AHD)	15.00		15.00		19.80		22.03
10 year ARI HGL level (m AHD)	12.71		14.56		17.96		22.06
100 year ARI HGL level (m AHD)	13.35		14.86		18.10		22.08
Invert level (m AHD)	- / 13.20		14.20 / 14.20		17.80 / 19.63		22.03 / -
Max 10 year ARI flow (m3/s)		0.24		0.10		0.10	
Max 100 year ARI flow (m3/s)		0.66		0.30		0.30	

DESIGN FILE: Figure 10-11.7 West Swan East.dgn

AUTHOR: A Santos

Government of Western Australia
Department of Water

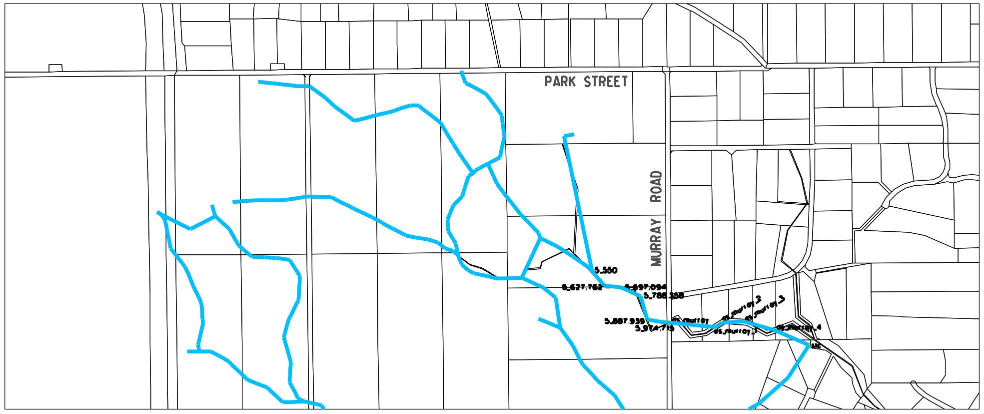
West Swan East to Bennet Brook
Part 1 of 1

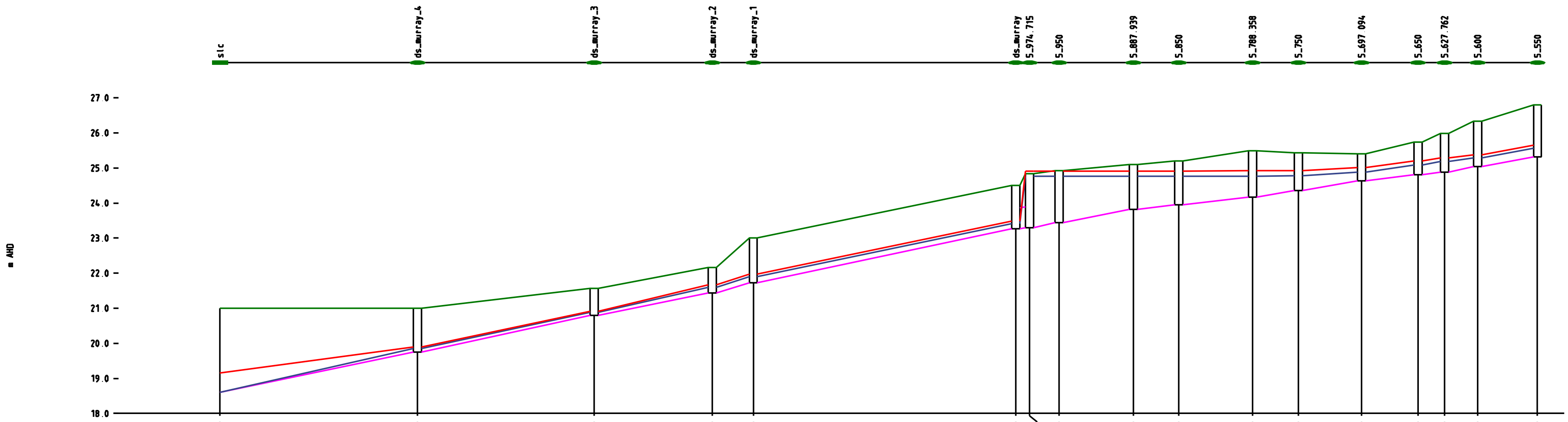
LONGITUDINAL SECTION
Existing System
Figure 10-11.7-R

PROJECT N°: 6121416 DATE: 21/05/2009 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





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	21.00	0.00	19.15	-	18.60
165	21.00	19.85	19.89	19.76	19.76
312	21.57	20.88	20.91	20.79	20.79
411	22.17	21.59	21.67	21.44	21.44
445	23.00	21.90	21.97	21.72	21.72
665	24.50	23.41	23.48	23.26	23.26
676	24.84	24.76	24.91	23.29	23.29
701	24.93	24.76	24.91	23.44	23.44
763	25.10	24.76	24.91	23.82	23.82
801	25.20	24.76	24.91	23.95	23.95
863	25.49	24.76	24.92	24.16	24.16
901	25.42	24.77	24.93	24.36	24.36
954	25.40	24.88	25.01	24.64	24.64
1001	25.73	25.08	25.19	24.80	24.80
1023	25.98	25.18	25.29	24.88	24.88
1051	26.32	25.29	25.38	25.03	25.03
1101	26.80	25.56	25.65	25.31	-

Reach (chainage, m)	Size (mm)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
0–165		1.05	2.38
165–312		1.05	2.38
312–411		1.05	2.38
411–445		1.05	2.38
445–665		1.05	2.38
665–676	600	0.91	0.98
676–701		0.91	2.05
701–763		0.92	2.05
763–801		0.93	2.05
801–863		0.94	2.05
863–901		0.95	2.05
901–954		0.96	2.05
954–1001		0.96	2.05
1001–1023		0.96	2.05
1023–1051		0.96	2.05
1051–1101		0.96	2.05

DESIGN FILE: Figure 10-11.8a Albion North.dgn

AUTHOR: A Santos

Government of Western Australia
Department of Water

Albion North to St Lenards Creek
Part 1 of 2

LONGITUDINAL SECTION
Existing System
Figure 10-11.8a-R

PROJECT N°: 6121416 DATE: 21/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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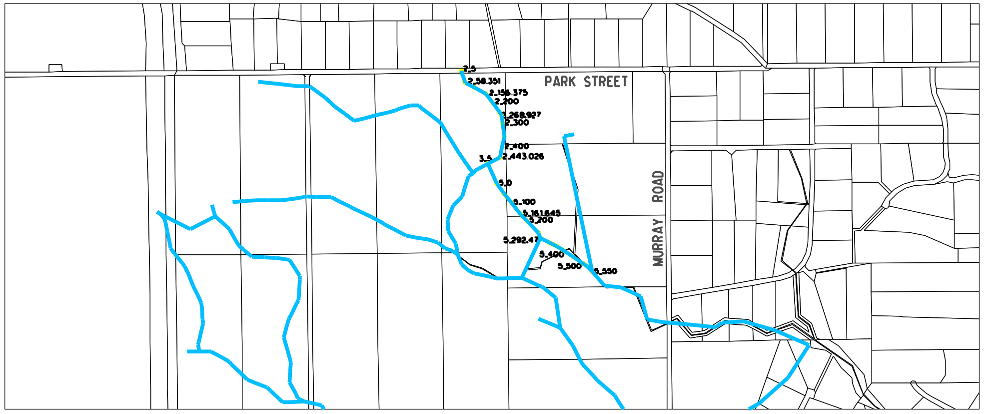

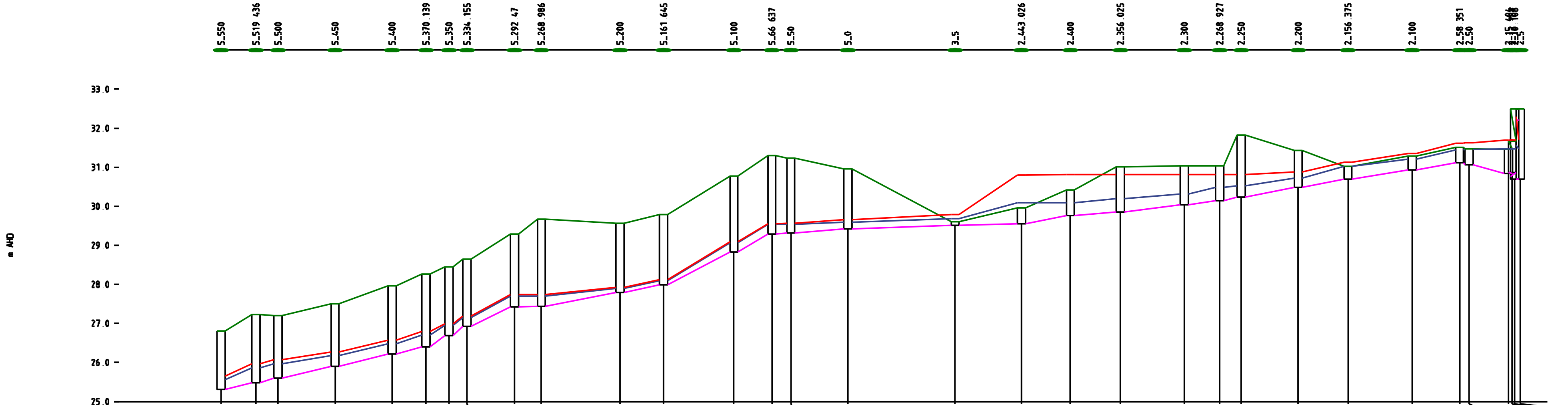

Chainage (m)	Size (mm)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)	
0		26.80	25.56	25.65	-	25.31
30		27.23	25.86	25.96	25.48	25.48
49		27.20	25.97	26.07	25.60	25.60
99		27.51	26.17	26.26	25.91	25.91
149		27.96	26.48	26.57	26.21	26.21
179		28.26	26.70	26.79	26.40	26.40
199		28.45	26.95	27.00	26.69	26.69
215		28.65	27.15	27.18	26.92	26.92
257		29.29	27.70	27.74	27.43	27.43
280		29.67	27.70	27.74	27.44	27.44
349		29.56	27.90	27.92	27.80	27.80
388		29.78	28.09	28.12	27.99	27.99
449		30.77	29.07	29.09	28.83	28.83
483		31.31	29.54	29.55	29.29	29.29
499		31.24	29.54	29.56	29.32	29.32
549		30.95	29.59	29.66	29.42	29.42
644		29.60	29.68	29.78	29.51	29.51
702		29.96	30.09	30.81	29.55	29.55
745		30.42	30.10	30.81	29.76	29.76
789		31.01	30.19	30.81	29.86	29.86
845		31.04	30.31	30.81	30.04	30.04
876		31.04	30.48	30.81	30.14	30.14
895		31.83	30.52	30.81	30.24	30.24
945		31.43	30.72	30.88	30.48	30.48
988		31.03	31.02	31.13	30.70	30.70
1045		31.28	31.21	31.34	30.93	30.93
1086		31.51	31.44	31.61	31.11	31.11
1095		31.48	31.45	31.63	31.06	31.06
1129		31.46	31.47	31.70	30.83	30.83
1132		31.67	31.47	31.70	30.87	30.87
1134		32.50	31.48	31.70	30.76	30.70
1139	1500	32.50	31.56	32.30	30.70	-

Segment chainage (m)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
0–30	0.96	2.05
30–49	0.96	2.05
49–99	0.96	2.05
99–149	0.96	2.05
149–179	0.96	2.05
179–199	0.96	2.05
199–215	0.96	2.05
215–257	0.96	2.24
257–280	0.04	0.12
280–349	0.04	0.12
349–388	0.04	0.12
388–449	0.04	0.12
449–483	0.04	0.12
483–499	0.04	0.12
499–549	0.04	0.12
549–644	0.04	0.12
644–702	0.55	1.09
702–745	0.55	1.14
745–789	0.58	1.29
789–845	0.59	1.42
845–876	0.59	1.60
876–895	0.59	1.67
895–945	0.59	1.70
945–988	0.59	1.74
988–1045	0.59	1.74
1045–1086	0.58	1.70
1086–1095	0.58	1.71
1095–1129	0.58	1.71
1129–1132	0.59	1.71
1132–1134	0.59	1.71
1134–1139	0.59	1.72

DESIGN FILE: Figure 10-11.8b Albion North.dgn

AUTHOR: A Santos

Government of Western Australia
Department of Water

Albion North to St Leonards Creek
Part 2 of 2

LONGITUDINAL SECTION
Existing System
Figure 10-11.8b-R

PROJECT N°: 6121416   DATE: 21/05/2009   COORDINATE SYSTEM: MGA94 - Zone 50

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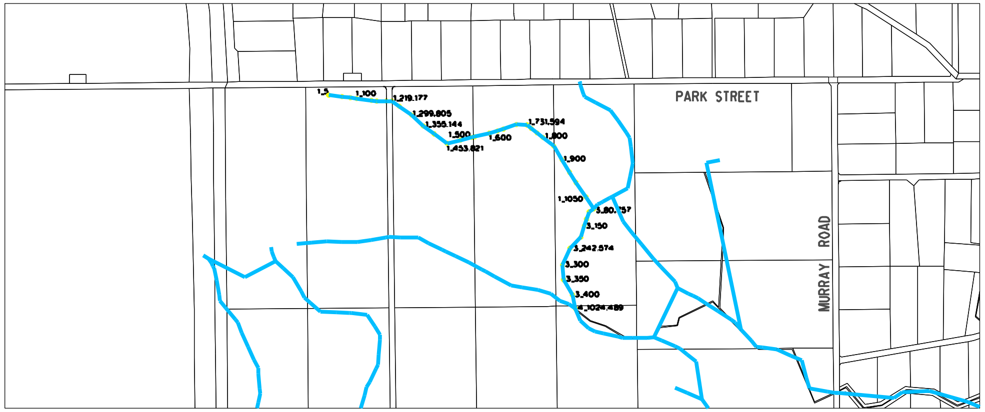
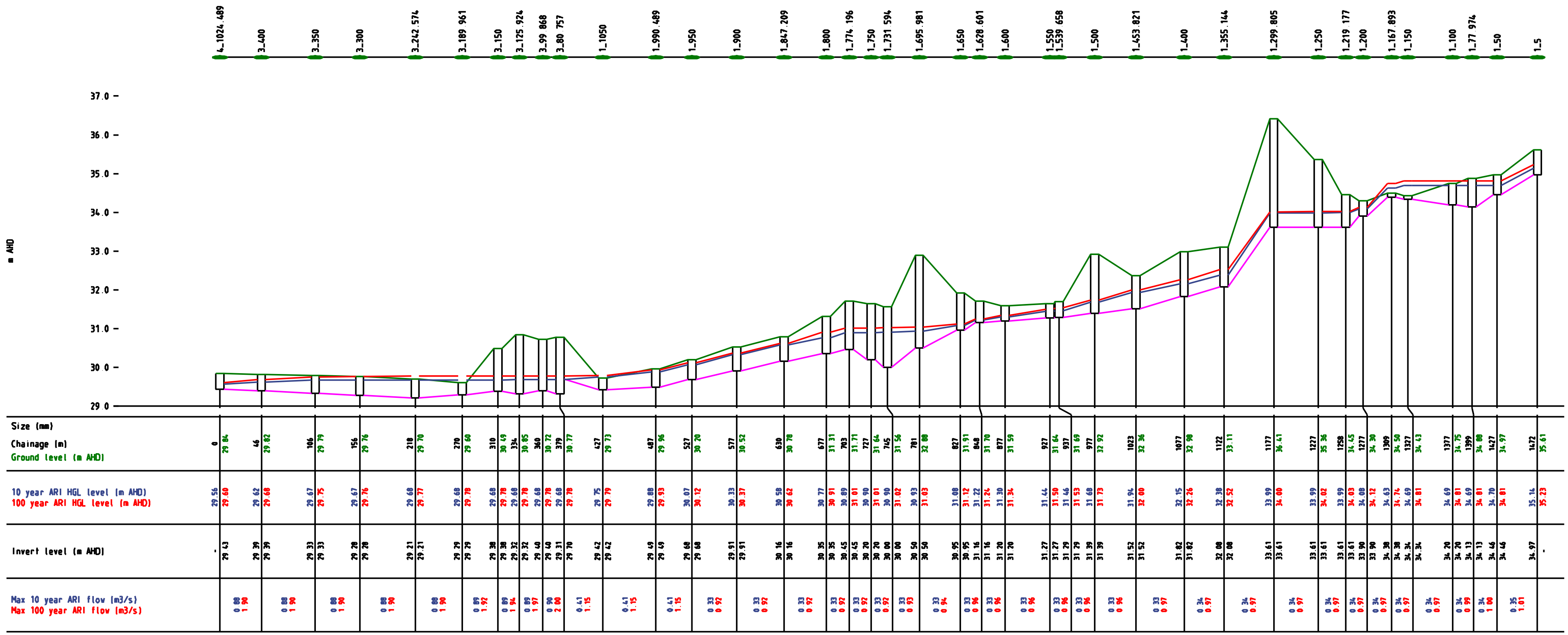
N





DESIGN FILE: Figure 10-11.9 Albion North.dgn

AUTHOR: A Santos

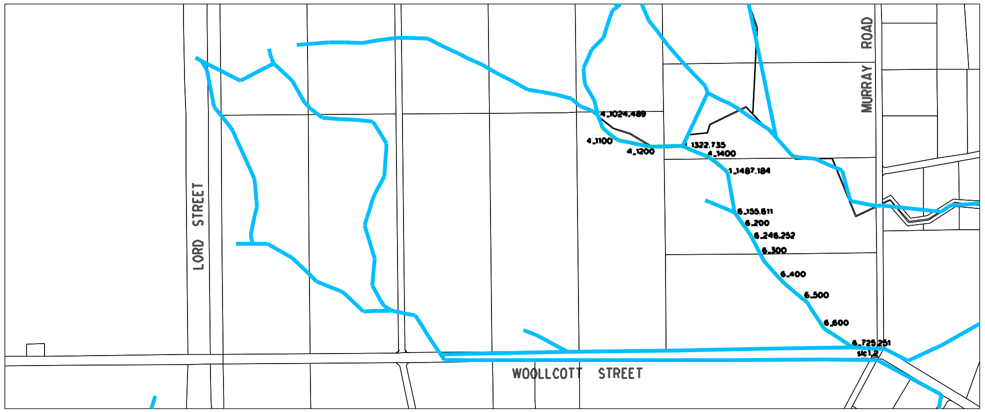
Government of Western Australia
Department of Water

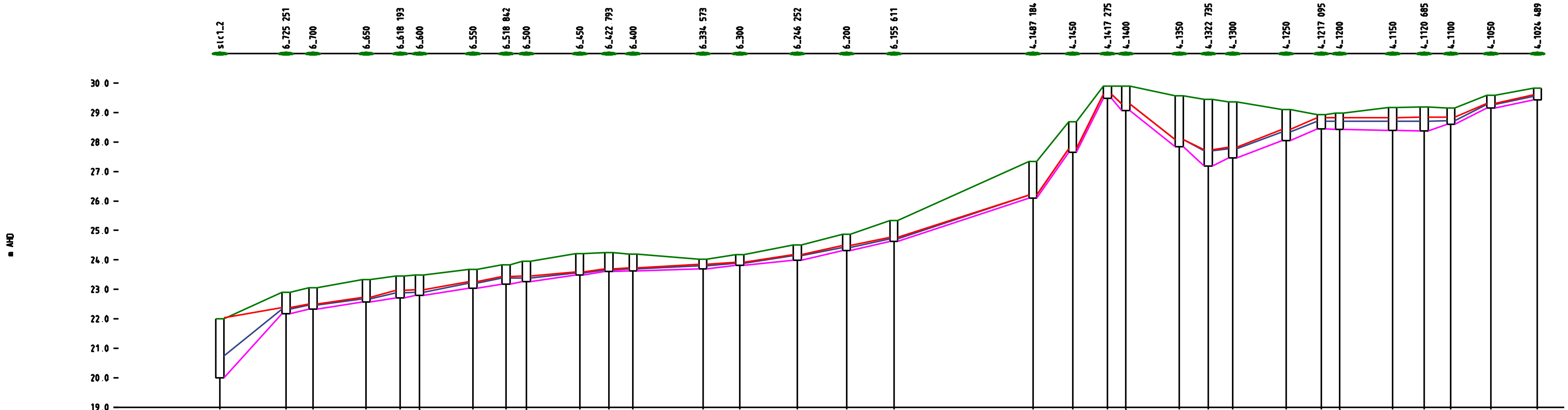
Albion North to St Leonards Creek
Part 1 of 1

LONGITUDINAL SECTION
Existing System
Figure 10-11.9-R

PROJECT N°: 6121416 DATE: 21/05/2009 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)	
0	22.00	20.73	22.04	-	20.00
61	22.91	22.32	22.38	22.18	22.18
87	23.05	22.47	22.50	22.33	22.33
137	23.34	22.68	22.73	22.57	22.57
168	23.45	22.88	22.96	22.72	22.72
187	23.49	22.91	22.98	22.80	22.80
237	23.68	23.20	23.27	23.03	23.03
268	23.83	23.38	23.44	23.18	23.18
287	23.95	23.38	23.45	23.26	23.26
337	24.21	23.56	23.59	23.49	23.49
364	24.25	23.67	23.69	23.61	23.61
386	24.20	23.69	23.73	23.63	23.63
452	24.03	23.80	23.84	23.69	23.69
486	24.19	23.88	23.92	23.81	23.81
540	24.50	24.14	24.18	23.99	23.99
586	24.86	24.43	24.49	24.31	24.31
631	25.34	24.72	24.76	24.62	24.62
761	27.34	26.19	26.19	26.09	26.09
798	28.69	27.78	27.78	27.65	27.65
831	29.90	29.63	29.63	29.48	29.48
848	29.91	29.29	29.29	29.06	29.06
898	29.57	28.08	28.08	27.85	27.85
925	29.45	27.70	27.74	27.19	27.19
948	29.37	27.77	27.83	27.46	27.46
998	29.11	28.35	28.44	28.05	28.05
1031	28.93	28.71	28.84	28.44	28.44
1048	28.98	28.71	28.84	28.43	28.43
1098	29.18	28.71	28.84	28.40	28.40
1127	29.19	28.71	28.84	28.38	28.38
1153	29.15	28.73	28.84	28.61	28.61
1190	29.59	29.28	29.31	29.15	29.15
1234	29.84	29.56	29.60	29.43	-

Reach (chainage, m)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
0–61	0.15	0.34
61–87	0.16	0.42
87–137	0.16	0.42
137–168	0.16	0.42
168–187	0.16	0.42
187–237	0.16	0.42
237–268	0.16	0.42
268–287	0.16	0.42
287–337	0.16	0.42
337–364	0.16	0.42
364–386	0.16	0.42
386–452	0.16	0.42
452–486	0.16	0.42
486–540	0.16	0.42
540–586	0.16	0.43
586–631	0.16	0.43
631–761	-	0.01
761–798	-	-
798–831	-	-
831–848	-	-
848–898	-	-
898–925	-	-
925–948	0.93	1.93
948–998	0.93	1.93
998–1031	0.93	1.93
1031–1048	0.93	1.93
1048–1098	0.93	1.93
1098–1127	0.93	1.93
1127–1153	0.93	1.94
1153–1190	0.93	1.94
1190–1234	0.93	1.94

DESIGN FILE: Figure 10-11.10a Albion North.dgn

AUTHOR: A Santos

Government of Western Australia
Department of Water

Albion North to St Leonards Creek
Part 1 of 2

LONGITUDINAL SECTION
Existing System
Figure 10-11.10a-R

PROJECT N°: 6121416   DATE: 21/05/2009   COORDINATE SYSTEM: MGA94 - Zone 50

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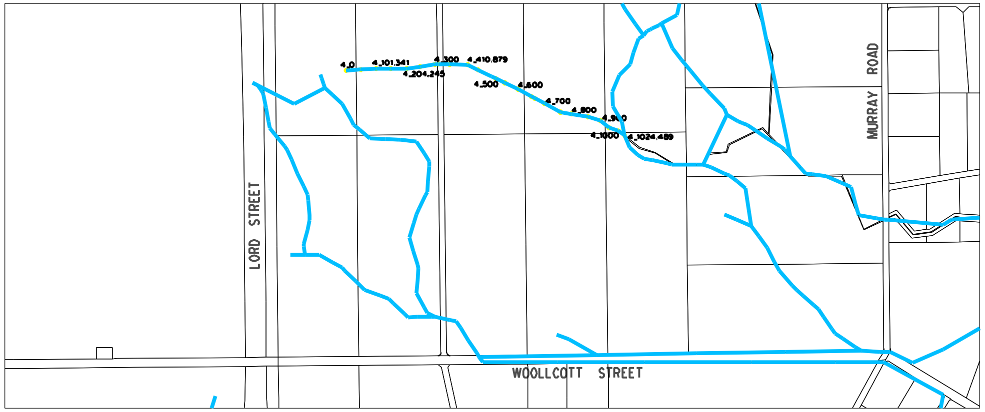

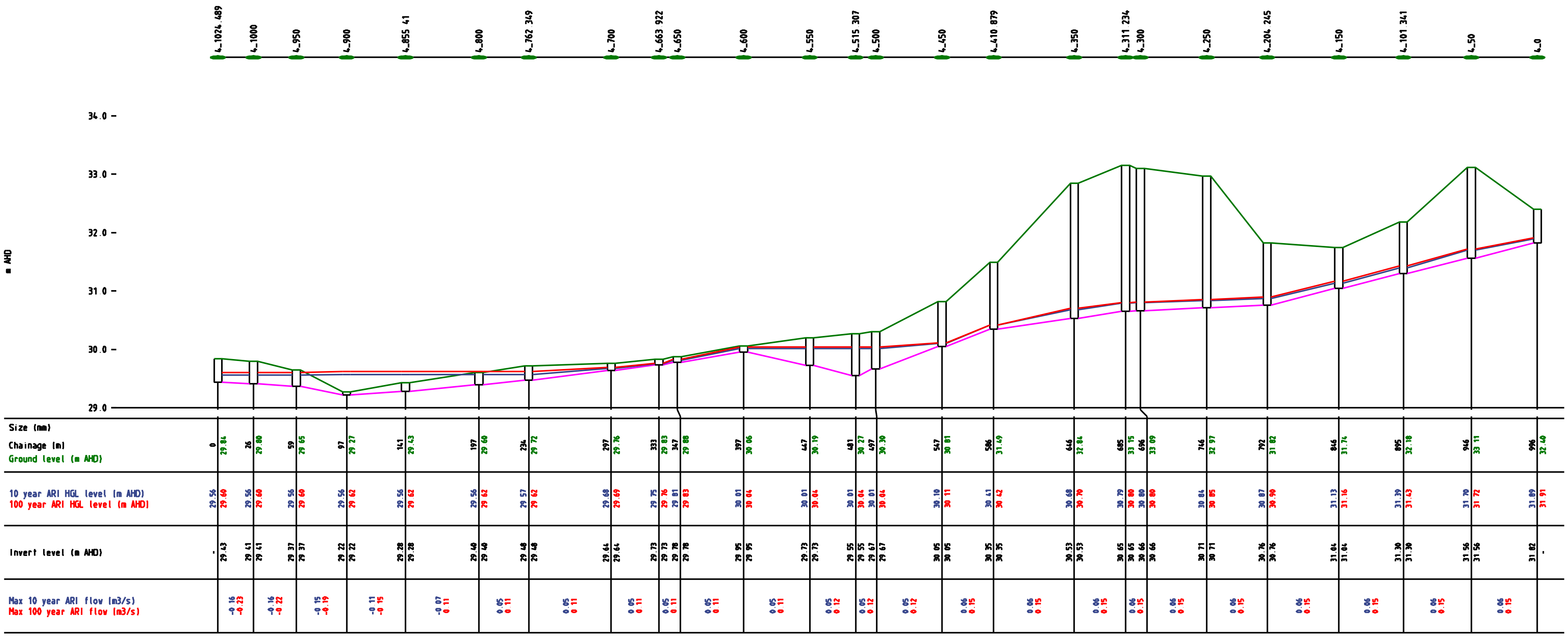

DESIGN FILE: Figure 10-11.10b Albion North.dgn

AUTHOR: A Santos

Government of Western Australia
Department of Water

Albion North to St Leonards Creek
Part 2 of 2

LONGITUDINAL SECTION
Existing System
Figure 10-11.10b-R

PROJECT N°: 6121416 DATE: 21/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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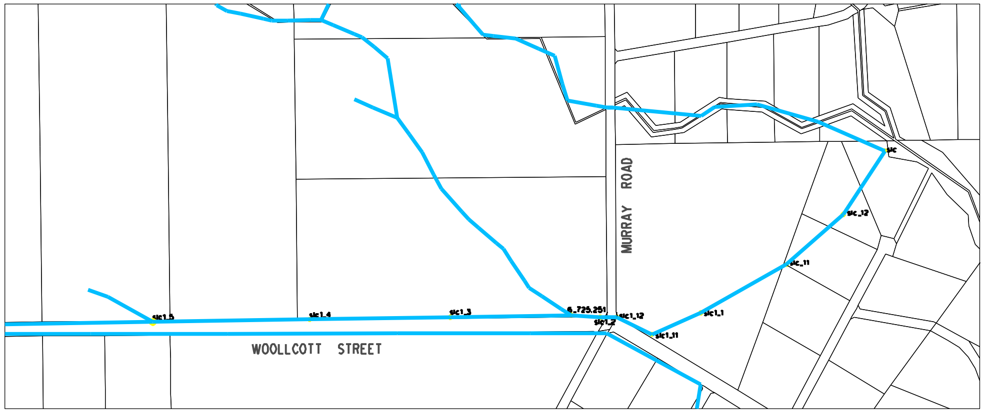

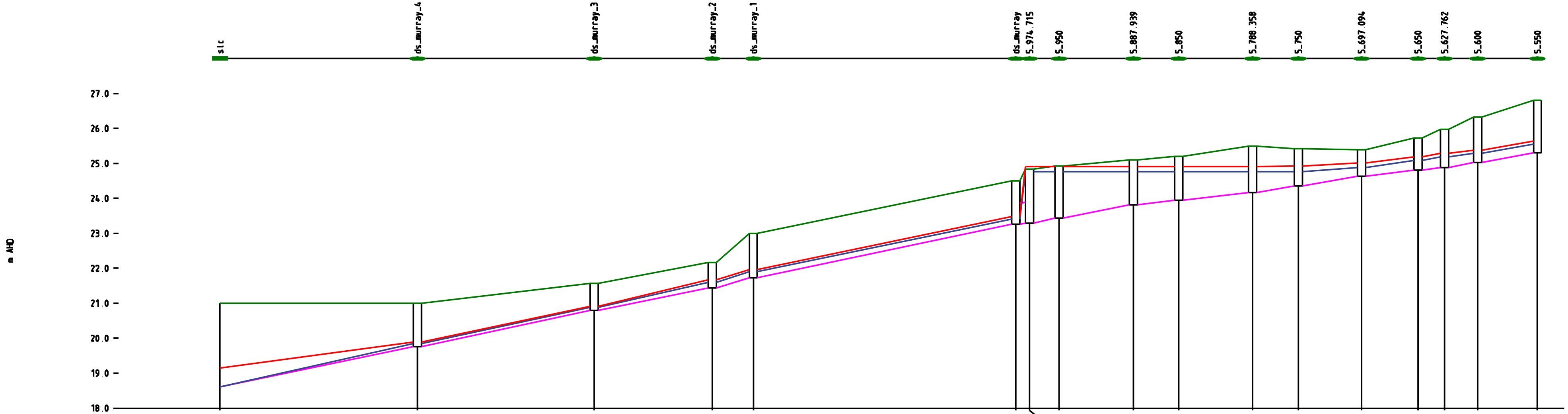

Chainage (m)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)
0	21.00	0.00	19.15	- / 18.60
165	21.00	19.85	19.89	19.76 / 19.76
312	21.57	20.88	20.91	20.79 / 20.79
411	22.17	21.59	21.67	21.44 / 21.44
445	23.00	21.90	21.97	21.72 / 21.72
665	24.50	23.41	23.48	23.26 / 23.26
676	24.84	24.76	24.91	23.29 / 23.29
701	24.93	24.76	24.91	23.44 / 23.44
763	25.10	24.76	24.91	23.82 / 23.82
801	25.20	24.76	24.91	23.95 / 23.95
863	25.49	24.76	24.92	24.16 / 24.16
901	25.42	24.77	24.93	24.36 / 24.36
954	25.40	24.88	25.01	24.64 / 24.64
1001	25.73	25.08	25.19	24.80 / 24.80
1023	25.98	25.18	25.29	24.88 / 24.88
1051	26.32	25.29	25.38	25.03 / 25.03
1101	26.80	25.56	25.65	25.31 / -

Size (mm): 600

Reach (chainage, m)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
0–165	1.05	2.38
165–312	1.05	2.38
312–411	1.05	2.38
411–445	1.05	2.38
445–665	1.05	2.38
665–676	0.91	0.98
676–701	0.91	2.05
701–763	0.92	2.05
763–801	0.93	2.05
801–863	0.94	2.05
863–901	0.95	2.05
901–954	0.96	2.05
954–1001	0.96	2.05
1001–1023	0.96	2.05
1023–1051	0.96	2.05
1051–1101	0.96	2.05

DESIGN FILE: Figure 10-11.11 Albion Central.dgn

AUTHOR: A Santos

Government of Western Australia
Department of Water

Albion Central to St Leonards Creek
Part 1 of 1

LONGITUDINAL SECTION
Proposed System
Figure 10-11.11-R

PROJECT N°: 6121416 DATE: 21/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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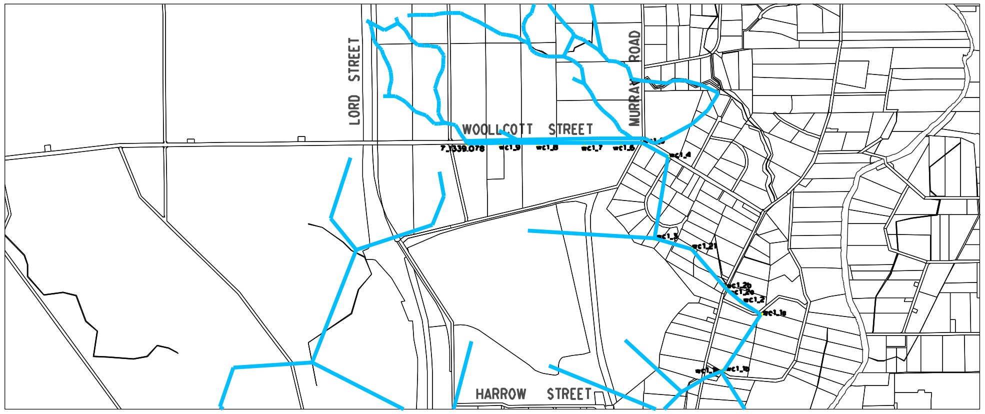

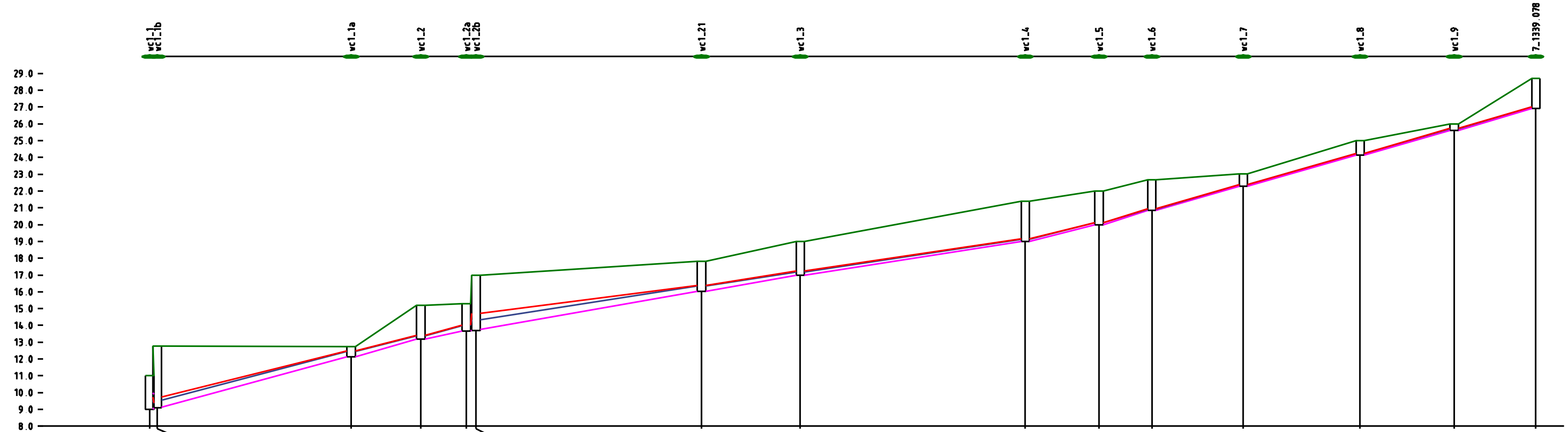

Node	Size (mm)	Chainage (m)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)
wc1_1	900	0	11.00	9.34	9.38	- / 9.00
wc1_1b		23	12.76	9.56	9.75	9.10 / 9.12
wc1_1a		622	12.74	12.46	12.49	12.12 / 12.12
wc1_2		837	15.20	13.39	13.39	13.20 / 13.20
wc1_2a	600	978	15.30	13.99	14.02	13.66 / 13.70
wc1_2b		1007	16.98	14.34	14.72	13.70 / 13.76
wc1_21		1704	17.82	16.34	16.37	16.01 / 16.01
wc1_3		2009	19.00	17.19	17.23	17.00 / 17.00
wc1_4		2704	21.39	19.14	19.16	19.00 / 19.00
wc1_5		2933	22.00	20.11	20.12	20.00 / 20.00
wc1_6		3095	22.67	20.93	20.94	20.83 / 20.83
wc1_7		3378	23.02	22.37	22.39	22.28 / 22.28
wc1_8		3739	25.00	24.22	24.23	24.12 / 24.12
wc1_9		4030	25.98	25.70	25.72	25.61 / 25.61
7_1339.078		4282	28.69	27.00	27.01	26.90 / -

Reach	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
wc1_1 – wc1_1b	0.66	1.16
wc1_1b – wc1_1a	0.66	1.16
wc1_1a – wc1_2	0.66	1.16
wc1_2 – wc1_2a	0.49	0.83
wc1_2a – wc1_2b	0.49	0.83
wc1_2b – wc1_21	0.49	0.83
wc1_21 – wc1_3	0.50	0.94
wc1_3 – wc1_4	0.19	0.32
wc1_4 – wc1_5	0.12	0.17
wc1_5 – wc1_6	0.12	0.17
wc1_6 – wc1_7	0.12	0.17
wc1_7 – wc1_8	0.12	0.17
wc1_8 – wc1_9	0.12	0.17
wc1_9 – 7_1339.078	0.12	0.17

DESIGN FILE: Figure 10-11.12a Albion North.dgn

AUTHOR: A Santos

Government of Western Australia
Department of Water

Albion North to Wandoo Creek
Part 1 of 2

LONGTUDINAL SECTION
Existing System
Figure 10-11.12a-R

PROJECT N°: 61221416 DATE: 21/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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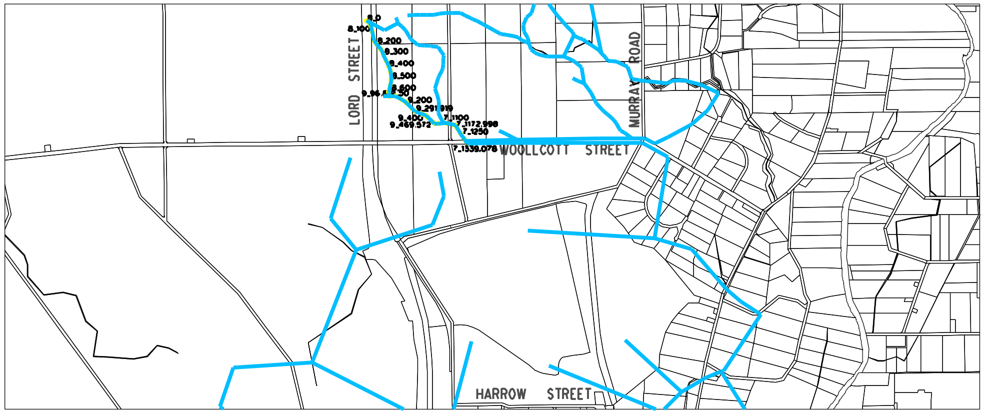

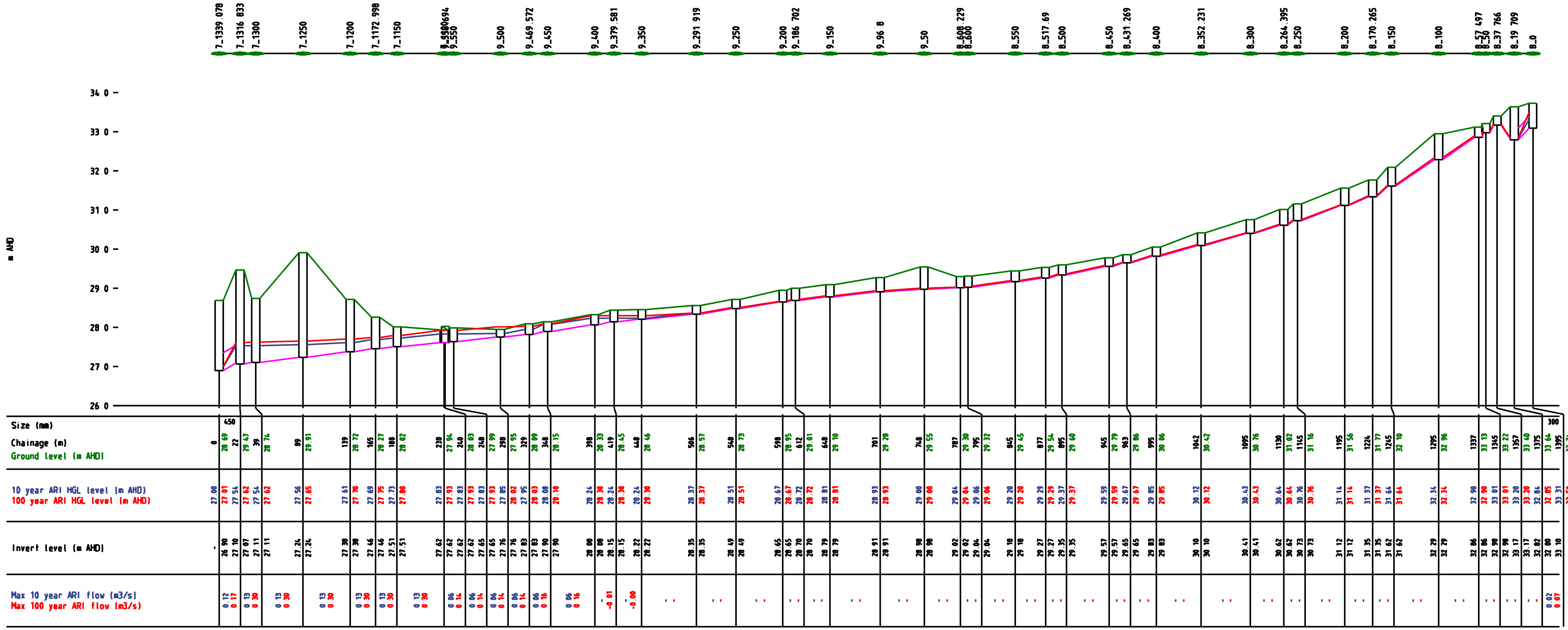

DESIGN FILE: Figure 10-11.12b Albion North.dgn

AUTHOR: A Santos

Government of Western Australia
Department of Water

Albion North to Wandoo Creek
Part 2 of 2

LONGITUDINAL SECTION
Existing System
Figure 10-11.12b-R

PROJECT N°: 61221416 DATE: 21/05/2009 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.

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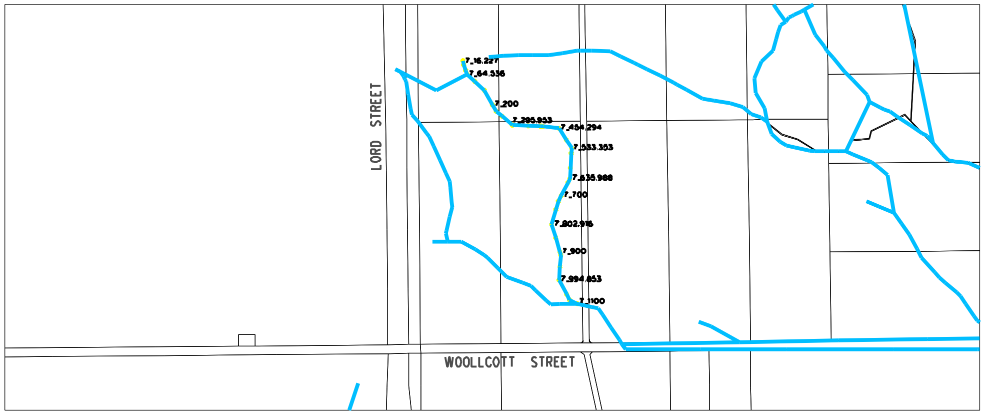

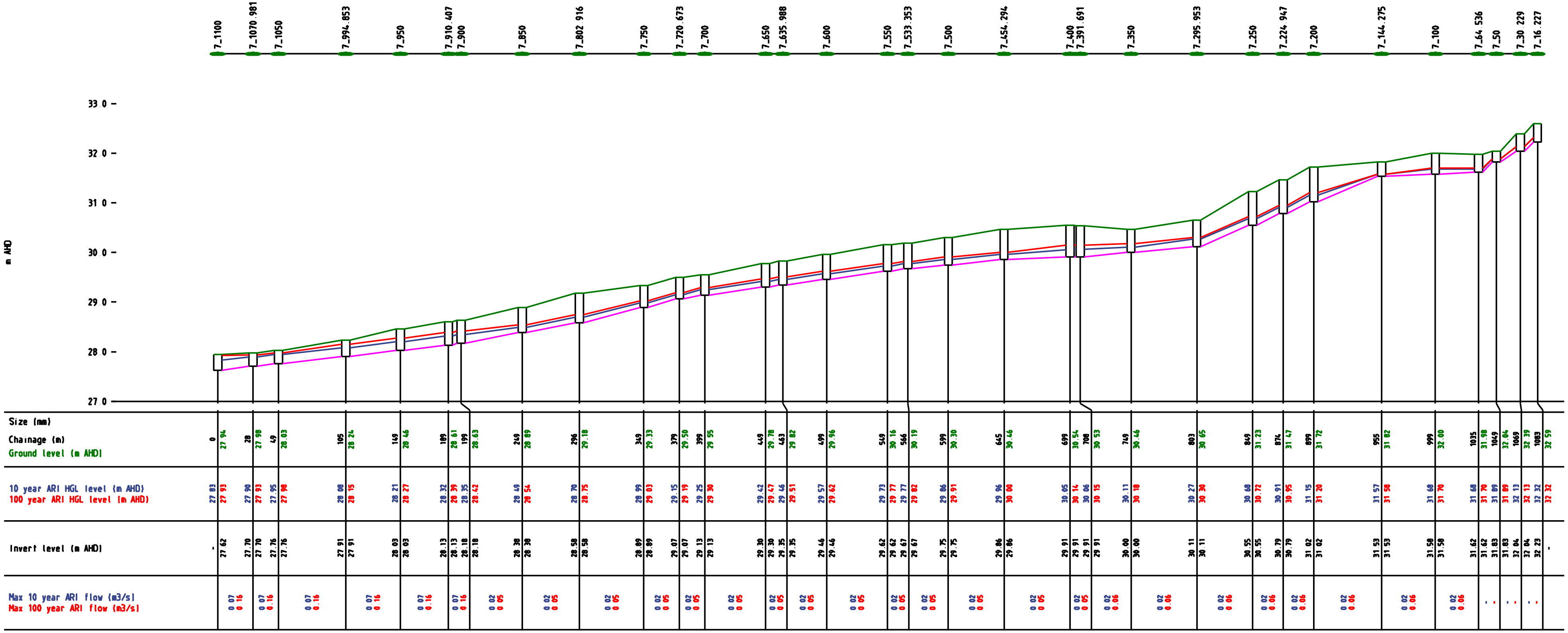

DESIGN FILE: Figure 10-11.13 Albion North.dgn

AUTHOR: A Santos

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Department of Water

PROJECT Nº: 6121416 DATE: 21/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

Albion North to Wandoo Creek

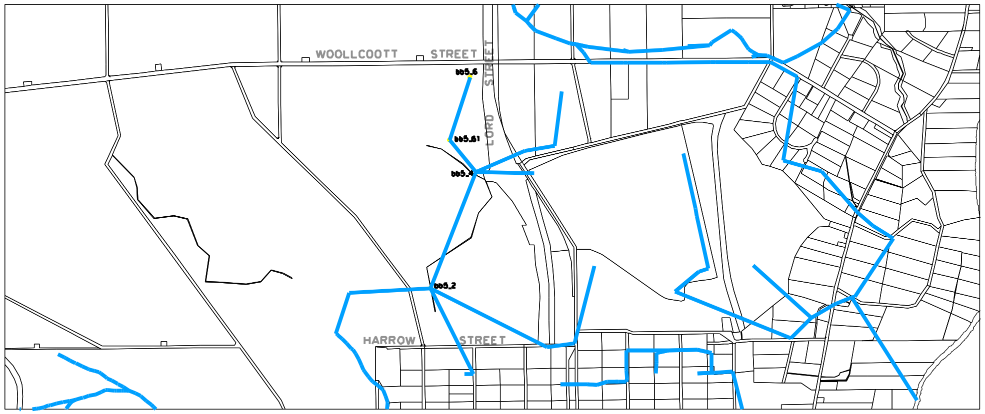
Part 1 of 1

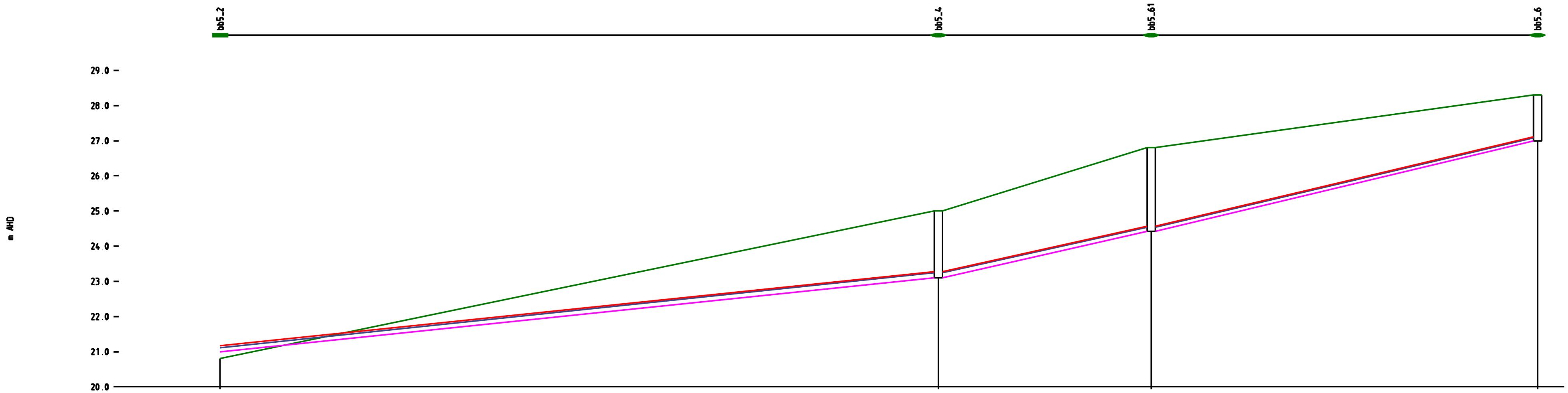
LONGITUDINAL SECTION

Existing System

Figure 10-11.13-R

N





	bb5.2		bb5.4		bb5.61		bb5.6
Size (mm)							
Chainage (m)	0		1120		1453		2056
Ground level (m AHD)	20.80		25.00		26.80		28.30
10 year ARI HGL level (m AHD)	21.11		23.24		24.54		27.08
100 year ARI HGL level (m AHD)	21.17		23.28		24.56		27.11
Invert level (m AHD)	- / 21.00		23.10 / 23.10		24.42 / 24.42		27.00 / -
Max 10 year ARI flow (m3/s)		0.37		0.16		0.16	
Max 100 year ARI flow (m3/s)		0.75		0.34		0.34	

DESIGN FILE: Figure 10-11.14_Horse_Swamp.dgn

AUTHOR: S Saveski

Government of Western Australia
Department of Water

Horse Swamp
Part 1 of 1

LONGITUDINAL SECTION

Proposed System

Figure 10-11.14-R

PROJECT N°: 6121416   DATE: 18/05/2009   COORDINATE SYSTEM: MGA94 - Zone 50

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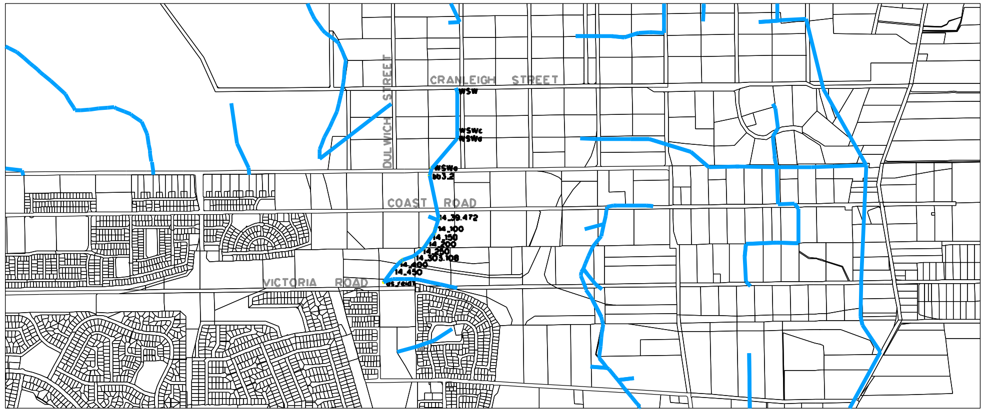

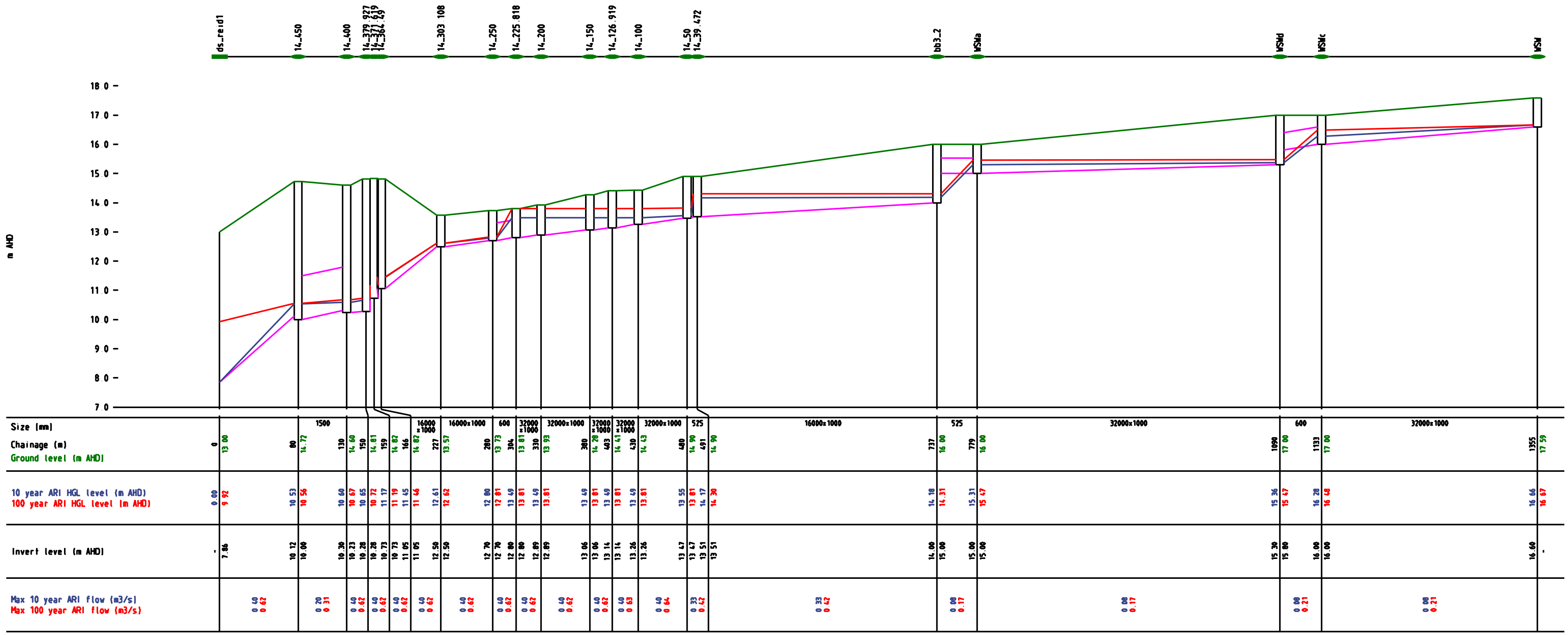

DESIGN FILE: Figure 10-11.15_West_Swan_West.dgn

AUTHOR: S Saveski

Government of Western Australia
Department of Water

West Swan West to Bennett Brook
Part 1 of 1

LONGITUDINAL SECTION

Proposed System

Figure 10-11.15-R

PROJECT N°: 6121416 DATE: 18/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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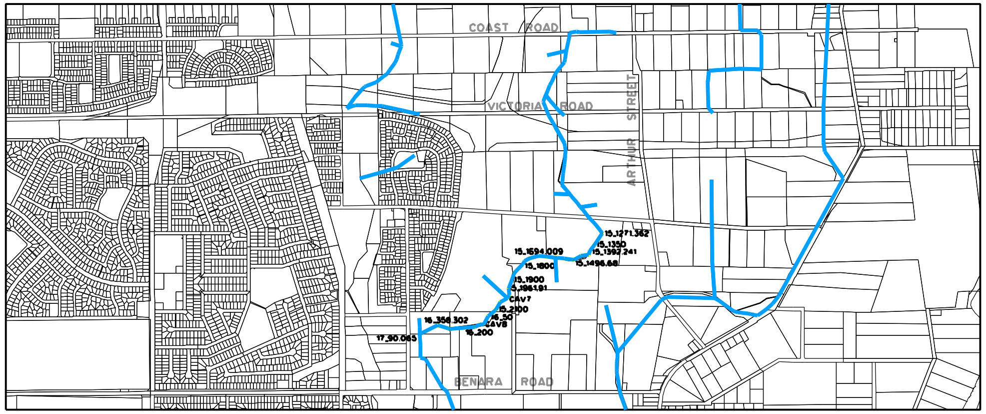

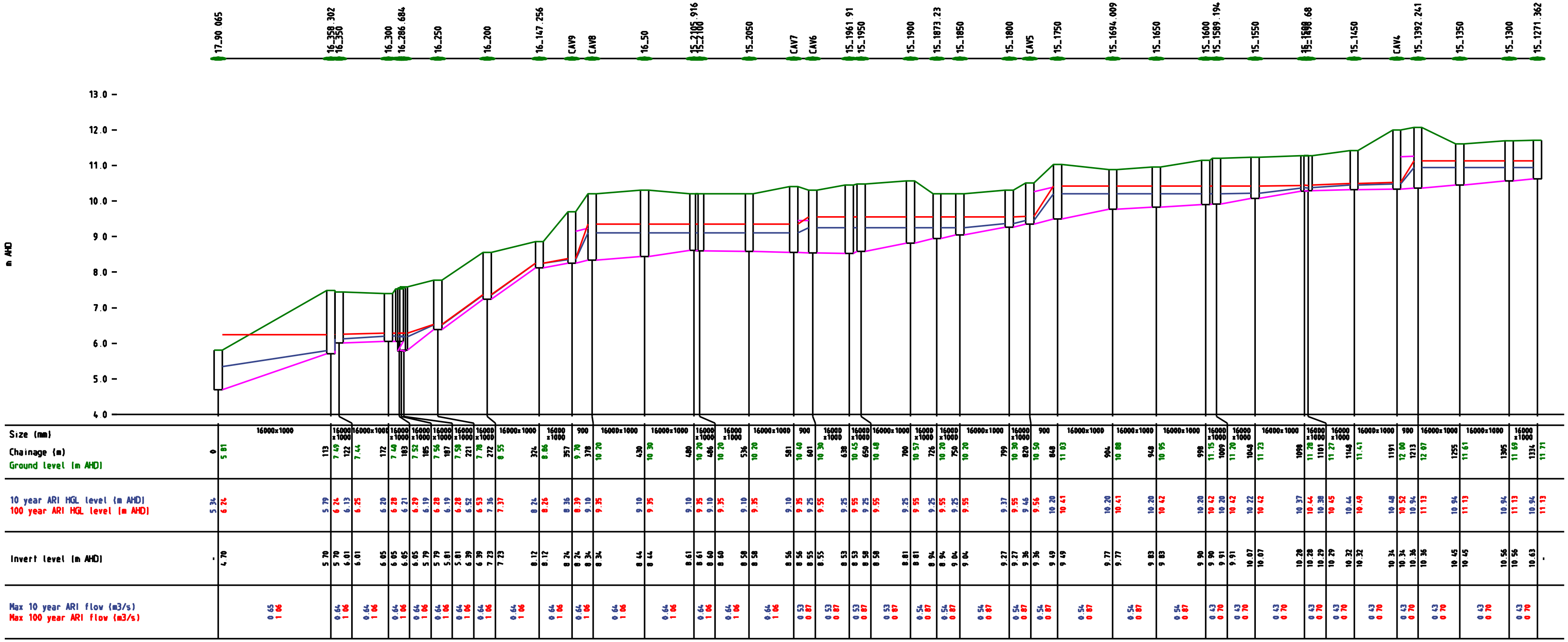

DESIGN FILE: Figure 10-11.16a_West_Swan_East.dgn

AUTHOR: S Saveski

Government of Western Australia
Department of Water

West Swan East and Caversham West to bennett Brook
Part 1 of 2

LONGITUDINAL SECTION
Proposed System
Figure 10-11.16a-R

PROJECT N°: 6121416 DATE: 18/05/2009 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.

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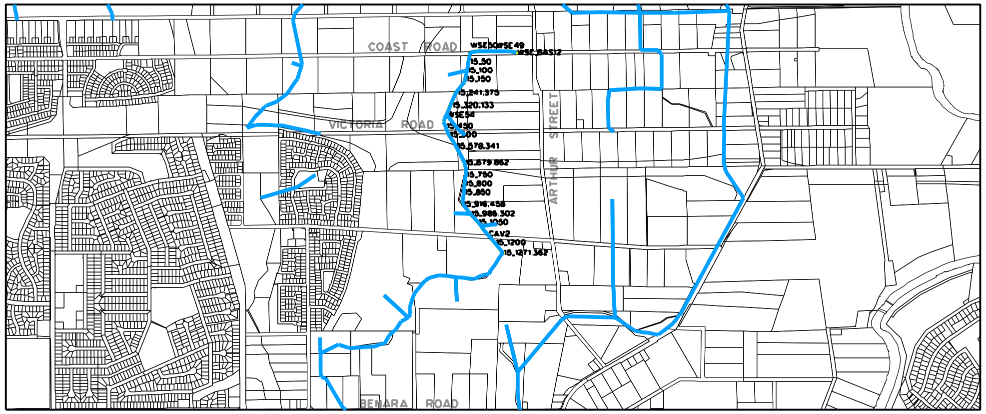
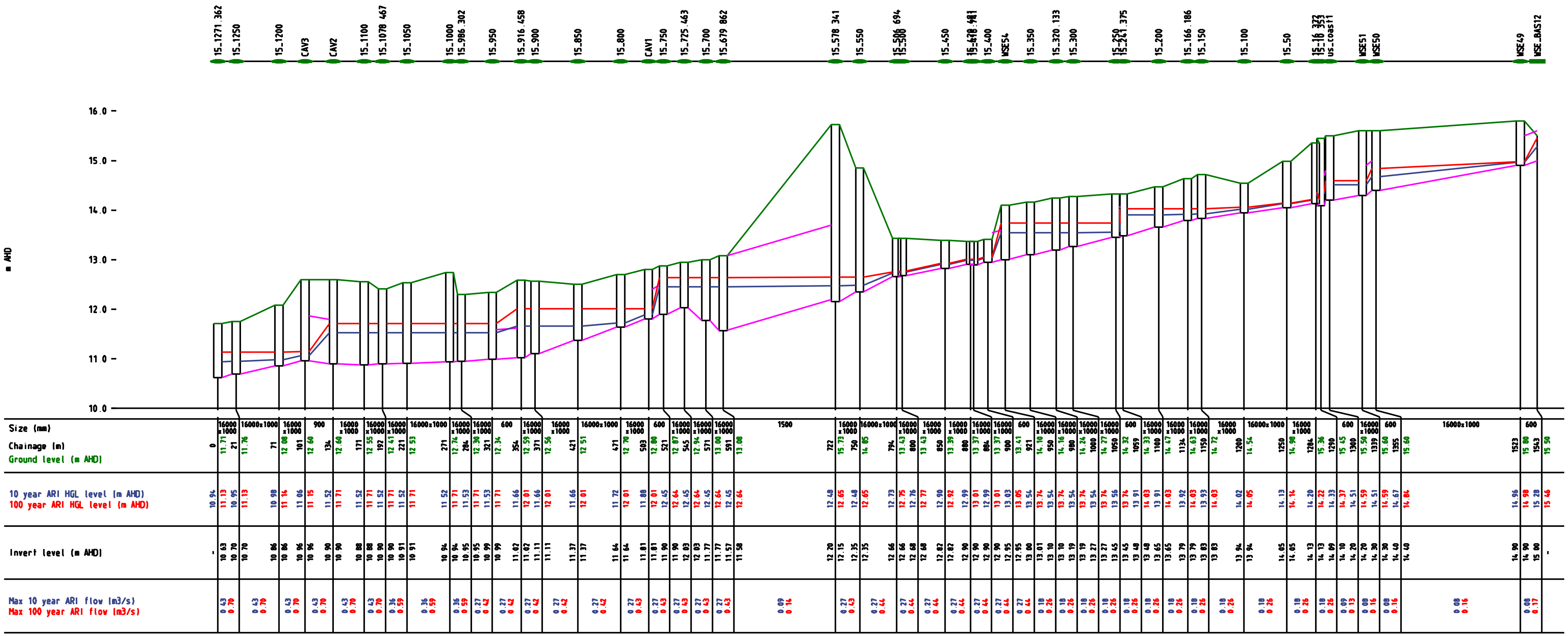




DESIGN FILE: Figure 10-11.16b_West_Swan_East.dgn

AUTHOR: S Saveski

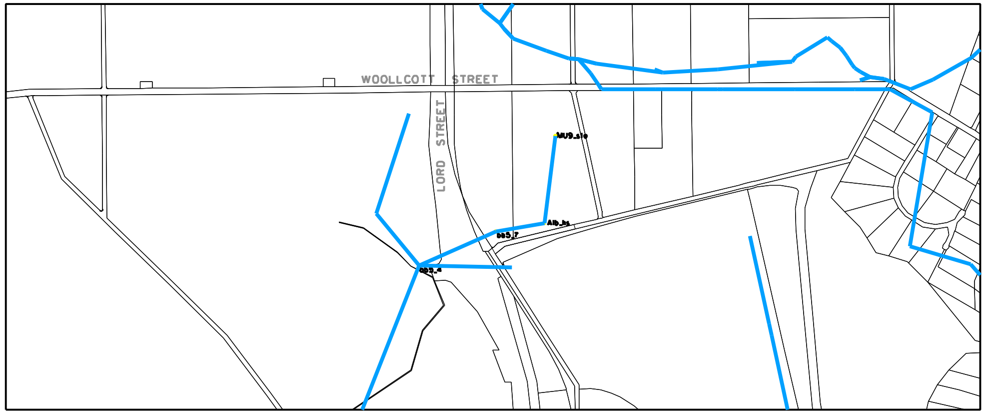
Government of Western Australia
Department of Water

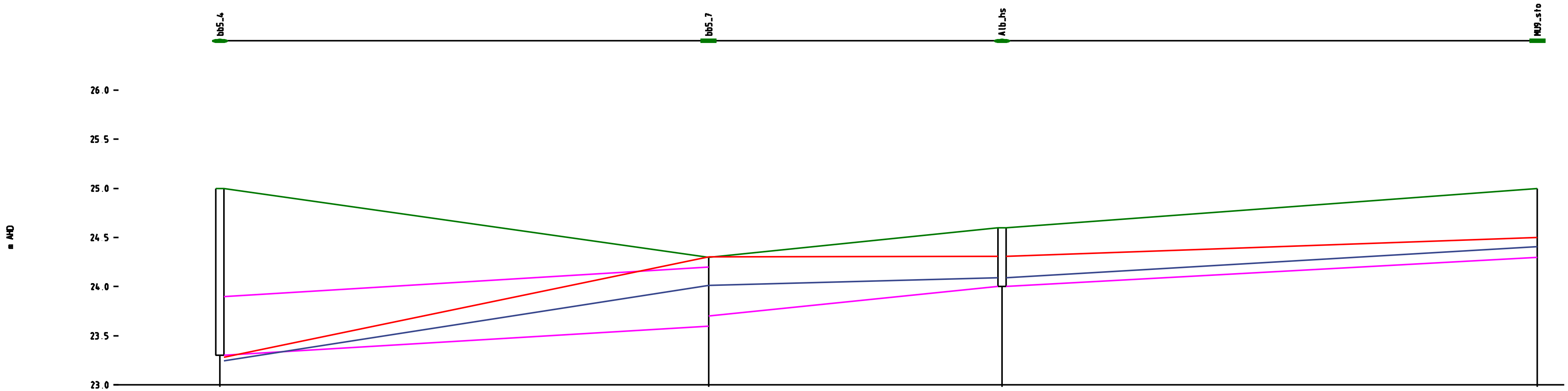
West Swan East and Caversham West to bennett Brook
Part 2 of 2

LONGITUDINAL SECTION
Proposed System
Figure 10-11.16b-R

PROJECT N°: 6121416 DATE: 18/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

N





	bb5_4		bb5_7		Alb_hs		MU9_sto
Size (mm)		600		16000x500		16000x500	
Chainage (m)	0		392		628		1059
Ground level (m AHD)	25.00		24.30		24.60		25.00
10 year ARI HGL level (m AHD)	23.24		24.02		24.09		24.41
100 year ARI HGL level (m AHD)	23.28		24.31		24.31		24.50
Invert level (m AHD)	- / 23.30		23.60 / 23.70		24.00 / 24.00		24.30 / -
Max 10 year ARI flow (m3/s)		0.13		0.27		0.27	
Max 100 year ARI flow (m3/s)		0.24		0.75		0.75	

DESIGN FILE: Figure 10-11.17 Albion.dgn

AUTHOR: S. Saveski

Government of Western Australia
Department of Water

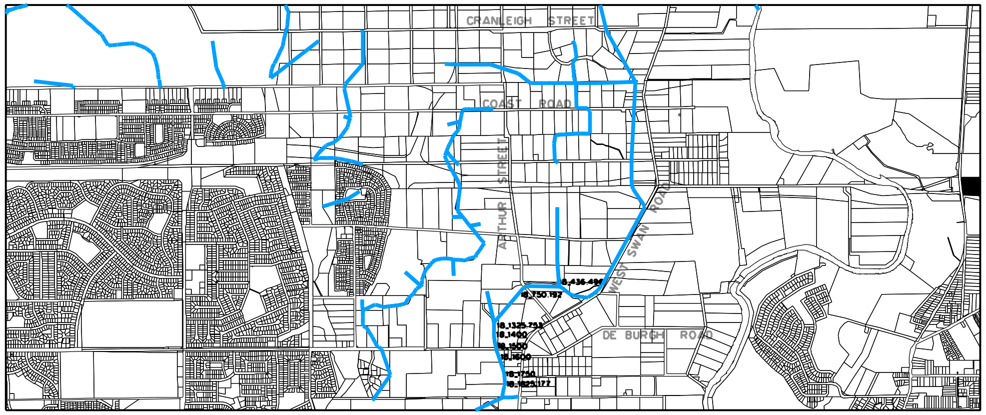
Albion to Horse Swamp
Part 1 of 1

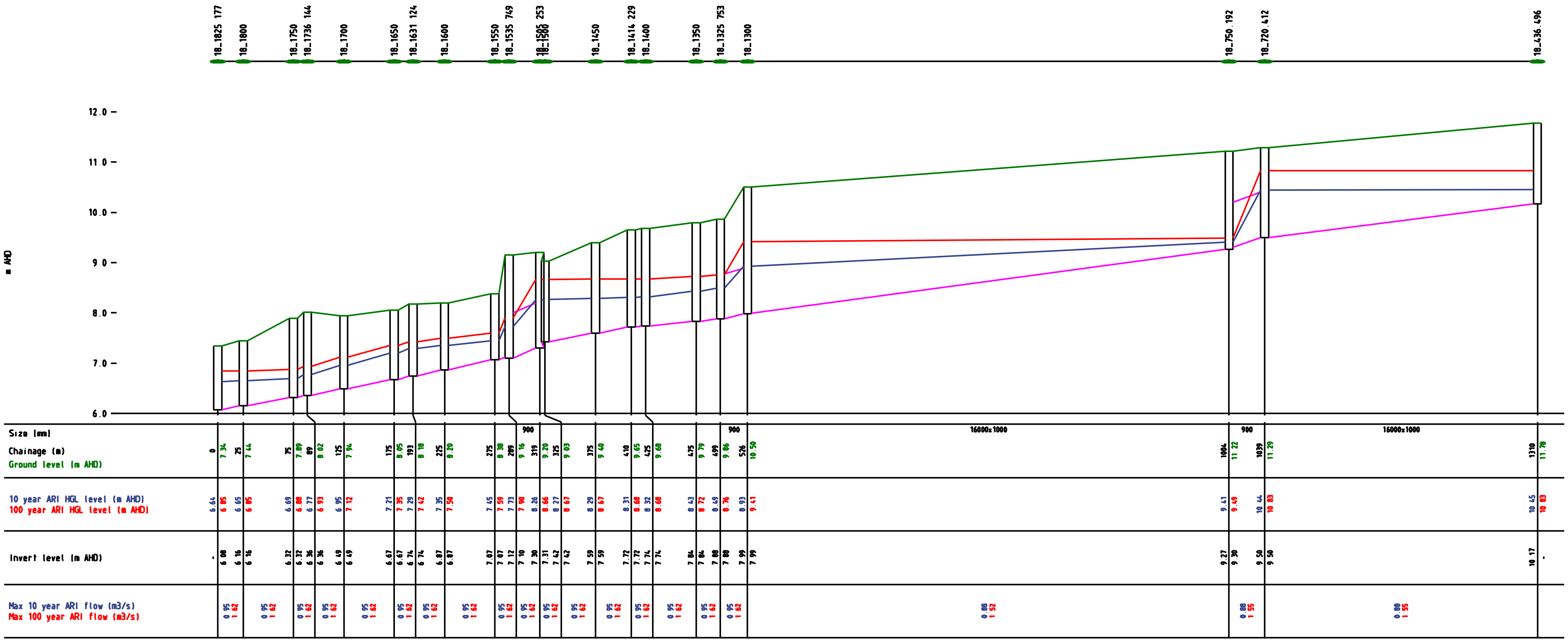
LONGITUDINAL SECTION
Proposed System
Figure 10-11.17-R

PROJECT N°: 6121416 DATE: 18/05/2009 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





DESIGN FILE: Figure 10-11.18a West Swan East.dgn

AUTHOR: S Saveski

Government of Western Australia
Department of Water

PROJECT N°: 6121416 DATE: 18/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

West Swan East and Caversham East to Bennet Brook
Part 1 of 3

LONGITUDINAL SECTION
Proposed System
Figure 10-11.18a-R

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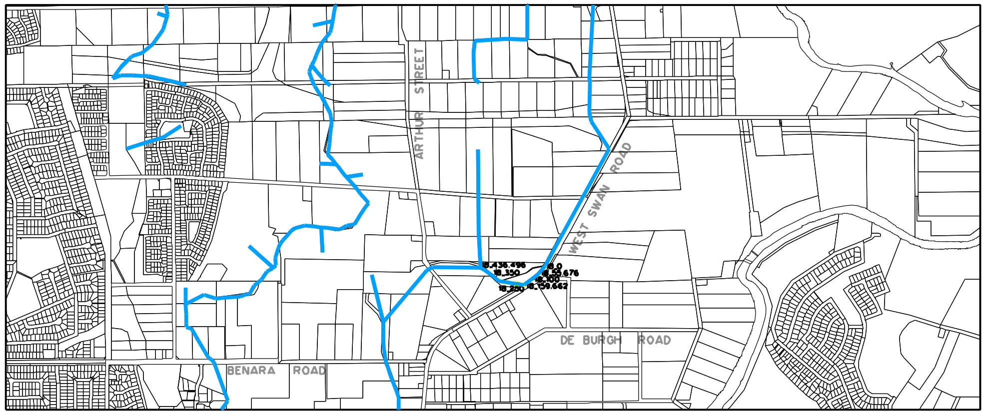
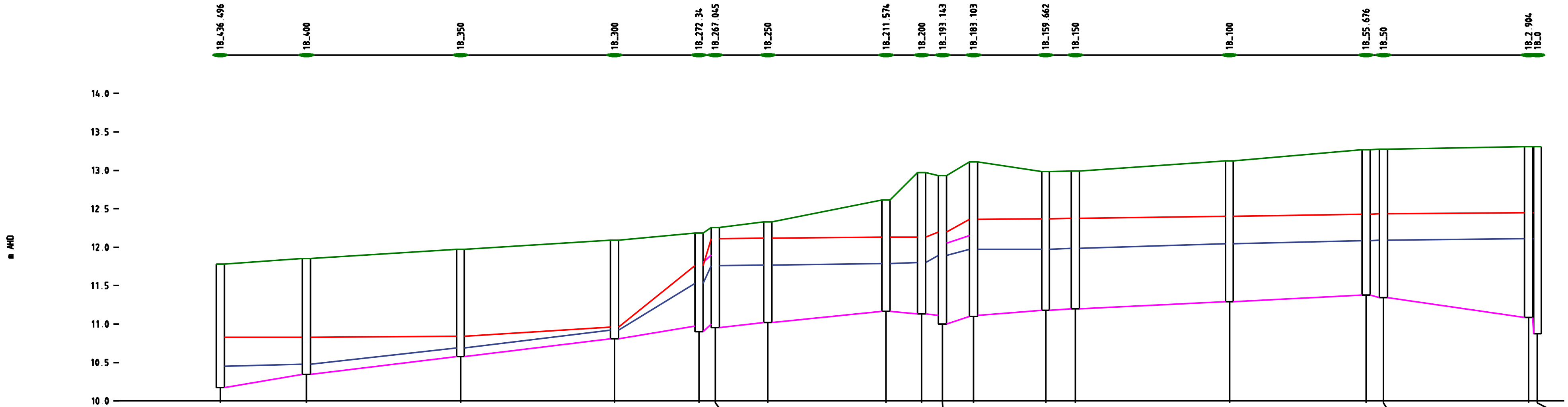
N





Chainage (m)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)		Size (mm)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
0	11.78	10.45	10.83	-	10.17	16000x1000	0.68	1.22
28	11.85	10.48	10.83	10.34	10.34	16000x1000	0.68	1.22
78	11.97	10.69	10.84	10.58	10.58	16000x1000	0.68	1.22
128	12.09	10.92	10.96	10.81	10.81		0.68	1.22
155	12.18	11.53	11.76	10.97	10.90	900	0.68	1.22
160	12.26	11.76	12.11	11.00	10.95		0.68	1.22
177	12.33	11.77	12.12	11.02	11.02		0.68	1.22
216	12.61	11.79	12.13	11.17	11.17		0.68	1.22
227	12.97	11.80	12.13	11.13	11.13		0.68	1.22
234	12.93	11.90	12.20	11.11	11.00	1050	0.68	1.22
244	13.11	11.97	12.36	11.10	11.11		0.68	1.22
267	12.99	11.98	12.37	11.18	11.18		0.68	1.22
277	12.99	11.98	12.37	11.20	11.20		0.68	1.22
327	13.12	12.04	12.40	11.29	11.29		0.68	1.22
371	13.27	12.09	12.43	11.38	11.38		0.68	1.22
377	13.27	12.09	12.43	11.35	11.35		0.68	1.22
424	13.31	12.11	12.45	11.09	11.09		0.68	1.22
427	13.31	12.11	12.45	10.87	-			

DESIGN FILE: Figure 10-11.18b West Swan East.dgn

AUTHOR: S Saveski

Government of Western Australia
Department of Water

West Swan East and Caversham East to Bennet Brook
Part 2 of 3

LONGITUDINAL SECTION
Proposed System
Figure 10-11.18b-R

PROJECT N°: 6121416 DATE: 19/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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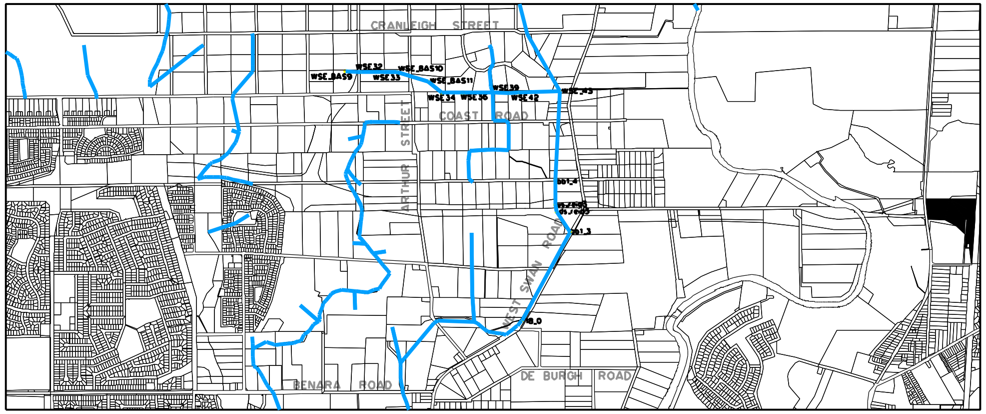
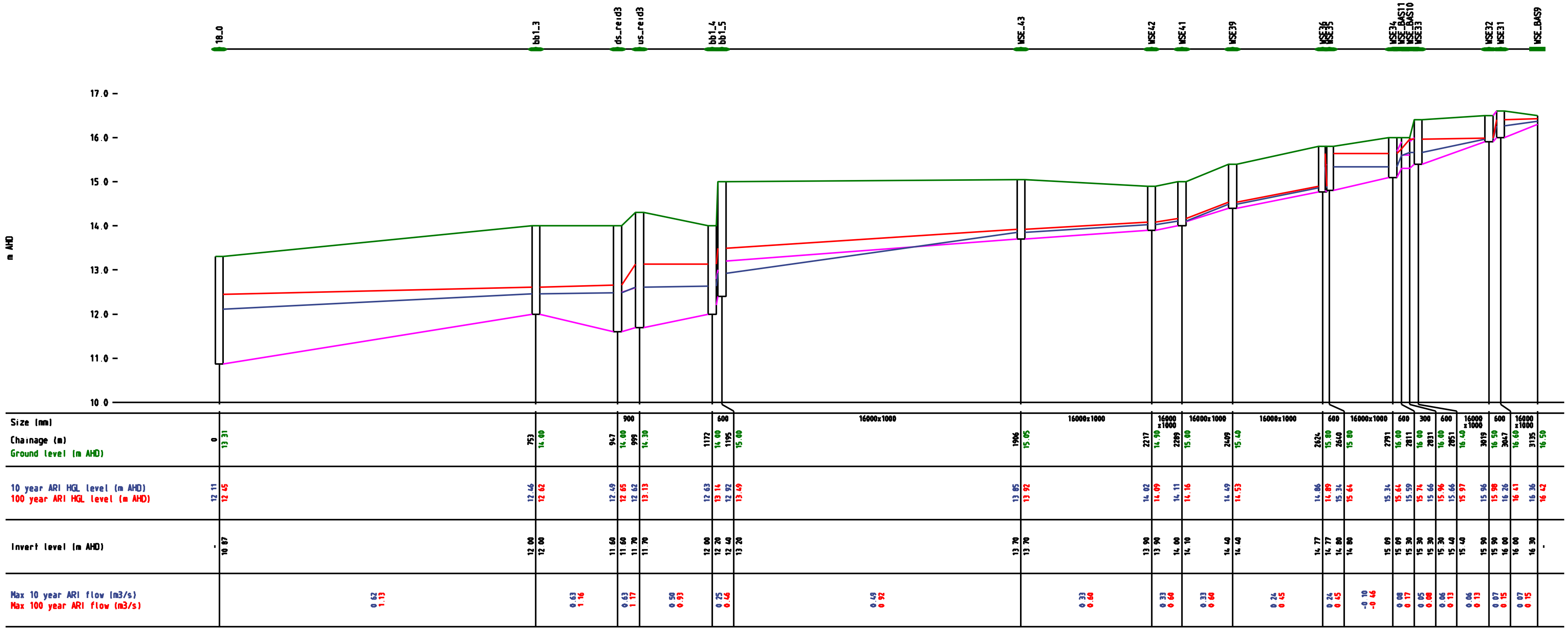
N





DESIGN FILE: Figure 10-11.18c West Swan East.dgn

AUTHOR: S Saveski

Government of Western Australia
Department of Water

West Swan East and Caversham East to Bennet Brook Part 3 of 3

LONGITUDINAL SECTION

Proposed System

Figure 10-11.18c-R

PROJECT N°: 6121416 DATE: 19/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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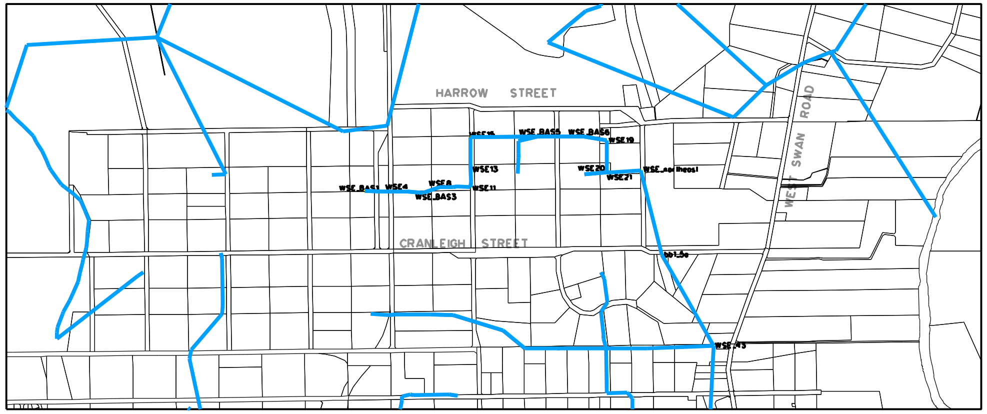
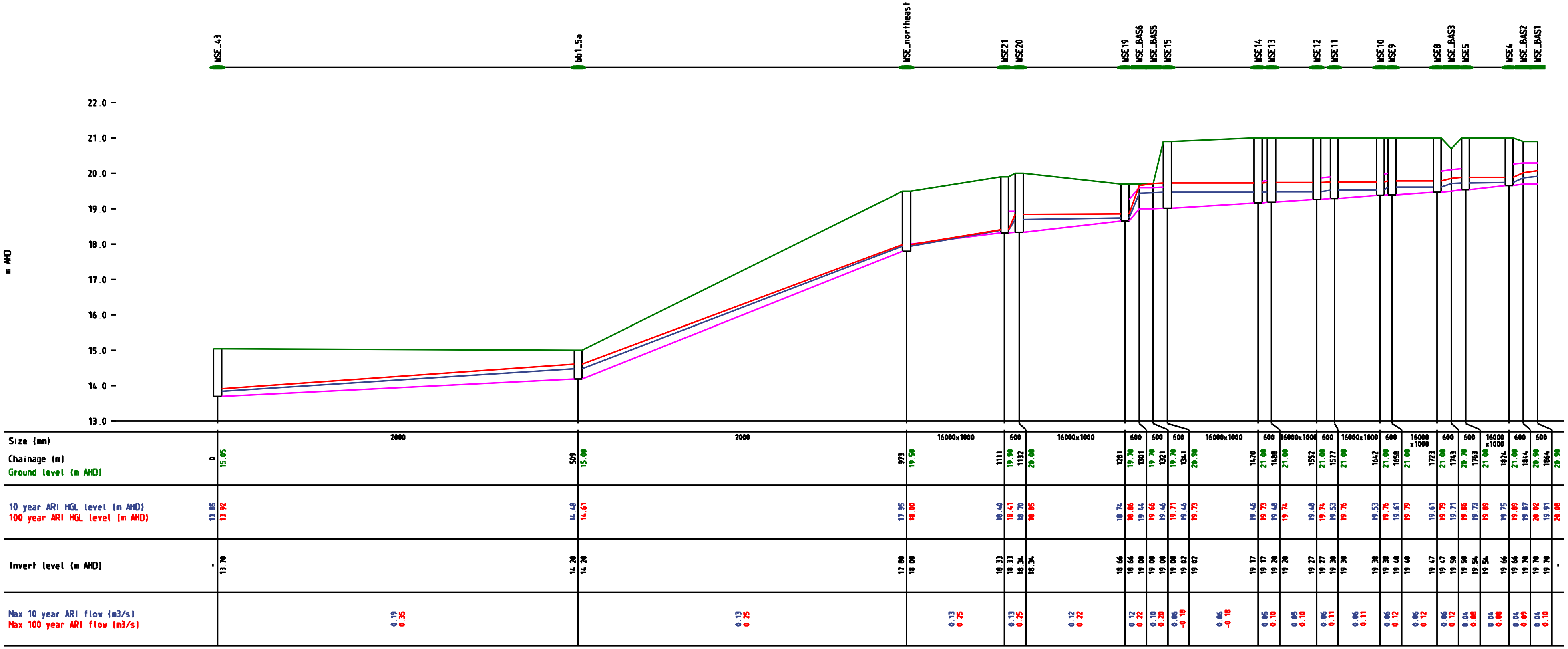
N





DESIGN FILE: Figure 10-11.19 West Swan East.dgn

AUTHOR: S Saveski

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Department of Water

West Swan East to Wandoo Creek
Part 1 of 1

LONGITUDINAL SECTION
Proposed System
Figure 10-11.19-R

PROJECT N°: 6121416 DATE: 19/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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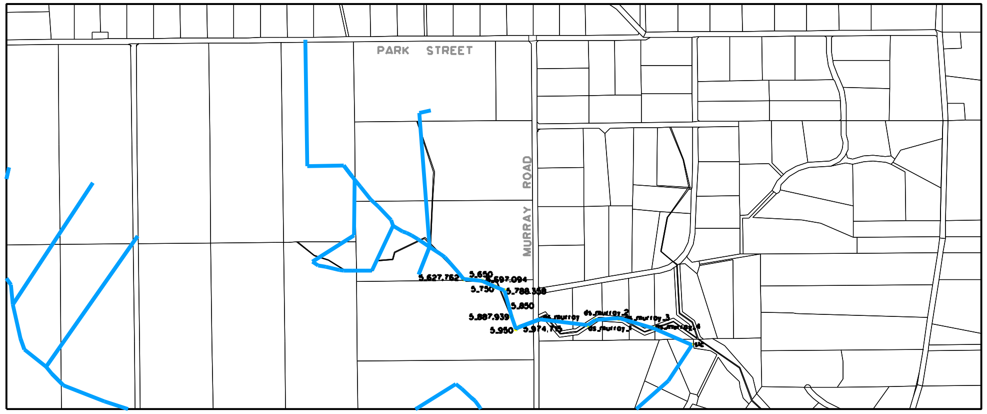
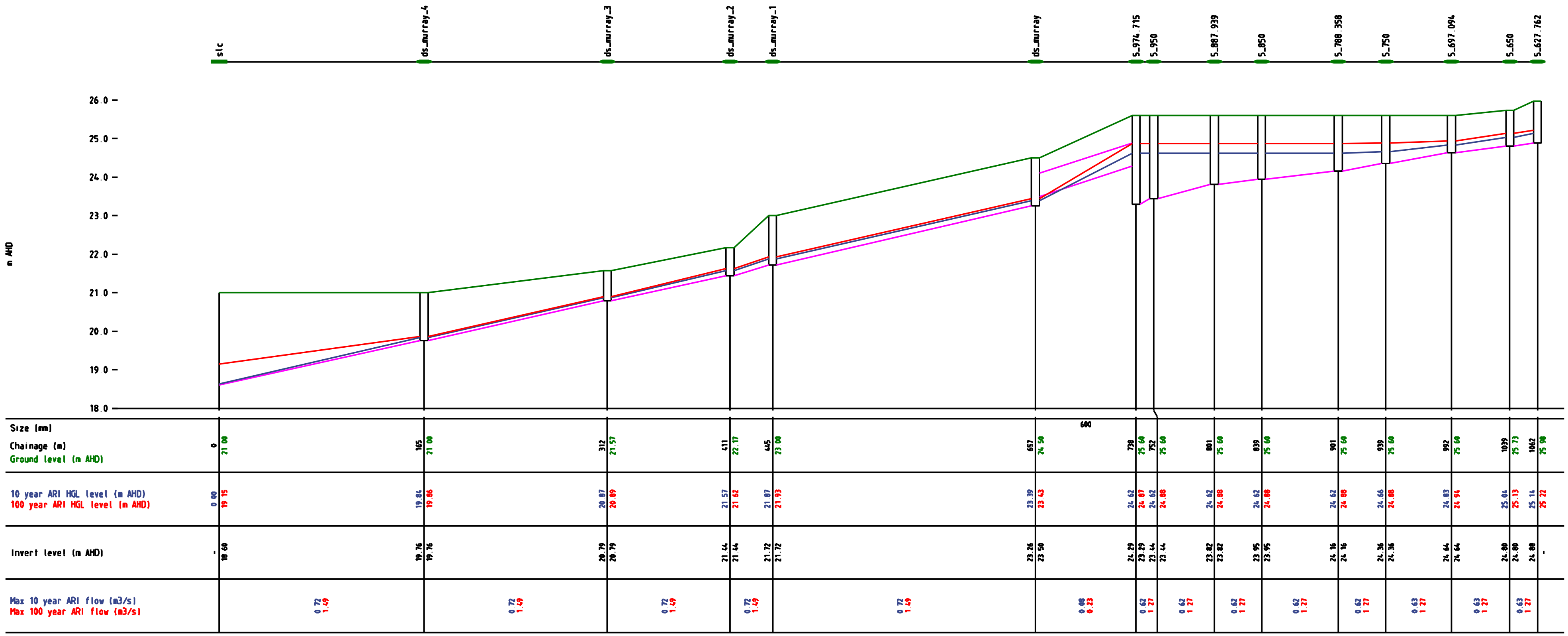
N





DESIGN FILE: Figure 10-11.20a Albion North.dgn

AUTHOR: S Saveski

Government of Western Australia
Department of Water

PROJECT N°: 6121416 DATE: 19/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

Albion North to St Leonards Creek
Part 1 of 2

LONGITUDINAL SECTION
Proposed System
Figure 10-11.20a-R

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

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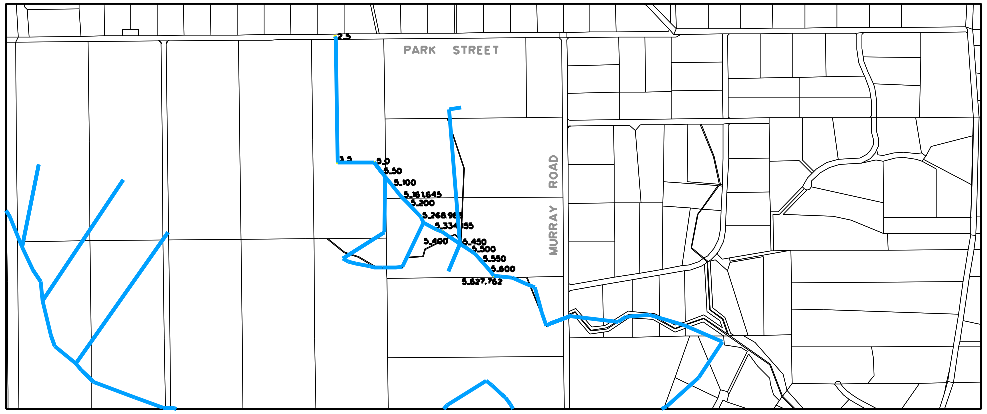

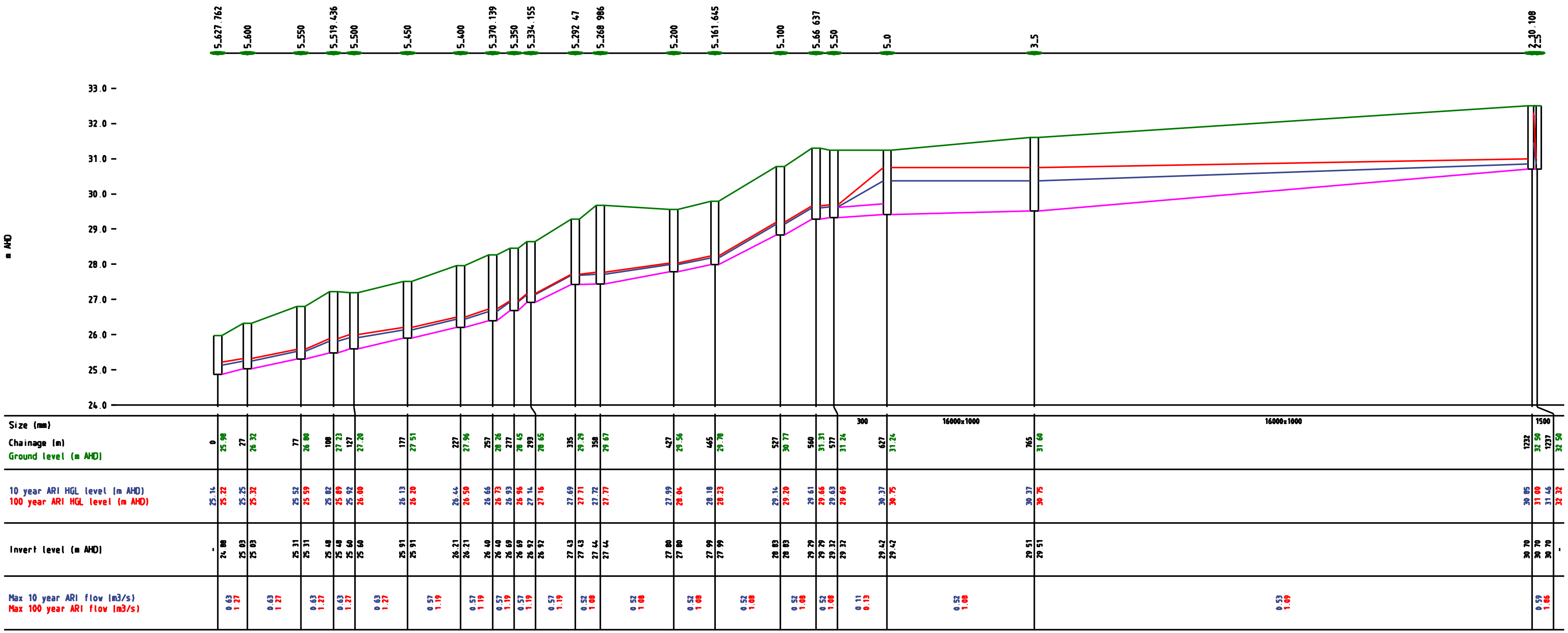

DESIGN FILE: Figure 10-11.20b Albion North.dgn

AUTHOR: S Saveski

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Department of Water

PROJECT N°: 6121416 DATE: 19/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

Albion North to St Leonards Creek
Part 2 of 2

LONGITUDINAL SECTION
Proposed System
Figure 10-11.20b-R

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

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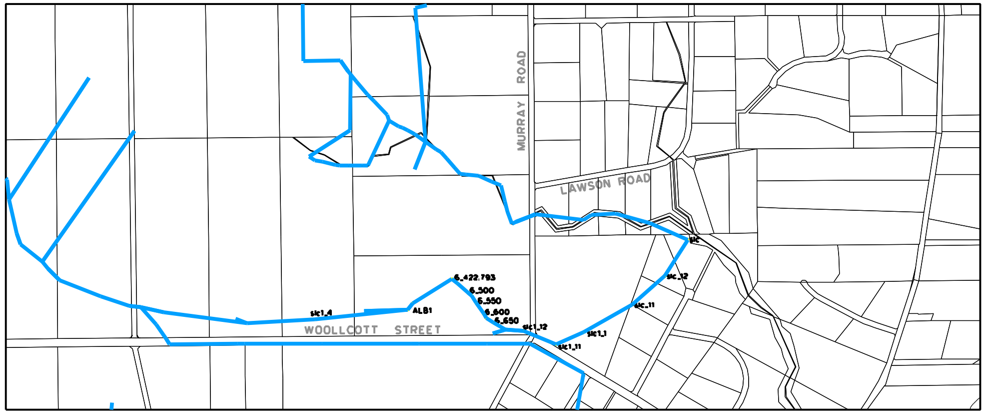

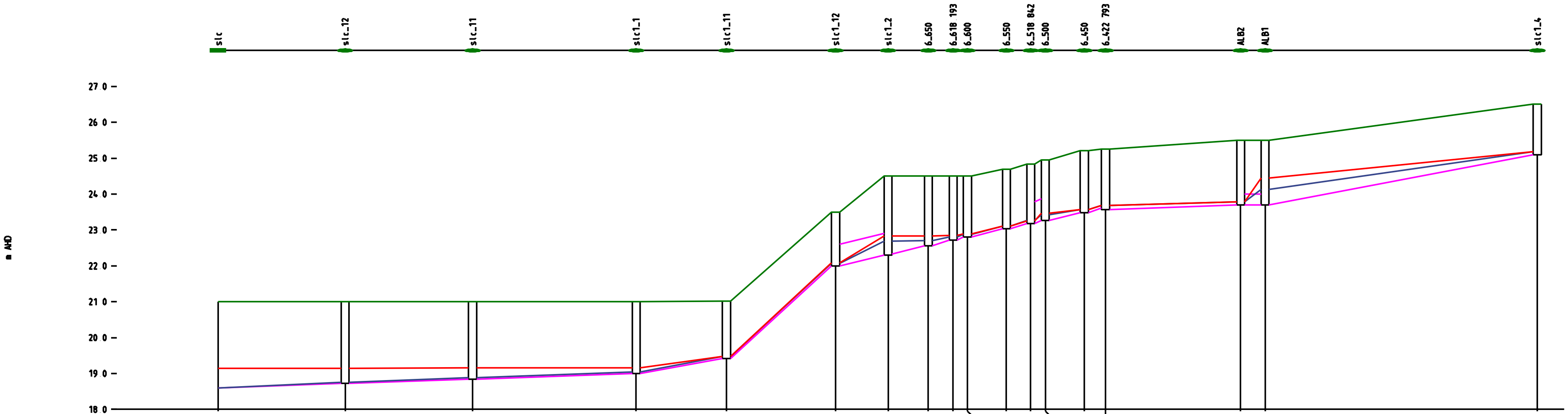

Chainage (m)	Ground level (m AHD)	10 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)
0	21.00	0.00	19.15	- / 18.60
162	21.00	18.76	19.15	18.72 / 18.72
326	21.00	18.88	19.15	18.84 / 18.84
535	21.00	19.04	19.15	19.00 / 19.00
651	21.01	19.48	19.48	19.42 / 19.42
790	23.50	22.07	22.08	22.00 / 22.00
858	24.50	22.69	22.83	22.30 / 22.33
909	24.50	22.70	22.84	22.57 / 22.57
941	24.50	22.80	22.85	22.72 / 22.72
959	24.50	22.88	22.89	22.80 / 22.80
1009	24.68	23.11	23.11	23.03 / 23.03
1041	24.83	23.26	23.26	23.18 / 23.18
1059	24.95	23.43	23.47	23.26 / 23.26
1109	25.21	23.57	23.57	23.49 / 23.49
1137	25.25	23.69	23.69	23.61 / 23.56
1310	25.50	23.78	23.78	23.70 / 23.70
1341	25.50	24.14	24.45	23.70 / 23.70
1690	26.50	25.18	25.18	25.10 / -

Reach (chainage, m)	Size (mm)	Max 10 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
0–162		0.19	0.31
162–326		0.19	0.31
326–535		0.19	0.31
535–651		0.15	0.26
651–790		0.15	0.26
790–858	600	0.15	0.26
858–909	50000x1500	0.07	0.12
909–941	50000x1500	0.07	0.11
941–959	50000x1500	0.07	0.11
959–1009	50000x1500	0.07	0.11
1009–1041	50000x1500	0.07	0.11
1041–1059	600	0.07	0.11
1059–1109	50000x1500	0.07	0.11
1109–1137	50000x1500	0.07	0.11
1137–1310	50000x1500	0.07	0.11
1310–1341	300	0.07	0.11
1341–1690	50000x1500	-0.06	-0.14

DESIGN FILE: Figure 10-11.21 Albion Central.dgn

AUTHOR: S Saveski

Government of Western Australia
Department of Water

Albion North to St Leonards Creek
Part 1 of 1

LONGITUDINAL SECTION
Proposed System
Figure 10-11.21-R

PROJECT Nº: 612416 DATE: 19/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

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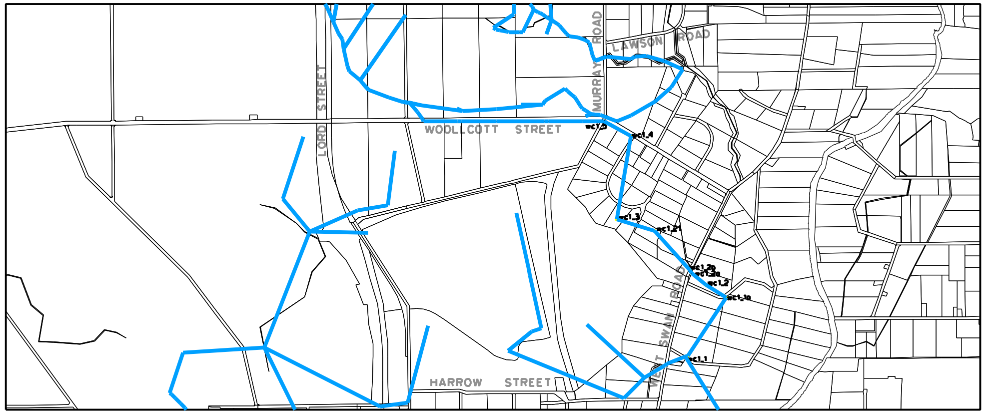
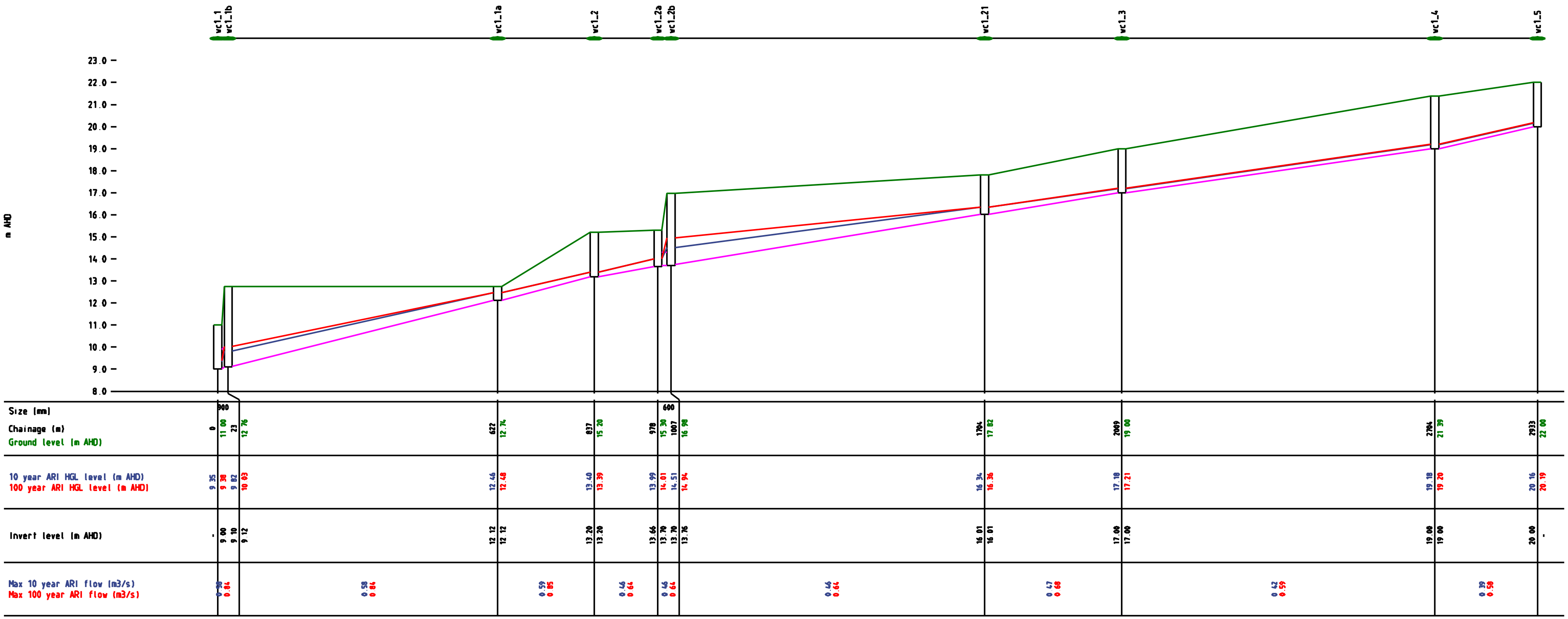
N





DESIGN FILE: Figure 10-11.22a Albion North.dgn

AUTHOR: S Saveski

Government of Western Australia
Department of Water

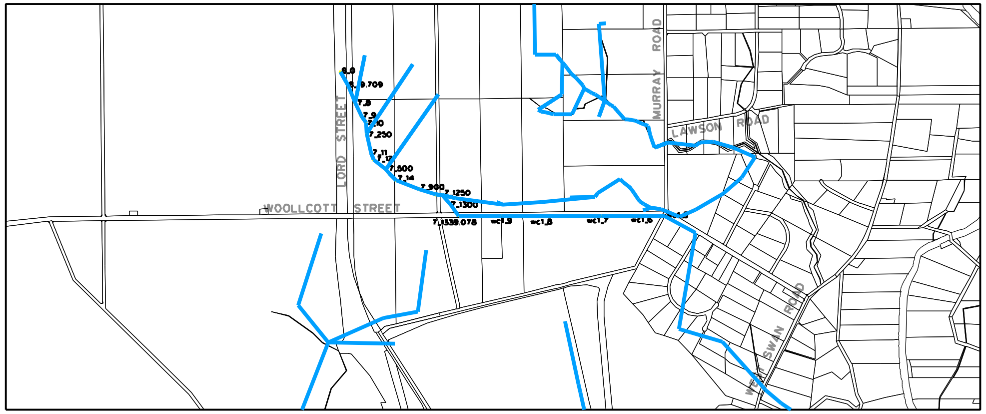
Albion North to Wandoo Creek
Part 1 of 2

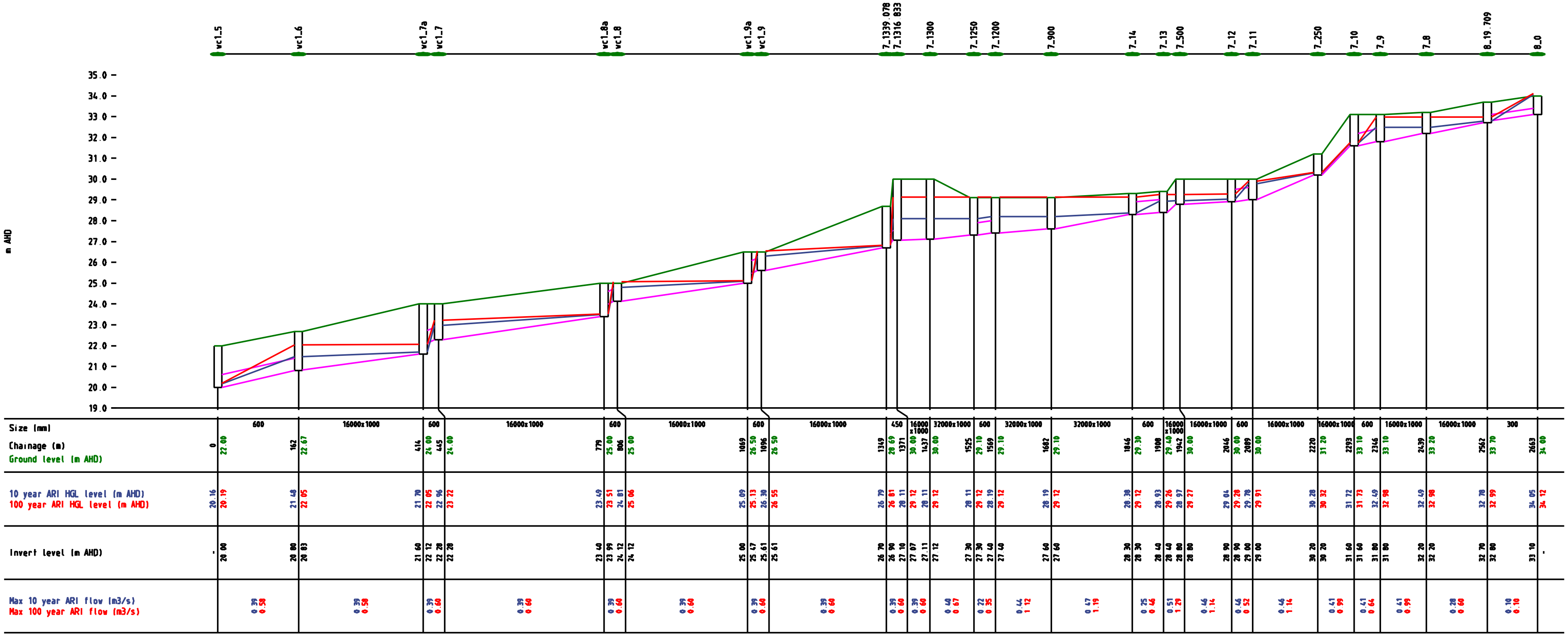
LONGITUDINAL SECTION
Proposed System
Figure 10-11.22a-R

PROJECT N°: 6121416 DATE: 19/05/2009 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





DESIGN FILE: Figure 10-11.22b Albion North.dgn

AUTHOR: S Saveski

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Department of Water

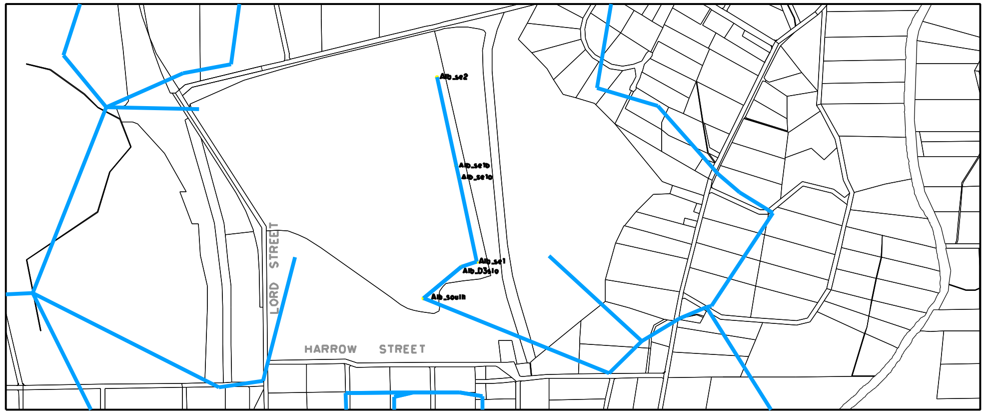
Albion North to Wandoo Creek
Part 2 of 2

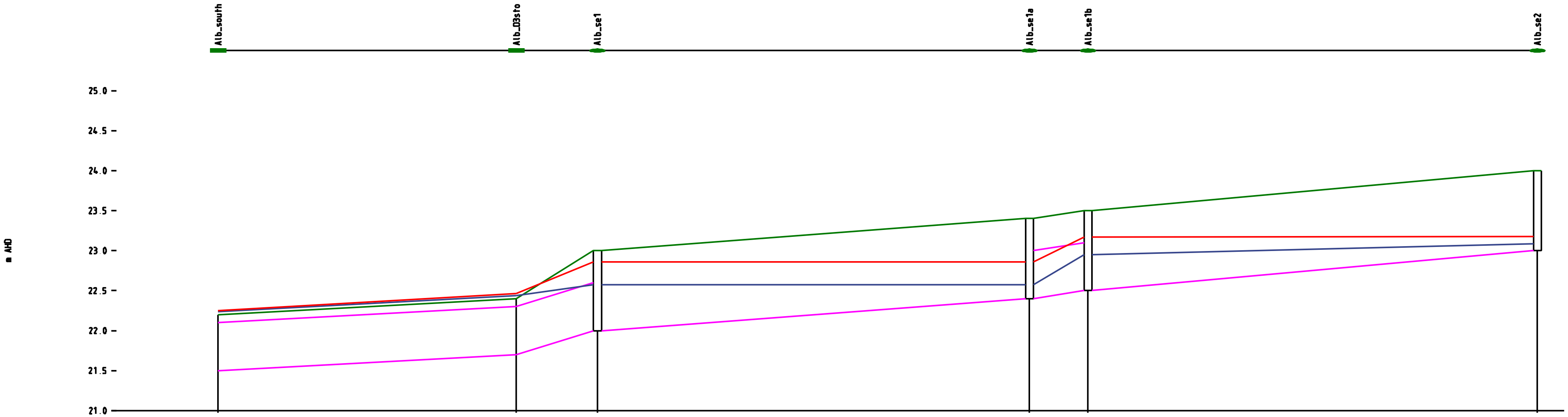
LONGITUDINAL SECTION
Proposed System
Figure 10-11.22b-R

PROJECT N°: 612416 DATE: 19/05/2009 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





	Alb_south		Alb_D3sto		Alb_se1		Alb_se1a		Alb_se1b		Alb_se2
Size (mm)		600		600		32000x1000		600		32000x1000	
Chainage (m)	0		279		355		761		815		1237
Ground level (m AHD)	22.20		22.40		23.00		23.40		23.50		24.00
10 year ARI HGL level (m AHD)	22.24		22.44		22.57		22.57		22.95		23.09
100 year ARI HGL level (m AHD)	22.25		22.46		22.86		22.86		23.17		23.18
Invert level (m AHD)	- / 21.50		21.70 / 21.70		22.00 / 22.00		22.40 / 22.40		22.50 / 22.50		23.00 / -
Max 10 year ARI flow (m3/s)		0.18		0.23		0.17		0.20		0.20	
Max 100 year ARI flow (m3/s)		0.20		0.39		-0.51		0.35		0.35	

DESIGN FILE: Figure 10-11.23 Albion South.dgn

AUTHOR: S Saveski

Government of Western Australia
Department of Water

Albion South to Wandoo Creek
Part 1 of 1

LONGITUDINAL SECTION
Proposed System
Figure 10-11.23-R

PROJECT N°: 6121416 DATE: 19/05/2009 COORDINATE SYSTEM: MGA94 - Zone 50

Appendices

Appendix A — Stormwater modelling in InfoWorks CS

Hydraulic modelling in InfoWorksCS

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, model the effect of backwater effect and reverse flow. The model is used predominantly for calculations of event-based simulations; therefore the initial conditions are usually set.

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 conduits are summarised in Table A-1.

Table A-1 Culverts roughness coefficient (Mannings n)

Drain type	Manning's coefficient of roughness
Maintained open drain	0.030
Unmaintained open drain	0.050
Circular culvert	0.012
Rectangular culvert	0.013
Over road flood route	0.015
Over land flood route	0.035

Regional flood storage volumes (detention basins) were calculated according to the principles outlined in 6 Stormwater management strategy. The numerical model is run for pre-development land use to determine maximum discharge from each subcatchment for critical 1-, 5- and 100-year average recurrence interval rainfall events. The peak pre-development discharge flow rates of the subcatchments are to be maintained in the post-development scenario.

The flood detention storage volume is tested by running critical 1-, 5- and 100-year average recurrence interval rainfall events for the post-development scenario. The peak discharge from the modelled flood storage area (detention basin) should not exceed the pre-development level, the storage volume should also be fully utilised. If the storage volume is inadequate, the volume is increased to achieve required volume utilisation, discharge out of the flood storage area (basin) and the shape of the hydrograph.

Groundwater levels in drains and flood storage area were modelled by the application of inflows directly into the drain. Groundwater levels and 100-year average recurrence interval event flood levels were used to determine flood peak water levels, indicative design ground levels and the invert of the flood storage area.

Modelling assumptions

The following assumptions apply to the modelling of the Swan urban growth corridor:

- average recurrence interval year rainfall events applied to whole catchment with a universal start time.
- Fixed tailwaters were applied to all simulations at the points of discharge into Bennet Brook and Henley Brook. Department of Water 100-year flood mapping levels were used for the 100-year simulations.
- The parameters presented in Table A-2 and Table A-3 for the proposed developments are based on an assumption that the one-year one-hour average recurrence interval event will be retained on site and therefore includes an initial loss of 10 mm. This initial loss is applied to all proposed development (including roads and lots on clay).
- A second assumption in these parameters is that the proposed development areas will achieve runoff performance at least as good as existing developed areas, however this may be dependent on proposed final design ground levels and subsurface drainage therefore these parameters are subject to review as more detailed information becomes available.

Land use for the existing and development scenarios (Table A-5) was developed based on cadastral information and the *Sub-regional structure plan for the Swan urban growth corridor* (Department for Planning and Infrastructure in press) and the more detailed structure plans supplied in the Caversham, West Swan Estate and Albion local water management strategies. The land use categories relate to hydrologic responses and do not necessarily relate directly to city planning or zoning categories.

Surface runoff parameters

The InfoWorks CS model of the Swan urban growth corridor uses a constant infiltration model to generate rainfall runoff and the SWMM single nonlinear reservoir routing model to provide inflows to the Hydraulic component of the model.

Catchment parameters are presented in Table A-2 and Table A-3 below and have been developed with consideration of the City of Swan *Stormwater drainage design specification D5* as well as other studies carried out for Department of Water.

The bulk of the pre-development catchment area is made up of mixed rural and bush land overlying sand and has very little existing impervious area, to further develop catchment parameters to represent this area consideration has been given to the adjacent (and partially overlapping) catchment of Bennett Brook that is gauged by the Department of Water.

A stream flow station (Site 616084) is operated in the catchment by the Department of Water. This station is located approximately 240 m south of Benara Road in Caversham. Stream flow data is available for periods January 1988–January 1993 and February 2001–July 2007.

Two significant rainfall events which resulted in identifiable peak flows in the Bennett Brook gauge record were selected. The first, a winter event, produced a peak flow rate of 3.12 m^3/s in the Bennett Brook. The second, a summer event, produced a peak flow rate of only 1.5 m^3/s. In order to replicate the winter event which approximated a 5-year average recurrence interval event catchment parameters and land use breakdown were developed resulting in a bulk catchment runoff parameter of 0.13. The catchment parameters developed in this investigation into the Bennett Brook catchment and therefore proposed for the bulk of the Swan urban growth corridor are presented in Table A-2.

The *Bennett Brook flood study* (GHD 1988) was carried out prior to the installation of a gauge in the Bennett Brook catchment and therefore used parameters calibrated for the Ellenbrook catchment. The bulk catchment runoff parameter used was 0.22 for the 5-year average recurrence interval event which resulted in a peak flow of 14.4 m^3/s in the Bennett Brook. Recorded gauge data since 1988 has never exceeded 3.5 m^3/s.

Table A-2 Catchment parameters for sand areas (derived from Bennett Brook)

Land use	**Surface roughness (Mannings N)**		**Initial loss (mm)**		**Runoff parameter (5yr ARI)**		**Runoff parameter (100yr ARI)**	
	Perv	Imperv	Perv	Imperv	Perv	Imperv	Perv	Imperv
Undeveloped rural land	0.035	0.015	10	10	0.1	0.2	0.2	0.3
Existing developed lots	0.025	0.015	10	10	0.1	0.2	0.2	0.3
Existing road network	0.025	0.015	10	1.5	0.1	0.4	0.2	0.6
Proposed developed lots	0.025	0.015	10	10	0.1	0.2	0.2	0.3
Proposed road network	0.025	0.015	10	10	0.1	0.2	0.2	0.3

Unlike the Bennett Brook catchment, the study area contains substantial areas of Guildford clay, most notably in the Caversham and West Swan East subcatchments close to the Swan River. Therefore a second set of catchment parameters are proposed for these areas and are presented in Table A-3.

Table A-3 Catchment parameters for clay areas

Modelled land use	Surface roughness (Mannings N)		Initial loss (mm)		Runoff parameter (5yr ARI)		Runoff parameter (100yr ARI)	
	Perv	Imperv	Perv	Imperv	Perv	Imperv	Perv	Imperv
Undeveloped rural land	0.035	0.015	10	10	0.2	0.3	0.3	0.4
Existing developed lots	0.025	0.015	10	1.5	0.2	0.3	0.3	0.4
Existing road network	0.025	0.015	10	1.5	0.2	0.6	0.3	0.8
Proposed developed lots	0.025	0.015	10	10	0.2	0.3	0.3	0.4
Proposed road network	0.025	0.015	10	10	0.2	0.3	0.3	0.4

Land use mapping of the pre-development subcatchments has been derived from aerial photography and cadastre and the following table provides the pervious/impervious breakdown applied to each of the categories used.

Table A-4 Pervious/impervious breakdown by mapped land use category

Mapped land use category	Undeveloped rural		Existing developed lots		Existing road network	
	Perv	Imperv	Perv	Imperv	Perv	Imperv
Bushland	100%	0%				
Commercial			70%	30%		
Drainage	50%	50%				
Education			80%	20%		
Rural	100%	0%				
POS			100%	0%		
Residential - higher density			50%	50%		
Road & road reserve					30%	70%
Special residential			50%	50%		
Vacant land	100%	0%				
Vineyard	100%	0%				
Public services			30%	70%		

The model was used to simulate flooding for the pre-development scenario (existing land use) and the post-development scenario (proposed development) as outlined in Table A-5.

Table A-5 Land use areas

Land Use	Area (ha)	
	Existing	Post-development
Bushland	1269.8	919.5
Commercial/church	12.19	31.1
Roads and road reserve	234.5	456.8
Drainage	39.0	26.8
Education	4.9	43.4
Multiple use	0	3.9
POS	10.4	214.9
Rural/rural residential	1114.0	694.7
Urban residential	47.1	738.8
Special residential	12.2	19.2
Public services/utility	0.9	48.5
Vacant land	493.3	51.1
Vineyard	104.3	91.9
Total	3342.6	3340.6

Design rainfall events for the 1h, 3h, 6h, 12h, 24h, 48h and 72h durations were run for 1-year, 5-year and 100-year average recurrence interval, the critical event duration was then selected for presentation of modelling results.

Sensitivity testing was carried out for both pre- and post-development critical 100-year average recurrence interval event scenarios with an additional 20% total rainfall depth. The purpose of this sensitivity test is to consider uncertainties in the intensity-frequency-duration curve and design temporal pattern information as well as to provide an indication of potential issues arising with climate change.

Both Engineers Australia and the Bureau of Meteorology have recently highlighted the need for a review of intensity-frequency-duration and design rainfall information and it has been suggested that future Australian Rainfall and Runoff updates may recommend a safety factor be applied to intensity-frequency-duration estimates in the absence of a review.

In the pre-development sensitivity test there was additional flooding predicted at locations throughout the study area with a few locations where the predicted depth of flooding increased by more than 500 mm.

In the post-development sensitivity test there was again additional flooding predicted at locations throughout the study area although in all locations the predicted additional depth of flooding was less than 300 mm. This suggests that the required 500 mm clearance from the predicted 100-year flood level will provide sufficient protection to properties with a 20% increase in total rainfall depths for events equivalent to the 100-year average recurrence interval event. This change could occur due to changes in design rainfall information or climate change.

Table A-6 InfoWorks model catchment properties for pre-development scenario

Subcatchment ID	Total area (ha)	Slope (m/m)	Catchment width (m)	% Impervious
10_0	34.998	0.003	333.8	0.3
10_1000	49.776	0.002	398	0
10_1000!	50.062	0.003	399.2	0
10_1387.333	15.291	0.003	220.6	0
10_650	37.042	0.003	343.4	4.3
13_100	49.101	0.003	395.3	0
7_1	45.842	0.002	382	12.9
7_2	72.929	0.003	481.8	0
Alb_centre	54.955	0.003	418.2	7.325
Alb_east	175.014	0.002	746.4	2.071
Alb_north	61.223	0.003	441.5	7.325
Alb_northeast	21.289	0.003	260.3	0.662
Alb_northeast!	29.195	0.003	304.8	0.662
Alb_northeast!!	7.074	0.003	150.1	0.662
Alb_northwest1	40.387	0.002	358.5	2.071
Alb_northwest2	44.569	0.002	376.7	2.071
Alb_northwest2!	35.114	0.002	334.3	2.071
Alb_northwest2!!	19.269	0.002	247.7	2.071
Alb_south	36.21	0.006	339.5	0.937
Alb_southeast	39.61	0.005	355.1	0
alb_southwest	52.787	0.003	409.9	2.908
Alb_west	96.257	0.001	553.5	10.298
bb1_1	67.927	0.005	465	8.782
bb1_2	194.333	0.002	786.5	8.517
bb1_3	27.238	0.002	294.5	8.517
bb1_4	49.324	0.001	396.2	14.137
bb1_5	25.768	0.001	286.4	5.354
bb2_1	41.838	0.005	364.9	30.198
bb2_2	22.272	0.005	266.3	30.198
bb3_1	29.201	0.002	304.9	40.528
bb5_1	210.879	0.005	819.3	1.791
bb5_2	154.384	0.005	701	0.795
bb5_3	115.922	0.002	607.4	1.699
Cav_northeast	26.372	0.005	289.7	9.989
Cav_northwest	49.009	0.003	395	8.626
Cav_southeast	43.122	0.005	370.5	9.989
Cav_southwest	74.185	0.003	485.9	8.626
slc1_1	19.084	0.002	246.5	8.96
slc1_2	87.758	0.003	528.5	7.325
slc1_3	462.094	0.003	1212.8	7.325
slc1_4	258.889	0.003	907.8	6.72
wc1_1	29.831	0.003	308.1	5.151
wc1_2	81.481	0.006	509.3	4.268
wc1_3	30.808	0.004	313.2	2.266
wc1_4	13.012	0.002	203.5	1.699

Subcatchment ID	Total area (ha)	Slope (m/m)	Catchment width (m)	% Impervious
wc2_1	39.156	0.001	353	5.354
WSwanE_centrenorth	28.504	0.001	301.2	3.126
WSwanE_centresouth	37.582	0.001	345.9	3.126
WSwanE_east	19.332	0.006	248.1	9.811
WSwanE_northeast	53.998	0.003	414.6	7.596
WSwanE_northwest	31.722	0.002	317.8	2.561
WSwanE_south	10.56	0.011	183.3	7.553
WSwanE_southeast	27.411	0.001	295.4	25.423
WSwanE_southwest	48.445	0.002	392.7	10.936
WSwanE_west	26.248	0.002	289.1	10.936
WswanW	71.915	0.003	478.4	10.038
WSwanW_north	22.995	0.007	270.5	9.028
WswanW_south	68.052	0.003	465.4	10.038
WSwanW_west	23.991	0.006	276.3	8.107
Subcatchment ID	Total area (ha)	Slope (m/m)	Catchment width (m)	% Impervious
10_0	34.998	0.003	333.8	0.3
10_1000	49.776	0.002	398	0
10_1000!	50.062	0.003	399.2	0
10_1387.333	15.291	0.003	220.6	0
10_650	37.042	0.003	343.4	4.3
13_100	49.101	0.003	395.3	0
7_1	45.842	0.002	382	12.9
7_2	72.929	0.003	481.8	0
Alb_centre	30.974	0.003	314	45.876
Alb_east	35.797	0.002	337.6	2.405
Alb_east1	36.118	0.002	339.1	56.597
Alb_east2	56.371	0.002	423.6	31.935
Alb_north	28.7	0.003	302.2	42.383
Alb_north2	35.362	0.002	335.5	60.71
Alb_north3	27.433	0.002	295.5	38.37
Alb_northeast	32.18	0.003	320	49.95
Alb_northeast2	25.494	0.002	284.9	39.198
Alb_northwest1	29.807	0.002	308	50.482
Alb_northwest2	67.483	0.002	463.5	53.036
Alb_northwest3	35.414	0.002	335.7	45.315
Alb_south	28.125	0.006	299.2	45.305
Alb_south2	19.152	0.002	246.9	51.36
Alb_southeast	32.505	0.005	321.7	4.646
alb_southwest1	40.066	0.003	357.1	18.896
alb_southwest2	30.202	0.003	310.1	18.367
Alb_west1	78.552	0.002	500	49.755
Alb_west2	43.199	0.001	370.8	55.597
bb1_1	67.927	0.005	465	8.783
bb1_2	194.333	0.002	786.5	9.347
bb1_3	27.15	0.002	294	9.935
bb1_4	48.311	0.001	392.1	23.363

Subcatchment ID	Total area (ha)	Slope (m/m)	Catchment width (m)	% Impervious
bb1_5	26.121	0.001	288.4	11.474
bb2_1	41.909	0.005	365.2	20.735
bb2_2	22.272	0.005	266.3	52.678
bb3_1	27.317	0.002	294.9	52.192
bb5_1	210.879	0.005	819.3	1.791
bb5_2	153.872	0.005	699.8	3.342
bb5_3	115.922	0.002	607.4	2.492
Cav_northeast	33.295	0.005	325.5	51.089
Cav_northwest1	25.523	0.003	285	55.353
cav_northwest2	19.417	0.002	248.6	54.497
Cav_southeast1	22.73	0.005	269	44.36
cav_southeast2	23.301	0.002	272.3	48.306
Cav_southwest1	36.102	0.003	339	46.451
Cav_southwest2	34.916	0.002	333.4	45.259
slc1_1	19.084	0.002	246.5	4.515
slc1_2	87.754	0.003	528.5	6.995
slc1_3	461.886	0.003	1212.5	7.506
slc1_4	259.544	0.003	908.9	2.355
wc1_1	29.831	0.003	308.1	3.198
wc1_2	81.481	0.006	509.3	5.094
wc1_3	30.808	0.004	313.2	6.724
wc1_4	13.012	0.002	203.5	4.801
wc2_1	39.147	0.001	353	11.064
WSwanE_centrenorth1	9.045	0.002	169.7	50.637
WSwanE_centrenorth2	26.245	0.001	289	41.247
WSwanE_east	38.223	0.006	348.8	50.377
WSwanE_northeast1	8.997	0.003	169.2	44.353
WSwanE_northeast2	5.001	0.002	126.2	39.173
WSwanE_northeast3	3.817	0.002	110.2	45.466
WSwanE_northeast4	12.644	0.002	200.6	46.958
WSwanE_northwest1	14.263	0.002	213.1	47.37
WSwanE_northwest2	24.883	0.002	281.4	43.652
WSwanE_northwest3	10.958	0.002	186.8	44.637
WSwanE_southeast1	14.088	0.001	211.8	48.812
WSwanE_southeast2	12.808	0.001	201.9	51.264
WSwanE_southeast3	12.427	0.002	198.9	46.213
WSwanE_southwest1	20.54	0.002	255.7	52.522
WSwanE_southwest2	23.25	0.011	272	53.456
WSwanE_southwest3	14.58	0.002	215.4	57.108
WSwanE_west1	13.234	0.002	205.2	59.229
WSwanE_west2	18.596	0.002	243.3	42.646
WswanW	72.069	0.003	479	45.225
WSwanW_north	24.17	0.007	277.4	46.468
WswanW_south	66.952	0.003	461.6	47.18
WSwanW_west	23.993	0.006	276.4	32.052

Appendix B — 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 Swan when an application for a local structure plan is lodged.

The checklist must 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: …………………………………………………………………

	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 CGL)				
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- and post-development identified				
3.10	Water sustainability Initiatives				
4.0	Stormwater 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 *Drainage and water management plan* section 6.2				

[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.

4.3	5-year ARI event managed for serviceability in accordance with *Drainage and water management plan* section 6.2				
4.4	100-year ARI event managed for flood protection in accordance with *Drainage and water management plan* section 6.2 (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 criteria: 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	Bio-retention system, subsurface drainage and drainage inverts				
5.3	Subsurface drainage design				
5.4	Groundwater management strategies to achieve: at least 60% reduction of total P at least 45% reduction of total N				
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 section 9.5 of *Drainage 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				

List of shortened forms

ADS	Arterial drainage scheme
AHD	Australian height datum
ARI	Average recurrence interval
BFS	Bush Forever site
CCW	Conservation category wetland
CGL	Controlled groundwater level
DEC	Department of Environment and Conservation
DPI	Department for Planning and Infrastructure
DRF	Declared rare flora
DSP	District structure plan
DWMP	Drainage and water management plan
DWMS	District water management strategy
EWR	Environmental water requirement
GDE	Groundwater-dependent ecosystem
HGL	Hydraulic grade line
LWMS	Local water management strategy
MUW	Multiple use wetland
PWSA	Public water supply area
REW	Resource enhancement wetland
TEC	Threatened ecological community
TN	Total nitrogen
TP	Total phosphorous
TWG	Technical working group
TWL	Top water level

UWMP	Urban water management plan
UWPCA	Underground water protection control area
WAPC	Western Australian Planning Commission
WDE	Water-dependent ecosystem

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