Department of Water
Government of Western Australia

Byford townsite drainage and water management plan

Looking after all our water needs

Department of Water

DWMP1

September 2008

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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 *Drainage and water management plan* presents the Department of Water's guidance for the Serpentine Jarrahdale Shire, the Western Australian Planning Commission, land developers and other state agencies about water management issues to help development proceed within the Byford Townsite area.

The *Drainage and water management plan* also assists in integrating land and water planning as required by *State planning policy 2.9* and outlined in *Better urban water management* (in preparation for the Department for Planning and Infrastructure, Department of Water, Western Australian Local Government Association and Department of Environment, Water, Heritage and the Arts by Essential Environmental Services, 2008).

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

A regional scale controlled groundwater level is established and advice for developers and stakeholders for the management of groundwater quantity and quality within the Byford townsite area is given.

Section 9 – implementation presents monitoring requirements for local water management strategies and an Implementation action plan.

1 Introduction

The Byford structure plan was approved in 2005 by the Serpentine Jarrahdale Shire and the Western Australian Planning Commission. The structure plan provides a guide to subdivision and development/redevelopment of the townsite and surrounding rural residential development.

The *Byford urban stormwater management strategy* was adopted by the Serpentine Jarrahdale Shire in 2003. The strategy set out guidelines for water-sensitive urban design. It was simplified to form the *Byford urban stormwater management strategy developer guidelines* in 2005. This *Drainage and water management plan supersedes* the *Byford urban stormwater management strategy* and *Byford urban stormwater management strategy developer guidelines.*

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 Water 2004, *Stormwater management manual for Western Australia*, Ch. 2, p. 14).

The scope of the *Drainage and water management p*lan is to cover all aspects of total water cycle management, including:

- protection of significant environmental assets within the structure plan area, including meeting water requirements and managing potential impacts from development
- water demands, supply options, opportunities for conservation and demand management measures and wastewater management
- surface runoff, including peak event (flood) management and the application of water-sensitive urban design principles to frequent events
- groundwater, including the impact of urbanisation, variation in climate, installation of drainage to reduce groundwater levels, potential impacts on the environment and the potential to use groundwater as a resource
- water quality management, which includes source control of pollution inputs by catchment management, acid 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* (prepared for the Department of Planning and Infrastructure, Department of Water, Western Australian Local Government Association and Department of Environment, Water, Heritage and the Arts by Essential Environmental Services, in press) and outlined in Figure 1-1 below.

Figure 1-1 Planning framework integrating drainage planning with land planning processes

This document presents the proposed arterial drainage scheme for the Byford townsite in accordance with the responsibilities for drainage planning assigned to the Department of Water by the state government.

1.1 Planning background

In addition to *Better urban water management,* the *Drainage and water management plan* uses the following documents to define its key principles and objectives:

- *Liveable Neighbourhoods - edition 4*
- *State Planning Policy no. 2.9: Water resources*
- *Byford townsite detailed area plan* (Statewest Surveying & Planning, Chris Antill Planning & Urban Design, McDowall Affleck, Thompson Partners and Landform Research, 2005)
- *Byford structure plan* (Taylor Burrell Barnett, 2005)

1.2 Previous studies

A number of key investigations have been undertaken in the Byford locality. 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.

The *Byford urban stormwater management strategy* was completed by Parsons Brinkerhoff in 2003. It presented stormwater management strategies for the study area and many of the proposed strategies have been incorporated into this study. The drainage hydraulic modelling carried out within this study has incorporated key hydraulic features of the strategy's XP-Storm model. The *Byford urban stormwater management strategy* was later simplified and issued as developer guidelines in 2005.

Local-scale groundwater modelling has recently been completed by CyMod Systems (2007) for the Department of Water to assess any impacts from variations in climate or planned development in the study area.

A floodplain management study including two-dimensional flood modelling has been completed by SKM (2007) for the Department of Water. A high resolution digital elevation model, created to assist flood modelling, has been made available as part of the surface water modelling outputs to supplement Landgate information.

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

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

1.3 Summary plan and checklist

Figure ES1 provides an overview of the arterial drainage scheme that is proposed for the Byford townsite area and which forms a major part of this *Drainage and water management plan*, addressing stormwater quantity management. In addition, recommendations and key design criteria for stormwater quality management are detailed.

Water Conservation

- Consumption target for water of 100 kL/person/yr including not more than 40-60 kL/person/yr scheme water;
- Meeting 5 Star Plus provisions for all new dwellings;
- The use of native plants is to be promoted, with native species constituting a minimum of 30-35% of total POS area;
- The use of on-site rainwater tanks is to be promoted, to achieve water consumption targets whilst also having the ability to fully or partially meet on site stormwater retention requirements.

Floodways

- Development outside of the Floodway should ensure finished floor levels at a minimum of 0.5 m above the 100 year flood level;
- The existing cross sectional area of waterways must be maintained. Restoration of waterways is essential and in some cases channel realignments and channel profile modifications may be carried out, provided it is demonstrated that the predevelopment cross-sectional area has been preserved subject to approval.

Roads

- Defined major arterial roads should remain passable in the 100 year ARI event;
- Minor roads should remain passable in the 5 year ARI event;
- Emergency evacuation areas defined at least 2.0 m above 100 year ARI event level.
- Water Quality treatment systems and Water Sensitive Urban Design structures must be designed in accordance with the Stormwater Management Manual for Western Australia (DoW, 2007) and Australian Runoff Quality (Engineers Australia, 2006).

Water Quality Design Targets

Water quality management BMPs to acheive design targets:

- Vegetated bioretention systems sized at 2% of the constructed impervious area they receive runoff from

OR

- to achieve:
  - At least 80% reduction of total suspended solids;
  - At least 60% reduction of total phosphorus;
  - At least 45% reduction of total nitrogen;
  - At least 70% reduction of gross pollutants

Approval Process

Proponents shall develop and present the strategies for water quantity and quality management in the Local Water Management Strategy and Urban Water Management Plans to support the 'Planning Approvals' required for the development to proceed.

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

It is strongly recommended that 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 LWMS or UWMP.

Groundwater Management

- The bio-retention system, subsurface drainag and drainage inverts are set at or above CGL although existing drainage inverts below CGL may remain;
- Subsurface drainage must be designed with free-draining outlets;
- Where development may discharge pollutants from the shallow groundwater to receiving environments, the following interim targets will be adopted:
  - 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.
- Discharge to water dependent ecosystems must be in accordance with the requirements of the Department of Environment and Conservation.

Fill

- The clean fill imported onto the site is to incorporate a band of material that will reduce phosphorus export via soil leaching, whilst also meeting soil permeability and soil compaction criteria specified by the Local Government Authority
- The development should ensure finished lot levels at a minimum of 0.8 m above the phreatic line;
- Where a perched water table exists or the predicted MGL is at or within 1.2 m of natural ground level, the importation of clean fill and/or the provision of sub surface drainage will be required.

Monitoring

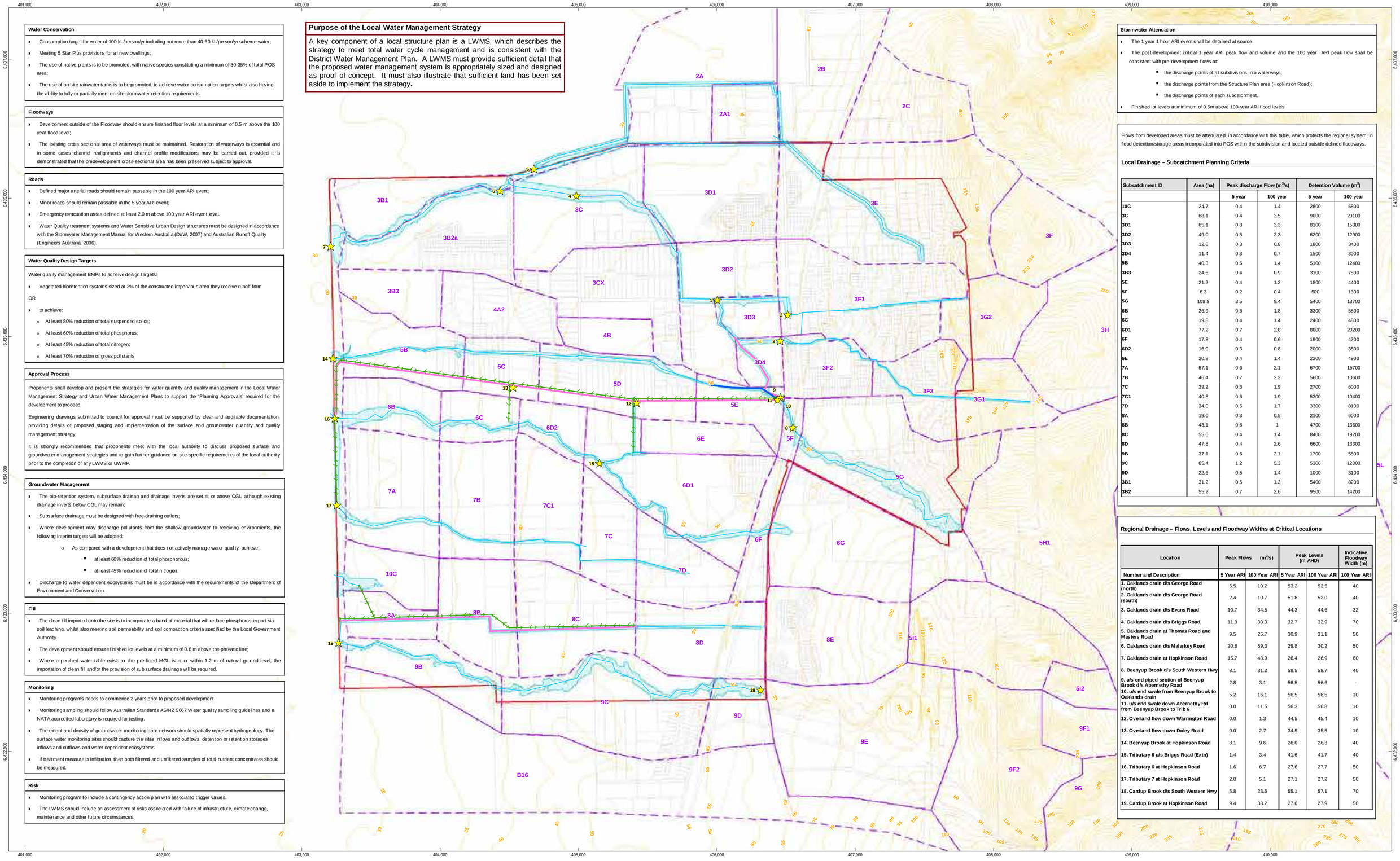
- Monitoring programs needs to commence 2 years prior to proposed development
- Monitoring sampling should follow Australian Standards AS/NZ 5667 Water quality sampling guidelines and a NATA accredited laboratory is required for testing.
- The extent and density of groundwater monitoring bore network should spatially represent hydrogeology. The surface water monitoring sites should capture the sites inflows and outflows, detention or retention storages inflows and outflows and water dependent ecosystems.
- If treatment measure is infiltration, then both filtered and unfiltered samples of total nutrient concentrates should be measured.

Risk

- Monitoring program to include a contingency action plan with associated trigger values.
- The LWMS should include an assessment of risks associated with failure of infrastructure, climate change, maintenance and other future circumstances.

Purpose of the Local Water Management Strategy

A key component of a local structure plan is a LWMS, which describes the strategy to meet total water cycle management and is consistent with the District Water Management Plan. A LWMS must provide sufficient detail that the proposed water management system is appropriately sized and designed as proof of concept. It must also illustrate that sufficient land has been set aside to implement the strategy.



Stormwater Attenuation

- The 1 year 1 hour ARI event shall be detained at source.
- The post-development critical 1 year ARI peak flow and volume and the 100 year ARI peak flow shall be consistent with pre-development flows at:
  - the discharge points of all subdivisions into waterways;
  - the discharge points from the Structure Plan area (Hopkinson Road);
  - the discharge points of each subcatchment.
- Finished lot levels at minimum of 0.5m above 100-year ARI flood levels

Flows from developed areas must be attenuated, in accordance with this table, which protects the regional system, in flood detention/storage areas incorporated into POS within the subdivision and located outside defined floodways.

Local Drainage – Subcatchment Planning Criteria

Subcatchment ID	Area (ha)	Peak discharge Flow (m^3/s)		Detention Volume (m^3)	
		5 year	100 year	5 year	100 year
10C	24.7	0.4	1.4	2800	5800
3C	68.1	0.4	3.5	9000	20100
3D1	65.1	0.8	3.3	8100	15000
3D2	49.0	0.5	2.3	6200	12900
3D3	12.8	0.3	0.8	1800	3400
3D4	11.4	0.3	0.7	1500	3000
5B	40.3	0.6	1.4	5100	12400
3B3	24.6	0.4	0.9	3100	7500
5E	21.2	0.4	1.3	1800	4400
5F	6.3	0.2	0.4	500	1300
5G	108.9	3.5	9.4	5400	13700
6B	26.9	0.6	1.8	3300	5800
6C	19.8	0.4	1.4	2400	4800
6D1	77.2	0.7	2.8	8000	20200
6F	17.8	0.4	0.6	1900	4700
6D2	16.0	0.3	0.8	2000	3500
6E	20.9	0.4	1.4	2200	4900
7A	57.1	0.6	2.1	6700	15700
7B	46.4	0.7	2.3	5600	10600
7C	29.2	0.6	1.9	2700	6000
7C1	40.8	0.6	1.9	5300	10400
7D	34.0	0.5	1.7	3300	8100
8A	19.0	0.3	0.5	2100	6000
8B	43.1	0.6	1	4700	13600
8C	55.6	0.4	1.4	8400	19200
8D	47.8	0.4	2.6	6600	13300
9B	37.1	0.6	2.1	1700	5800
9C	85.4	1.2	5.3	5300	12800
9D	22.6	0.5	1.4	1000	3100
3B1	31.2	0.5	1.3	5400	8200
3B2	55.2	0.7	2.6	9500	14200

Regional Drainage – Flows, Levels and Floodway Widths at Critical Locations

Location	Peak Flows (m^3/s)		Peak Levels (m AHD)		Indicative Floodway Width (m)
Number and Description	5 Year ARI	100 Year ARI	5 Year ARI	100 Year ARI	100 Year ARI
1. Oaklands drain d/s George Road (north)	5.5	10.2	53.2	53.5	40
2. Oaklands drain d/s George Road (south)	2.4	10.7	51.8	52.0	40
3. Oaklands drain d/s Evans Road	10.7	34.5	44.3	44.6	32
4. Oaklands drain d/s Briggs Road	11.0	30.3	32.7	32.9	70
5. Oaklands drain at Thomas Road and Masters Road	9.5	25.7	30.9	31.1	50
6. Oaklands drain d/s Malarkey Road	20.8	59.3	29.8	30.2	50
7. Oaklands drain at Hopkinson Road	15.7	48.9	26.4	26.9	60
8. Beenyup Brook d/s South Western Hwy	8.1	31.2	58.5	58.7	40
9. u/s end piped section of Beenyup Brook d/s Abernethy Road	2.8	3.1	56.5	56.6	-
10. u/s end swale from Beenyup Brook to Oaklands drain	5.2	16.1	56.5	56.6	10
11. u/s end swale down Abernethy Rd from Beenyup Brook to Trib 6	0.0	11.5	56.3	56.8	10
12. Overland flow down Warrington Road	0.0	1.3	44.5	45.4	10
13. Overland flow down Doley Road	0.0	2.7	34.5	35.5	10
14. Beenyup Brook at Hopkinson Road	8.1	9.6	26.0	26.3	40
15. Tributary 6 u/s Briggs Road (Extn)	1.4	3.4	41.6	41.7	40
16. Tributary 6 at Hopkinson Road	1.6	6.7	27.6	27.7	50
17. Tributary 7 at Hopkinson Road	2.0	5.1	27.1	27.2	50
18. Cardup Brook d/s South Western Hwy	5.8	23.5	55.1	57.1	70
19. Cardup Brook at Hopkinson Road	9.4	33.2	27.6	27.9	50

1:12,500 at A1

0 100 200 400 600 800 1,000

Metres

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

N

LEGEND

- Byford Drainage and Water Management Plan Area - GHD - 20070625
- Modelled Subcatchment - GHD - 20070823
- Cadastre - DLI - 20061201
- Critical Flow and Level Locations - GHD - 20080718

Drains - GHD - 20080131

- Main Waterway (Restored)
- Modelled Overland Flowpath
- Modelled Swale Drain
- Modelled Piped Drain

- 100 Year ARI Floodways (Not to be developed or obstructed in any way) - GHD - 20080215
- 5m Contours - GHD - 20080718

Byford Drainage & Water Management Plan
Summary Plan & Checklist

Department of Water
Government of Western Australia

Job Number	6122524
Revision	1
Date	17 Sept 2008

Figure ES1

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Dataset names include published date where available. Created by: N Tan

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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 Serpentine Jarrahdale Shire 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: ……...

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

Date: ……

	Item	Submission		Assessment	
		Document ref. 1	Comments2	Compliance	Comment
1.0	Introduction				
1.1	Drainage and water management principles and design objectives for this structure plan				
1.2	Planning background (subject land)				
1.3	Previous studies (related to drainage and water)				
2.0	Proposed development				
2.1	Key elements of structure plan				
2.2	Previous land use and potential sources of contamination				
2.3	Finished lot levels – (determined by greater of 100 year flood protection criteria or minimum separation of building foundations to MGL or 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-development 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				
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				

[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.

	access routes and fully identify flood plain and protection measures)				
4.5	Finished lot levels at minimum of 0.5m above 100-year ARI flood levels.				
4.6	POS credits identified				
4.7	Water quality management BMPs to achieve design targets: Vegetated bioretention systems sized at 2% of the constructed impervious area they receive runoff from OR to achieve: at least 80% reduction of total suspended solids at least 60% reduction of total phosphorus at least 45% reduction of total nitrogen at least 70% reduction of gross pollutants				
5.0	Groundwater management				
5.1	Groundwater level management strategy				
5.2	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				

2 Pre-development environment

Documents referred to for background information include:

- *Byford urban stormwater management strategy developer guidelines* (Parsons Brinkerhoff 2005)
- *Byford floodplain management strategy* (SKM, 2007)
- *Byford townsite detailed area plan* (Statewest et al. 2005)
- *Framework for developing the Jandakot water resources management strategy* (Parsons Brinkerhoff B 2004)
- *Planning bulletin No. 64* (Western Australian Planning Commission 2003)
- *Swan coastal geomorphic wetland mapping*

2.1 Study area

The study area of the *Drainage and water management plan* is the Byford townsite and surrounding locality as covered by the 2005 Byford structure plan).

The Byford town centre is located approximately 35 km south-east of the Perth CBD, within the Serpentine Jarrahdale Shire.

The *Byford structure plan* site is approximately 1500 ha and is bounded by Thomas Road to the north, Hopkinson Road and the future Tonkin Highway to the west, Cardup Siding Road to the south and the Byford townsite and Darling Range foothills to the east. Although the Byford Trotting Centre and surrounding rural residential area were excluded from the 2005 *Byford structure plan*, they will be included in this *Drainage and water management plan*.

The existing catchment land use is predominantly rural or rural residential, with the majority of rural land consisting of open grassland. The urban areas, which contain a mix of urban residential, commercial, light industrial, community and public open space, are currently concentrated between the South Western Highway and the lower foothills of the Darling Range.

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

2.2 Geotechnical information

The topography of the Byford locality is characterised by steep slopes in the foothills of the Darling Range, with an elevation of 120 m AHD falling rapidly to 80 m AHD at Linton Street and then gradually to 55 to 60 m AHD at the South Western Highway. To the west of the South Western Highway, the terrain is relatively flat palusplain (seasonally waterlogged land) (Figure A-2).

2.3 Soils

There are three primary soil types across the study area (Figure A-2). The soil types are:

- Ridge Hill colluvium from the Yogannup formation – highly variable layers of gravelly to sandy clay with lenses of silt and gravel
- Guildford clay – lenses of sandy clay, clayey sand, iron-rich cemented sand and sand. Low horizontal conductivity and very low vertical conductivity
- Bassendean sand – bleached grey to pale yellow sand with little ability to retain moisture or nutrients

Ridge Hill colluvium is found to the east of the study area, in the region of the Darling Scarp. To the west of the study area Guildford clay can be found interlaced with Ridge Hill colluvium. Overlaying the Guildford clay is Bassendean sand, which occurs in thin layers across the majority of the site.

The on-site soils are highly variable in phosphorous retention capacity, with grey-brown sands having a low capacity to retain phosphorous.

Acid sulphate soils

The Western Australian Planning Commission's *Planning Bulletin No. 64 (2003),* which is based upon a review of existing geomorphological, geological and hydrological information, indicates that the soils in the Byford area to the west of the South Western Highway consist of moderate to low risk of actual acid sulphate soils or potential acid sulphate soils occurring generally at greater than 3 m depth.

Low to no risk of actual acid sulphate soils or potential acid sulphate soils occurring generally at greater than 3 m depth can be found to the east of the South Western Highway in the Byford area (Figure A-3).

The risk of acid sulphate soils being exposed to oxidation due to development in the study area is considered low. As part of development requirements, new developments will need to introduce fill to a depth that is acceptable for residential construction as well as provide suitable flood clearance and adequate subsoil drainage.

2.4 Environmental assets and water-dependent ecosystems

Environmental assets and water-dependent ecosystems are presented in Figure A-4.

The Department of Environment and Conservation's *Swan coastal geomorphic wetland mapping* indicates there are wetlands classified as conservation category and resource enhancement within the Brickwood Reserve in the south-eastern section of the study area. Conservation category wetland classification also applies to the area of land between the South Western Highway and rail line north of Cardup Brook and along Cardup Brook to the east of the South Western Highway. These

wetlands are under the protection of the *Revised draft environmental protection policy wetlands* (EPA, 2004) with high conservation and environmental values.

Brickwood Reserve also contains remnant vegetation that is considered highly significant. The reserve is listed as Bush Forever site 321 and contains at least five priority taxa and three declared rare flora species (Statewest 2005), as well as eucalyptus woodland.

The northern portion of the remnant vegetation between the rail line and South Western Highway north of Cardup Brook is currently proposed to be listed as Bush Forever site 350.

Cardup nature reserve, which lies just outside the southern boundary of the study area, is classified as Bush Forever sites 271 and 352 and contains at least four priority taxa.

The two old shale quarries at the base of the scarp carry permanent water and have some conservation value, but are not now listed as wetlands under the *EPP policy* (Statewest et al. 2005).

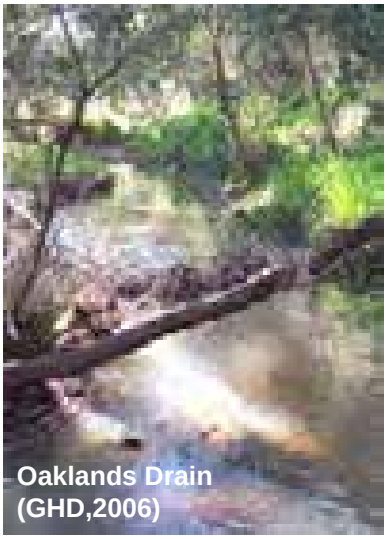
2.5 Social considerations

The Department of Indigenous Affairs has previously identified several sites of indigenous significance in the Byford townsite study area. These sites are mostly concentrated around the Cardup Brook and its floodplain, but also other smaller sites around the catchment.

The locations of these sites are identified in Figure A-4 and have been considered in developing this report. Prior to construction of individual developments, assessment should be undertaken by a qualified consultant to determine whether a more thorough Aboriginal heritage investigation of the area needs to be undertaken for any specific location to identify unregistered sites.

2.6 Surface water

A number of small creeks drain across the site from the scarp, including Oaklands Drain, Beenyup Brook and Cardup Brook. The most ecologically significant of these is Cardup Brook. The brook touches the southern edge of the study area. Beenyup Brook drains through the central south and two small creek lines drain across the northern parts. Each of these creeks is highly incised and the bottoms of these creeks are usually a few metres below the surrounding land surface.


Oaklands Drain
(GHD,2006)

Beenyup and Cardup Brooks have linkages to the west through constructed drains and discharge to the Birrega main drain. These watercourses eventually discharge to the Serpentine River system, which links to the Peel-Harvey Estuary.

To the west of Hopkinson Road, surface drainage consists of rural open drains. Some of these drains are declared and managed by the Water Corporation. They were originally designed to carry specified flows that would comply with the Department of Agriculture and Food's requirement that inundation of rural land should last no longer than three days. More recent monitoring and modelling, carried out by the Water Corporation, have indicated that this design criterion is approximately equivalent to the two-year average recurrence interval for main drains and the six-month interval for sub-drains.

The surface water drainage system comprises numerous small catchments draining from east to west. The upper catchments of the Darling Range foothills are well defined with steep catchment slopes, whereas the lower catchments are less defined.

The Byford area is known to experience regular water logging in the low-lying areas to the west of the study area. This inundation is due to a combination of persistent winter rainfall elevating the shallow water table, which rises to the surface and inundates vast areas of the flat terrain, as well as poor drainage, with insufficient capacity that does not allow runoff to leave the area. There is also potential for wetlands within the study area to receive additional flood water from outside their natural catchment by overtopping of drains and watercourses.

There are several local depressions east and west of the South Western Highway, which result in local perching of surface water after a large rainfall event.

Virtually the whole study area is designated as multiple use wetlands, with several areas designated resource enhancement or conservation category. The most significant of these wetlands lie within the Brickwood Reserve and along the course of the Cardup Brook (Figure A-4). A further conservation category is located downstream of the study area on the Beenyup Brook.

Surface water quality

Limited surface water quality data is available within the study area. The S*napshot survey of the Serpentine, Murray and Harvey catchments of the Peel-Harvey Estuary* (Wilson & Paling, 2002) included 10 sites within the Byford catchment. Samples were recorded for October 2001 and September 2002 but were only reported for 2002.

Four sites were located in Oaklands drain, one at Hopkinson Road and one on each of the three upstream branches. There were two sites on the Cardup Brook, one at Hopkinson Road and one close to the railway. Beenyup Brook was also served by two sites, again at Hopkinson Road, and close to the railway. The two remaining sites were at the Hopkinson Road end of two of the minor drains between Beenyup Brook and Cardup Brook.

Total phosphorous concentrations recorded at most of the sites in the Byford catchment were below 0.065 mg/L. This was the target concentration suggested by the *Byford urban stormwater management strategy* (PB 2003), although the downstream end of Beenyup Brook recorded total phosphorus concentrations in the range 0.065-0.20 mg/L and the downstream ends of both of the minor drains recorded total phosphorus concentrations greater than 0.20 mg/L.

Total nitrogen concentrations recorded in two of the upstream branches of Oaklands drain were below 1.2 mg/L, which was the target concentration suggested by the *Byford urban stormwater management strategy* (PB 2003). Total nitrogen concentrations in the third branch and the downstream end were in the range 1.2-3.0 mg/L. Beenyup Brook was also below 1.2 mg/L upstream, but was greater than 3.0 mg/L at its downstream location. In Cardup Brook, this trend was reversed with total nitrogen concentrations greater than 3.0 mg/L recorded upstream and less than 1.2 mg/L downstream. One of the minor drains was in the range 1.2-3.0 mg/L and the other was greater than 3.0 mg/L.

The *Draft water quality improvement plan for the rivers and estuary of the Peel-Harvey System* (2007) has considered further the water quality of the Serpentine, Harvey and Murray catchments. Specifically this plan states objectives for total phosphorous and indicates the percentage reduction required in each subcatchment to achieve the objectives. Recommendations from the plan have been incorporated into the water quality management strategies presented in section 6.3.

2.7 Groundwater

Groundwater flows

Geotechnical and groundwater investigations have been undertaken by Parsons-Brinkerhoff as part of the *Byford urban stormwater management strategy* and separately by the Water Corporation. Results from field measurements indicate that groundwater levels are typically shallow across the study area, varying between 0 – 6 m below natural surface level. Near Beenyup Brook for example, Department of Water data indicate groundwater varies between 1 – 5.4 m below natural surface level.

There are approximately 100 private groundwater bores in the study area, the majority of which target groundwater in sand lenses at the base of the Guildford clay at 17.5 – 25 m below natural surface level. For details of current groundwater allocations in Byford townsite, the Department of Water should be contacted directly.

Because of the local geology, groundwater in the study area is often perched during the winter months. The installation of improved surface and subsurface drainage systems is likely to quickly export this perched water into the drainage system, rather than allowing it to sit and gradually subside. This is likely to result in reduced deep aquifer recharge and increased drain baseflows.

Local scale groundwater modelling has also been completed by CyMod Systems (2007) for the Department of Water to assess any impacts from variations in climate or planned development in the study area.

The groundwater model was run for three scenarios: no development under average rainfall conditions (current climate); proposed development under average conditions;

and proposed development under wet rainfall conditions. Dry conditions were not selected as a post-development groundwater model.

Further information regarding the selection of pre- and post-development model scenarios and the construction and calibration of the groundwater model may be gained by requesting a copy of the *Groundwater modelling report* (CyMod Systems, 2007) from the Department of Water.

The study suggests that historical groundwater levels may be used as a basis for groundwater design objectives, given the overall downward trend in groundwater levels after 1995 due to the combination of abstraction of groundwater from bores and decreased rainfall.

There is only one long-term monitoring bore within the study area (T170, AWRC site No - 61410153), which is situated close to the intersection of Thomas Road and Hopkinson Road/Tonkin Highway (Figure A-5). The long-term maximum groundwater level at this location is 26.8 m Australian height datum, which correlates well to the *Perth groundwater atlas* 27 m maximum groundwater level contour that passes within 70 m of the bore's location. However, because the groundwater atlas coverage extends less than a kilometre into the study area and the CyMod model has not been used to analyse a pre-development wet scenario, maximum groundwater level cannot be presented at this time.

In order to provide recommendations for fill requirements appropriate to protection of infrastructure against likely maximum groundwater levels, further groundwater measurement, modelling or investigation must be carried out by developers to determine maximum groundwater levels over the proposed development site.

Groundwater quality

There is very limited groundwater quality data available for the study area. The *Byford urban stormwater management strategy* stated that shallow groundwater quality monitoring shows low levels of total phosphorous and very small concentrations of ortho-phosphorous in the groundwater. Total nitrogen concentrations were moderate, with moderate concentrations of nitrate and nitrite.

The report states that although these concentrations exceed relevant water quality guidelines, these concentrations are relatively low compared to other typical sites on the Swan Coastal Plain with historically pastoral or horticultural land uses.

Regarding salinity of groundwater within the study area, CyMod Systems (2007) found that the surface superficial groundwater is generally fresh or slightly brackish, whilst the groundwater of the Leederville aquifer is generally fresh (<1000 mg/L TDS).

3 Proposed development

3.1 Key elements of the structure plan

The *Byford structure plan* (Taylor Burrell Barnett, 2005) (Figure A-7) outlines the Serpentine Jarrahdale Shire's proposed plan for future subdivision and development/ redevelopment of the townsite and the surrounding rural residential area. The plan will have an impact on the surface water management strategy for the study area, as it will define on a district-scale the areas available for surface drainage infrastructure and corridors. There is flexibility within the plan on the types of best management practices that may be used for surface and groundwater quantity and quality management.

The *Byford structure plan* excludes the Byford Trotting Complex and surrounding rural residential areas that are not intended to be developed within the next 20 years.

The plan proposes substantial development of low-lying, rural floodplain areas. Much of the proposed development is residential (R2.5 to R60) and rural residential with a number of schools and pockets of mixed commercial and town centre.

Drainage corridors and proposed drainage basin locations have been included in the plan in accordance with the *Byford urban stormwater management strategy* (PB, 2003).

Since 2004, residential subdivisions in the *Byford structure plan* area have commenced. These developments have involved some minor clearing of trees and very extensive amounts of filling.

A particular concern, raised by the *Byford floodplain management study* (SKM, 2007), and confirmed by hydrologic and hydraulic modelling carried out as a part of this study, is that the main proposed town centre site is situated in an area at substantial risk of flooding. The *Byford structure plan* currently indicates that drainage through this area will be piped (there are no indicated drainage corridors) with an indicative overland flow path down Abernethy Road. However, the plan does include a public open space corridor between the railway line to the east and the trotting complex to the west and it may be possible to incorporate a waterway into this corridor subject to detailed engineering design at the local structure plan stage.

Future local structure plans, accompanied by local water management strategies, must address this issue. They must incorporate appropriate drainage corridors and infrastructure for the Beenyup Brook at this location as well as making provision for overland flood routing between the Beenyup Brook, Abernethy Road and the most southerly branch of the Oaklands drain as outlined in Section 6.2 of this report.

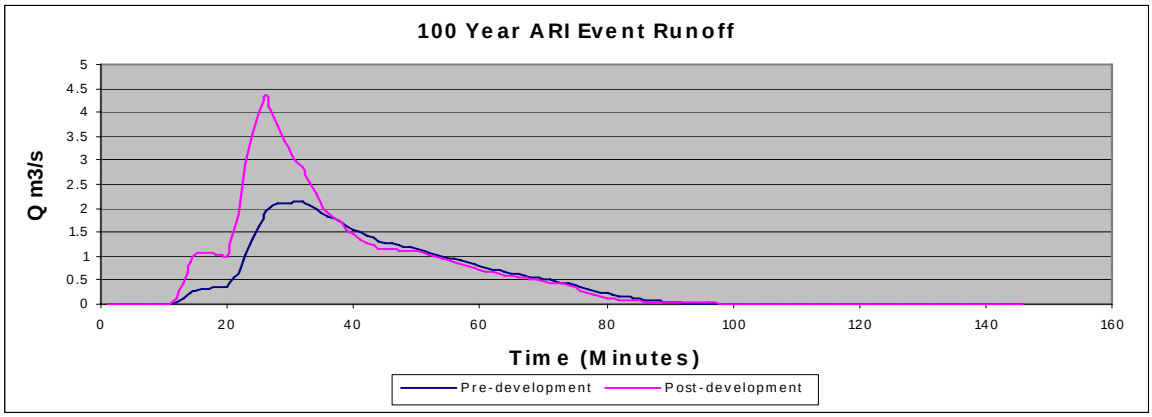
4 Protection of environmental assets

The following strategies have been developed to protect and enhance the value of environmental assets in the Byford structure plan area.

Minimise changes to hydrology to prevent impacts on watercourses and wetlands

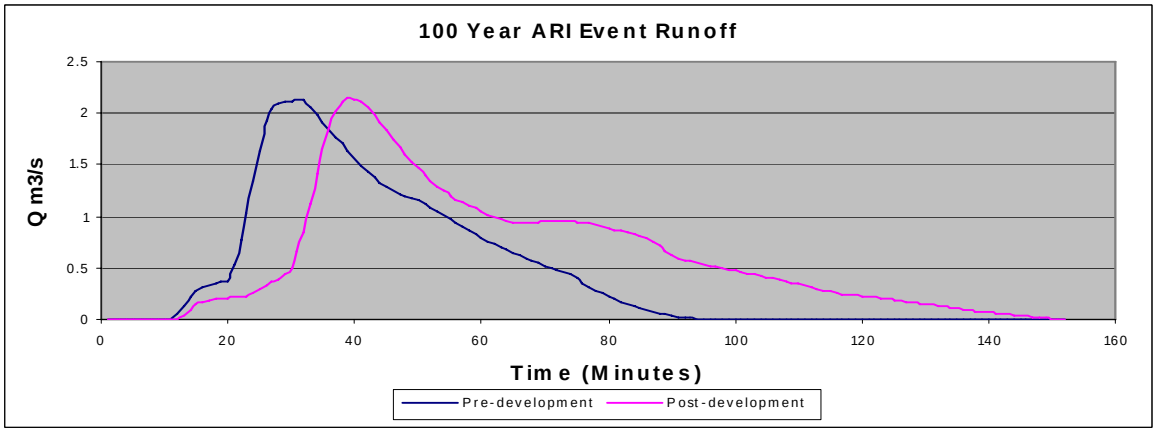
Changes in land use from rural to urban may lead to local increases in peak flows and volumes of runoff due to increases in impervious area (Figure 4.1 below). Large increases in peak flows and volumes have the potential to adversely impact on receiving environments by causing erosion and increasing the period of inundation of vegetation.

Figure 4-1 Typical pre- and post-development runoff hydrograph comparison.



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 below). 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 Typical pre- and post-development runoff hydrograph comparison, with compensated post-development flows.



Virtually the whole study area is designated as multiple use wetlands, with several areas designated resource enhancement wetlands or conservation category. The

most significant of these wetlands lie within the Brickwood Reserve and along the course of the Cardup Brook (Figure A-4). The Brickwood Reserve is upstream of the proposed development area and as such, no significant impact is anticipated. The preservation of the pre-development hydraulic grade line along the Cardup Brook will ensure that the potential for development impacts to this area will be minimised.

A further conservation category is located downstream of the study area on the Beenyup Brook. It is anticipated that the maintenance of pre-development peak flow rates at the downstream end of the study area, using the Hopkinson Road culverts as a critical control point, will ensure that there is no impact on this wetland.

Development will result in the loss of significant areas of multiple use wetlands. The addition of imported fill and subsurface drainage will control groundwater levels and soil wetness and therefore reduce the extent of inundated areas. In addition, improvements to surface water drainage will result in less extensive surface inundation, which will be confined to predetermined locations within public open space areas.

Manage and restore watercourses and wetlands

There are wetlands classified as conservation category and resource enhancement wetlands within the Brickwood Reserve in the south-eastern section of the study area (Figure A-4). The Environmental Protection Agency requires all conservation categories to be protected and managed for conservation purposes. The agency 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 Department of Environment and Conservation.

Assess and manage impacts on native flora and fauna

There are a number of declared rare and priority flora species within the study area, with one species shown (CALM 2003). 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 of and sensitive to the protection of native flora and fauna.

Assess and manage impacts on sites of indigenous significance

As discussed in section 2.5 of this report, the Department of Indigenous Affairs has identified several sites of indigenous significance in the study area (Figure A-4). Prior to construction of individual developments, assessment should be undertaken by a qualified consultant to determine whether a more thorough Aboriginal heritage investigation of the area needs to be undertaken for any specific location to identify unregistered sites.

5 Urban water use

The key objectives for urban water use are to:

- ensure the efficient use of all water resources in the newly-developing urban form and aim to achieve highest value use of fit-for-purpose water
- maintain opportunities for future generations by using water more efficiently. This is best achieved by combining several approaches such as raising community awareness, regulation, market mechanisms to facilitate recognition of the true value of water and financial incentives/assistance to facilitate change

5.1 Potable water supply

The State Government has identified demand reduction and efficient use of potable water as a priority. The *State water plan* (Government of Western Australia 2007) sets household consumption targets of less than 100 kilolitres per person per year (kL/person/year for consumers within Perth and not more than 40 to 60 kL/person/yr of scheme water.

Gardens (private and public) and public open space areas need to be waterwise in design to minimise irrigation requirements. Low water requirement plants should be predominantly used and turf areas should be kept to a minimum.

Tools

5 star plus: water use in houses code–stage 1

5 star plus is based around two new codes: the *Energy use in houses code* and the *Water use in houses code* The *Water use in houses code* has two stages; stage 1 apples to new homes approved for construction after 1 September 2007. The implementation date for stage 2 is yet to be determined (Department of Housing and Works 2007).

Water Efficiency Labelling and Standards Example Label, 2008.

5.2 Fit-for-purpose use water


Recycled water tap, GHD, 2006.

Fit-for-purpose water is often used in applications outside buildings, commonly for maintenance of public open space and passive and active recreation areas. Traditionally demand has been met by groundwater resources.

Development pressure and the drying climate have influenced the need for smarter urban form design and use of water in the urban landscape. Various programs are in place to build in water conservation and efficiency measures for public facilities and space.

The *State water recycling strategy* (Department of Premier and Cabinet and Department of Water 2008) identifies opportunities for new housing developments in Western Australia to access a variety of alternative water supplies. Innovative alternative water supply projects will come to the fore in a time when traditional water

sources reach maximum allocation limits. Assessment of risk, cost-benefit and practicality of these projects will be critical to the success of alternative water supply proposals.

Tools

H2Options (Water Corporation 2008) – a seven-step guide for developers to maximise water efficiency in the Perth metropolitan area. More information can be found at www.watercorporation.com.au/P/publications_alternative_water_supply.cfm

Water conservation/efficiency plans– – the State water recycling strategy (Department of Premier and Cabinet and Department of Water 2008) 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 s enable licensees to obtain a thorough knowledge of their water use and then provide details of a water efficiency implementation program to achieve improved water use efficiency.

International council for local environmental issues (ICLEI) water campaign™ – a collaborative program (of which the State Government is a partner) to build the capacity of local government to reduce water consumption and improve local water quality. More information about this program can be found at <www.iclei.org>.

Other documents that may provide guidance are:

- *Interim position statement: constructed lakes* (Department of Water 2007)
- *Interim position statement: third pipe (community bores*) (Department of Water in press)
- *Structural controls, stormwater management manual for Western Australia* (Department of Environment and Swan River Trust 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

Recommendations for floodplain management are presented in the *Floodplain management strategy* (SKM, 2007). This study developed two-dimensional modelling of the Byford catchment 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 focussed on managing potential flooding impacts on the site and to the immediate neighbouring land and drainage infrastructure.

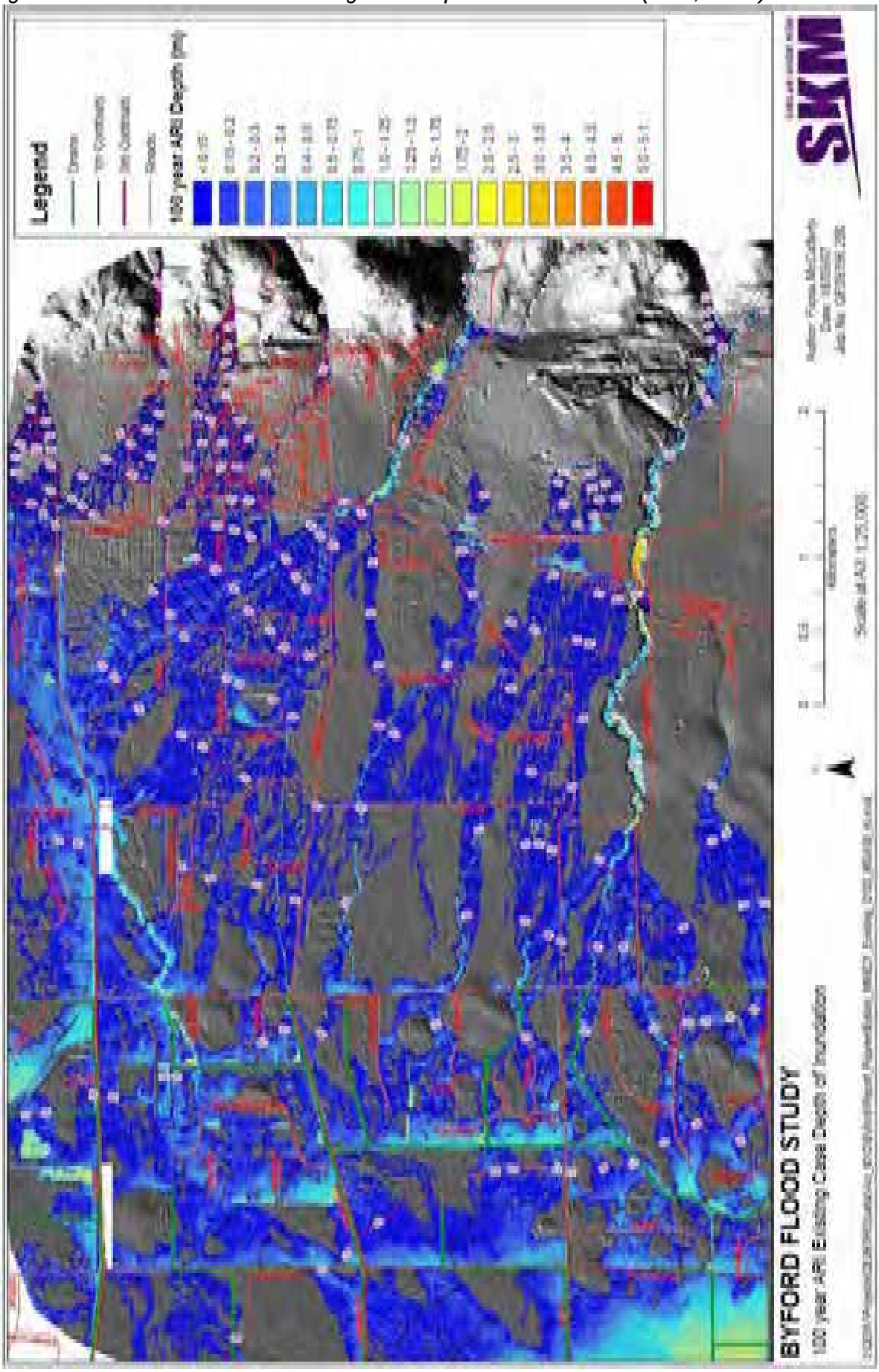
Flood mitigation measures

Flood mitigation measures are focussed on correct planning for appropriate land use in the structure plan areas and setting aside the land required for floodplain inundation depths. Existing and developed scenarios were presented within the *Floodplain management strategy* (SKM, 2007) and the 100-year *existing case depth of inundation* is reproduced in Figure 6-1 below. The ‘developed’ case includes raised ground levels within subdivisions but no other modifications, such as waterway realignments or new or modified road crossings and so has not been reproduced in this report.

Planning measures recommended by the *Flood plain management strategy* are:

- New dwellings in proposed and existing residential areas must have their floor levels elevated 500 mm above the 100 year annual recurrence interval flood level.
- New industrial or commercial premises should have their floor levels elevated 500 mm above the 100 year annual recurrence interval flood level.
- Major arterial roads with immunity to the 100-year annual 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 five-year annual recurrence interval flood event.

Figure 6-1 100 Year ARI existing case depth of inundation (SKM, 2007)



- The design of the new urban areas should incorporate current best practice in water-sensitive urban design to mitigate the impacts of urbanisation in the catchments on regional water quantity and quality.
- The proposed town centre in the structure plan was found by the *Floodplain management strategy,* to be located in an area of existing high or extreme flood hazard. *Drainage and water management plan* modelling indicates that this risk is manageable and a strategy for addressing the flood risk for the proposed town centre is presented in Section 6.2 of this plan.
- Waterways within the structure plan area should be constructed to manage the flooding from the 100-year annual recurrence interval flood event within their channels and floodplains without allowing flooding from the upstream catchment to enter adjacent residential areas.
- New drainage corridors should be designed with consideration of the current practice in water-sensitive urban design by incorporating water quality management controls and riparian vegetation to allow the drainage paths to recover to a more natural state once the agricultural pressures are removed.

A key recommendation within the *Flood management study* (SKM, 2007) was that emergency management planning should be undertaken to identify evacuation routes access for critical emergency services, as well as ensuring that locations are identified for temporary shelter that have sufficient floor level flood clearance.

6.2 Surface water quantity management

Minimise changes in hydrology to prevent impacts on receiving environments

Urbanisation results in increased impervious area. Increased rates and volumes of stormwater runoff must be managed to protect infrastructure and assets from flooding and inundation, while 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 annual recurrence interval event, the post-development discharge volume and peak flow rates shall be maintained relative to pre-development conditions in all parts of the catchment. Where there are identified impacts on significant ecosystems, desirable environmental flows and/or hydrological cycles shall be maintained or restored as outlined in this report and approved by the Department of Water.
- The catchment runoff shall be managed for all annual recurrence interval events up to and including the 100-year event within the development area to pre-

development peak flow rates. Pre-development critical five and 100-year annual recurrence interval event peak flow rates are specified in Table 6.1 of this report.

- Water-sensitive urban design and best management practices promoting on-site retention of events up to the one–year annual recurrence interval form the basis of the surface water quantity management strategy for minor events.
- The critical five and 100-year annual recurrence interval peak surface water flow rates shall be managed at the downstream end of the development area (Hopkinson Road) to pre-development peak flow rates to minimise the impacts on downstream rural areas to the west of Hopkinson Road.

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

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

Detention volumes required to meet the specified five and 100-year annual recurrence interval peak flows are presented in Table 6.1 of this report.

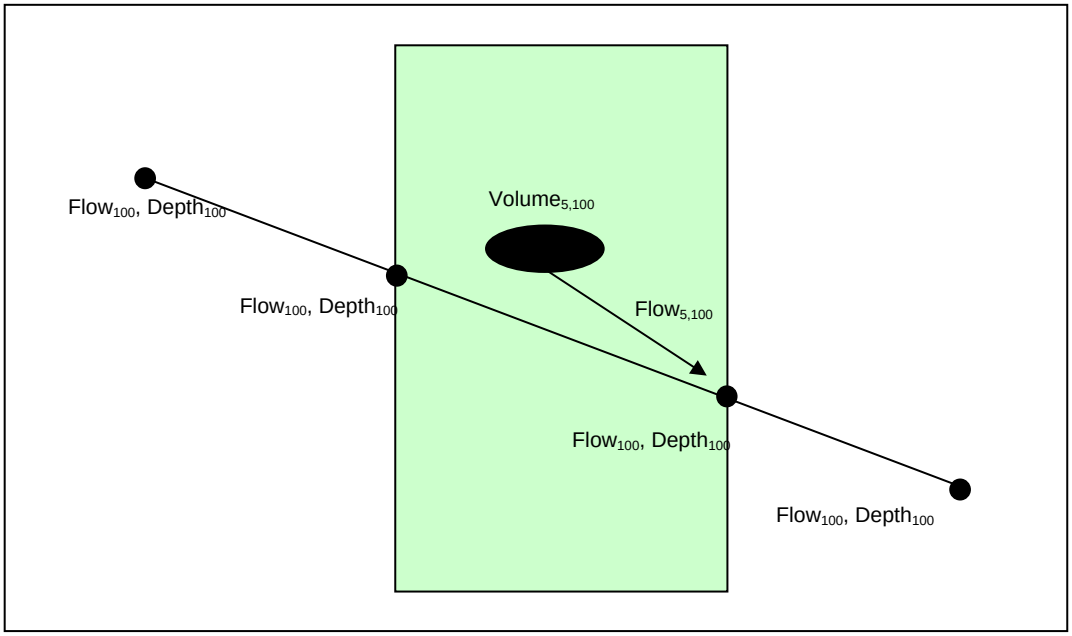
Figure A-8 in Appendix C and Table 6-1 below present the proposed surface water management strategy for Byford townsite. Indicative 100-year annual recurrence interval flood levels, overland flow paths, subcatchment delineation (Figure A-8), and discharge flows and detention volumes (Table 6-1), are provided at critical locations as a guide to developers and should be refined and located during local structure planning via the local water management strategy and finalised during subdivision scale planning via the urban water management plan. Longitudinal sections (Figures C-10a-p) of each main watercourse are provided to assist with the design of subdivisional drainage and may be used to accurately determine flows and levels as the waterways pass specific locations that are not necessarily indicated in Figure A-8.

For each subcatchment, the critical five and 100-year annual recurrence interval event pre-development discharge flow rates are presented in Table 6.1 along with an indicative post-development storage volume required to maintain that flow rate. The five-year year event is recommended by the Department of Water as the appropriate event for assessing the serviceability of local drainage, while flow paths and storage areas for the 100-year annual recurrence interval event should be provided for flood management purposes in accordance with the *Australian rainfall and runoff* (IEA,2001) concept of a minor/major drainage system.

It is important to note that the *Drainage and water management plan* model assumes that the one year one hour annual recurrence interval event (from allotments and also from the road network) is retained at source, so this volume is not included in the indicative flood detention volumes provided in table 6.1. Flows from the road network in a one-year annual recurrence interval event should be retained (or detained for the duration of the one-year event) within the road reserve network in a manner that mitigates pollutant export.

Discharge flow rates quoted in Table 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 as indicated by Figure 6.2 below.

Figure 6-2 Schematic presentation of information provided for subcatchments and main waterways



For each modelled node (Figure 6.2) along the main waterways, the critical 100-year annual recurrence interval event hydraulic grade line with associated peak flow rates is presented on longitudinal sections (Figures C-10a-p).

Where a proposed development forms a part of one or more of the subcatchments presented in Figure A-8, the storage volume to be provided by that development should be calculated based on the subcatchment surface area as a percentage of the total subcatchment surface area.

Where there is an inconsistency between the drainage planning criteria presented in this report (Table 6-1) and a previous approval, then the previous approval, and associated developers' obligations, should prevail. However, in a case where greater detention volumes are required by this report (Table 6-1) than those previously approved, an assessment will need to be made of the impact on public and private amenity for the determining event and a judgement made on whether remedial work is required. The issue of who has responsibility for investigation and any remedial work need to be discussed and determined.

Waterway dimensions and alignments as originally developed in the *Byford urban stormwater management strategy* have been retained where possible. Typical cross-sections are presented in Figure A-9. A summary of peak flows, levels and indicative floodway widths at critical locations (Figure A-8) is presented in table 6.2 below.

Table 6-1 Subcatchment drainage planning criteria – ultimate development

Subcatchment ID	Area	Peak discharge flow (m^3/s)		Detention volume (m^3)	
Subdivisional storage basins	**(ha)**	**5 year**	**100 year**	**5 year**	**100 year**
10C	24.7	0.4	1.4	2800	5800
3C	68.1	0.4	3.5	9000	20100
3D1	65.1	0.8	3.3	8100	15000
3D2	49.0	0.5	2.3	6200	12900
3D3	12.8	0.3	0.8	1800	3400
3D4	11.4	0.3	0.7	1500	3000
5B	40.3	0.6	1.4	5100	12400
3B3	24.6	0.4	0.9	3100	7500
5E	21.2	0.4	1.3	1800	4400
5F	6.3	0.2	0.4	500	1300
5G	108.9	3.5	9.4	5400	13700
6B	26.9	0.6	1.8	3300	5800
6C	19.8	0.4	1.4	2400	4800
6D1	77.2	0.7	2.8	8000	20200
6F	17.8	0.4	0.6	1900	4700
6D2	16.0	0.3	0.8	2000	3500
6E	20.9	0.4	1.4	2200	4900
7A	57.1	0.6	2.1	6700	15700
7B	46.4	0.7	2.3	5600	10600
7C	29.2	0.6	1.9	2700	6000
7C1	40.8	0.6	1.9	5300	10400
7D	34.0	0.5	1.7	3300	8100
8A	19.0	0.3	0.5	2100	6000
8B	43.1	0.6	1	4700	13600
8C	55.6	0.4	1.4	8400	19200
8D	47.8	0.4	2.6	6600	13300
9B	37.1	0.6	2.1	1700	5800
9C	85.4	1.2	5.3	5300	12800
9D	22.6	0.5	1.4	1000	3100
3B1	31.2	0.5	1.3	5400	8200
3B2	55.2	0.7	2.6	9500	14200

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

Location	Peak flows (m^3/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. Oaklands drain d/s George Road (north)	5.5	10.2	53.2	53.5	40
2. Oaklands drain d/s George Road (south)	2.4	10.7	51.8	52.0	40
3. Oaklands drain d/s Evans Road	10.7	34.5	44.3	44.6	32
4. Oaklands drain d/s Briggs Road	11.0	30.2	32.7	32.9	70
5. Oaklands drain at Thomas Road and Masters Road	9.5	25.7	30.9	31.1	50
6. Oaklands drain d/s Malarkey Road	20.8	59.3	29.8	30.2	50
7. Oaklands drain at Hopkinson Road	15.7	48.9	26.4	26.9	60
8. Beenyup Brook d/s South Western Hwy	8.1	31.2	58.5	58.7	40
9. u/s end piped Beenyup Brook d/s Abernethy Road	2.8	3.1	56.5	56.6	-
10. u/s end swale from Beenyup Brook to Oaklands drain	5.2	16.1	56.5	56.6	10
11. u/s end swale down Abernethy Rd from Beenyup Brook to Trib 6	0.0	11.5	56.3	56.8	10
12. overland flow down Warrington Road	0.0	1.3	44.5	45.4	10
13. overland flow down Doley Road	0.0	2.7	34.5	35.5	10
14. Beenyup Brook at Hopkinson Road	8.1	9.6	26.0	26.3	40
15. Tributary 6 u/s Briggs Road (Extn)	1.4	3.4	41.6	41.7	40
16. Tributary 6 at Hopkinson Road	1.6	6.7	27.6	27.7	50
17. Tributary 7 at Hopkinson Road	2.0	5.1	27.1	27.2	50
18. Cardup Brook d/s South Western Hwy	5.8	23.5	55.1	57.1	70
19. Cardup Brook at Hopkinson Road	9.4	33.2	27.6	27.9	50

Notes:

- Flows at Hopkinson Road in the 100 year ARI event provided in this table include flow overtopping the road and are therefore greater than those shown on the longitudinal sections (Figure A-10).

A regional flood management strategy has been developed to address the flood risk at the town centre. The strategy is presented in Figure A-8 and Table 6.2 above and includes the construction of a new high-level overflow into a swale drain along the length of Abernethy Road, as well as provision of an overland flow path or swale connecting Beenyup Brook with Oaklands drain and a piped section of Beenyup Brook.

The location and design of this infrastructure are conceptual only and may be modified to suit local design requirements.

Funding for the design and construction of regional flood management measures will need to be provided via a developer contribution scheme. Details of this scheme are being developed by the Serpentine Jarrahdale Shire and the Western Australian Planning Commission.

There will be some flooding of the road surface in Warrington and Doley Roads. Modelling indicates that the product of depths and velocities on these road surfaces will not exceed 0.4 m^2/s as recommended in *Australian rainfall and runoff* (IEA, 2001) to prevent pedestrians being swept along.

6.3 Surface water quality management

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

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

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

To minimise the average annual load of pollutants discharged by stormwater management systems into receiving environments, appropriate site-specific targets will be developed and adopted as indicated by the *Draft water quality improvement plan for the rivers and estuary of the Peel-Harvey system, Environmental Protection (Peel Inlet-Harvey Estuary) Policy 1992* (Government of Western Australia) and other investigations underway.

The *Water quality improvement plan* has been developed to address catchment management measures and control actions relating to phosphorus, but does not specify site-specific design criteria. Until the outcomes of other investigations are known, and site-specific targets have been developed, interim targets will be adopted and are presented in section 6.4 of this *Drainage and water management plan*.

The water quality objectives of the plan are:

Median loadings of total phosphorus to estuarine waters should be less than 75 tonnes per annum in an average year with;

- the median load of total phosphorus flowing in the estuary from the Serpentine River being less than 21 tonnes

Water qualities in streams in winter are to meet mean concentrations of 0.1 mg/L TP at current mean flows.

In the Upper Serpentine catchment, the plan found that winter concentrations were in

the range 0.1-0.2 mg/l and total winter loads were in the range 15-20 tonnes.

The draft *Water quality improvement plan* specifies that reductions of 30-40 per cent for load and concentration are required in the upper Serpentine catchment to meet its objectives and recommends the following best management practices for urban areas:

Table 6-3 Recommended best management practices

Best management practices	Definition of recommended action
Residential fertiliser	Use low water soluble fertiliser applied to sandy textured soils, applied sparingly to gardens and turf. Minimise lawn areas or plant an alternative lawn. Fertilise only when symptoms of nutrient deficiency occur e.g. yellowing. Use a complete lawn fertiliser containing nitrogen, phosphorus and potassium, if fertiliser is required. Apply fertiliser at the maximum individual application rate that is 25 grams per square metre for couch and 12 grams per square metre for kikuyu and buffalo grass. If fertiliser is required apply in spring or early autumn (Sept, Oct, Nov, Mar and Apr). Do not fertilise during summer or winter months. Do not over-water.
Full sewerage connection	Connect all new urban developments to sewerage. Build into approvals conditions by decision-making authorities for all new subdivisions and new homes to be connected to reticulated sewerage.
Soil remediation	Ensure all new urban developments in areas with sandy soils undergo soil remediation at the estate scale. At the lot scale blend or apply a layer of higher PRI soil 0-50 cm beneath the finished ground level to provide increased phosphorus retention. Use soil amendment materials such as yellow Spearwood sands, Karrakatta soils or brown loams. Remediate soil in accordance with Peel-Harvey coastal catchment water-sensitive urban design technical guidelines. Take care to maintain soil permeability.
Water and nutrient sensitive principles	Decision-making authorities should take a lead planning role in incorporating best management practices including water-sensitive urban design principles, criteria and outcomes in its strategic landuse planning, policies structure plans and subdivision conditions.
Water-sensitive urban design	Comply with environmental quality criteria should be incorporated in local planning policy Ensure design complies with stormwater management policies Apply water-sensitive urban design treatment trains Prepare water management strategies Undertake soil amendment. Ensure total phosphorus and total nitrogen import and export criteria are met. Meet the minimum percentage area of deep-rooted perennial vegetation Impose building and landscaping covenants Ensure sound construction and building site management.

Best management practices	Definition of recommended action
Drainage reform	Modify drainage management practices to reduce in-channel sediment movement as opportunities arise. Manage drainage as part of the total water cycle with the dual objectives of optimising stormwater runoff and reducing nutrient flows into the rivers and streams

The *Water quality improvement plan* has been developed to address catchment management measures and control actions relating only to phosphorus loads to the waterways. The Environmental Protection Authority recognises that there are other problems within the Peel-Harvey system. These include the nitrogen concentrations in estuarine waters; estuarine and riverine habitat loss; acid soil drainage; and bacteria concentrations – animal and human effluent. All of these problems require action.

Further investigations are already underway on these issues and will become components of a catchment management plan, as required in the 1989 environmental conditions, subsequently amended in 1991 and 1993 (Environmental Protection Authority, 2003).

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* (Engineers Australia, 2006).

6.4 Key design criteria

Surface water quantity

- The one-year one-hour annual recurrence interval event shall be detained at source for the duration of the event through the use of retention (soakage) or storage devices. Refer to Chapter 9 of the *Stormwater management manual for Western Australia* (Department of Water, 2007) for devices suited to the soil types for this catchment. The manual contains guidance for the appropriate design of retention and detention systems.
- The post-development critical one-year annual recurrence interval peak flow and volume and the 100-year annual recurrence interval peak flow shall be consistent with pre-development flows at:
    - the discharge points of all subdivisions into waterways
    - the discharge points from the structure plan area (Hopkinson Road)
    - the discharge points of each subcatchment
- Flows from developed areas must be attenuated, in accordance with Table 6-1 in flood detention/storage areas incorporated into public open space within the subdivision and located outside defined floodways(Figure A-8);

- Post-development flows for all annual recurrence interval events must be discharged at flow rates that are consistent with pre-development flow rates for those same events.
- Floodways are defined on Figure A-8 and contain the regional 100-year annual 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.
- Developments outside the floodway should ensure finished floor levels at a minimum of 0.5 m above the 100 year flood level.
- The existing cross-sectional area of waterways must be maintained. Restoration of waterways is essential and in some cases channel realignments and channel profile modifications may be carried out, provided it is demonstrated that the pre-development cross-sectional area has been preserved. A permit may be required to alter the beds and banks of waterways under the *Rights in Water and Irrigation Act 1914.*
- Public open space and retention basins should operate as dry basins with a minimum clearance of 0.3 m between the controlled groundwater level and the invert of the basin. Wet basins are not recommended by the Department of Water and are unlikely to be approved by the Serpentine Jarrahdale Shire.
- Defined major arterial roads should remain passable in the 100-year annual recurrence interval event. This requirement applies to but is not confined to Abernethy Road, Kardan Boulevard, Thomas Road and South Western Highway. The local authority should be contacted to identify other roads where this requirement applies.
- Minor roads should remain passable in the five- year annual recurrence interval event.
- Emergency evacuation areas should be defined at least 2.0 m above the 100-year annual recurrence interval event level.
- 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 2007) and *Australian runoff quality* (Engineers Australia 2006).

Surface water quality

The Department of Water is currently developing water quality targets that will be finalised in 2008. In the interim, designs may be based on the methodology established in the *Stormwater management manual for Western Australia* (Department of Water 2007).

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

- non-structural measures to reduce applied nutrient loads
- on-site retention of one-year one-hour annual recurrence interval events

- bioretention structures/systems, (also referred to as ‘rain gardens’) to be sized at two per cent of connected impervious areas

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

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

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

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

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

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

7 Groundwater management strategy

The key objectives for groundwater management are:

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

7.1 Glossary of groundwater terms

Controlled groundwater level

Controlled groundwater level is a groundwater level endorsed by the Department of Water. Sub-surface drainage may not be installed below the controlled groundwater level.

The actual level selected will vary according to availability of data and/or modelling results. Commonly, when a modelling approach is used, the rainfall record for a year with close to average rainfall for the current climate is run and the winter maximum groundwater level for this scenario becomes the controlled groundwater level. Alternatively, where a historical groundwater record is available, the average of recorded maxima for a selected period of record that is representative of the current climate may be chosen.

Maximum groundwater level

Maximum groundwater level is a groundwater level endorsed by the Department of Water. The actual level selected will vary according to availability of data and/or modelling results, but is commonly the maximum recorded groundwater level for a high rainfall condition.

Developments will be required to make the development surface level 1.2 m above the maximum groundwater level, if subsurface drainage is not installed.

Phreatic line

The phreatic line is the modified (post-development) maximum groundwater level following the installation of subsurface drainage and is in fact an arc in between subsurface drainage lines, as indicated on the diagram below.

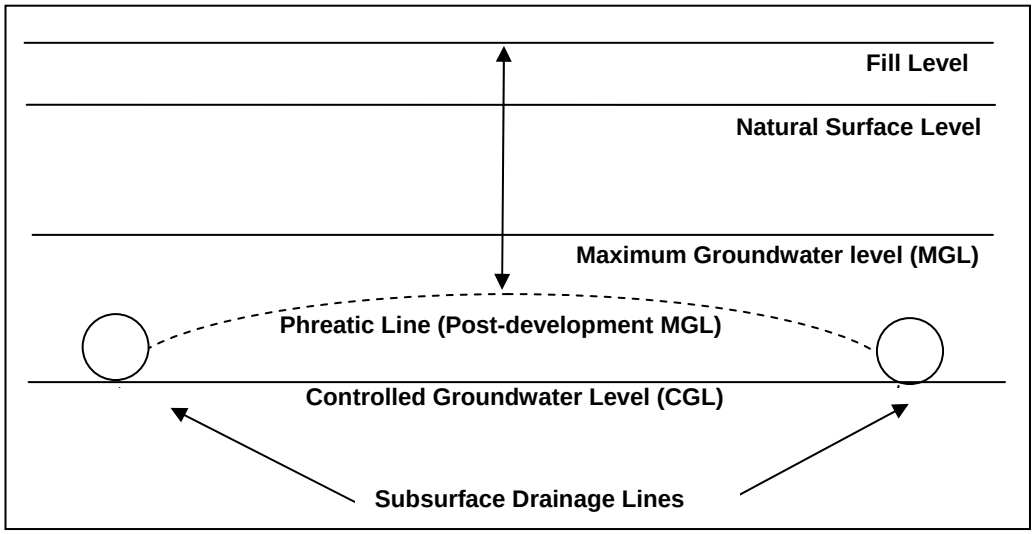
When subsurface drainage is installed the phreatic line becomes the level from which building floor level clearance to groundwater is measured.

Meeting the groundwater clearance and subsurface drainage criteria

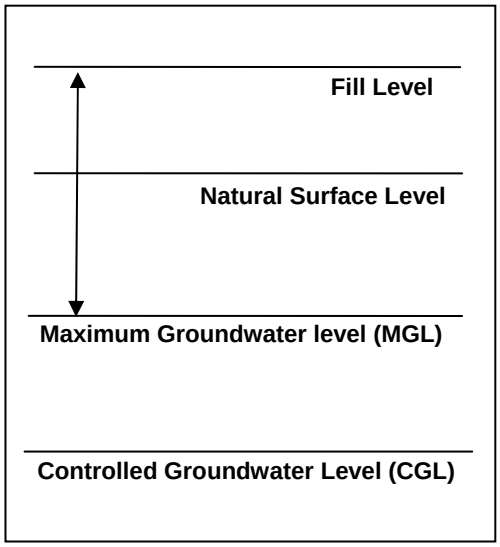
Examples of different ways in which the groundwater clearance and subsurface drainage criteria may be met under different conditions are presented below.

Case 1: The natural surface is less than 1.2 m above maximum groundwater level. Subsurface drainage is installed at controlled groundwater level to control the maximum groundwater level. However, because the natural surface is less than 1.2

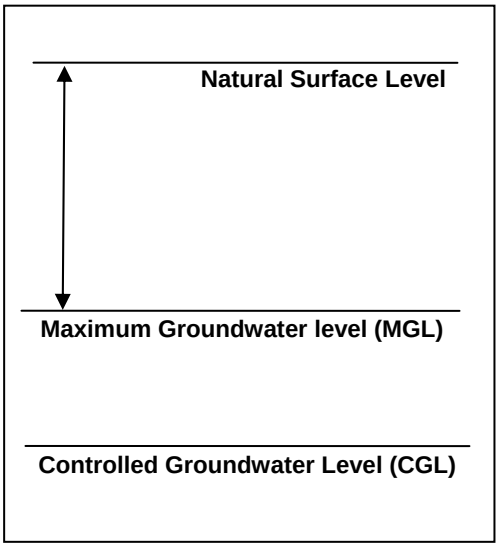
m above the resultant phreatic line, some additional fill has also been provided to meet the minimum clearance requirement.



Case 2: The natural surface is less than 1.2 m above maximum groundwater level. Fill is provided to meet the minimum clearance requirement.



Case 3: The natural surface is greater than 1.2 m above maximum groundwater level. No fill or subsurface drainage is required to meet the minimum clearance requirement.



7.2 Groundwater quantity management

Manage groundwater levels to protect infrastructure and assets

To protect housing from flooding and damage from groundwater, the predicted maximum groundwater level must be determined, through modelling and/or measurement. Where this information is not available, local studies shall be undertaken and endorsed by the Department of Water. Where the predicted maximum groundwater level is at or within 1.2 m of the surface the importation of clean fill and/or the provision of sub surface, drainage will be required to ensure that

adequate separation of building floor slabs from groundwater is achieved. In such instances, the sub-surface drainage will need to be placed at a Department of Water/Department of Environment and Conservation approved controlled groundwater level.

Groundwater modelling (CyMod Systems, 2007) included three scenarios – no development under average rainfall conditions (current climate) and proposed development under both average and wet rainfall conditions. Dry conditions were not selected as a post-development groundwater model.

Further information regarding the selection of pre- and post-development model scenarios and the construction and calibration of the groundwater model may be gained by requesting a copy of the *Groundwater modelling report* (CyMod Systems, 2007) from the Department of Water.

The district scale predicted maximum groundwater level has not been defined at this time for the study area. Localised perching that is common within this catchment cannot be accurately represented by district scale modelling and must be considered when determining the local scale predicted maximum groundwater level, which is important for the protection of urban infrastructure.

The district scale controlled groundwater level adopted for the study area and presented in Figure A-5 is the pre-development average rainfall scenario as modelled by CyMod Systems (2007).

Further investigations will be required to determine local scale predicted maximum groundwater level for individual developments to determine whether subsurface drainage is required for protection of urban infrastructure. This drainage should always be located at or above the district scale controlled groundwater level as presented in Figure A-5.

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 district scale controlled groundwater level shall be undertaken and endorsed by the Department of Water.

It has been identified that localised perching of groundwater is quite extensive within the development area. Where there is a groundwater-dependent ecosystem that is reliant on this seasonal perched groundwater, it will be necessary to maintain this regime. Investigations to derive a local scale controlled groundwater level shall be undertaken and endorsed by the Department of Water.

Local controlled groundwater levels 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 outlined in the *Urban development and determination of ecological water requirements of groundwater-dependent ecosystems* (Department of Water, in preparation).

Once the ecological water requirements have been determined, controlled groundwater levels can then be finalised in accordance with the requirements of the *Decision process for stormwater management in WA* (Department of Environment and Swan River Trust, 2005). Controlled groundwater 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.

Any proposals to control the seasonal or long-term maximum groundwater levels through a controlled groundwater level approach should demonstrate through adequate field investigations, to the satisfaction of the Department of Water, how any local and regional impacts are to be managed.

Manage the shallow aquifer to protect the value of groundwater resources

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

Groundwater modelling (CyMod Systems, 2007) has indicated that unmanaged future bore usage will result in long-term lowering of groundwater levels. Results for both of the proposed development scenarios predict decreases in groundwater levels when compared to the pre-development case. These results indicate that the level of bore usage assumed for the purposes of groundwater modelling cannot be supported. The post-development wet rainfall sequence scenario predicts groundwater levels of 0.40 m higher than those predicted for the average rainfall scenario, although they are still lower than those in the pre-development scenario.

In addition, the introduction of subsurface drainage may result in reduced aquifer recharge as a result of the loss of seasonal perching and its slow subsidence.

If groundwater abstraction is to be supported for new development in the area, a water balance should be prepared as a part of a local water management strategy to identify the potential long-term impacts. Ongoing monitoring and control will be essential.

7.3 Groundwater quality management

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

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

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

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

Where appropriate, field investigations 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*.

7.4 Key design criteria

- Where a perched water table exists or the predicted maximum groundwater level is at or within 1.2 m of the natural ground level, the importation of clean fill and/or the provision of sub-surface drainage will be required to ensure that adequate separation of building floor slabs from groundwater is achieved. In such instances, the sub-surface drainage will need to be placed at or above the approved controlled groundwater level.
- The bio-retention system and drainage inverts are set at or above controlled groundwater level although existing inverts below the level may remain.
- Subsurface drainage is to be installed at or above controlled groundwater level.
- Subsurface drainage must be designed with free-draining outlets.
- Development should ensure finished lot levels at a minimum of 0.8 m above the phreatic line.
- The clean fill imported onto the site is to incorporate a band of material that will reduce phosphorus export via soil leaching, whilst also meeting soil permeability and soil compaction criteria specified by the local government authority.
- Where development is associated with any new or existing waterway or open drain that intersects the shallow water table, and that may discharge pollutants from the shallow groundwater to receiving environments, the following interim targets will be adopted until such time as appropriate site-specific targets are developed:

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

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

Where development is associated with an ecosystem that is dependent on a particular hydrologic regime for survival, the water quality discharged to the

groundwater 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 strategy.

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

8 Commitment to best management practice

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

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

The existing *Byford structure plan* (Figure A-7) includes realignment of some multiple use corridors away from existing natural drainage features and alignments. It is the recommendation of this study that the *Byford structure plan* should be amended to rectify this anomaly and include the drainage corridors presented in Figure A-8 of this *Drainage and water management plan.*

The hierarchy of best management practice principles is as follows:

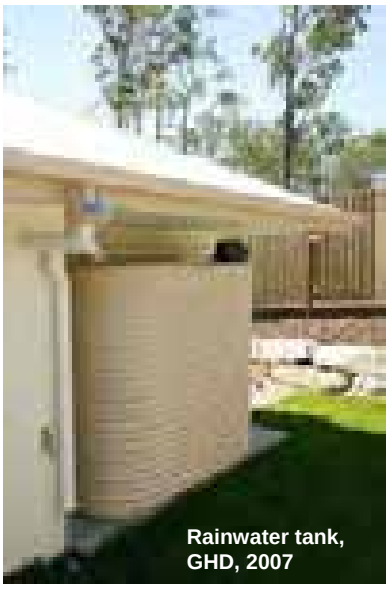
implement controls at or near the source to prevent pollutants entering the system and/or treat stormwater

- install in-transit measures to treat stormwater and mitigate pollutants that have entered the conveyance system
- implement end-of-pipe 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 in increasing order of scale include:

- residential lot scale:
    - on-site soakage devices, where appropriate, with overflow outlets (detention)
    - 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



Rainwater tank, GHD, 2007

  - porous pavements
  - amended topsoils
  - landscaped infiltration structures
  - hydrocarbon management and sediment traps
  - 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*(In preparation)
  - use of imported fill material with a high phosphorous retention capability
  - retention of existing waterways and restoration of 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

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 authority on the practices most appropriate for adoption within the Byford townsite.

9 Implementation

9.1 Requirements for following stages

State planning policy 2.9: water resources (Government of WA, 2006) 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* (in preparation for the Department of Planning and Infrastructure, Department of Water, Western Australian Local Government Authority and Department of Environment, Water, Heritage and the Arts by Essential Environmental Services, 2008 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

In summary, 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 an urban water management plan where required by the Department of Water and Serpentine Jarrahdale Shire, 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.* Guidelines for local water management strategies and urban water management plans are in preparation by the Department of Water. In the interim the Department of Water regional office can be contacted for guidance on the requirements of these documents. Developers are encouraged to contact the Department of Water and Serpentine Jarrahdale Shire early in the planning process to discuss specific water management requirements for proposals

It is recommended that the *Byford structure plan* (Figure A-7) be modified to reflect the recommendations of this *Drainage and water management plan* and to remove reference to the *Byford urban stormwater management strategy* (SJ Shire 2003). Furthermore, it is recommended that the *Shire of Serpentine Jarrahdale town planning scheme No. 2* be amended to remove reference to the *Byford stormwater management strategy.*

9.2 Review of Drainage and water management plan

It is intended that the *Drainage and water management plan* be reviewed within ten years or earlier if deemed necessary until development has occurred consistent with the Byford structure plan.

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

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

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 the monitored hydrology and hydrogeology is considered suitably reflective of the long-term environment, and approval has been given by the Department of Water. 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, to the satisfaction of the local government and Department of Water.

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:

- *in-situ* pH, electrical conductivity and temperature
- heavy metals - arsenic, cadmium, chromium, copper, lead, nickel, zinc, mercury
- total suspended solids
- total nitrogen and total kjeldahl nitrogen
- ammonia (NH4)
- 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 below. The format and frequency of post-development reporting should be proposed within the local water management strategy and approved by the local government 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	-**In-situ** 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)	-**In-situ** 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.

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 DoW)	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
DoW	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
SJ Shire – with funding from developer contributions scheme	From 3 years post-development	Monitor key criteria for maintenance of hydrologic regimes, buffers and ecological corridors/linkages of environmental assets Monitor local superficial aquifer groundwater levels Monitor water quality and flows within developments and wetlands Monitor behavioural patterns with respect to non-structural measures for water quality management
DEC	Ongoing	Evaluate health of significant environmental assets

9.4 Action plan

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

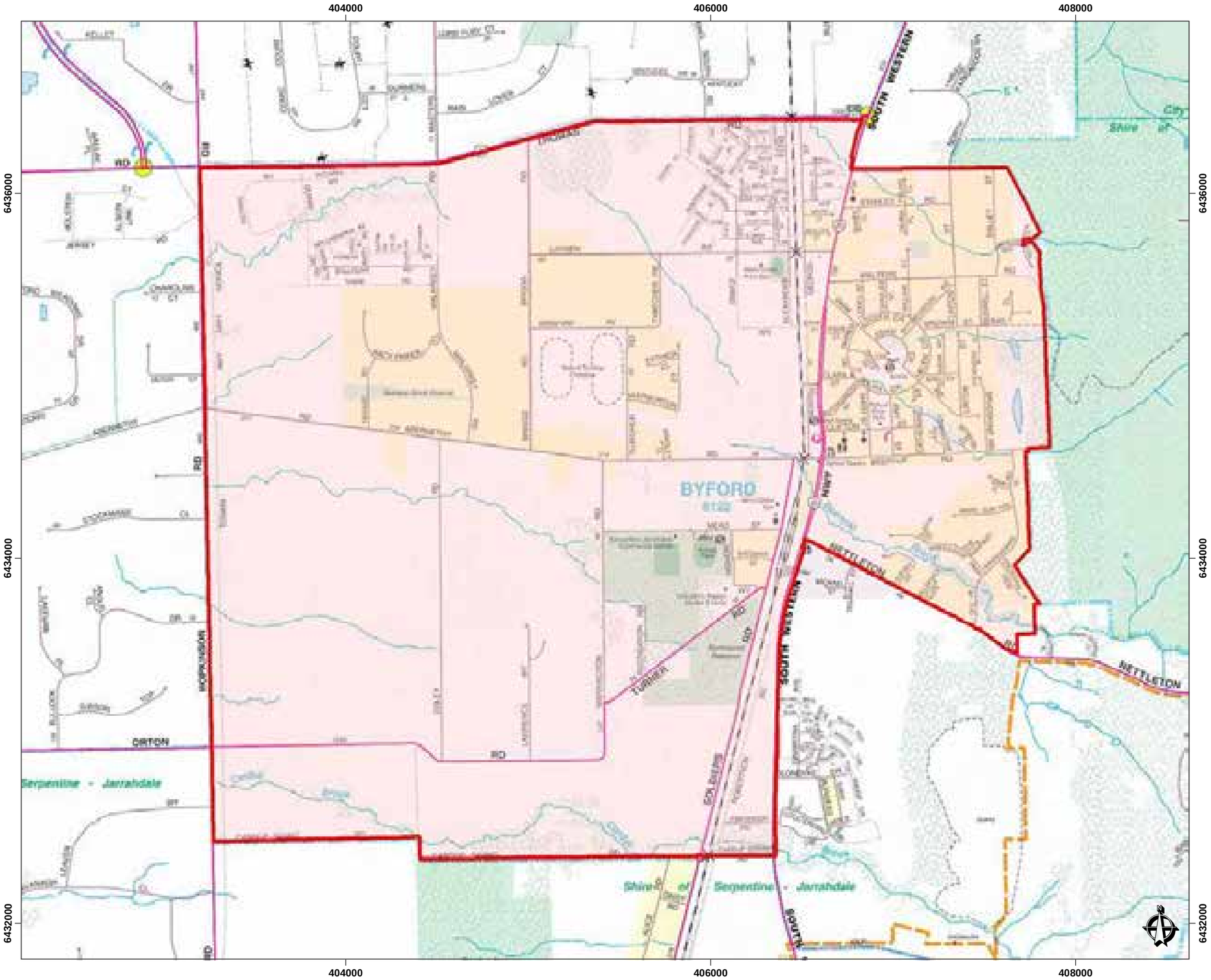
Table 9-3 Actions and responsibilities for implementation of the Drainage and water management plan

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	As part of the planning process
	Identify land required for protection of environmental assets and to allow for the management of their hydrologic regimes	DEC	As part of the planning process
	Incorporate environmental assets as a key part of community planning	DPI and SJ Shire	Through assessment of planning proposals
Manage and restore watercourses and wetlands	Determine post development hydrology for the Cardup and Beenyup Brooks	DoW	Through assessment of LWMS/UWMP
	Develop management plans for the Cardup and Beenyup Brooks consistent with the post development hydrology	SJ Shire	Commencing immediately & ongoing
Assess and manage impacts on native flora and fauna	Provide appropriate buffers and ecological corridors/linkages in local structure plans	WAPC and SJ Shire	Through assessment of planning proposals
	Establish responsibilities for ongoing management of natural areas	DEC and SJ Shire	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 SJ Shire	Through assessment of planning proposals
Assess and manage impacts on sites of indigenous significance	Undertake more detailed assessments at the local structure plan stage, including details of management measures as required	Developers in consultation with DIA and SJ Shire	Through local structure planning
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	DoW	Through assessment of LWMS/UWMP
Manage surface water flows from major events to protect infrastructure and assets	Ensure development in the DSP area complies with the stormwater design criteria for flood management in this *Drainage and water management plan*	SJ Shire	Through assessment of LWMS/UWMP
	Secure land that might be required for arterial drainage in the Byford townsite catchment	WAPC and SJ Shire	Through local structure planning

Strategy	Action	Lead agency	Timing
	Design and construct regional flood management infrastructure	SJ Shire with funding from developer contribution scheme	Through local structure planning
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	SJ Shire	Through assessment of local structure plans
	Retain existing natural waterways and drainage lines in the design of stormwater management systems for urban development – requires modification of existing BSP	SJ Shire	Through modification of BSP and assessment of LWMS/UWMP
Adopt nutrient load reduction design objectives for stormwater runoff	Ensure development in the DSP area complies with the design objectives for stormwater quality	SJ Shire	Through assessment of LWMS/UWMP
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 SJ Shire to DoW for collation	3 years each pre- and post-development
	Monitor confined aquifer groundwater levels and regional superficial aquifer groundwater levels	DoW	Commencing immediately and ongoing
	Investigate potential changes to local water balance and implications for groundwater rise	DoW	Through assessment of LWMS/UWMP
	Manage groundwater levels within ranges reported in this *Drainage and water management plan* via a combination of subsoil drainage at local CGLs, imported fill and groundwater abstraction as appropriate for management of groundwater rise, and via recharge mechanisms for falling groundwater levels	Developers for 3 years post-development, after that time responsibility of SJ Shire	Commencing immediately and ongoing
Maintain groundwater regimes for groundwater dependent ecosystems	Review developers' investigations of local groundwater regime to establish local groundwater management criteria near GDEs	DoW	Through assessment of LWMS/UWMP
Protect the value of groundwater resources	Prepare a groundwater allocation plan for the DSP area	DoW	Commencing immediately and ongoing
Adopt nutrient load reduction design objectives for discharges to groundwater	Ensure development in the DSP area complies with the design objectives for groundwater quality	DoW	Through assessment of LWMS/UWMP
Monitoring and implementation			
Adopt an adaptive management approach	Monitor water quality and flows pre- and post-development, 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 SJ Shire, data to be passed to DoW for collation At the regional scale (sub-catchment outlets): DoW	3 years pre- and post-development, then ongoing

Strategy	Action	Lead agency	Timing
	Collate and analyse monitoring data to establish baseline water quality data throughout DSP area	Developer to pass data to DoW, DoW to collate and organise data, CSIRO's real-time data collection system to support the data analysis	Commencing immediately and ongoing
	Assess behavioural patterns with respect to non-structural measures and the effectiveness of non-structural measures, using a method such as community-based social marketing	Developer to implement with guidance from local government, local government to take over responsibility 3 years post-development	Ongoing
	Determine efficacy of structural BMPs, provide feedback to developers and allow for alteration of practices if necessary	DoW and local government with advice from the BMP technical reference group	Ongoing
	Engage the research community in the process of evaluation and feedback	DoW with advice from the BMP technical reference group	Ongoing
Water Conservation			
Adopt drinking water consumption target	Ensure that residential development complies with the water conservation design objectives	DoW	Through assessment of LWMS/UWMP
	Ensure scheme water substitution does not lead to an overall increase in water consumption	DoW	Through assessment of LWMS/UWMP
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	DoW	Through assessment of LWMS/UWMP
	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	DoW	Through assessment of LWMS/UWMP
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)	DoW	Through assessment of LWMS/UWMP
	Reach agreement between the developer, SJ Shire 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	DoW	Through assessment of LWMS/UWMP

10 Figures



LEGEND

Byford Drainage and Water Management Plan Area (GHD, 20070601)

MAP UNITS PROJECTED IN MGA ZONE 50
NOTE THAT POSITIONAL ERRORS CAN BE > 5M IN SOME AREAS.
BACKGROUND TAKEN FROM STREETSMART STREETEXPRESS 2007 EDITION.
CURRENT TO 2006 ONLY.

SCALE

200 0 200 400 600 m

1:20,000 at A3

LOCALITY MAP

South West WA

CREATED BY	CHECKED	APPROVED
NT		

HORIZONTAL DATUM: GDA94 **PROJECTION:** MGA ZONE 50

HEIGHT DATUM: **METADATA RECORDED:**

DATE	FILE LOCATION
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REVISION	DRAWING NO
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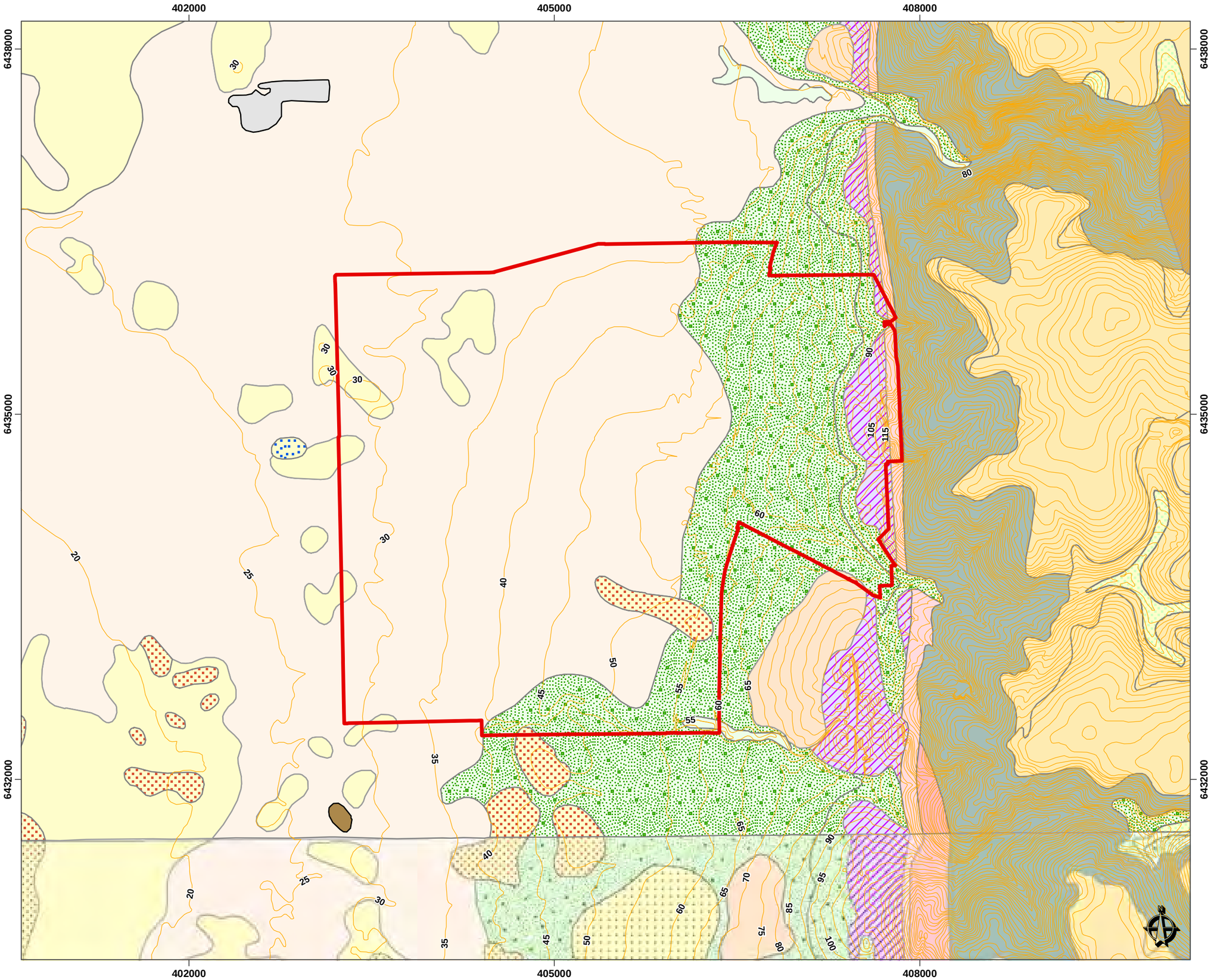
BYFORD TOWNSITE - DRAINAGE & WATER MANAGEMENT PLAN

Figure A-1
Location Map



LEGEND

Byford Drainage and Water Management Plan Area (GHD, 20070601)

5m Contours (GHD, 20080718)

Armadale & Serpentine 1:50,000 Geology (Geological Survey of WA, 19860101)

- Qpw — Sand: white to pale brown, fine-grained to medium-coarse grained rounded quartz
- Qa — Alluvium and minor colluvium
- Qpo — Colluvium, soil and undifferentiated sand
- Qpb — Bassendean Sand: quartz sand (fixed dunes)
- Qpb/Qa — Bassendean sand over alluvium and minor colluvium
- Qpa — Guildford Formation: alluvium (clay, loam, sand, gravel) variably lateritized and podsolized
- Qpr — Yoganup Formation: leached and ferruginised beach sand, conglomerate and dunes
- Qc — Gravelly Sandy Clay
- Qha — Sandy Silty Clay - pale brown
- Czl — Laterite- chiefly massive, but includes overlying pisolithic gravel and laterized sand
- Pa — Armadale Shale - brown green to black, silty thinly bedded with interbeds of siltstone & fine-grained sandstone
- Age, Agr, Agp — Granite: fine to course-grained mesocratic rocks, of granite granodiorite and adamellite composition, even-grained or porphyritic
- Am — Migmatite - banded and nebulitic
- An — Gneiss - fine to medium-grained mesocratic gneiss, planar gneissic fabric, occasional fine mesocratic rocks representing sheared dolerites
- Ironstone — Red-brown, grading from coffee rock through vuggy and pisolitic to massive, of alluvial origin
- SS2 — Sandstone - basal conglomerate and silty
- Made ground

For more information, see Perth Metropolitan Region 1:50,000 Environmental and Urban Geology Series map sheets for Armadale and Serpentine

MAP UNITS PROJECTED IN MGA ZONE 50
NOTE THAT POSITIONAL ERRORS CAN BE > 5M IN SOME AREAS.

SCALE

275 0 275 550 825 m

1:30,000 at A3

LOCALITY MAP

South West WA

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NT	ML	

HORIZONTAL DATUM: GDA94 **PROJECTION:** MGA ZONE 50

HEIGHT DATUM: **METADATA RECORDED:**

DATE	FILE LOCATION
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REVISION	DRAWING NO
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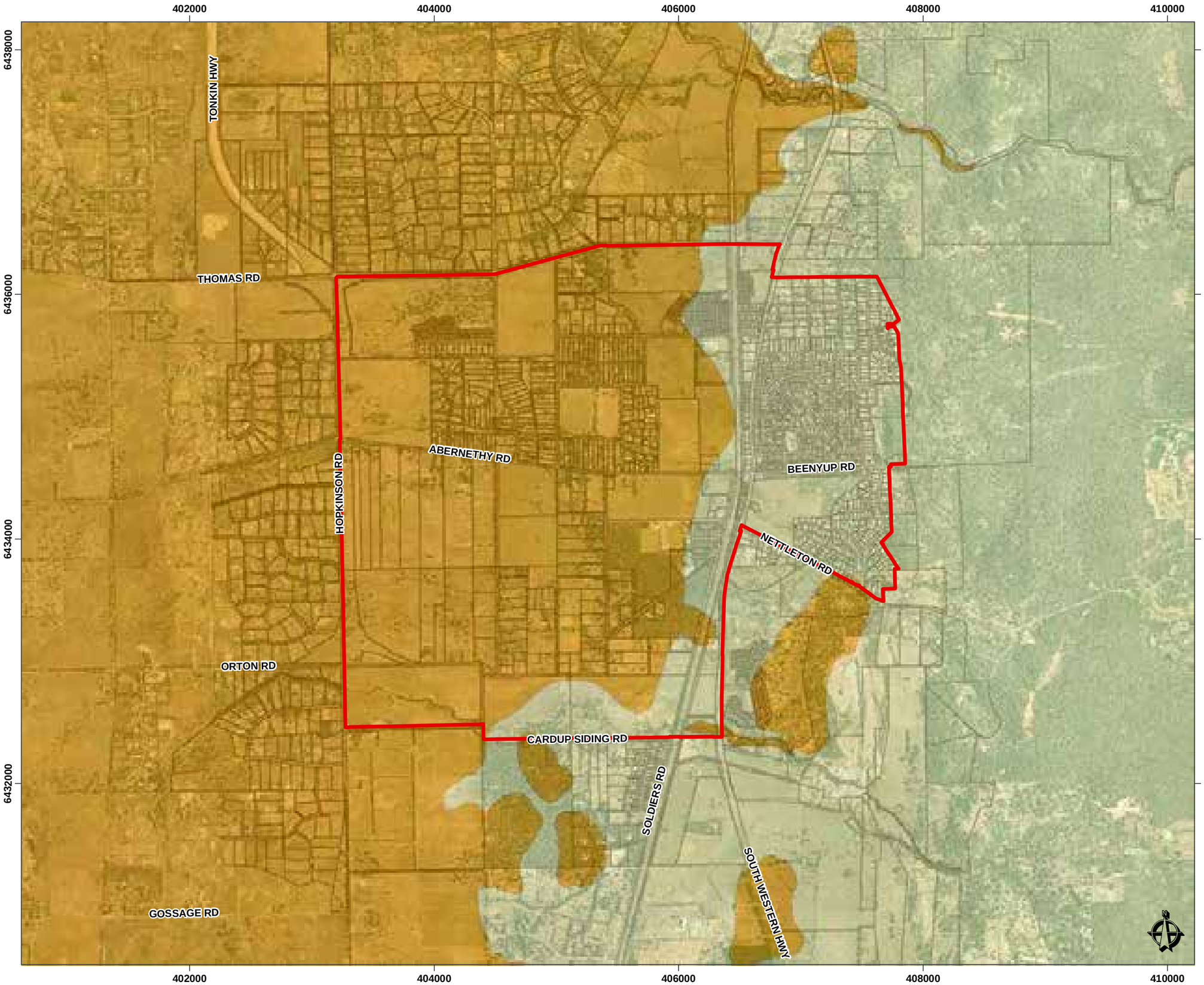
BYFORD TOWNSITE - DRAINAGE & WATER MANAGEMENT PLAN

Figure A-2
Topography & Geology



LEGEND

- Byford Drainage and Water Management Plan Area (GHD, 20070601)
- Cadastre (DLI, 20061201)

Acid Sulfate Soil Risk Map, Swan Coastal Plain (DEC, 20060807)

- 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)

MAP UNITS PROJECTED IN MGA ZONE 50
NOTE THAT POSITIONAL ERRORS CAN BE > 5M IN SOME AREAS
AERIAL PHOTOGRAPHY SOURCED FROM
LANDGATE - 2005 METRO SOUTH MOSAIC

SCALE

325 0 325 650 975 m

1:30,000 at A3

LOCALITY MAP

South West WA

CREATED BY	CHECKED	APPROVED
NT		

HORIZONTAL DATUM: GDA94 **PROJECTION:** MGA ZONE 50
HEIGHT DATUM: **METADATA RECORDED:**

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REVISION	DRAWING NO
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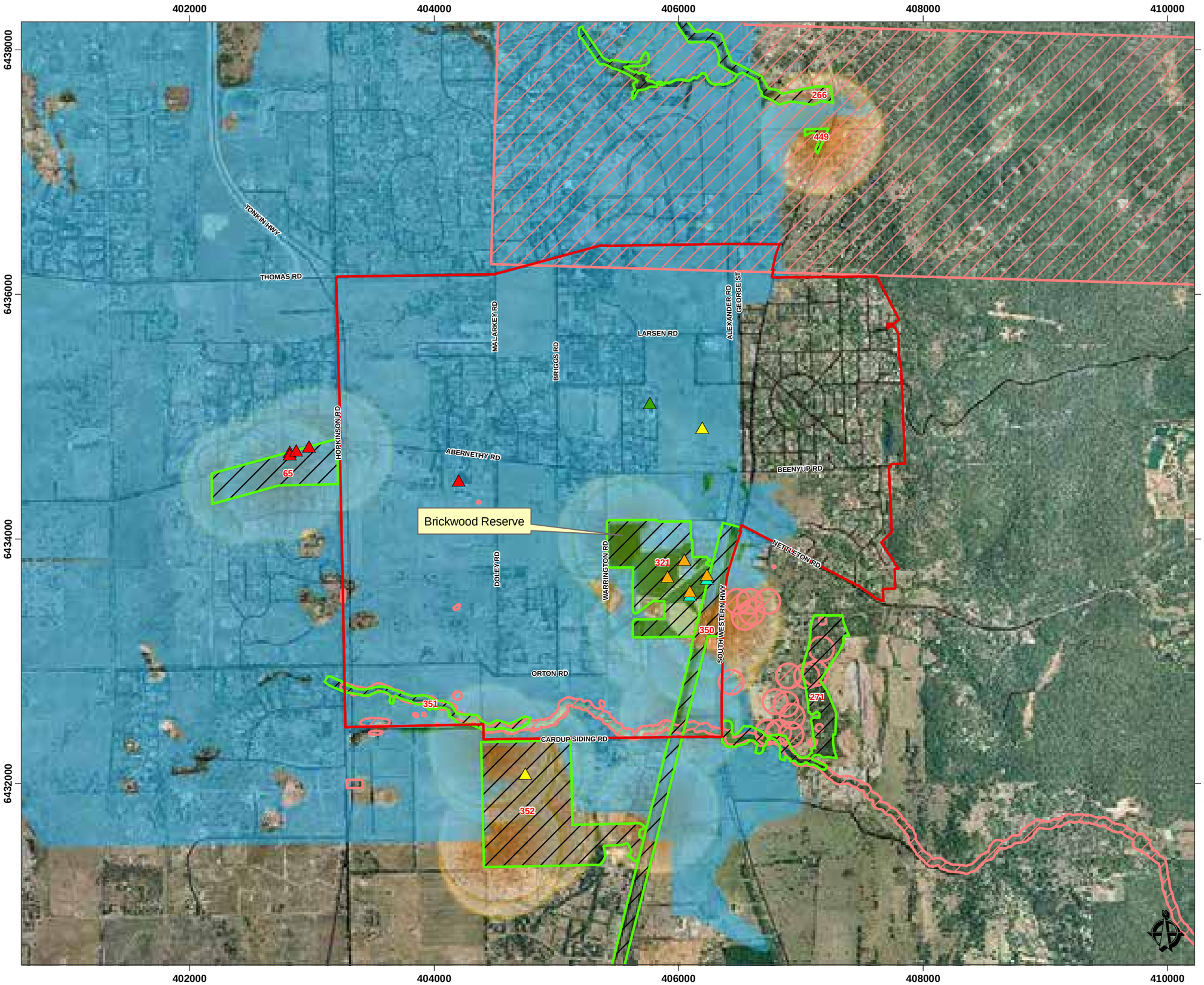
BYFORD TOWNSITE - DRAINAGE & WATER MANAGEMENT PLAN

Figure A-3
Acid Sulfate Soil Risk Map



LEGEND

- Byford Drainage and Water Management Plan Area (GHD, 20070601)
- Road Centreline (DLI, 2007)
- Bush Forever Sites (DPI, 2000)
- Threatened Ecological Communities Buffer (CALM, 200702)
- Aboriginal Heritage Sites (DIA, 200712)

Geomorphic Wetlands (DEC, 200706)

- Conservation
- Resource Enhancement
- Multiple Use
- Not Assessed
- Not Applicable

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

MAP UNITS PROJECTED IN MGA ZONE 50
NOTE THAT POSITIONAL ERRORS CAN BE > 5M IN SOME AREAS
AERIAL PHOTOGRAPHY SOURCED FROM
LANDGATE - 2005 METRO SOUTH MOSAIC

SCALE

300 0 300 600 900 m

1:30,000 at A3

LOCALITY MAP

South West WA

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NT		

HORIZONTAL DATUM: GDA94 **PROJECTION:** MGA ZONE 50

HEIGHT DATUM: **METADATA RECORDED:**

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REVISION	DRAWING NO
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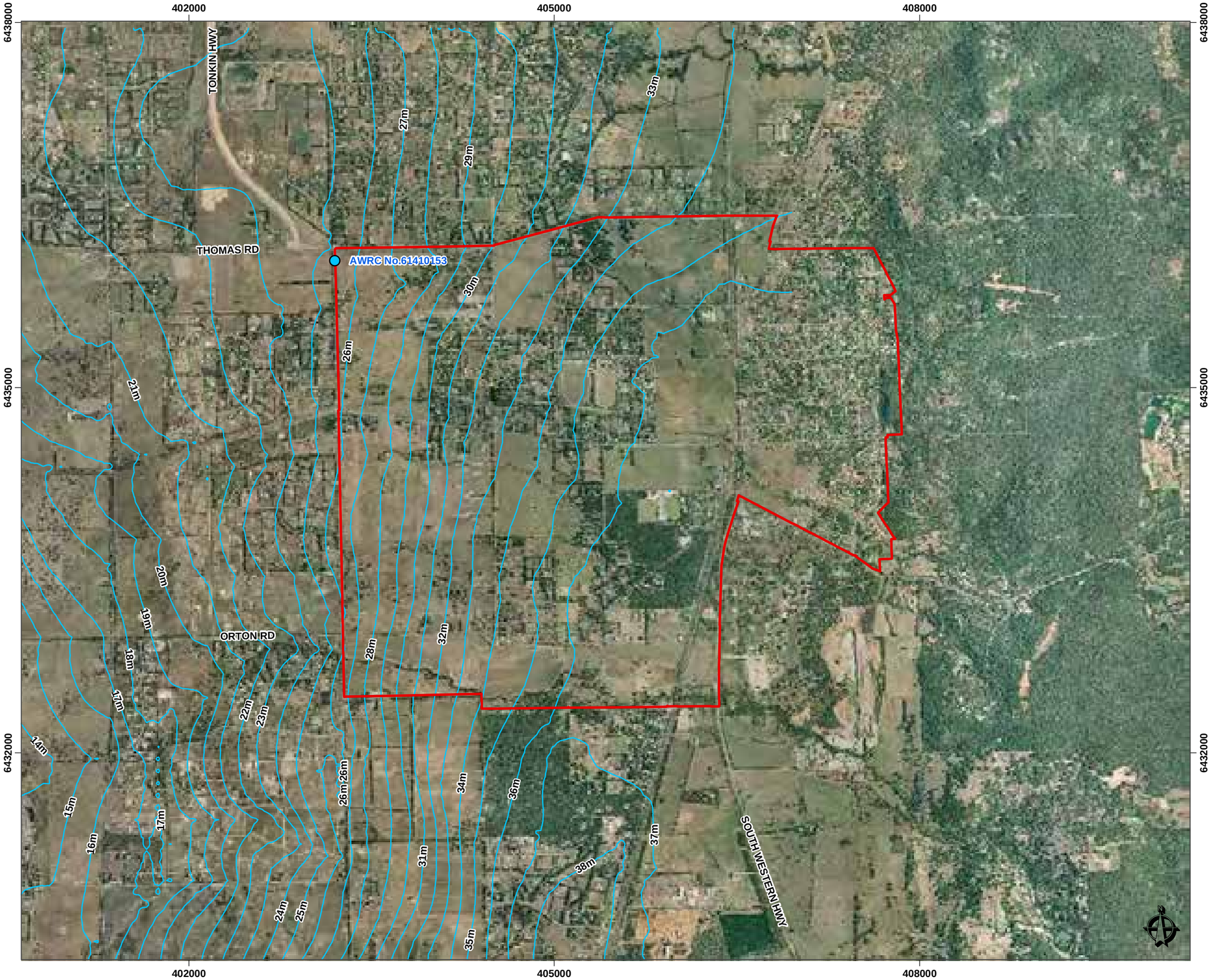
BYFORD TOWNSITE - DRAINAGE & WATER MANAGEMENT PLAN

Figure A-4
Environmental and Social Considerations



LEGEND

- Byford Drainage and Water Management Plan Area (GHD, 20070601)
- AWRC No.61410153
- Modelled Maximum Groundwater Level (Current Climate) 1 m Contour*

* Interpolated from data published in CyMod Report "Local Scale Groundwater Modelling for Assess Effects of Climatic Variations and Planned Development", May 2007

MAP UNITS PROJECTED IN MGA ZONE 50
NOTE THAT POSITIONAL ERRORS CAN BE > 5M IN SOME AREAS.
AERIAL PHOTOGRAPHY SOURCED FROM
LANDGATE - 2005 METRO SOUTH MOSAIC.

SCALE

300 0 300 600 900 m

1:30,000 at A3

LOCALITY MAP

South West WA

CREATED BY	CHECKED	APPROVED
NT		

HORIZONTAL DATUM: GDA94 **PROJECTION:** MGA ZONE 50

HEIGHT DATUM: **METADATA RECORDED:**

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REVISION	DRAWING NO
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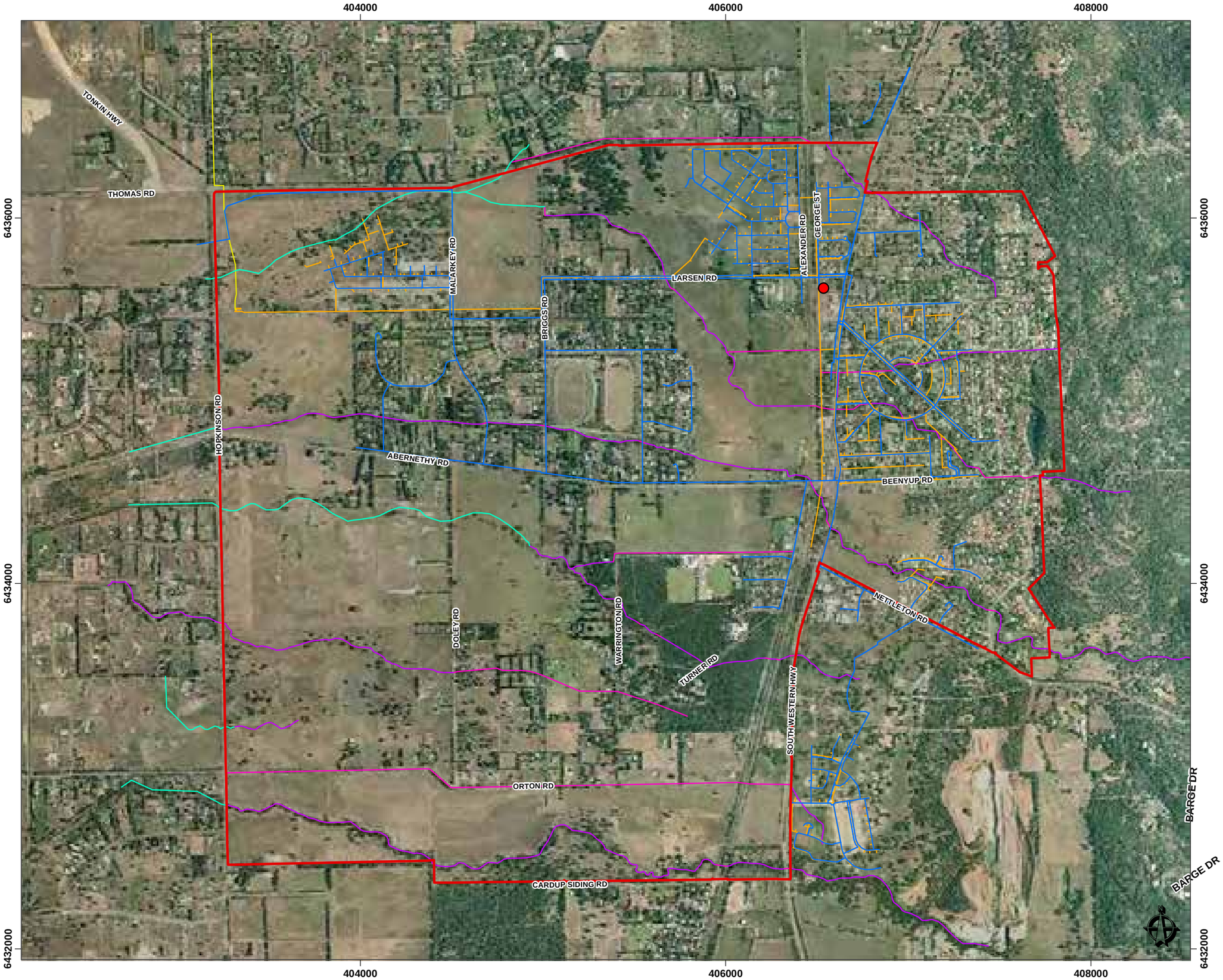
BYFORD TOWNSITE - DRAINAGE & WATER MANAGEMENT PLAN

Figure A-5
Controlled Groundwater Level



LEGEND

- Byford Drainage and Water Management Plan Area (GHD, 20070601)

Water Corporation Infrastructure

- Water Pumping Installation Location
- Water Main
- Drain
- Sewer (Rising Main)
- Sewer (Gravity Pipe)

Local Authority Infrastructure

- Drain
- Natural Stream

MAP UNITS PROJECTED IN MGA ZONE 50
NOTE THAT POSITIONAL ERRORS CAN BE > 5M IN SOME AREAS
AERIAL PHOTOGRAPHY SOURCED FROM
LANDGATE - 2005 METRO SOUTH MOSAIC

SCALE

200 0 200 400 600 m

1:20,000 at A3

LOCALITY MAP

South West WA

CREATED BY	CHECKED	APPROVED
NT		

HORIZONTAL DATUM: GDA94 **PROJECTION:** MGA ZONE 50

HEIGHT DATUM: **METADATA RECORDED:**

DATE	FILE LOCATION
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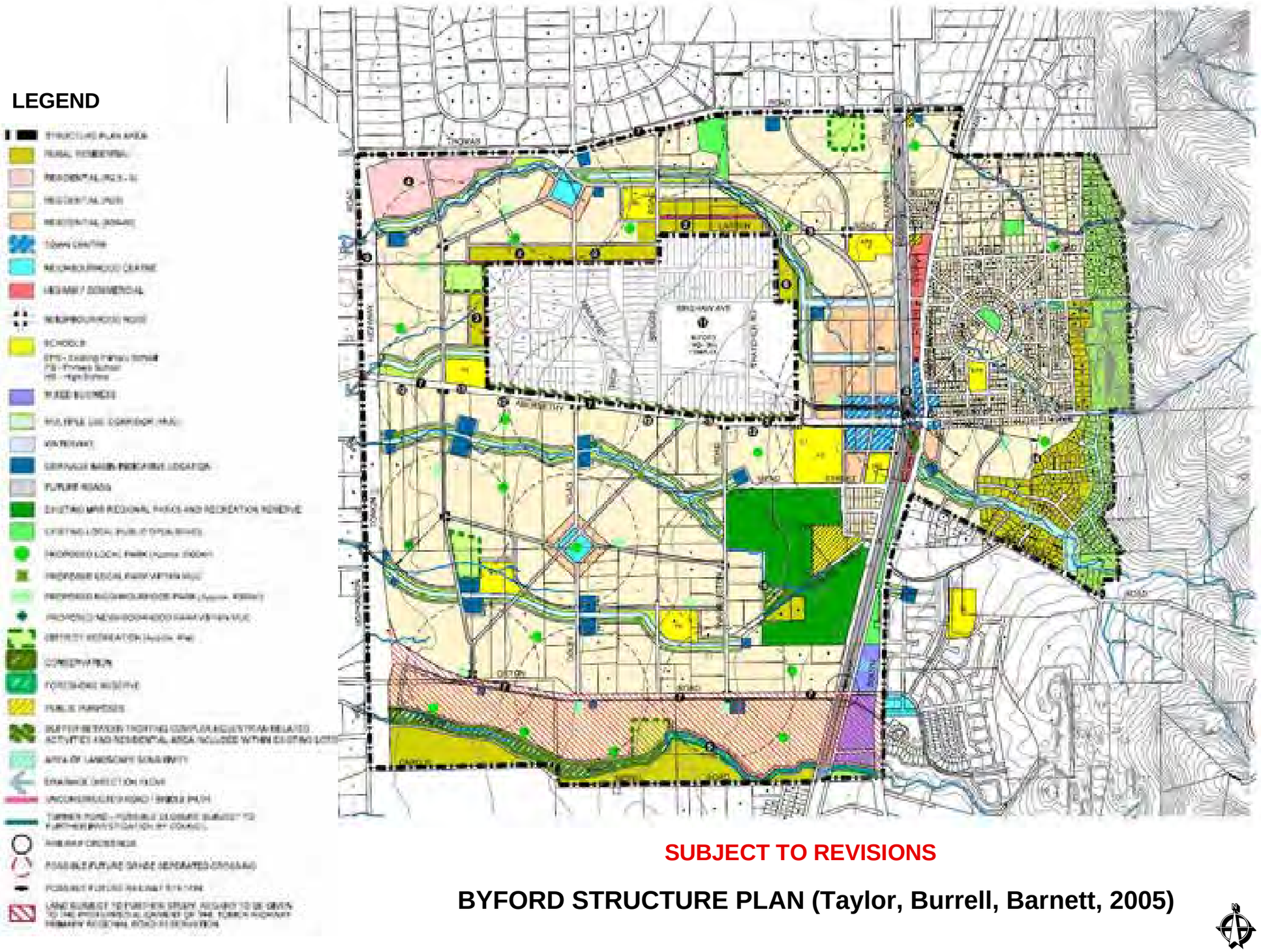
REVISION	DRAWING NO
2	6119569-G6

BYFORD TOWNSITE -
DRAINAGE & WATER MANAGEMENT PLAN

Figure A-6
Existing Infrastructure



SUBJECT TO REVISIONS

BYFORD STRUCTURE PLAN (Taylor, Burrell, Barnett, 2005)

LEGEND

Byford Structure Plan
(Taylor Burrell Barnett, 2005)

NOT TO SCALE

LOCALITY MAP

South West WA

CREATED BY	CHECKED	APPROVED
NT		

HORIZONTAL DATUM:	PROJECTION:
HEIGHT DATUM:	METADATA RECORDED:

DATE	FILE LOCATION
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REVISION	DRAWING NO
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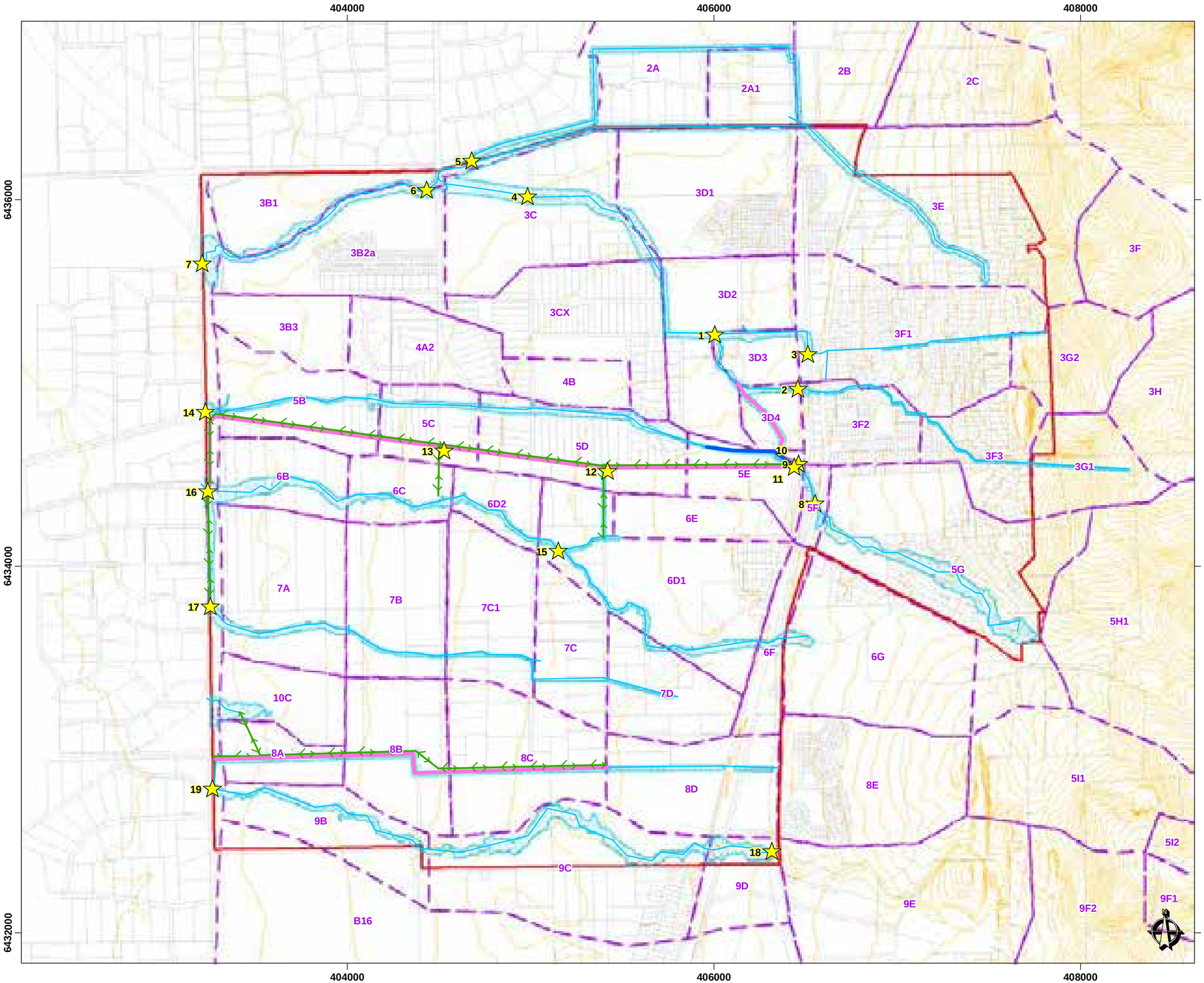
BYFORD TOWNSITE -
DRAINAGE & WATER MANAGEMENT PLAN

Figure A-7
Byford Structure Plan



LEGEND

- Byford Drainage and Water Management Plan Area (GHD, 20070625)
- Modelled Subcatchment (GHD, 20070823)
- Cadastre (DLI, 20061201)
- 100 Year ARI Floodways (GHD, 20080215)
- 5m Contours (GHD, 20080718)
- Critical Flow and Level Locations (GHD, 20080718)

Drains (GHD, 20080131)

- Main Waterway (Restored)
- Modelled Overland Flowpath
- Modelled Swale Drain
- Modelled Piped Drain

MAP UNITS PROJECTED IN MGA ZONE 50
NOTE THAT POSITIONAL ERRORS CAN BE > 5M IN SOME AREAS.

SCALE

200 0 200 400 600 m

1:20,000 at A3

LOCALITY MAP

South West WA

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HORIZONTAL DATUM: GDA94 **PROJECTION:** MGA ZONE 50

HEIGHT DATUM: **METADATA RECORDED:**

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REVISION	DRAWING NO
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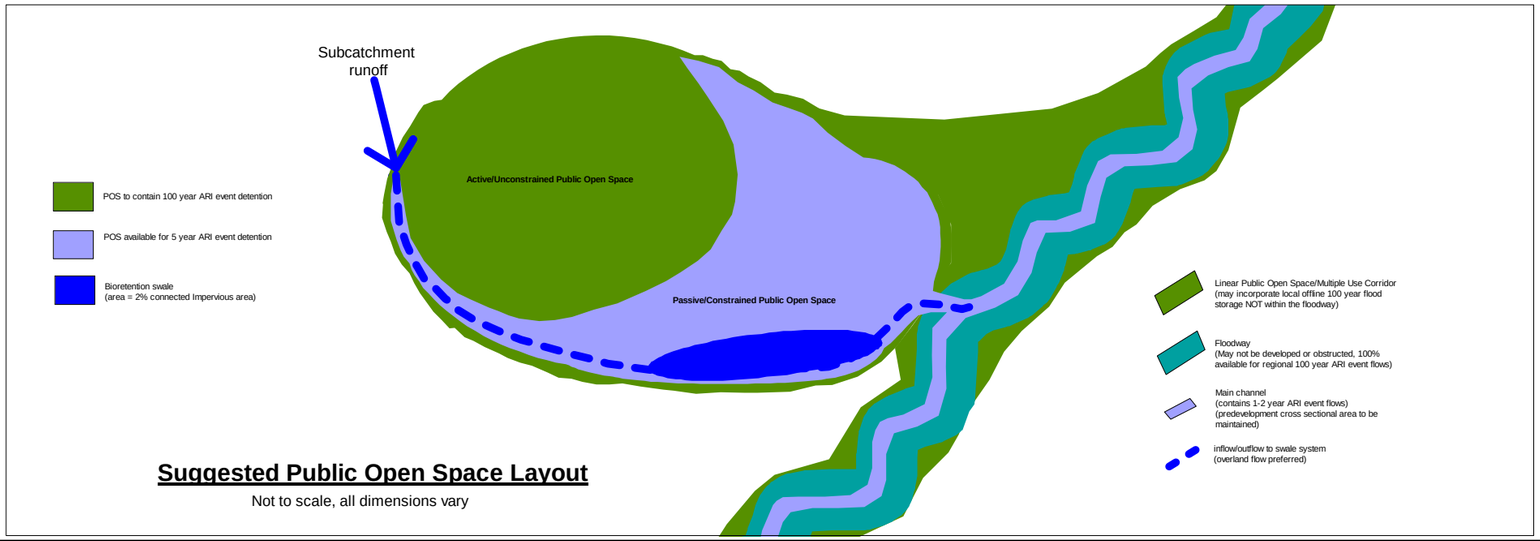
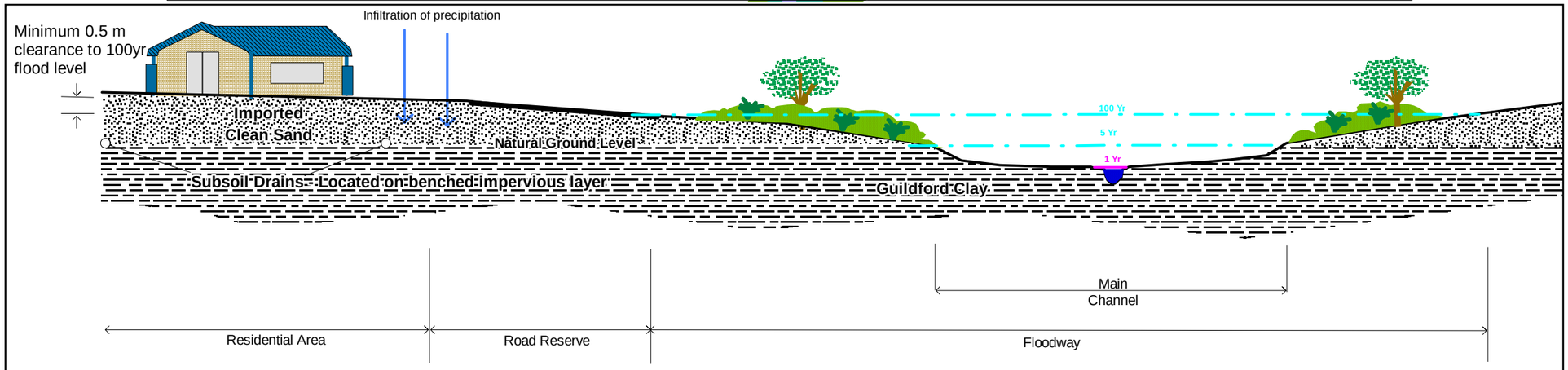
BYFORD TOWNSITE -
DRAINAGE & WATER MANAGEMENT PLAN

Figure A-8
Stormwater Strategy



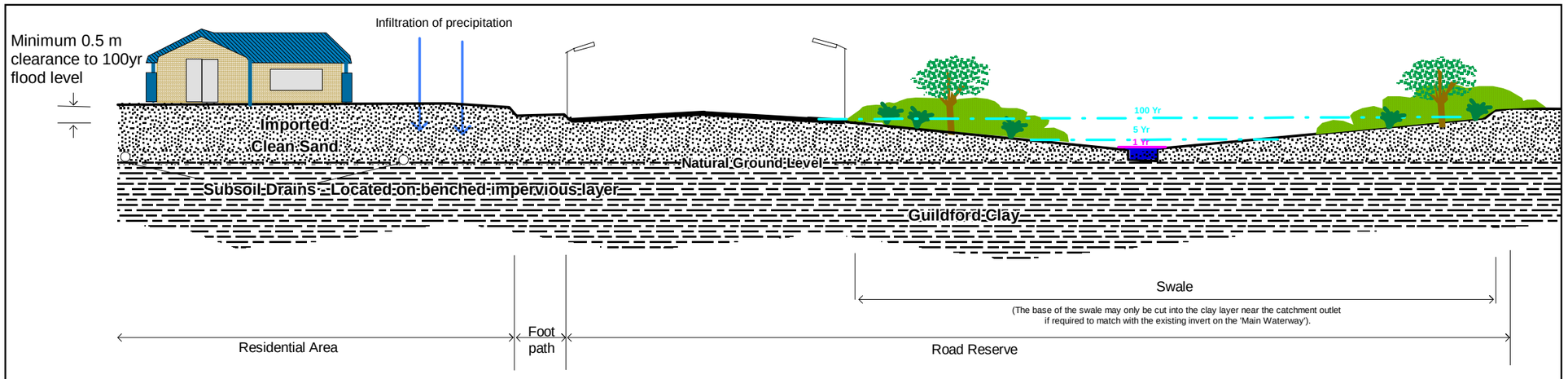
Suggested Public Open Space Layout

Not to scale, all dimensions vary



Main Waterway with Fill

Not to scale, all dimensions vary



Major Swale in Road Reserve with Fill

Not to scale, all dimensions vary

LEGEND

SCALE

Not to scale

LOCALITY MAP

South West WA

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CREATED BY	CHECKED	APPROVED
HB	DH	

HORIZONTAL DATUM: GDA94 **PROJECTION:** MGA ZONE 50
HEIGHT DATUM: m AHD **METADATA RECORDED:** 100%

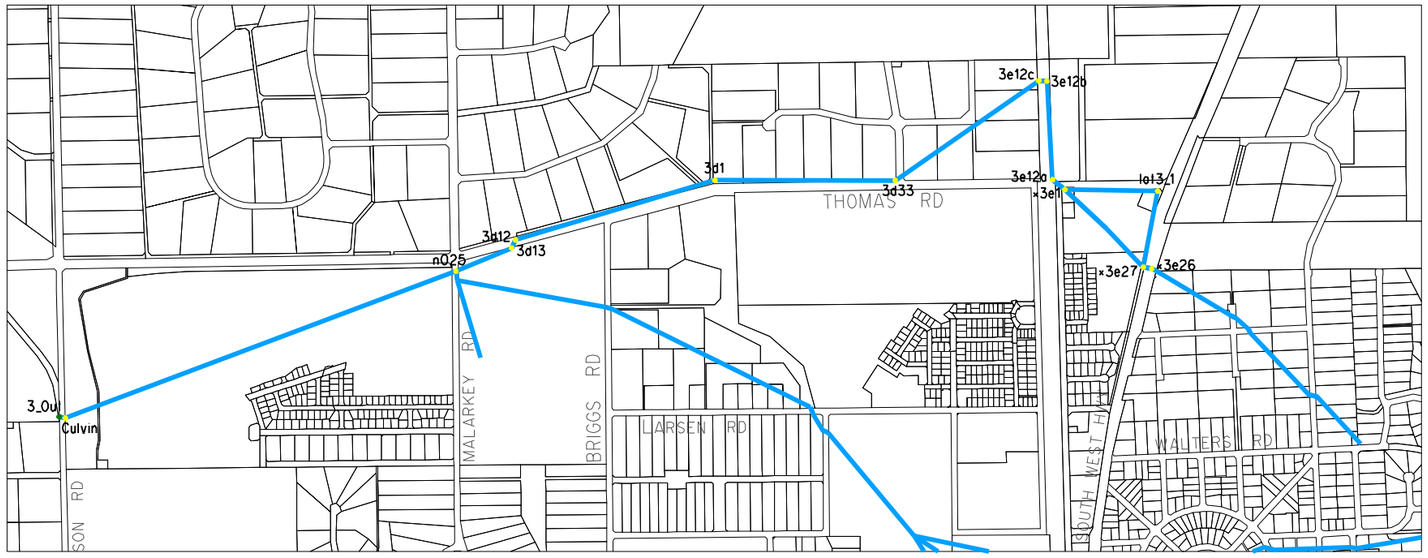
DATE	FILE LOCATION
14.12.2007	N:\61\19569\GIS\WORS\6119569-G9.wor
REVISION 2	DRAWING NO 6119569-G9

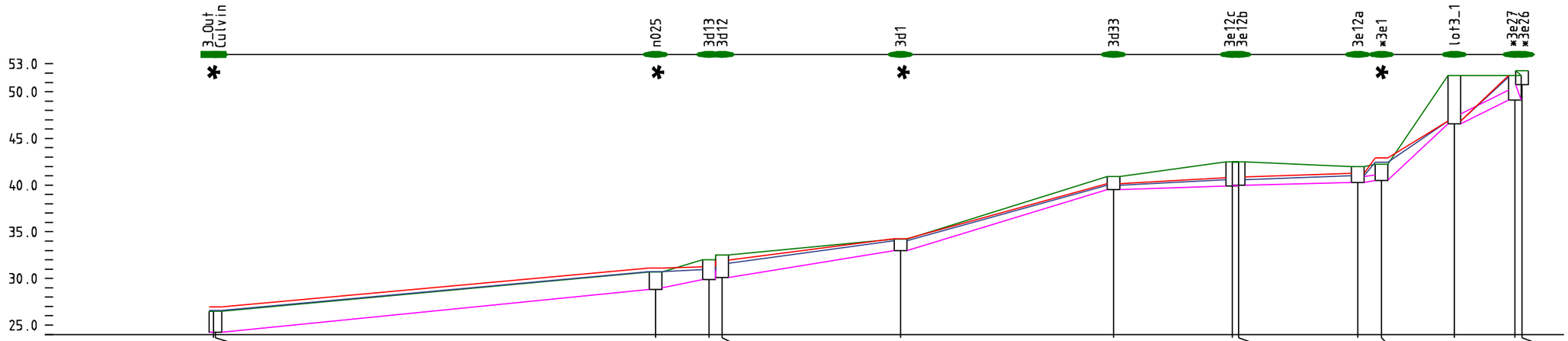
BYFORD TOWNSITE - DRAINAGE & WATER MANAGEMENT PLAN

Figure A-9
Proposed Drain Cross sections

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

N





Size (mm)		3600 x1900															600				2x600	15000x2000		1050		900		
Chainage (m)	0	26.50	8	26.50	1858	30.67	2082	32.00	2137	32.50	2887	34.20	3783	40.90	4283	42.50	4310	42.50	4810	42.00	4910	42.25	5216	51.75	5472	51.75	5500	52.25
Ground level (m AHD)																												
5 year ARI HGL level (m AHD)	0.00	25.20	26.57	26.97	30.75	31.12	30.96	31.25	31.61	31.95	34.05	34.27	40.00	40.16	40.56	40.79	40.58	40.87	41.00	41.27	42.45	42.92	46.86	46.86	51.57	51.73	51.64	52.19
100 year ARI HGL level (m AHD)																												
Invert level (m AHD)	-	24.22	24.25	24.25	28.84	29.00	29.87	29.87	31.00	30.09	33.00	33.00	39.50	39.50	39.90	39.90	40.00	40.00	40.30	40.30	40.50	40.52	46.58	46.58	49.13	49.13	50.75	-
Max 5 year ARI flow (m3/s)	23.68	21.50		23.61		10.25		2.29		10.60		9.84		8.48		0.08		8.20		0.69		3.72		3.63		0.29		
Max 100 year ARI flow (m3/s)				49.54		24.62		15.54		26.54		24.25		20.32		0.21		20.02		0.70		4.06		3.69		0.85		

✱ INDICATES FLOODING DURING 100 YR ARI STORM EVENT

Department of Water
Government of Western Australia

OAKLANDS DRAIN NORTH Part 1 of 2

LONGITUDINAL SECTION
EXISTING SYSTEM
Figure A10.1a

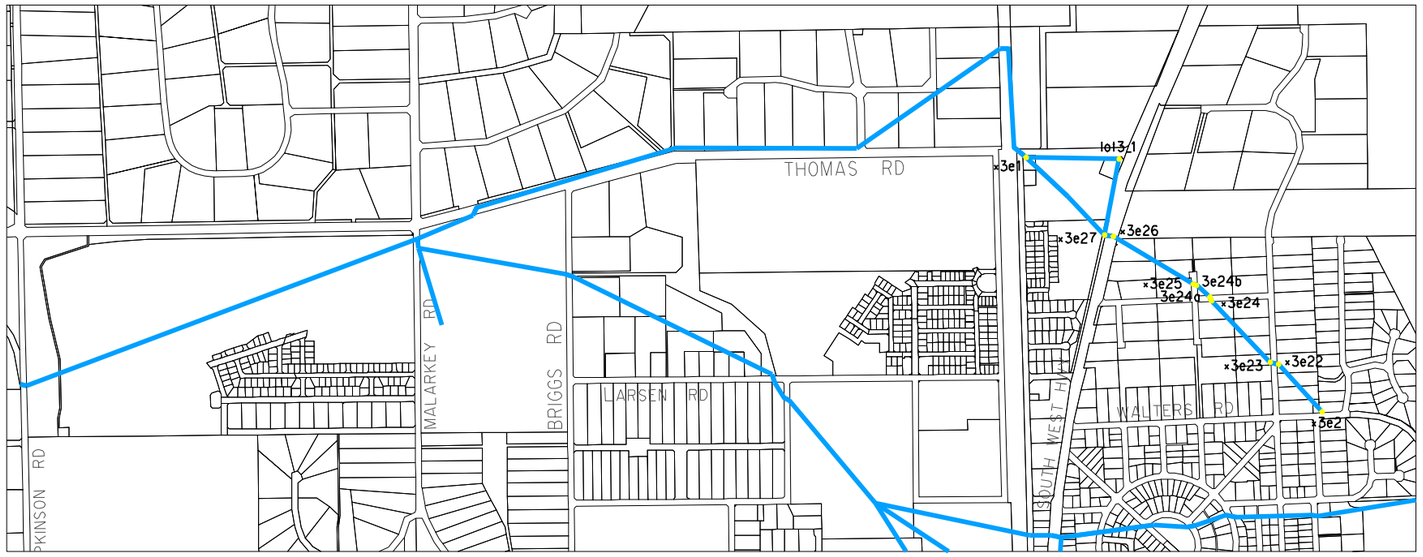
PROJECT N°: 6119569 DATE: 04/08/2008 COORDINATE SYSTEM: MGA94 - Zone 50

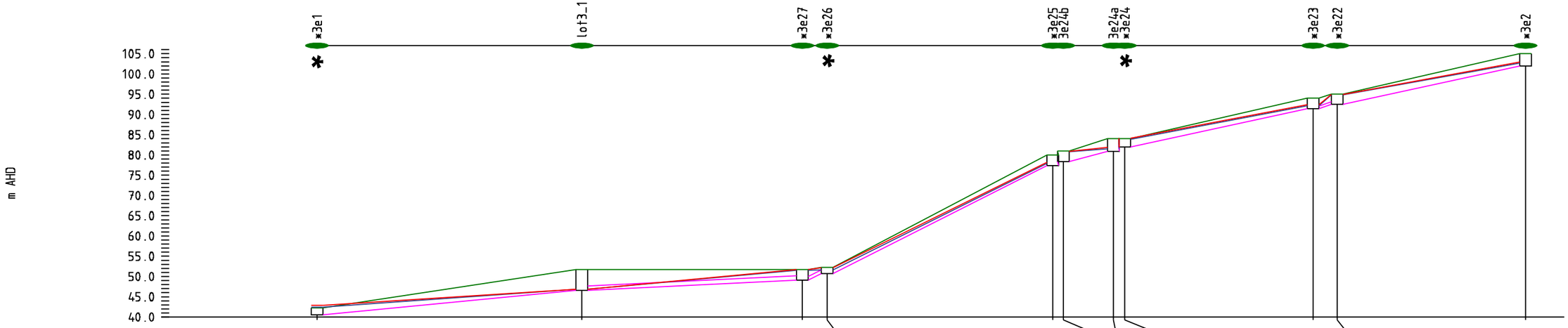
AUTHOR: P Haywood DESIGN FILE: Fig10-01a OaklandsDrainNorth pre.dgn

...\FigA10-01a OaklandsDrainNorth pre.dgn 5/08/2008 10:52:28 AM

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

N





Size (mm)		15000x2000		1050		2x900				2x600		2x600		2x600					
Chainage (m)	0	42.25	306	51.75	562	51.75	590	52.25	851	80.00	864	81.00	922	84.00	935	84.00	1153	94.00	1181	95.00	1399	105.00
Ground level (m AHD)																						
5 year ARI HGL level (m AHD)	42.45	42.92	46.86	46.86	51.57	51.73	51.64	52.19	77.94	78.17	80.81	80.89	81.55	81.84	83.90	84.10	92.11	92.39	94.82	94.94	102.67	102.94
100 year ARI HGL level (m AHD)																						
Invert level (m AHD)	-	40.52	46.58	46.58	49.13	49.13	50.75	50.75	77.37	77.37	78.34	78.34	80.87	80.87	81.98	81.98	91.45	91.45	92.53	92.53	102.00	-
Max 5 year ARI flow (m3/s)		3.72		3.63		0.29		5.32		0.52		5.33		0.33		5.33		1.03		5.34		
Max 100 year ARI flow (m3/s)		4.06		3.69		0.85		15.30		0.59		15.37		0.40		15.38		1.34		15.43		

✱ INDICATES FLOODING DURING 100 YR ARI STORM EVENT

AUTHOR: P Heywood DESIGN FILE: Fig10-01b OaklandsDrainNorth pre.dgn

Department of Water
Government of Western Australia

OAKLANDS DRAIN NORTH Part 2 of 2

LONGITUDINAL SECTION
EXISTING SYSTEM
Figure A10.1b

PROJECT N°: 6119569 DATE: 04/08/2008 COORDINATE SYSTEM: MGA94 - Zone 50

...\FigA10-01b OaklandsDrainNorth pre.dgn 5/08/2008 9:40:41 AM

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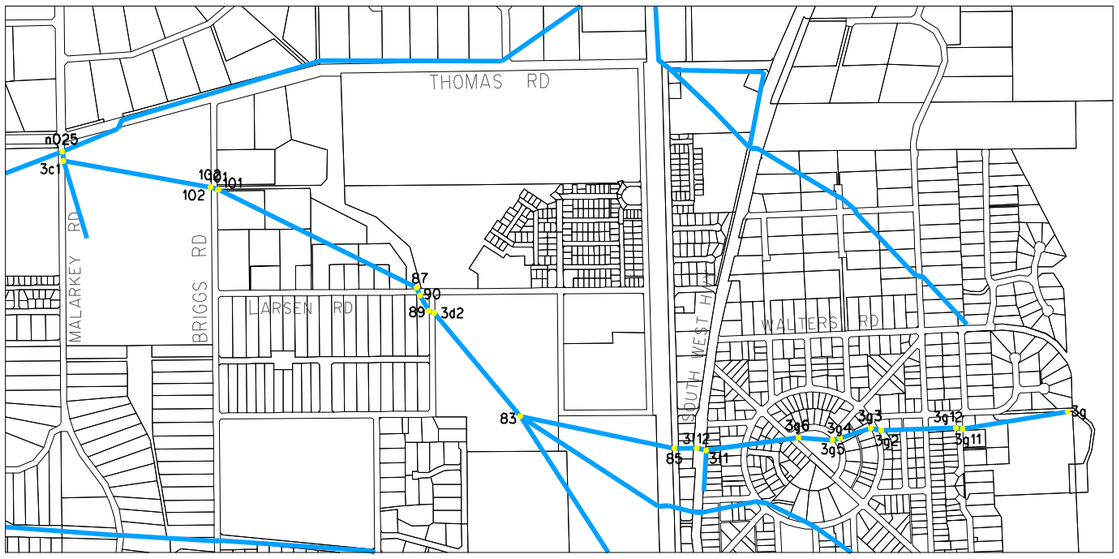
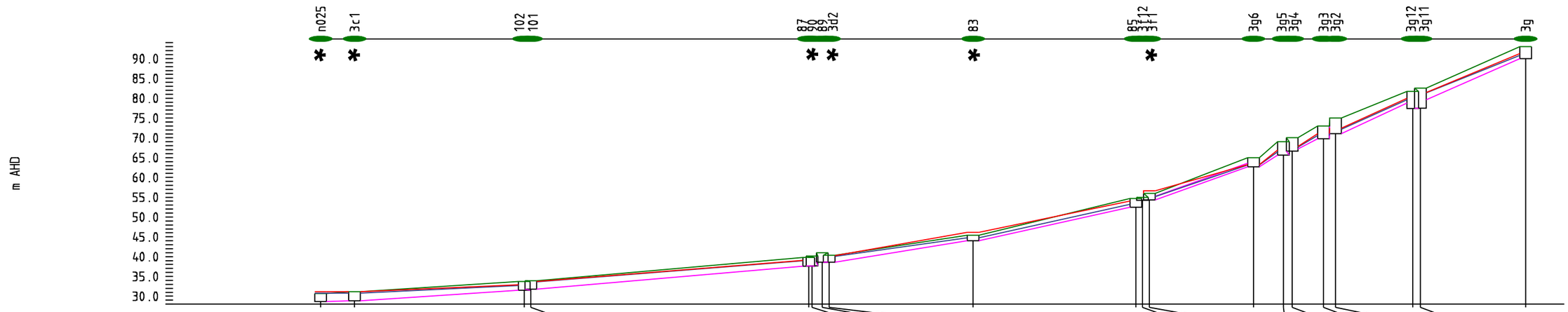




Chainage (m)	Ground level (m AHD)	5 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)	Invert level (m AHD)
0	30.67	30.75	31.12	-	28.67
100	31.16	30.79	31.17	28.84	28.84
600	33.70	32.74	32.85	31.56	31.56
620	33.90	33.59	33.71	31.76	31.76
1440	39.80	38.93	39.06	37.61	37.61
1450	40.11	39.63	39.75	37.71	37.71
1480	41.00	39.89	40.04	38.60	38.60
1500	40.30	40.09	40.23	38.60	38.60
1925	45.43	44.72	46.12	44.00	44.00
2405	54.70	53.25	54.01	52.50	54.20
2425	55.00	54.84	54.93	54.70	54.20
2445	56.00	55.14	56.61	54.30	54.30
2752	65.00	63.14	63.25	62.69	62.69
2840	69.00	66.49	66.90	65.67	65.67
2866	70.00	67.67	67.80	66.68	67.18
2959	73.00	70.63	71.05	69.78	69.80
2993	75.00	72.19	72.39	72.00	71.08
3221	81.74	79.57	79.99	78.74	77.40
3244	82.57	81.36	81.45	77.50	79.57
3555	93.00	90.83	91.26	90.00	-

Chainage (m)	Size (mm)	Max 5 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
0 – 100		12.59	28.83
100 – 600		13.62	26.05
600 – 620	1880 x1220	6.39	7.03
620 – 1440		14.43	25.58
1440 – 1450	1220	4.34	4.37
1450 – 1480		13.45	24.10
1480 – 1500	1220 x1200	2.37	2.37
1500 – 1925		13.45	24.10
1925 – 2405		4.87	10.31
2405 – 2425		3.47	10.18
2425 – 2445	2x1520 x640	1.73	5.09
2445 – 2752	900	0.17	0.19
2752 – 2840		3.47	10.21
2840 – 2866	900	0.32	0.46
2866 – 2959		3.47	10.22
2959 – 2993	900	0.07	0.14
2993 – 3221		3.47	10.24
3221 – 3244	300	0.26	0.26
3244 – 3555		3.47	10.28

*** INDICATES FLOODING DURING 100 YR ARI STORM EVENT**

Department of Water
Government of Western Australia

OAKLANDS DRAIN CENTRAL

LONGITUDINAL SECTION

EXISTING SYSTEM

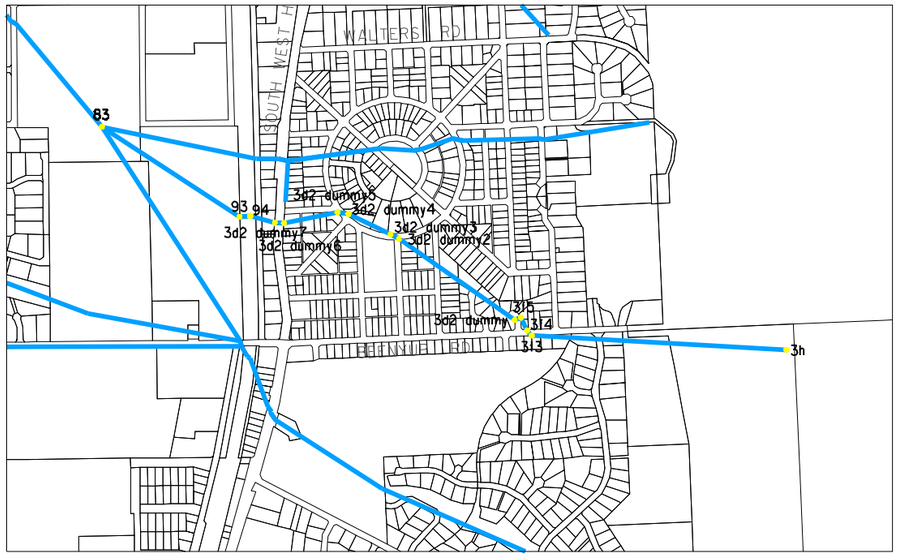
Figure A10.2

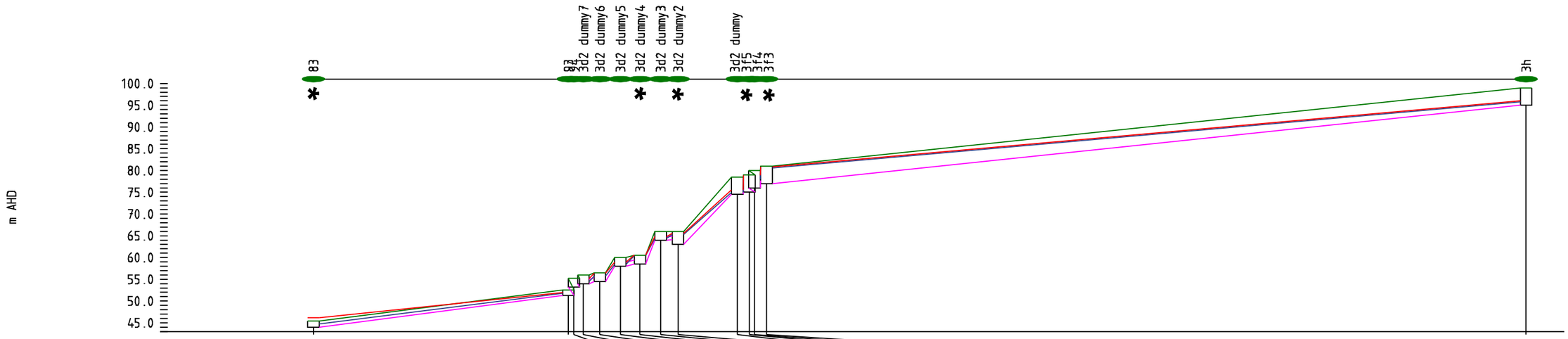
PROJECT N°: 6119569 DATE: 04/08/2008 COORDINATE SYSTEM: MGA94 - Zone 50

AUTHOR: P Haywood DESIGN FILE: Fig10-02 OaklandsDrainCentral pre.dgn

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

N





Size (mm)	Chainage (m) / Ground level (m AHD)	5 year ARI HGL level (m AHD) / 100 year ARI HGL level (m AHD)	Invert level (m AHD)	Max 5 year ARI flow (m3/s) / Max 100 year ARI flow (m3/s)
	0	44.72	-	
	45.43	46.12	44.00	
				2.56 7.39
	470	51.80	51.25	
4000 x1200	52.56	51.99	51.25	2.57 3.60
	480	53.83	53.25	
	55.24	54.41	53.25	2.57 11.41
	497	54.48	54.00	
3x900	56.00	55.10	54.00	0.86 2.23
	527	55.74	54.50	
	56.50	56.36	54.50	2.57 11.41
	565	58.41	58.00	
900	60.00	58.91	58.00	2.15 2.51
	601	60.44	58.50	
	60.50	60.60	58.50	2.57 11.42
	640	64.38	64.00	
750	66.00	64.81	64.00	1.07 1.16
	672	65.33	64.10	
	66.00	65.53	63.00	2.57 11.42
	781	74.96	74.50	
750	78.50	75.54	74.50	2.39 2.66
	803	77.91	75.00	
	79.00	78.88	75.00	3.06 10.66
	813	77.91	76.00	
750	80.00	78.90	76.00	16.45 2.35
	835	80.57	77.00	
	81.00	80.85	77.00	16.94 10.66
	2235	95.76	95.00	
	99.00	96.06	-	

* INDICATES FLOODING DURING 100 YR ARI STORM EVENT

AUTHOR: P Haywood DESIGN FILE: Fig10-03 OaklandsDrainSouth pre.dgn

Department of Water
Government of Western Australia

OAKLANDS DRAIN SOUTH

LONGITUDINAL SECTION

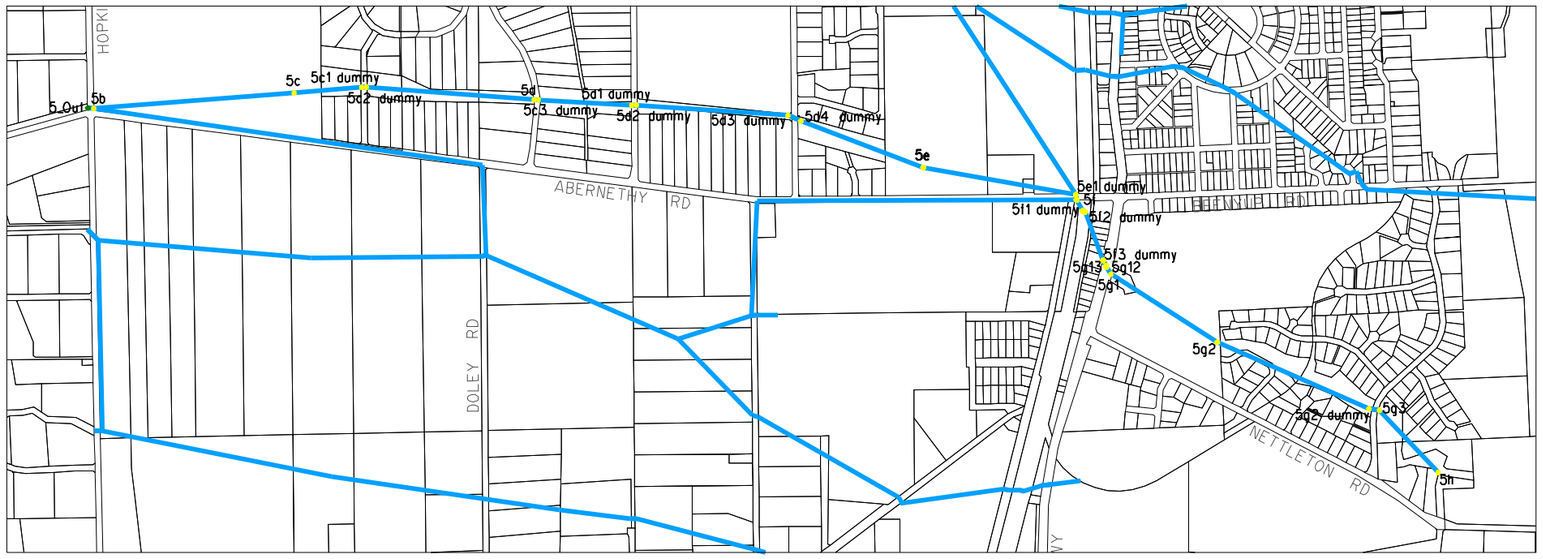
EXISTING SYSTEM

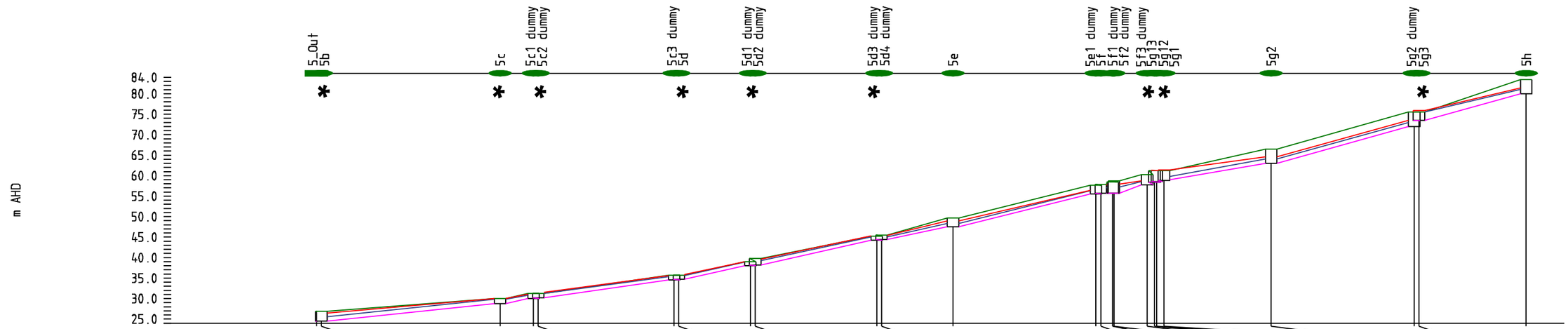
Figure A10.3

PROJECT N°: 6119569 DATE: 04/08/2008 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)	5 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)	Invert level (m AHD)
0	26.80	0.00	25.40	-	24.40
20	26.90	25.57	26.48	24.50	24.50
770	30.00	29.82	30.02	28.75	28.75
910	31.25	30.85	31.09	30.00	30.00
930	31.25	31.29	31.52	30.20	30.20
1500	35.70	35.34	35.63	34.50	34.50
1520	35.70	35.62	35.87	34.70	34.70
1820	39.00	38.87	38.98	38.00	38.00
1840	39.75	39.29	39.60	38.20	38.20
2350	45.25	45.07	45.29	44.20	44.20
2370	45.50	45.08	45.38	44.40	44.40
2670	49.64	48.34	48.92	47.50	47.50
3270	57.70	56.36	56.44	55.50	55.50
3290	57.80	56.93	57.63	55.70	55.70
3340	58.50	57.17	57.83	55.75	55.75
3345	58.75	57.20	57.93	55.75	55.75
3485	60.25	58.54	58.74	57.75	57.85
3515	61.25	59.48	61.21	58.40	58.40
3525	61.25	59.64	61.29	58.55	58.55
3555	61.25	59.83	61.43	58.85	59.00
4005	66.50	64.10	64.61	63.00	63.00
4605	75.50	72.94	73.48	72.00	73.40
4625	75.50	75.53	75.91	73.50	73.50
5075	83.50	81.03	81.44	80.00	-

Chainage (m)	Size (mm)	Max 5 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
0 – 20	3700 x1560	4.98	9.74
20 – 770		4.98	9.74
770 – 910		4.99	9.91
910 – 930	3x900	1.20	1.30
930 – 1500		4.34	8.01
1500 – 1520	3x900	0.90	0.99
1520 – 1820		3.97	6.61
1820 – 1840	2x1210 x920	1.92	2.26
1840 – 2350		3.98	7.02
2350 – 2370	2x1500 x600	0.53	1.64
2370 – 2670		2.66	12.05
2670 – 3270		2.66	3.44
3270 – 3290	5x1240 x1200	2.33	4.16
3290 – 3340		8.94	31.08
3340 – 3345		8.94	31.08
3345 – 3485		8.94	31.08
3485 – 3515	7500 x2000	9.09	26.77
3515 – 3525	4750 x2500	9.09	31.63
3525 – 3555	7500 x2000	9.09	22.91
3555 – 4005		8.97	31.20
4005 – 4605		9.01	31.26
4605 – 4625	3x1100	3.35	3.94
4625 – 5075		9.07	31.32

* INDICATES FLOODING DURING 100 YR ARI STORM EVENT

AUTHOR: P Haywood DESIGN FILE: Fig10-04 BeenyupBrook pre.dgn

Department of Water
Government of Western Australia

BEENYUP BROOK

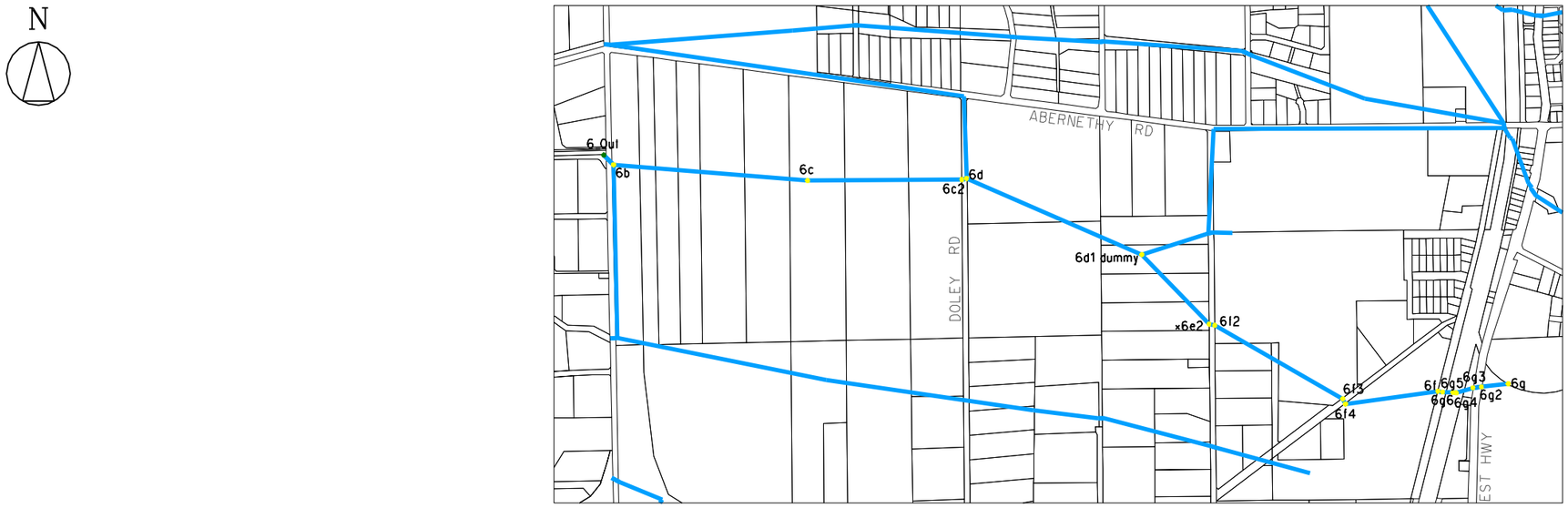
LONGITUDINAL SECTION

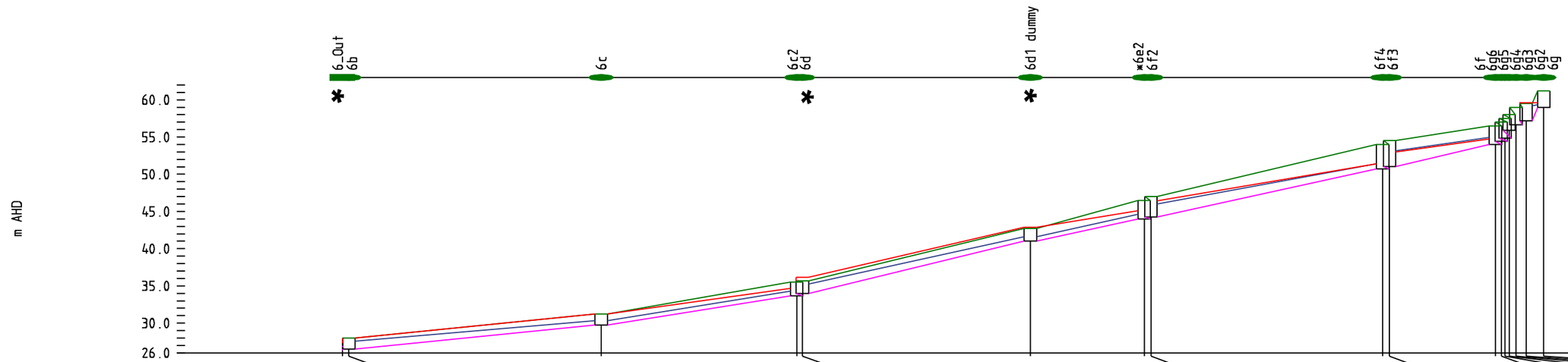
EXISTING SYSTEM

Figure A10.4

PROJECT Nº: 6119569 DATE: 04/08/2008 COORDINATE SYSTEM: MGA94 - Zone 50

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





Size (mm)		2x455									2x750							1200 x450					1500 x600			2x1200 x450			1220 x920			2x380		
Chainage (m)	0	27.80	20	28.00			795	31.25			1395	35.50	1413	35.70			2113	42.70	2463	46.50	2483	47.00		3195	54.00	3216	54.50	3542	56.50	3559	57.00	3571	57.50	3584	58.00	3605	59.00	3636	59.50	3690	61.20
Ground level (m AHD)																																								
5 year ARI HGL level (m AHD)	0.00	27.30	27.55	27.98			30.33	31.21			34.28	34.64	35.27	35.98			41.60	42.72	44.60	45.12	45.99	46.42		51.40	51.40	53.13	53.00	54.97	54.73	55.47	56.42	55.49	56.42	57.58	57.30	57.47	57.30	59.18	59.59	59.36	59.61
100 year ARI HGL level (m AHD)																																								
Invert level (m AHD)	-	26.30	26.50	26.50			29.75	29.75			33.68	33.68	34.00	34.00			41.00	41.00	44.00	44.00	44.24	44.24		50.71	50.71	51.04	51.04	54.00	54.00	54.45	54.45	54.84	54.84	55.92	55.92	56.62	56.62	57.20	57.20	59.00	-
Max 5 year ARI flow (m3/s)	0.79	0.82			2.00			1.89				0.94		1.80				1.57		1.57		1.57			2.02		2.02		0.71		0.78		0.78		0.78		0.41		0.81	
Max 100 year ARI flow (m3/s)					12.23			11.71				1.40		11.74				2.20		2.20		2.20			3.60		3.60		2.17		3.02		2.25		4.20		0.44		4.14	

✱ INDICATES FLOODING DURING 100 YR ARI STORM EVENT

AUTHOR: P Heywood DESIGN FILE: Fig10-05 Catchment 6 pre.dgn

Department of Water
Government of Western Australia

CATCHMENT 6

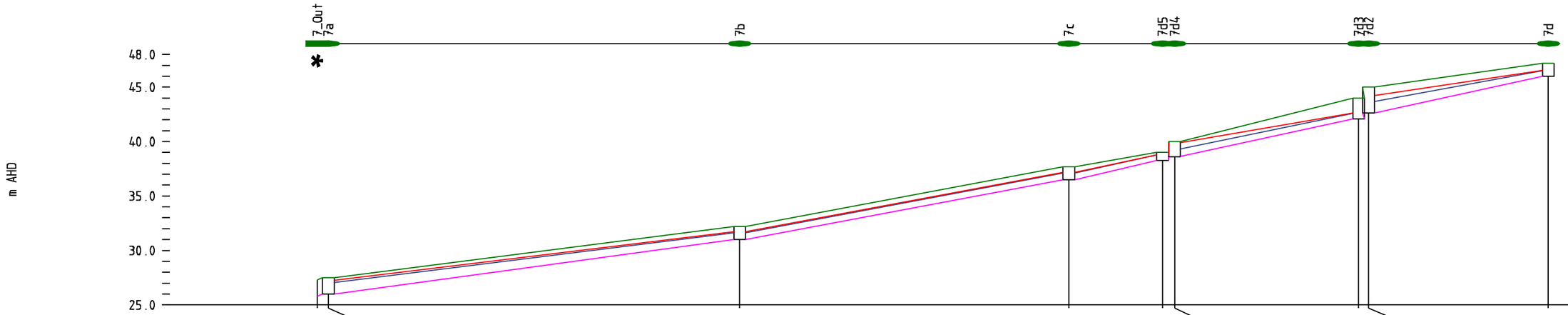
LONGITUDINAL SECTION
EXISTING SYSTEM
Figure A10.5

PROJECT N°: 6119569 DATE: 04/08/2008 COORDINATE SYSTEM: MGA94 - Zone 50

...\FigA10-05 Catchment 06 pre.dgn 5/08/2008 9:17:14 AM

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

N



Size (mm)		1200 x500												2x450					2x450			
Chainage (m)	0	27.30	20	27.50				770	32.20			1370	37.70	1540	39.00	1562	40.00		1898	44.00	1916	45.00		2244	47.20
Ground level (m AHD)																									
5 year ARI HGL level (m AHD)	0.00	26.80	27.05	27.27				31.64	31.72			37.11	37.19	38.78	38.79	39.33	39.90		42.59	42.61	43.69	44.22		46.53	46.55
100 year ARI HGL level (m AHD)																									
Invert level (m AHD)	-	25.80	26.00	26.00				31.00	31.00			36.50	36.50	38.26	38.26	38.62	38.63		42.07	42.08	42.63	42.63		46.00	-
Max 5 year ARI flow (m3/s)	1.97	2.16			2.22				1.87				1.09		0.30			0.59		0.33			0.65		
Max 100 year ARI flow (m3/s)					6.43				4.46				2.28		0.47			0.93		0.59			1.17		

✱ INDICATES FLOODING DURING 100 YR ARI STORM EVENT

Department of Water
Government of Western Australia

CATCHMENT 7

LONGITUDINAL SECTION

EXISTING SYSTEM

Figure A10.6

PROJECT N°: 6119569 DATE: 04/08/2008 COORDINATE SYSTEM: MGA94 - Zone 50

AUTHOR: P Haywood DESIGN FILE: Fig10-06 Catchment 07 pre.dgn

...\FigA10-06 Catchment 07 pre.dgn 5/08/2008 10:04:31 AM

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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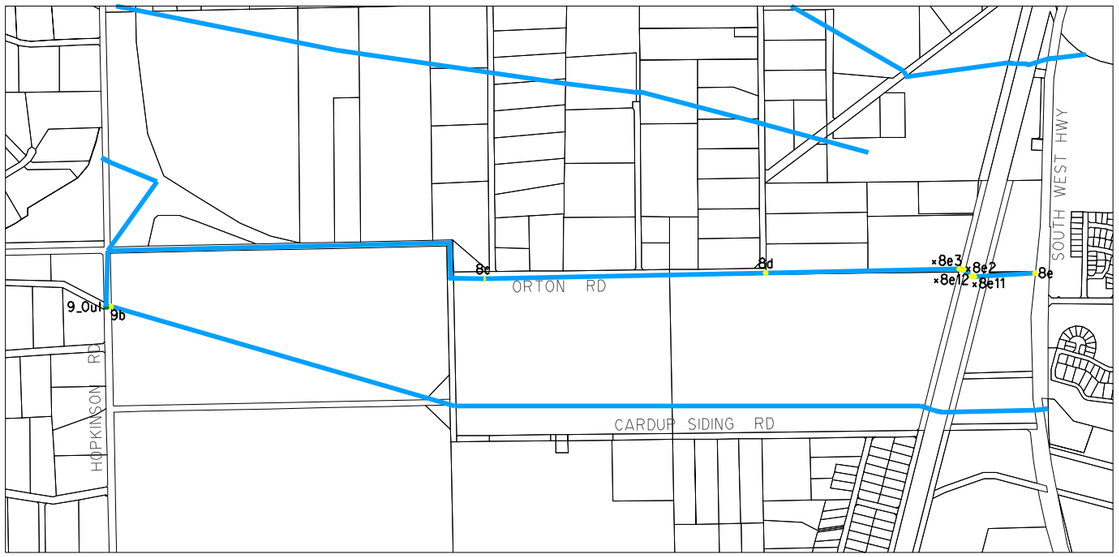
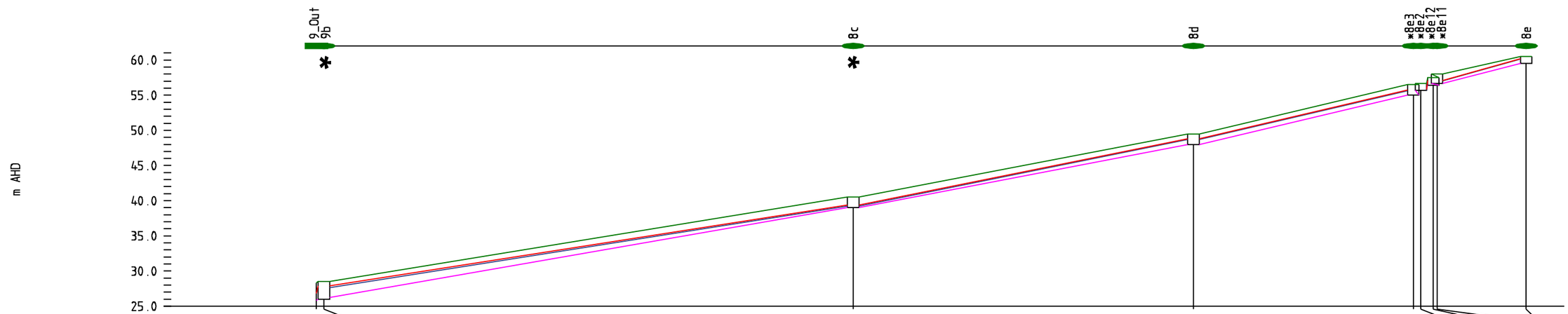




Size (mm)		1800 x1500														3x300			1220 x920			
Chainage (m)	0	28.30	20	28.50					1420	40.50			2320	49.50		2901	56.50	2921	2954	57.50	2964	58.00	3199	60.50
Ground level (m AHD)																								
5 year ARI HGL level (m AHD)	0.00	26.80	27.64	27.90					39.25	39.36			48.69	48.82		55.66	55.72	55.67	55.77	57.08	57.03	57.10	60.12	60.18
100 year ARI HGL level (m AHD)																			57.02					
Invert level (m AHD)	-	25.80	26.00	26.25					39.00	39.00			48.00	48.00		55.04	55.04	55.10	55.50	56.40	56.64	56.64	59.50	-
Max 5 year ARI flow (m3/s)	10.72	11.44				3.45					3.51				2.71		0.77		2.75	2.73		2.75		
Max 100 year ARI flow (m3/s)						11.11					9.28				6.91		2.34		7.02	7.02		7.02		

✱ INDICATES FLOODING DURING 100 YR ARI STORM EVENT

Department of Water
Government of Western Australia

CATCHMENT 8

LONGITUDINAL SECTION

EXISTING SYSTEM

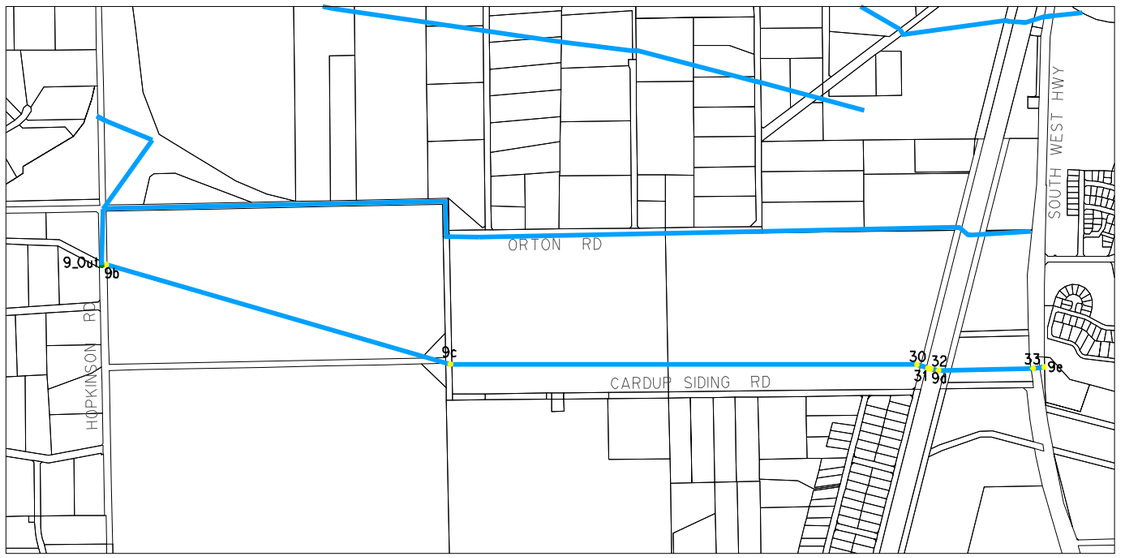
Figure A10.7

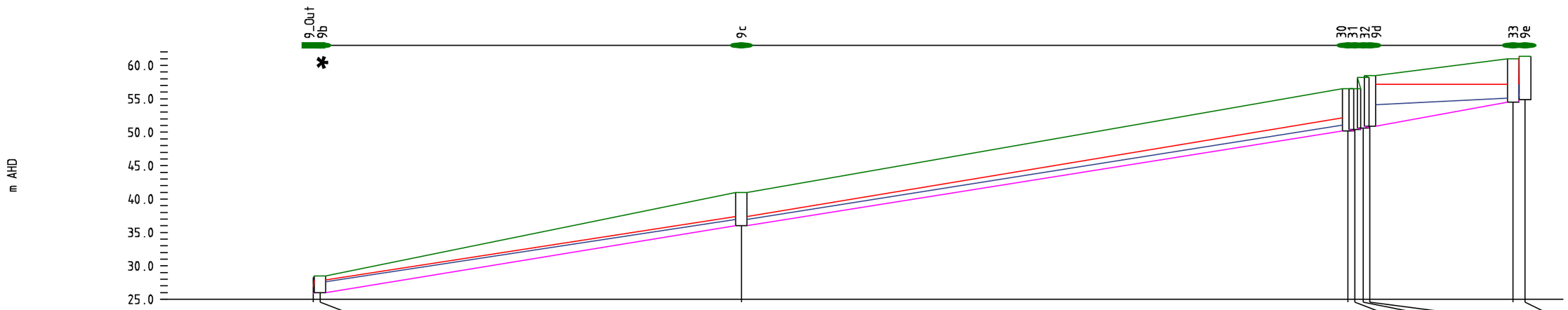
PROJECT N°: 6119569 DATE: 04/08/2008 COORDINATE SYSTEM: MGA94 - Zone 50

AUTHOR: P Heywood DESIGN FILE: Fig10-07 Catchment 08 pre.dgn

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

N





Size (mm)		1800 x1500												1700		1700			900		
Chainage (m)	0	28.30	20					1270					3070	56.50	3090	56.50	3115	58.20	3135	58.50	3560	61.00	3595	61.35
Ground level (m AHD)			28.50					41.00																
5 year ARI HGL level (m AHD)	0.00	26.80	27.64					36.92					51.07	52.14	53.43	55.70	53.43	55.70	54.10	57.15	55.12	57.15	61.01	61.27
100 year ARI HGL level (m AHD)			27.90					37.36																
Invert level (m AHD)	-	25.80	26.00					36.00					50.20	50.20	50.40	50.40	50.60	50.60	50.90	50.90	54.50	54.50	54.85	-
Max 5 year ARI flow (m3/s)	10.72	11.44			10.72				7.67					7.67		7.67		6.66		6.66		4.73		
Max 100 year ARI flow (m3/s)					35.38				27.71					15.77		27.85		12.21		24.95		4.80		

* INDICATES FLOODING DURING 100 YR ARI STORM EVENT

AUTHOR: P Haywood DESIGN FILE: Fig10-08 CardupBrook pre.dgn

Department of Water
Government of Western Australia

CARDUP BROOK

LONGITUDINAL SECTION

EXISTING SYSTEM

Figure A10.8

PROJECT N°: 6119569 DATE: 04/08/2008 COORDINATE SYSTEM: MGA94 - Zone 50

...\FigA10-08 CardupBrook pre.dgn 5/08/2008 9:03:52 AM

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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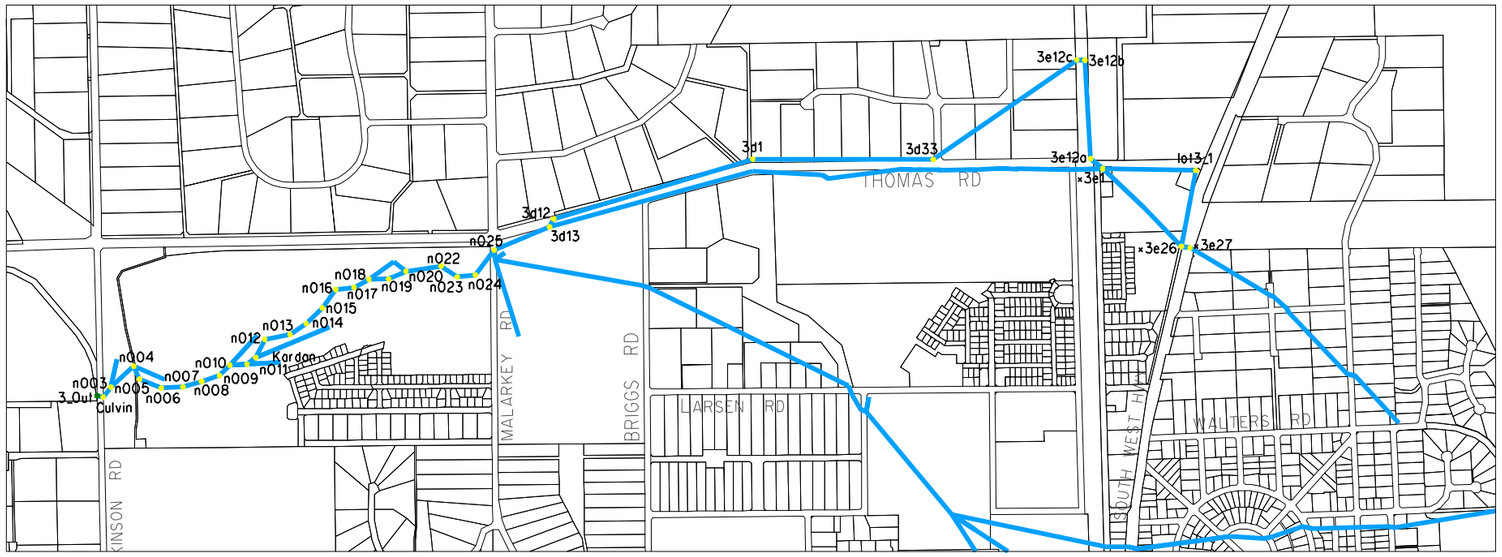
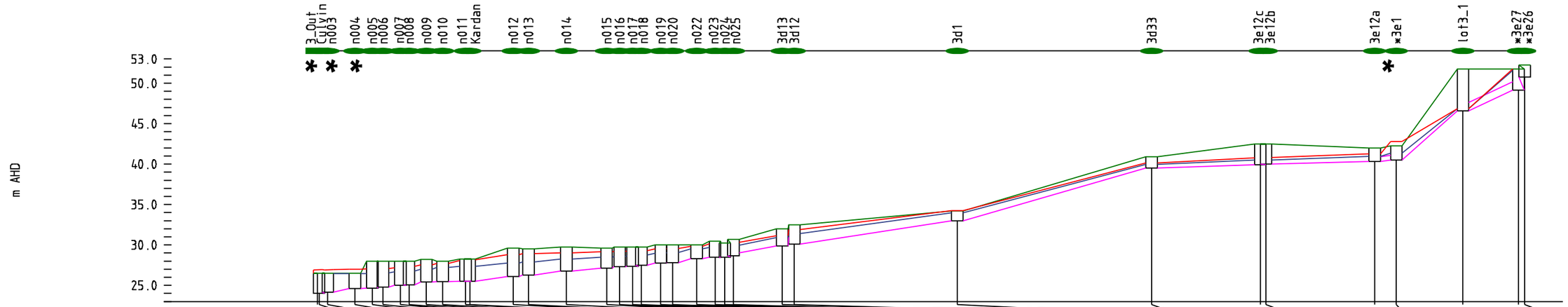




Size (mm)		3600 x1900														
Chainage (m) Ground level (m AHD)	0	26.50	8	26.50	48	26.50	173	26.50	253	28.00	302	28.00	382	28.00	422	28.00
5 year ARI HGL level (m AHD) 100 year ARI HGL level (m AHD)	0.00	25.20	26.44	26.92	26.44	26.93	26.46	26.99	26.46	27.02	26.52	27.07	26.69	27.16	26.76	27.37
Invert level (m AHD)	-	24.22	24.25	24.00	24.15	24.15	24.60	24.60	24.63	24.63	24.80	24.80	25.00	25.00	25.06	25.06
Max 5 year ARI flow (m3/s) Max 100 year ARI flow (m3/s)	15.70	20.87	15.70	48.93	16.08	50.46	17.96	52.10	19.82	53.46	19.93	53.56	20.03	53.76	20.04	53.81

Size (mm)					10x2400											
Chainage (m) Ground level (m AHD)	502	28.20	577	28.00	682	28.25	702	28.25	902	29.60	972	29.50	1147	29.75	1332	29.60
5 year ARI HGL level (m AHD) 100 year ARI HGL level (m AHD)	27.01	27.53	27.23	27.70	27.34	28.09	27.36	28.15	27.77	28.79	27.87	28.90	28.26	29.01	28.45	29.15
Invert level (m AHD)	25.40	25.40	25.45	25.45	25.50	25.50	25.50	25.50	26.10	26.10	26.27	26.27	26.77	26.77	27.12	27.12
Max 5 year ARI flow (m3/s) Max 100 year ARI flow (m3/s)	20.07	53.87	19.81	53.13	1.99	5.32	19.68	52.56	19.72	53.01	19.74	55.59	19.76	57.00	19.79	58.22

Size (mm)																
Chainage (m) Ground level (m AHD)	1392	29.75	1452	29.75	1491	29.75	1581	30.00	1636	30.00	1746	30.00	1831	30.45	1876	30.25
5 year ARI HGL level (m AHD) 100 year ARI HGL level (m AHD)	28.57	29.18	28.67	29.22	28.76	29.27	28.98	29.50	29.05	29.55	29.52	29.83	29.71	30.14	29.79	30.21
Invert level (m AHD)	27.29	27.29	27.33	27.33	27.50	27.50	27.75	27.75	27.78	27.78	28.28	28.28	28.47	28.47	28.47	28.53
Max 5 year ARI flow (m3/s) Max 100 year ARI flow (m3/s)	19.81	58.45	19.83	58.69	19.77	58.72	19.78	58.90	20.82	59.05	20.83	59.23	20.84	59.29	20.85	59.34

Size (mm)														600		
Chainage (m) Ground level (m AHD)	1916	30.67	2141	32.00	2196	32.50	2946	34.20	3842	40.90			4342	42.50	4368	42.50
5 year ARI HGL level (m AHD) 100 year ARI HGL level (m AHD)	29.98	30.31	30.90	31.13	31.38	31.89	33.96	34.23	39.96	40.14			40.51	40.77	40.52	40.84
Invert level (m AHD)	28.67	29.00	29.87	29.87	31.00	30.09	33.00	33.00	39.50	39.50			39.90	39.90	40.00	40.00
Max 5 year ARI flow (m3/s) Max 100 year ARI flow (m3/s)	9.46	25.54	0.38	10.77	6.92	21.49	7.30	22.16			6.30	18.28		0.06	0.19	

Size (mm)				2x600			15000x2000					1050			900	
Chainage (m) Ground level (m AHD)			4868	42.00	4968	42.25			5275	51.75			5530	51.75	5559	52.25
5 year ARI HGL level (m AHD) 100 year ARI HGL level (m AHD)			40.95	41.25	41.15	42.81			46.85	46.85			51.58	51.74	51.65	52.19
Invert level (m AHD)			40.30	40.30	40.50	40.52			46.58	46.58			49.13	49.13	50.75	-
Max 5 year ARI flow (m3/s) Max 100 year ARI flow (m3/s)	6.26	18.03		0.69	0.70		3.36	3.41			3.23	3.27		0.41	0.85	

*** INDICATES FLOODING DURING 100 YR ARI STORM EVENT**

Department of Water
Government of Western Australia

OAKLANDS DRAIN NORTH Part 1 of 2

LONGITUDINAL SECTION

POST-DEVELOPMENT SYSTEM

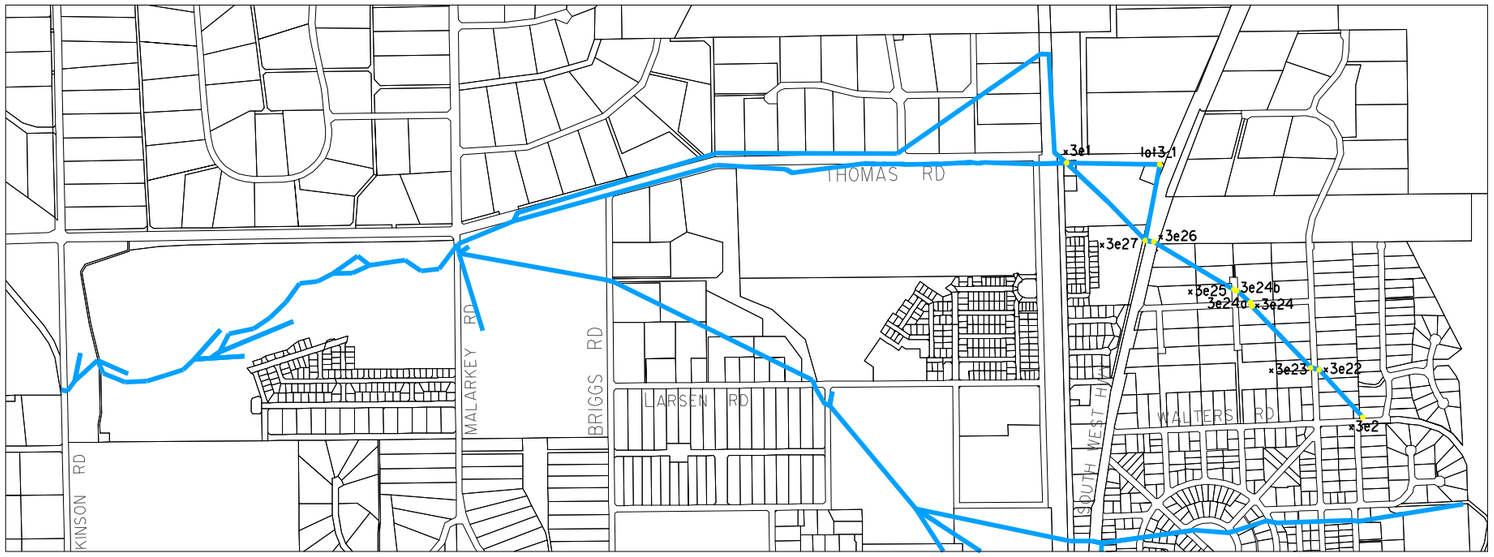
Figure A10.9a

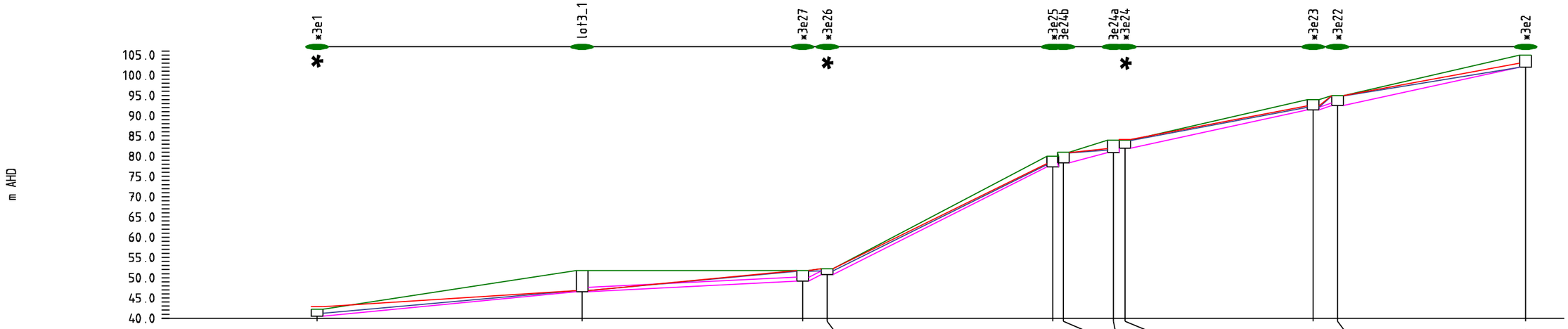
PROJECT Nº: 6119569 DATE: 04/08/2008 COORDINATE SYSTEM: MGA94 - Zone 50

AUTHOR: P Haywood DESIGN FILE: Fig10-09a Oaklands Drain North post.dgn

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

N





Size (mm)		15000x2000				1050				2x900				2x600			2x600			2x600		
Chainage (m)	0	42.25		306	51.75			562	51.75	590	52.25		851	80.00	864	81.00	922	84.00	935	84.00	1153	94.00	1181	95.00		1399	105.00
Ground level (m AHD)																											
5 year ARI HGL level (m AHD)	41.15	42.81		46.85	46.85			51.58	51.74	51.65	52.19		77.94	78.17	80.81	80.89	81.55	81.84	83.90	84.10	92.11	92.39	94.82	94.94		102.01	102.94
100 year ARI HGL level (m AHD)																											
Invert level (m AHD)	-	40.52		46.58	46.58			49.13	49.13	50.75	50.75		77.37	77.37	78.34	78.34	80.87	80.87	81.98	81.98	91.45	91.45	92.53	92.53		102.00	-
Max 5 year ARI flow (m3/s)			3.36			3.23			0.41		7.40			0.53		7.42		0.34		7.43		1.36		7.50		
Max 100 year ARI flow (m3/s)			3.41			3.27			0.85		15.32			0.59		15.39		0.40		15.40		1.34		15.49		

✱ INDICATES FLOODING DURING 100 YR ARI STORM EVENT

Department of Water
Government of Western Australia

OAKLANDS DRAIN NORTH Part 2 of 2

LONGITUDINAL SECTION
POST-DEVELOPMENT SYSTEM
Figure A10.9b

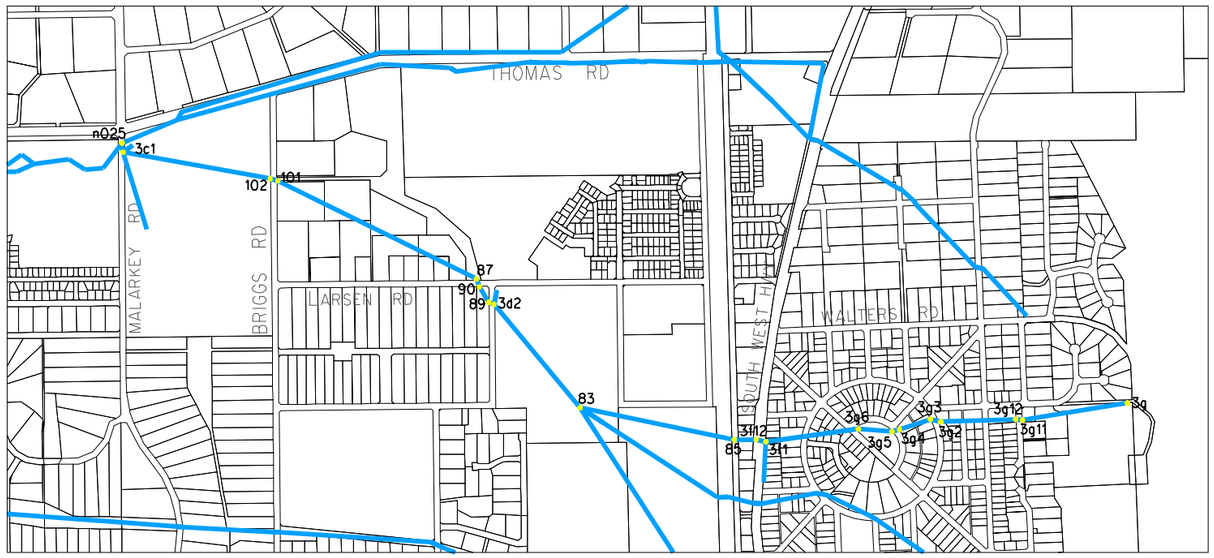
PROJECT N°: 6119569 DATE: 04/08/2008 COORDINATE SYSTEM: MGA94 - Zone 50

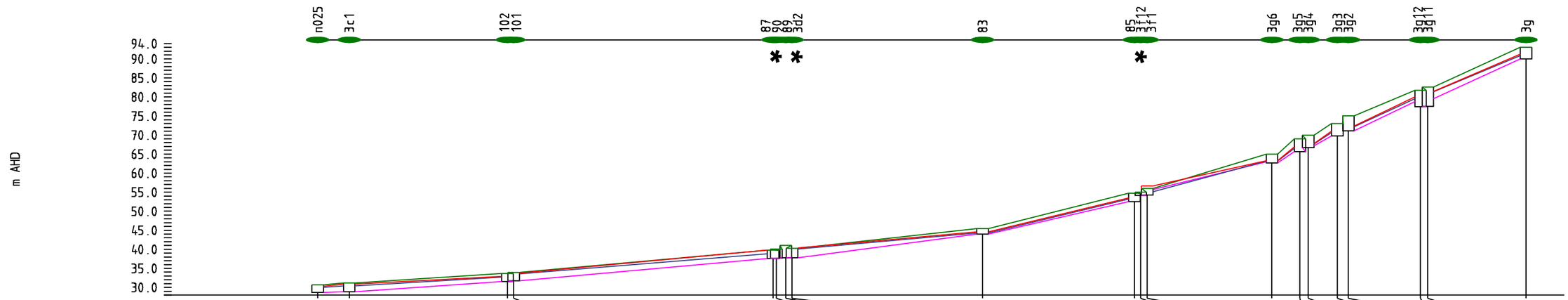
AUTHOR: P Haywood DESIGN FILE: Fig10-09b Oaklands Drain North post.dgn

...\FigA10-09b_OaklandsDrainNorth_post.dgn 5/08/2008 9:00:30 AM

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

N





Size (mm)						1880 x1220						1220			1220 x1200		32000x2000						2x1520 x640	20000x300			900			900			300			
Chainage (m)	0	30.67	100	31.16	600	33.70	620	33.90	1440	39.80	1450	40.11	1480	41.00	1500	40.30	2102	45.43	2582	54.70	2602	55.00	2622	56.00	3016	65.00	3105	69.00	3131	70.00	3223	73.00	3258	75.00	3486	81.74	3509	82.57	3820	93.00
Ground level (m AHD)																																								
5 year ARI HGL level (m AHD)	29.98	30.31	30.42	30.85	32.70	32.88	33.54	33.76	38.88	39.75	39.58	39.86	39.59	39.93	40.03	40.32	44.34	44.59	53.25	53.53	54.84	54.93	55.13	56.61	63.14	63.25	66.49	66.90	67.67	67.80	70.63	71.05	72.19	72.39	79.57	79.99	81.36	81.45	90.83	91.26
100 year ARI HGL level (m AHD)																																								
Invert level (m AHD)	-	28.67	28.84	28.84	31.56	31.56	31.76	31.76	37.61	37.61	37.71	37.71	37.75	37.75	37.80	37.80	44.00	44.00	52.50	54.20	54.70	54.20	54.30	55.70	63.00	62.69	65.67	65.67	66.68	67.18	69.78	69.80	72.00	71.08	78.74	77.40	77.50	79.57	90.00	-
Max 5 year ARI flow (m3/s)		11.02		10.47		6.12		10.98		4.28		11.00		3.64		10.62		5.38		5.49		2.74		5.33		5.51		0.34		5.51		0.10		5.52		0.26		5.55		
Max 100 year ARI flow (m3/s)		33.24		30.20		7.19		30.25		4.37		35.23		3.72		34.34		10.05		10.20		5.10		10.02		10.22		0.46		10.24		0.14		10.25		0.26		10.30		

✱ INDICATES FLOODING DURING 100 YR ARI STORM EVENT

AUTHOR: P Haywood DESIGN FILE: Fig10-10 Oaklands Drain Central post.dgn

Department of Water
Government of Western Australia

OAKLANDS DRAIN CENTRAL

LONGITUDINAL SECTION
POST-DEVELOPMENT SYSTEM
Figure A10.10

PROJECT N°: 6119569 DATE: 04/08/2008 COORDINATE SYSTEM: MGA94 - Zone 50

...\Fig10-10_OaklandsDrainCentral_post.dgn 5/08/2008 8:59:09 AM

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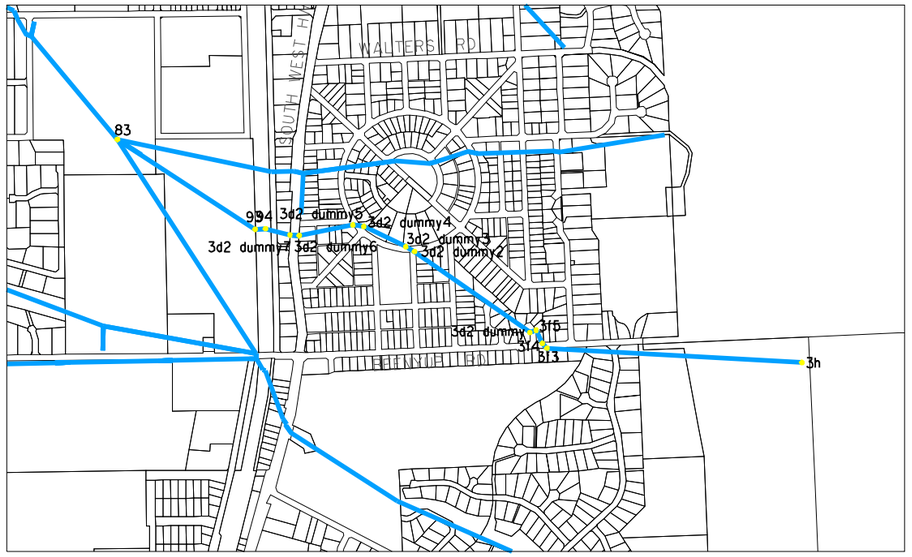
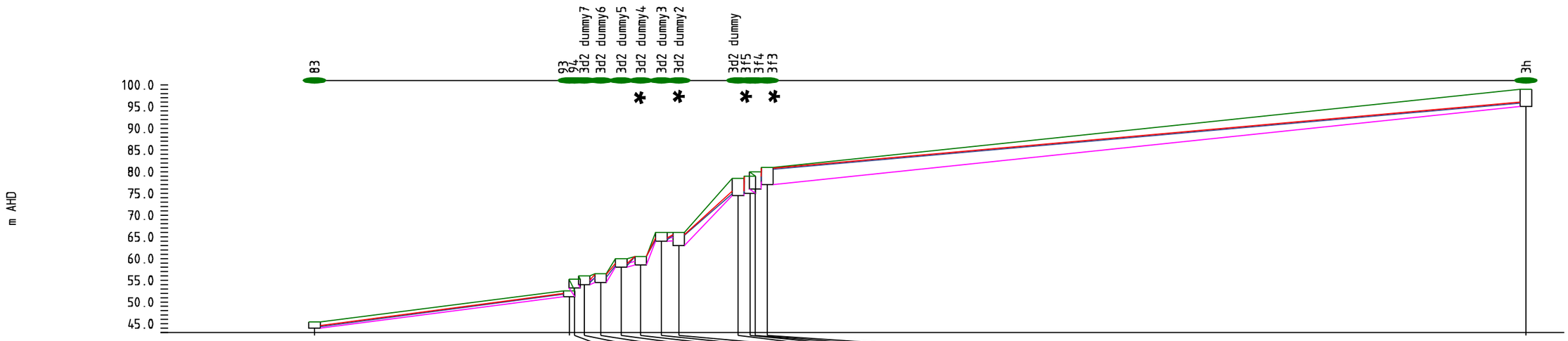




Size (mm)						4000 x1200			3x900			900			750			750			750			
Chainage (m)	0			470	52.56	480	55.24	497	56.00	527	56.50	565	60.00	601	60.50	640	66.00	672	66.00	781	78.50	803	79.00	813	80.00	835	81.00		2235	99.00
Ground level (m AHD)	45.43																													
5 year ARI HGL level (m AHD)	44.34			51.79	51.99	53.65	54.40	54.46	55.08	55.65	56.35	58.39	58.88	60.44	60.59	64.36	64.79	65.32	65.51	74.94	75.50	77.89	78.88	77.89	78.90	80.52	80.85		95.76	96.06
100 year ARI HGL level (m AHD)	44.59																													
Invert level (m AHD)	-	44.00		51.25	51.25	53.25	53.25	54.00	54.00	54.50	54.50	58.00	58.00	58.50	58.50	64.00	64.00	64.10	63.00	74.50	74.50	75.00	75.00	76.00	76.00	77.00	77.00		95.00	-
Max 5 year ARI flow (m3/s)			2.29		2.36		2.39		0.76		2.29		2.14		2.29		1.06		2.29		2.37		2.43		2.29			2.29		
Max 100 year ARI flow (m3/s)			10.52		3.59		10.68		2.22		10.68		2.50		10.68		1.16		10.68		2.66		10.68		2.35			10.68		

✱ INDICATES FLOODING DURING 100 YR ARI STORM EVENT

Department of Water
Government of Western Australia

OAKLANDS DRAIN SOUTH

LONGITUDINAL SECTION

POST-DEVELOPMENT SYSTEM

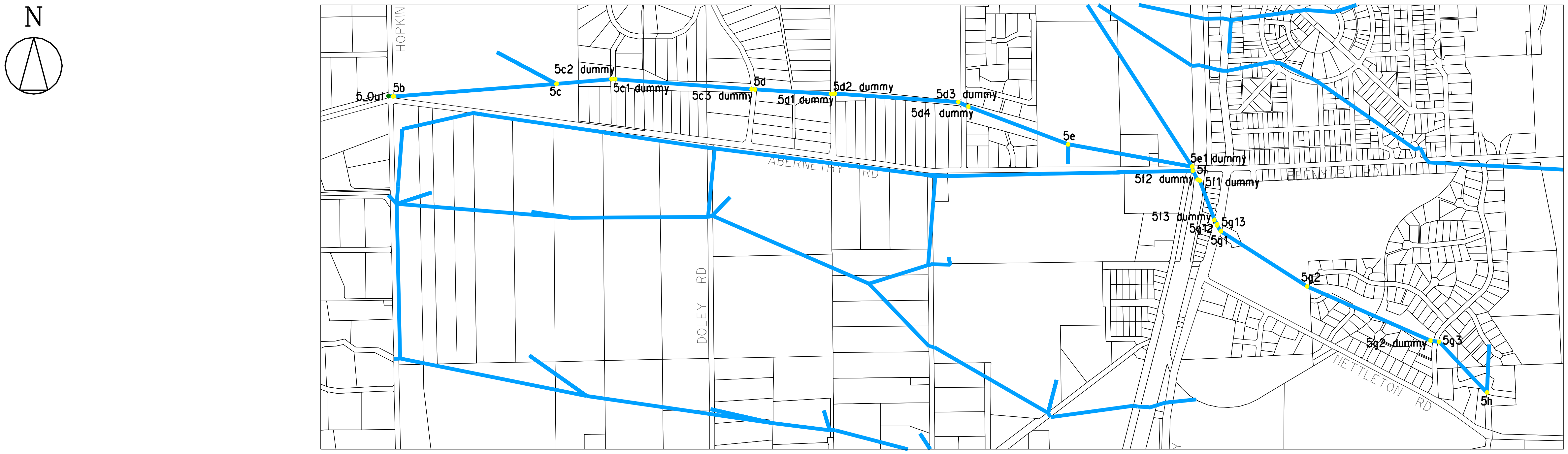
Figure A10.11

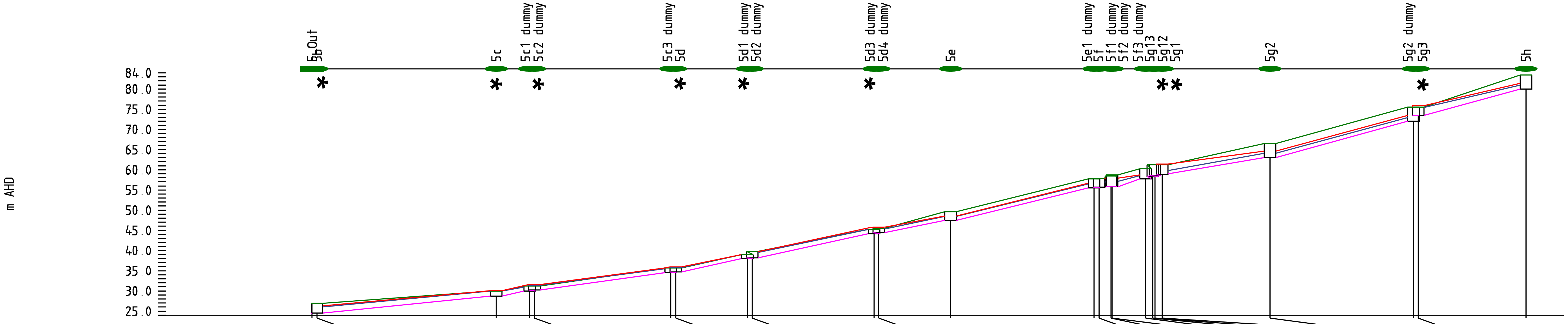
PROJECT N°: 6119569 DATE: 04/08/2008 COORDINATE SYSTEM: MGA94 - Zone 50

AUTHOR: P Heywood DESIGN FILE: Fig10-11 Oaklands Drain South post.dgn

...\FigA10-11 OaklandsDrainSouth post.dgn 4/08/2008 5:19:49 PM

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





Size (mm)	Chainage (m)	Ground level (m AHD)	5 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)	Max 5 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
	0		0.00		-	8.11	9.62
3700 x1560		26.80		25.40	24.40		
	20		25.99		24.50		
		26.90		26.27	24.50		
						8.11	9.62
	770		29.94		28.75		
		30.00		30.06	28.75	8.41	8.93
	910		30.98		30.00		
3x900		31.25		31.22	30.00	1.35	1.36
	930		31.42		30.20		
		31.25		31.59	30.20		
						8.48	8.95
	1500		35.51		34.50		
3x900		35.70		35.70	34.50	1.01	1.01
	1520		35.76		34.70		
		35.70		35.93	34.70		
						8.88	8.00
	1820		38.94		38.00		
2x1210 x920		39.00		39.01	38.00	2.45	2.39
	1840		39.48		38.20		
		39.75		39.66	38.20		
						9.69	8.86
	2350		45.21		44.20		
2x1500 x600		45.25		45.24	44.20	1.63	1.64
	2370		45.31		44.40		
		45.50		45.74	44.40		
						20.71	17.68
	2670		48.47		47.50		
		49.64		48.51	47.50		
2x1200						1.51	1.57
	3270		56.52		55.50		
5x1240 x1200		57.70		56.63	55.50	2.00	4.81
	3290		56.83		55.70		
		57.80		57.73	55.70	8.00	30.75
	3340		57.09		55.75		
		58.50		57.88	55.75	8.00	30.75
	3345		57.13		55.75		
		58.75		57.96	55.75	8.00	30.75
	3485		58.52		57.75		
7500 x2000		60.25		58.74	57.85	8.07	26.70
	3515		59.28		58.40		
4750 x2500		61.25		61.21	58.40	8.07	31.20
	3525		59.59		58.55		
7500 x2000		61.25		61.29	58.55	8.07	22.99
	3555		59.76		58.85		
		61.25		61.43	59.00	8.07	31.20
	4005		64.06		63.00		
		66.50		64.62	63.00		
						8.09	31.26
	4605		72.90		72.00		
3x1100		75.50		73.49	73.40	3.10	3.94
	4625		75.39		73.50		
		75.50		75.91	73.50		
						8.10	31.29
	5075		81.00		80.00		
		83.50		81.45	-		

* INDICATES FLOODING DURING 100 YR ARI STORM EVENT

BEENYUP BROOK

LONGITUDINAL SECTION

POST-DEVELOPMENT SYSTEM

Figure A10.12

AUTHOR: P Haywood DESIGN FILE: Fig10-12 Beenyup Brook post.dgn

Department of Water
Government of Western Australia

PROJECT N°: 6119569 DATE: 04/08/2008 COORDINATE SYSTEM: MGA94 - Zone 50

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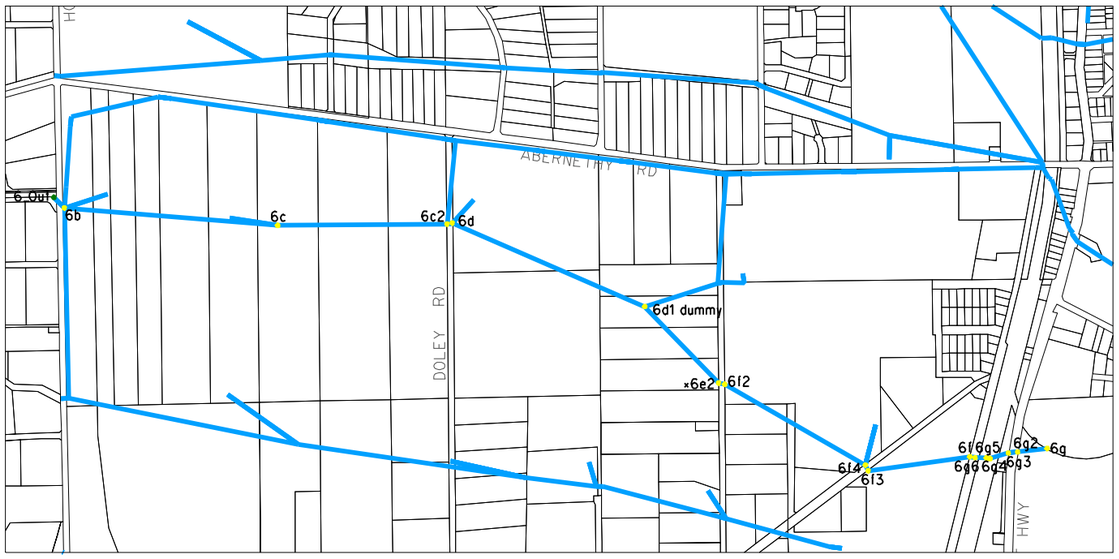

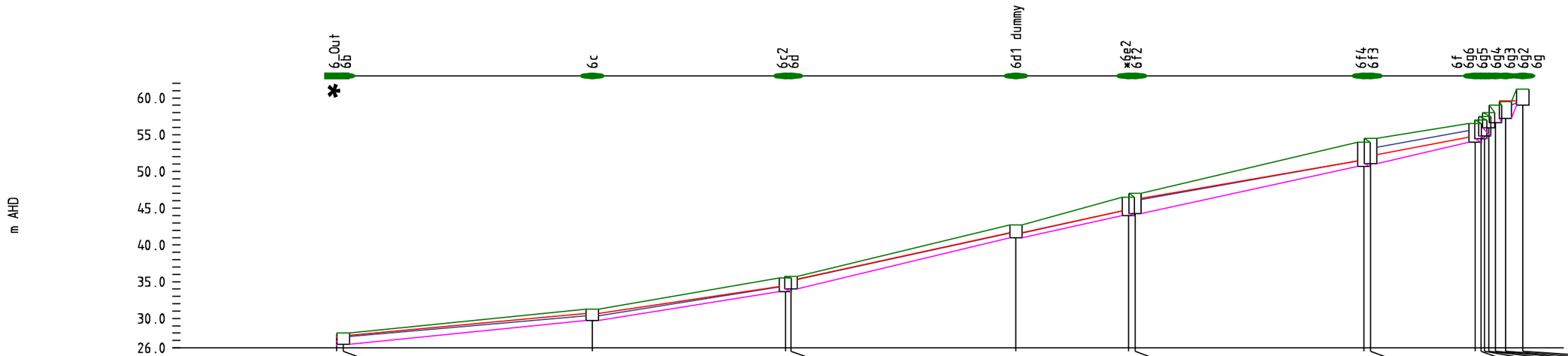

Size (mm)		2x455							2x750							1200 x450						1500 x600			2x1200 x450			1220 x920			2x380		
Chainage (m)	0	27.80	20	28.00	795	31.25	1395	35.50	1413	35.70	2113	42.70	2463	46.50	2483	47.00	3195	54.00	3216	54.50	3542	56.50	3559	57.00	3571	57.50	3584	58.00	3605	59.00	3636	59.50	3690	61.20
Ground level (m AHD)																																	
5 year ARI HGL level (m AHD)	0.00	27.30	27.56	27.69	30.35	30.66	34.29	34.36	35.29	35.35	41.61	41.66	44.61	44.62	46.19	46.33	51.41	51.42	53.28	52.27	55.56	54.67	56.07	56.41	56.10	56.41	57.75	57.30	57.33	57.30	59.00	59.59	59.34	59.61
100 year ARI HGL level (m AHD)																																		
Invert level (m AHD)	-	26.30	26.50	26.50	29.75	29.75	33.68	33.68	34.00	34.00	41.00	41.00	44.00	44.00	44.24	44.24	50.71	50.71	51.04	51.04	54.00	54.00	54.45	54.45	54.84	54.84	55.92	55.92	56.62	56.62	57.20	57.20	59.00	-
Max 5 year ARI flow (m3/s)	0.79	0.29			1.59		1.45	0.72			1.43		1.28	1.28			1.28	0.75		0.75		0.67		0.76		0.76		0.76		0.39		0.78	
Max 100 year ARI flow (m3/s)							5.95	1.12			3.32		2.15	2.14			2.14	2.54		2.54		2.19		3.02		2.24		4.19		0.44		4.14	

✱ INDICATES FLOODING DURING 100 YR ARI STORM EVENT

AUTHOR: P Heywood DESIGN FILE: Fig10-13 Catchment 06 post.dgn

Department of Water
Government of Western Australia

CATCHMENT 6

LONGITUDINAL SECTION

POST-DEVELOPMENT SYSTEM

Figure A10.13

PROJECT N°: 6119569 DATE: 04/08/2008 COORDINATE SYSTEM: MGA94 - Zone 50

...\FigA10-13 Catchment 06 post.dgn 4/08/2008 4:41:06 PM

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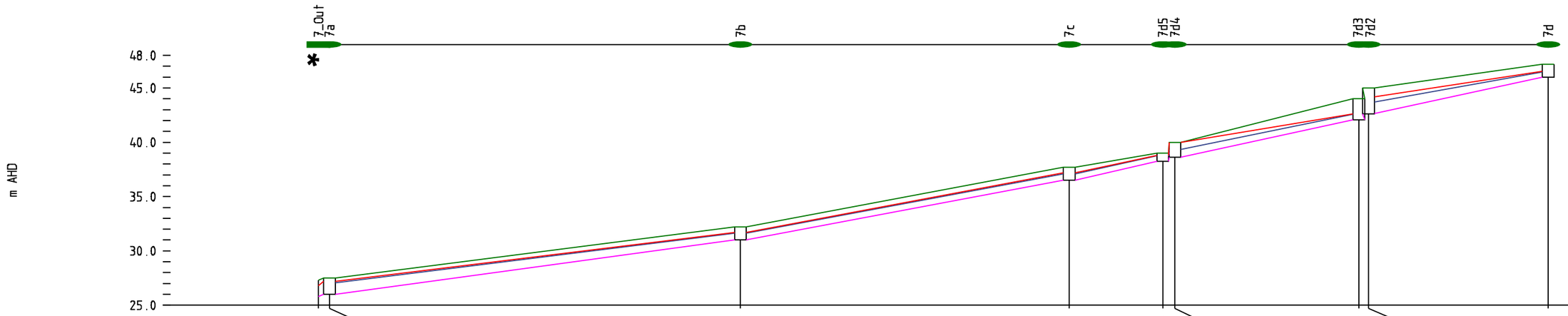

Size (mm)		1200 x500											2x450					2x450		
Chainage (m)	0	27.30	20	27.50			770	32.20			1370	37.70	1540	39.00	1562	40.00	1898	44.00	1916	45.00	2244	47.20
Ground level (m AHD)																						
5 year ARI HGL level (m AHD)	0.00	26.80	27.05	27.20			31.61	31.70			37.07	37.18	38.78	38.79	39.34	39.98	42.59	42.60	43.69	44.19	46.48	46.53
100 year ARI HGL level (m AHD)																						
Invert level (m AHD)	-	25.80	26.00	26.00			31.00	31.00			36.50	36.50	38.26	38.26	38.62	38.63	42.07	42.08	42.63	42.63	46.00	-
Max 5 year ARI flow (m3/s)	1.97	2.16			1.97			1.40			0.95			0.31		0.61		0.33		0.54		
Max 100 year ARI flow (m3/s)					5.05			3.65			1.95			0.47		0.95		0.58		1.05		

* INDICATES FLOODING DURING 100 YR ARI STORM EVENT

Department of Water
Government of Western Australia

CATCHMENT 7

LONGITUDINAL SECTION
POST-DEVELOPMENT SYSTEM
Figure A10.14

PROJECT N°: 6119569 DATE: 04/08/2008 COORDINATE SYSTEM: MGA94 - Zone 50

AUTHOR: P Haywood DESIGN FILE: Fig10-14 Catchment 07 post.dgn

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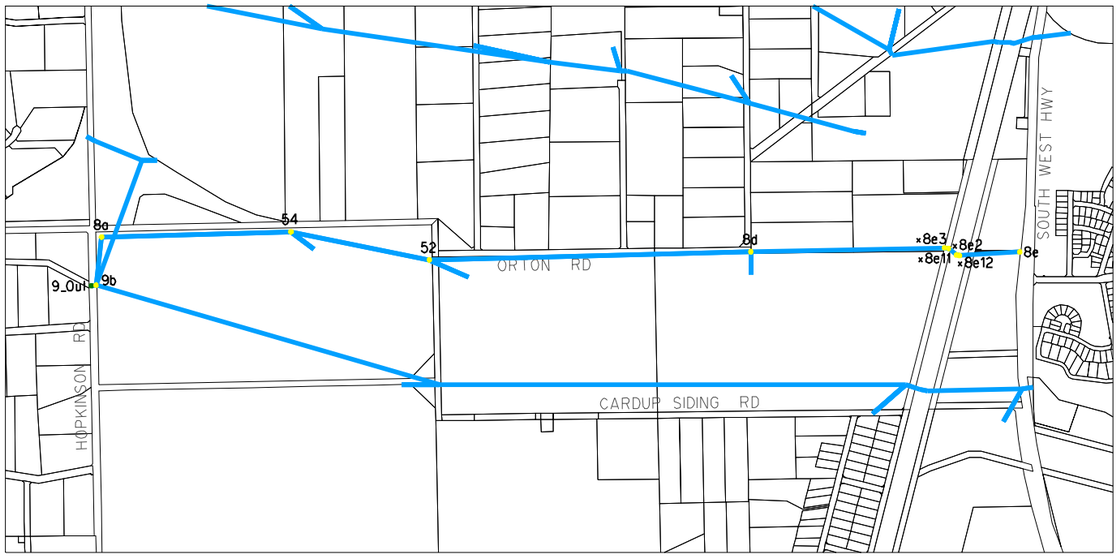

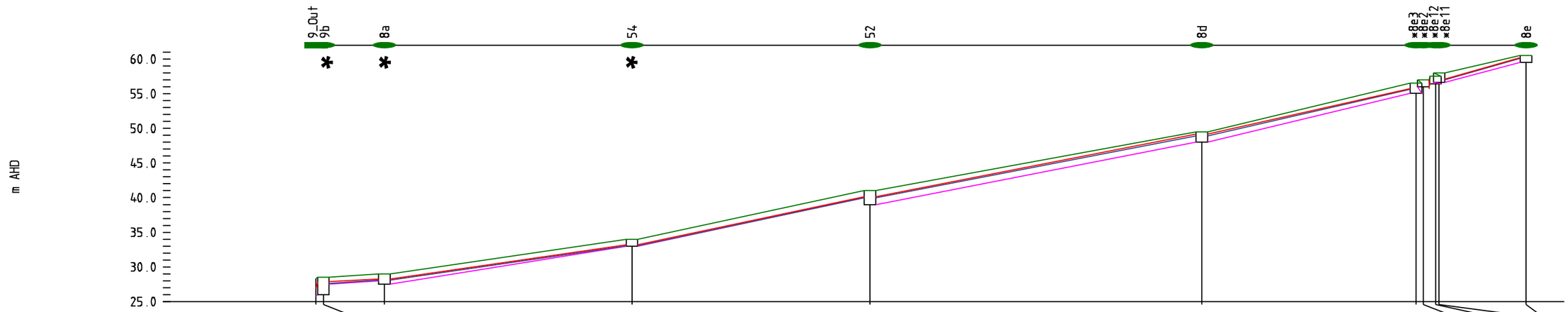

Size (mm)		1800 x1500		20000 x300		20000x300			20000x300			3000x1000					3x300			1220 x920		
Chainage (m)	0	20	28.30	185	28.50	857	29.00	34.00	1502	41.00	2402	49.50	2984	56.50	3004	57.00	3037	57.50	3046	58.00	3282	60.50
Ground level (m AHD)																						
5 year ARI HGL level (m AHD)	0.00	26.80	27.88	28.09	28.24	33.06	33.18	39.97	40.15	48.93	49.15	55.65	55.72	55.67	55.77	57.02	57.08	57.02	57.10	60.12	60.18	
100 year ARI HGL level (m AHD)		27.62																				
Invert level (m AHD)	-	25.80	27.50	28.00	27.50	33.00	33.00	40.00	39.00	48.00	48.00	55.04	55.04	56.00	56.00	56.40	56.40	56.64	56.64	59.50	-	
Max 5 year ARI flow (m3/s)	9.36	11.44	1.95	2.36	2.65	2.31	1.90	-0.00	2.40	-0.41	2.41											
Max 100 year ARI flow (m3/s)			6.35	6.04	4.58	2.79	5.46	-0.00	5.86	-0.47	5.86											

✱ INDICATES FLOODING DURING 100 YR ARI STORM EVENT AS PER FIGURE •••

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Government of Western Australia

CATCHMENT 8

LONGITUDINAL SECTION
POST-DEVELOPMENT SYSTEM
Figure A10.15

PROJECT N°: 6119569 DATE: 04/08/2008 COORDINATE SYSTEM: MGA94 - Zone 50

AUTHOR: P Haywood DESIGN FILE: Fig10-15 Catchment 08 post.dgn

...\FigA10-15 Catchment 08 post.dgn 5/08/2008 10:10:09 AM

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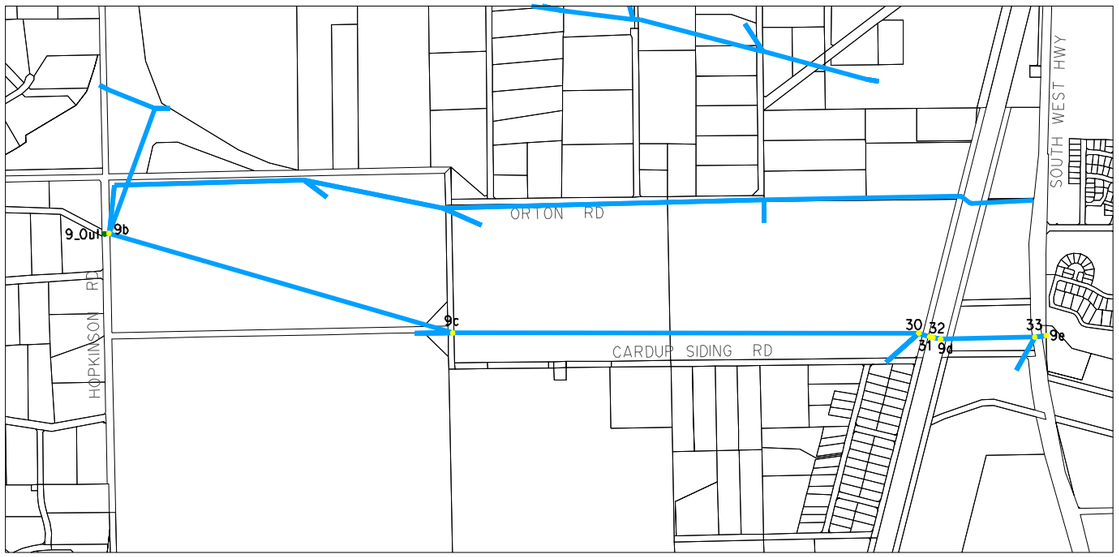

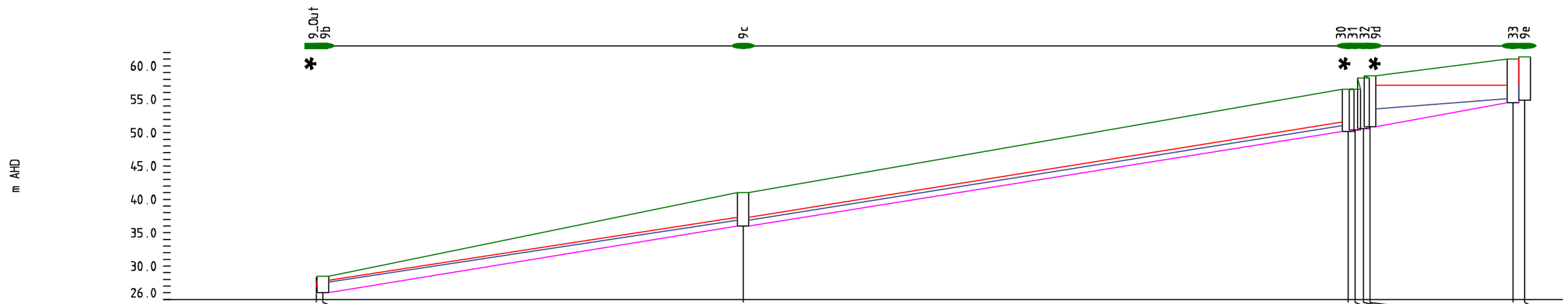

Size (mm)		1800 x1500												1700			1700				900	
Chainage (m)	0	28.30	20						1270					3070	56.50	3090	56.50	3115	58.20	3135	58.50		3560	61.00	3595	61.35
Ground level (m AHD)			28.50							41.00																
5 year ARI HGL level (m AHD)	0.00	26.80	27.62						36.89					51.03	51.57	53.05	55.66	53.05	55.66	53.57	57.12		55.08	57.13	60.97	61.25
100 year ARI HGL level (m AHD)			27.88							37.33																
Invert level (m AHD)	-	25.80	26.00						36.00					50.20	50.20	50.40	50.40	50.60	50.60	50.90	50.90		54.50	54.50	54.85	-
Max 5 year ARI flow (m3/s)	9.36	11.44			9.36						6.89				5.77		5.77		5.78			5.78		4.72		
Max 100 year ARI flow (m3/s)					33.17						25.93				15.67		23.49		12.71			23.49		4.80		

* INDICATES FLOODING DURING 100 YR ARI STORM EVENT

Department of Water
Government of Western Australia

CARDUP BROOK

LONGITUDINAL SECTION
POST-DEVELOPMENT SYSTEM
Figure A10.16

PROJECT N°: 6119569 DATE: 04/08/2008 COORDINATE SYSTEM: MGA94 - Zone 50

AUTHOR: P Heywood DESIGN FILE: Fig10-16 Cardup Brook post.dgn

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Appendices

Appendix A – Stormwater modelling in InfoWorks CS

A.1 Hydraulic modelling in InfoWorks CS

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

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

Mannings roughness coefficients applied to the conduits are summarised in Table A.1.

Table A.1 Culverts roughness coefficients (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

Local detention basins were sized according to the principles outlined in Chapter 6. The numerical model is run for pre-development land use to determine maximum discharge from each subcatchment for critical one, five and 100-year annual recurrence interval rainfall events. The peak discharges of the subcatchments are to be maintained in the post-development scenario.

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

Groundwater levels in drains and basins were modelled by the application of inflows directly into the drain. Groundwater levels and 100-year annual recurrence interval event flood levels were used to determine indicative fill requirements and the invert of the detention basin.

A.2 Initial modelling assumptions

The following assumptions used for modelling of the Byford townsite:

- Peak winter groundwater levels (controlled groundwater levels) applied as starting water levels in basins and as baseflows in drains.
- Annual recurrence interval year rainfall events applied to whole catchment with universal start time.
- 100-year flood levels taken from *the Byford floodplain management strategy* SKM, 2007) applied as constant tailwater at the Hopkinson Road end of each modelled waterway.
- Infiltration modelled at a constant rate of 4 mm/hour.
- Catchment parameterisation (pervious/impervious breakdown, catchment slope, roughness and losses) adopted from the *Byford floodplain management strategy* (SKM, 2007).

A.3 Surface runoff parameters

Recorded stream flow information was not available for the Byford catchments to enable calibration of the loss parameters adopted within runoff routing models of the catchments. When deciding on the appropriate loss parameters applicable to the Byford catchments, the Department of Water considered:

- adopted parameters for calibrated runoff routing models of nearby similar catchments
- incorporation of antecedent flow from the catchment (baseflow)
- adopted parameters during modelling for other major infrastructure projects on the Swan Coastal Plain
- catchment soil characteristics
- vegetation coverage
- future expansion of Tonkin Highway
- uncertainty in design rainfall depths and temporal patterns
- uncertainty due to the impact of climate change
- uncertainty in upper catchment land use/vegetation coverage into the future

The F*loodplain management strategy* adopted runoff coefficients of 10 mm initial loss and 50 per cent continuing proportional loss for the upper catchments and 10 mm initial loss and 4 mm/hr continuing loss on the flatter heavy soils downstream of South Western Highway.

The InfoWorks CS model of Byford townsite uses a constant infiltration model to generate rainfall runoff and the SWMM single non-linear reservoir routing model to provide inflows to the hydraulic component of the model. Each subcatchment in the study area is subdivided into pervious and impervious areas that have surface

roughness, initial losses and infiltration losses applied according to land use (Table A-2).

The land use of the existing catchments was adopted from the *SKM flood management strategy. The distinct structure plan* (Table A-3) provided the land use breakdown for the ultimate development. The percentage of surface types for individual catchments was calculated from the existing land use and district structure plan; the results are summarised in Table A-4 (pre-development scenario) and Table A-5 (post-development scenario).

Design rainfall events for the 1h, 3h, 6h, 12h, 24h, 48h and 72h durations were run for 1y, 5y and 100y ARI.

Table A.2 InfoWorks model runoff area properties

Land use	surface roughness (Mannings N)		initial loss (mm)		infiltration loss (mm/hour)		fixed runoff coefficient	
	Perv	Imperv	Perv	Imperv	Perv	Imperv	Perv	Imperv
Upper forested	0.080	0.015	10	1.5	N/A	N/A	0.2 - 10y 0.5 - 100y (calib.) 0.4 - 100y (design)	1.0
Rural pasture	0.050	0.015	10	1.5	4	0	N/A	N/A
Existing urban	0.025	0.015	10	1.5	4	0	N/A	N/A
Constructed urban	0.025	0.015	10	15	4	0	N/A	N/A

Table A.3 InfoWorks model land use surface breakdown

Land use category	Pervious area 1 (%)	Effective impervious area 2 (%)
Roads	30%	70%
Mixed business	25%	75%
Neighbourhood centres	45%	55%
Town centres	40%	60%
Residential (R20-R60)	50%	50%
Rural residential (R2)	100%	0%
Schools	50%	50%

Notes:

- Effective impervious areas presented in this table are for modelling at the catchment scale and are not to be used for individual lot runoff calculations.

Table A.4 InfoWorks model catchment properties for pre-development scenario

Subcatchment ID	Total area (ha)	Vector slope (%)	Catchment width (m)	% Impervious
10C	24.672	1.4	280.2	0
2A	95.713	1.5	552.0	3.049
2A1	20.593	2.0	256.0	29.798
2B	79.625	4.1	503.4	1.517
2C	44.476	11.8	376.3	1.538

Subcatchment ID	Total area (ha)	Vector slope (%)	Catchment width (m)	% Impervious
3B1	29.222	1.8	305.0	0
3B2	54.433	1.8	416.3	0
3B3	24.668	1.8	280.2	0
3C	68.105	1.4	465.6	0
3CX	56.251	2.0	423.1	47.952
3D1	65.070	3.4	455.1	0
3D2	49.011	2.1	395.0	0
3D3	12.820	2.1	202.0	0
3D4	11.409	2.5	190.6	0
3E	136.379	10.8	658.9	42.016
3F	45.228	26.3	379.4	0
3F1	80.810	5.6	507.2	53.968
3F2	27.055	3.8	293.5	60.000
3F3	31.540	13.0	316.8	47.969
3G1	30.298	24.6	310.6	0
3G2	33.347	24.3	325.8	0
3H	109.757	16.4	591.1	0
4A2	34.352	1.8	330.7	54.023
4B	16.631	2.0	230.1	5.988
5B	40.298	1.6	358.2	1.467
5C	22.714	1.7	268.9	26.840
5D	47.859	2.0	390.3	24.008
5E	21.189	2.1	259.7	0
5F	6.314	3.8	141.8	0
5G	108.901	8.1	588.8	24.022
5H1	182.568	17.1	762.3	0
5H2	108.331	13.2	587.2	0
5I1	74.415	17.1	486.7	0
5I2	13.563	19.8	207.8	0
5J	268.448	8.8	924.4	0
5K	163.319	11.0	721.0	0
5L	246.591	5.4	886.0	0
5M	188.239	5.8	774.1	0
6B	26.896	1.8	292.6	0
6C	19.783	1.9	250.9	0
6D1	77.237	2.1	495.8	0
6D2	16.049	1.5	226.0	0
6E	20.920	1.8	258.1	0
6F	17.800	3.6	238.0	0
6G	74.373	4.3	486.6	0
7A	57.144	1.2	426.5	0
7B	46.436	1.4	384.5	0
7C	29.203	1.8	304.9	0
7C1	40.756	1.3	360.2	0
7D	34.041	1.9	329.2	0
8A	18.977	1.3	245.8	0
8B	43.128	1.5	370.5	0
8C	55.552	1.5	420.5	0

Subcatchment ID	Total area (ha)	Vector slope (%)	Catchment width (m)	% Impervious
8D	47.806	1.9	390.1	0
8E	65.206	6.6	455.6	0
9B	37.144	2.0	343.9	0
9C	85.439	3.9	521.5	6.007
9D	22.645	4.0	268.5	0
9E	113.147	9.5	600.1	0
9F1	22.219	27.0	265.9	0
9F2	101.466	21.1	568.3	0
9G	355.666	15.7	1064.0	0
9H	463.327	10.4	1214.4	0
9I	232.132	5.7	859.6	0
B16	224.573	2.0	845.5	0

Table A.5 InfoWorks model catchment properties for post-development scenario

Subcatchment ID	Total area (ha)	Vector slope (%)	Catchment width (m)	% Impervious
10C	24.672	1.4	280.2	38.486
2A	95.713	1.5	552.0	3.049
2A1	20.593	2.0	256.0	29.798
2B	79.625	4.1	503.4	1.517
2C	44.476	11.8	376.3	1.538
3B1	29.222	1.8	305.0	28.681
3B2a	10.392	1.8	180.8	31.570
3B2b	15.680	1.8	201.5	28.800
3B2c	30.907	1.8	290.2	21.370
3B3	24.668	1.8	280.2	47.952
3C	68.105	1.4	465.6	38.265
3CX	56.251	2.0	423.1	26.702
3D1	65.070	3.4	455.1	33.162
3D2	49.011	2.1	395.0	27.361
3D3	12.820	2.1	202.0	42.016
3D4	11.409	2.5	190.6	53.968
3E	136.379	10.8	658.9	60.000
3F	45.228	26.3	379.4	0
3F1	80.810	5.6	507.2	47.969
3F2	27.055	3.8	293.5	0
3F3	31.540	13.0	316.8	0
3G1	30.298	24.6	310.6	26.976
3G2	33.347	24.3	325.8	36.151
3H	109.757	16.4	591.1	0
4A2	34.352	1.8	330.7	54.023
4B	16.631	2.0	230.1	5.988
5B	40.298	1.6	358.2	34.950
5C	22.714	1.7	268.9	31.609
5D	47.859	2.0	390.3	20.449
5E	21.189	2.1	259.7	35.969
5F	6.314	3.8	141.8	28.798
5G	108.901	8.1	588.8	31.791
5H1	182.568	17.1	762.3	0

Subcatchment ID	Total area (ha)	Vector slope (%)	Catchment width (m)	% Impervious
5H2	108.331	13.2	587.2	0
5I1	74.415	17.1	486.7	0
5I2	13.563	19.8	207.8	0
5J	268.448	8.8	924.4	0
5K	163.319	11.0	721.0	0
5L	246.591	5.4	886.0	0
5M	188.239	5.8	774.1	0
6B	26.896	1.8	292.6	15.110
6C	19.783	1.9	250.9	29.278
6D1	77.237	2.1	495.8	39.315
6D2	16.049	1.5	226.0	5.331
6E	20.920	1.8	258.1	0
6F	17.800	3.6	238.0	33.378
6G	74.373	4.3	486.6	40.158
7A	57.144	1.2	426.5	39.404
7B	46.436	1.4	384.5	40.196
7C	29.203	1.8	304.9	24.176
7C1	40.756	1.3	360.2	23.179
7D	34.041	1.9	329.2	39.852
8A	18.977	1.3	245.8	37.906
8B	43.128	1.5	370.5	42.541
8C	55.552	1.5	420.5	1.765
8D	47.806	1.9	390.1	4.672
8E	65.206	6.6	455.6	11.069
9B	37.144	2.0	343.9	4.190
9C	85.439	3.9	521.5	15.879
9D	22.645	4.0	268.5	4.190
9E	113.147	9.5	600.1	0
9F1	22.219	27.0	265.9	0
9F2	101.466	21.1	568.3	0
9G	355.666	15.7	1064.0	0
9H	463.327	10.4	1214.4	0
9I	232.132	5.7	859.6	0
B16	224.573	2.0	845.5	0

A.4 Hydrologic model validation

Peak and total pre-development catchment runoff generated by the InfoWorks model was compared to peak and total catchment output from the RAFTS model used in the SKM floodplain management study.

In general, the fit is good, though at high flows the peak flows generated by InfoWorks are somewhat smaller than those generated by RAFTS. Figure 1 shows the peak outputs of each model plotted against each other (the 1:1 line is provided for comparison, Figure 2) for the critical 6 hour 100-year event.

A comparison of total generated runoff volume has also been carried out for the six-hour 100-year annual recurrence interval event and shows a good calibration

between the RAFTS and InfoWorks models. The results are presented in Figure 3 below.

Figure 1 Hydrologic model validation – peak flow: 6h 100y

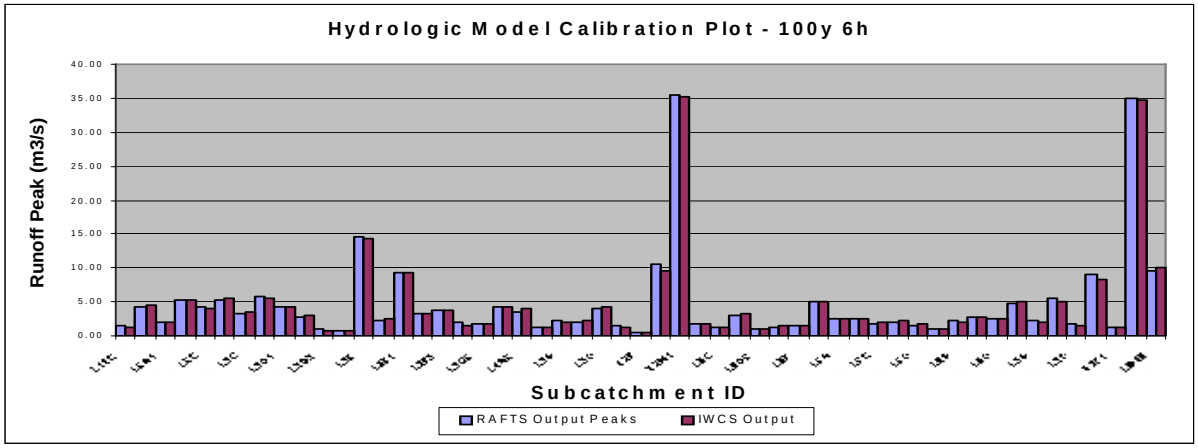


Figure 2 Hydrologic model validation – peak flow: 6h 100y

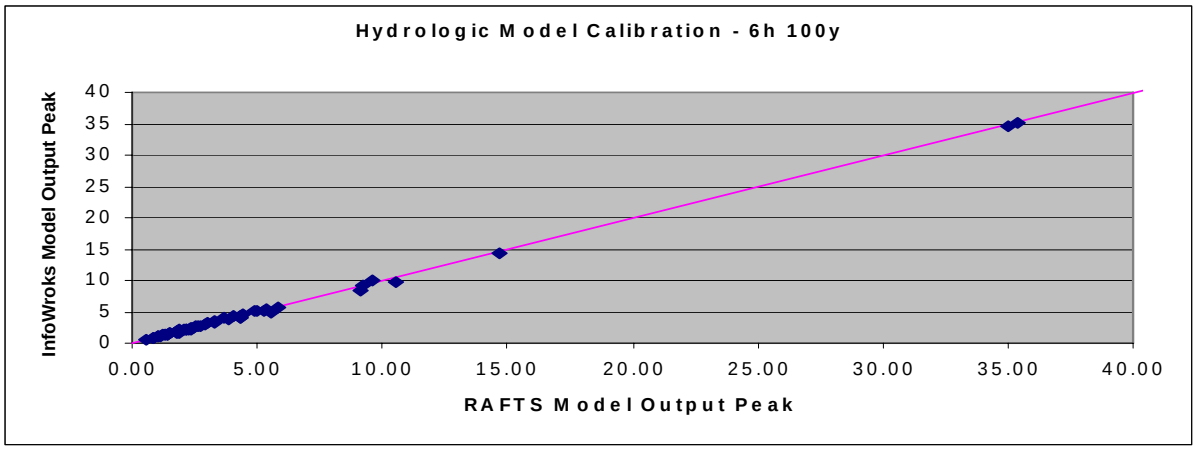
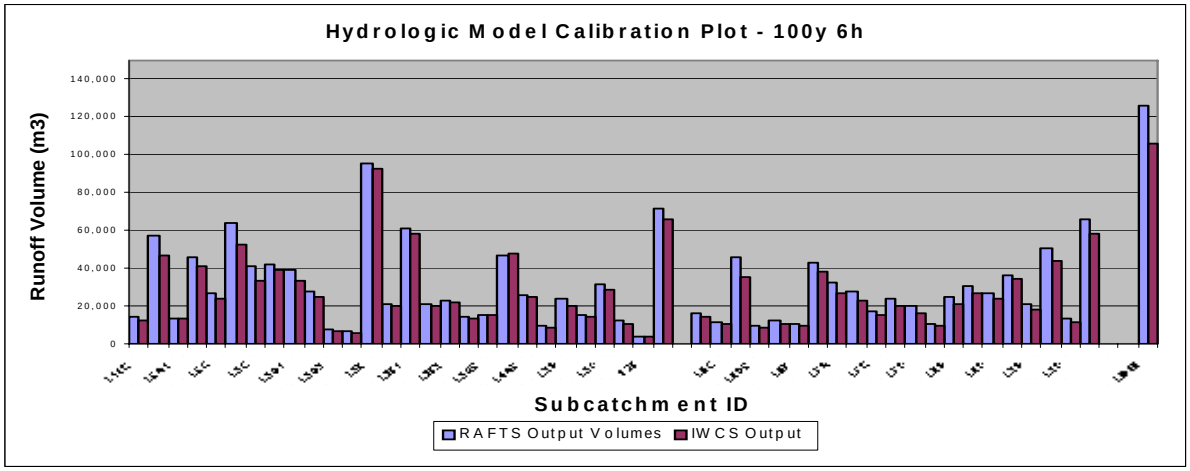


Figure 3 Hydrologic model validation – total volume: 6h 100y



A.5 Hydraulic model validation

Peak pre-development flows generated by the InfoWorks model at various critical locations within the major waterways were compared to peak flows reported in the *Floodplain management study* (SKM, 2007) and are presented in Table A-6 below.

In general the InfoWorks model flows compare well to those generated by the flood model (SKM, 2007).

Table A-6 Pre-development peak flow comparison between SKM flood study and Drainage and water management plan InfoWorks CS Model

Location	10 Year ARI Peak Flows (m^3/s)		100 Year ARI Peak Flows (m^3/s)	
	Flood Study	DWMP model	Flood Study	DWMP model
Oaklands drain at Hopkinson Road	30.0	32.9	53.0	50.4
WC drain downstream of catchment 5B	5.2	6.1	9.4	9.9
WC drain downstream of catchment 6B	3.3	1.9	8.0	8.1
WC drain downstream of catchment 7A	5.0	2.9	10.0	9.7
Cardup Brook at Hopkinson Road	19.0	18.8	56.0	55.3

Table A-7 presents the significant hydraulic structures that have been included within the InfoWorks model of the Byford townsite catchment.

Table A-7 Modelled hydraulic structures

Location		Shape	Diameter/ width (mm)	Height (mm)	Invert level (m AHD)	Number of barrels
X	Y					
403208.5	6435653	Rect	3600	1900	24.3	1
403229.3	6434846	Rect	3700	1560	24.5	1
403239.8	6434410	Circ	455		26.5	2
403253.7	6433783	Rect	1200	500	26.0	1
403262.8	6433262	Circ	720		26.5	2
403273.1	6432784	Rect	1800	1500	26.0	1
404128.2	6434914	Circ	900		30.2	3
404524.3	6434359	Circ	750		34.0	2
404696.5	6434870	Circ	900		34.7	3
404696.9	6436247	Rect	3200	1200	30.1	1
405008.4	6434863	Rect	1210	920	38.2	2
405010	6436013	Rect	1880	1220	31.8	1
405015.2	6433493	Circ	450		38.6	2
405415.5	6433829	Rect	1200	450	44.2	1
405416.3	6434165	Circ	450		44.1	2
405419.4	6433387	Circ	450		42.6	2
405555.7	6434803	Rect	1500	600	44.4	2
405674.3	6435663	Rect	1220	1220	37.7	1
405721.7	6435606	Rect	1220	1200	38.6	1
405888.7	6433545	Rect	1500	600	51.0	1
405948.4	6432459	Circ	600		52.0	2
405965.5	6432457	Circ	1700		50.4	1
406015.3	6432454	Circ	1700		50.9	1

Location X	Location Y	Shape	Diameter/ width (mm)	Height (mm)	Invert level (m AHD)	Number of barrels
406075.1	6432908	Circ	300		56.0	3
406118.2	6432906	Rect	1220	920	56.6	1
406240.7	6433588	Rect	1200	450	54.4	2
406294.5	6433581	Rect	1220	920	55.9	1
406346.6	6432438	Circ	900		54.9	1
406381.3	6433607	Circ	380		57.2	2
406470.4	6434539	Rect	1240	1200	55.7	4
406493.3	6434972	Rect	4000	1200	47.7	1
406560.8	6434328	Rect	7500	1500	60.2	1
406577.9	6434299	Rect	4500	1500	60.5	1
406604.7	6434949	Circ	900		54.5	3
406610.4	6435019	Circ	900		54.4	1
406618.1	6435153	Rect	1520	640	54.3	2
406789.4	6436146	Circ	900		66.0	2
406809.9	6434986	Circ	900		58.5	1
406926.3	6435191	Circ	900		62.7	1
406969.5	6434893	Circ	750		64.1	1
407055.4	6435204	Circ	900		66.7	1
407064.5	6435984	Circ	600		78.3	2
407113.2	6435934	Circ	600		82.0	2
407189.3	6435228	Circ	900		72.0	1
407334.3	6435724	Circ	600		92.5	2
407381.5	6434623	Circ	750		75.0	1
407422.1	6434579	Circ	750		77.0	1
407462.3	6433851	Circ	1100		73.5	3
407467.3	6435252	Circ	300		77.5	1

A.6 Modified parameterisation

The original 100 -year annual recurrence interval event upper catchment runoff parameter of 0.5 (or 50% continuing proportional loss) developed for the *Floodplain management strategy* included allowances for the following uncertainties:

- uncertainty in design rainfall depths and temporal patterns
- uncertainty due to the impact of climate change
- uncertainty in upper catchment landuse / vegetation coverage into the future

These allowances provided a conservative analysis of potential flood risk for the catchment. However, it is appropriate to reduce this allowance for design purposes, and so for the design scenarios presented in the main text of this report the Department of Water have adopted runoff coefficients of:

- 10 mm initial loss and 60 per cent continuing proportional loss for the upper catchments
- 10 mm initial loss and 4 mm/hr continuing loss on the flatter heavy soils downstream of the South Western Highway

These adopted parameters are not expected to account for the full extent of the uncertainties in estimating the 100-year annual recurrence interval flow for the catchments but are considered appropriate for providing an adequate level of flood protection to the new residential areas. Table A-8 below presents the results of this modification.

Table A-8 Pre-development peak flow comparison between parameters

Location	100 Year ARI Peak Flows (m^3/s)	
	Design parameter – 60% continuing loss	Calibration parameter – 50% continuing loss
Oaklands drain at Hopkinson Road	49.5	50.4
WC drain downstream of catchment 5B	9.7	9.9
WC drain downstream of catchment 6B	7.2	8.1
WC drain downstream of catchment 7A	9.0	9.7
Cardup Brook at Hopkinson Road	43.8	55.3

A.7 Historic rainfall event – February 1992

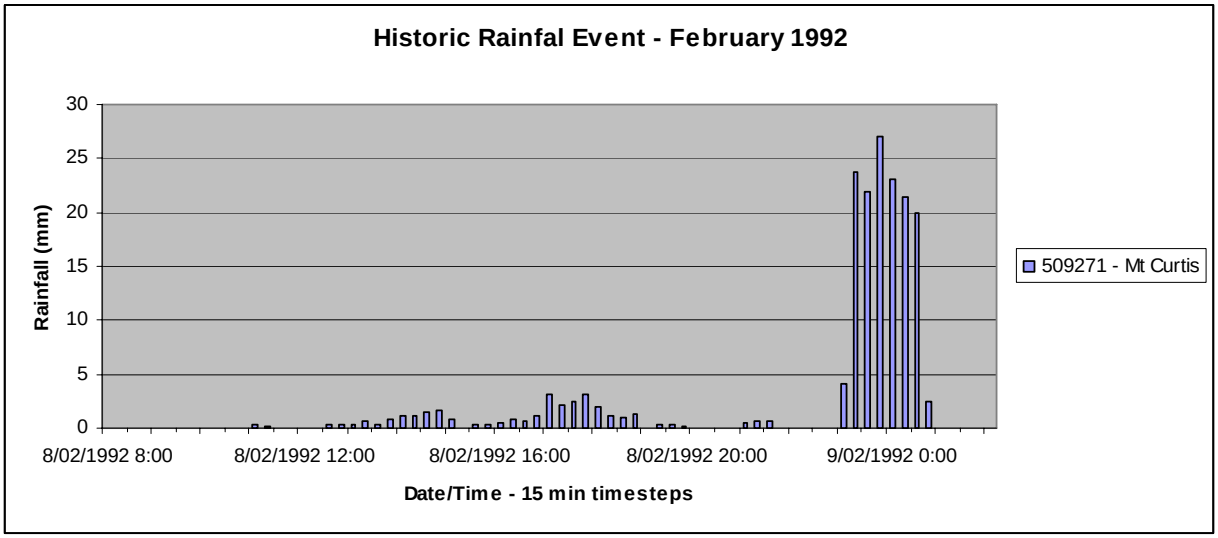
Historic rainfall records were available at two locations close to the study area for the significant historic rainfall event that occurred in February 1992. Although no flow or level data exist for any of the waterways within the catchment, it is known that whilst widespread flooding occurred elsewhere on the Swan Coastal Plain, there was no recorded flooding within the study area as a result of this event.

In order to examine the performance of the model in simulating this event, the initial losses of the catchment were increased to 100 mm to allow for the summer conditions within the catchment. The 1992 rainfall event, as recorded at Mt Curtis (see Figure 4) was then run with the InfoWorks model.

The results of this scenario show that while there was some flooding predicted at the inlets to several culverts at road and rail crossings throughout the catchment, the flooding was short-lived (one to two hours) and occurred during and immediately following the most intense part of the event (between midnight and 2 am). The nature of this predicted flooding is such that it would be unlikely to cause any significant disruption to traffic and would not have endangered any dwellings.

It is considered sufficiently unlikely that the type and extent of flooding predicted by the model for this event would be reported, so that the model can be considered to not be significantly over-predicting flooding in the catchment.

Figure 4 Historic rainfall event – February 1992



List of shortened forms

ADS	Arterial drainage scheme
AHD	Australian height datum
ARI	Annual recurrence interval
BFS	Bush Forever site
CCW	Conservation category wetland
CGL	Controlled groundwater level
DEC	Department of Environment and Conservation
DoW	Department of Water
DPI	Department of 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
SJ Shire	Serpentine Jarrahdale Shire
TEC	Threatened ecological community
ToK	Town of Kwinana
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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