APPENDIX 7
LOCAL URBAN STORMWATER MANAGEMENT REPORT
(JDA CONSULTING)

LWP Property Group Ltd

The Glades at Byford
Local Water Management Strategy (LWMS)

June 2009

JDA Consultant Hydrologists

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1. INTRODUCTION

1.1 Background

This local water management strategy (LWMS) has been prepared by JDA Consultant Hydrologists on behalf of LWP Property Group Pty Ltd in support of the Local Structure Plan addressing the landholding shown in Figure 1 and herein referred to as the Study Area.

The LWMS provides the framework for the application of total water cycle management to the proposed urban structure consistent with Better Urban Water Management (WAPC, 2008) and Department of Water (DoW) principles of Water Sensitive Urban Design (WSUD) described in the Stormwater Management Manual (DoW, 2007).

1.2 Key Design Principles and Objectives

The LWMS employs the following key documents to define its content, key principles and objectives:

- Peel Harvey WSUD Local Planning Policy (Peel Development Commission, 2006)
- Stormwater Management Manual for Western Australia (DoW, 2007)
- Better Urban Water Management (WAPC, 2008)
- Byford Townsite Drainage and Water Management Plan (DoW, 2008)

A summary of the key design principles and objectives from these documents is provided in Table 1 and summarised below in chronological order.

1.2.1 Peel Harvey WSUD Local Planning Policy (2006)

The *Peel Harvey WSUD Local Planning Policy* (Peel Development Commission 2006) was developed through the Federal Governments Coastal Catchments Initiative and endorsed by the Environmental Protection Authority (EPA). It aims to assist local government to help integrate catchment management objectives with land and resource planning in urban landscapes.

The policy identifies broad policy objectives against which strategic and statutory proposals can be assessed. WSUD principles, in order of priority, are outlined below:

- Provide protection to life and property from flooding that would occur in a 100 year Average Recurrence Interval (ARI) flood event
- Manage rainfall events to minimise runoff as high in the catchment as possible. Use multiple low cost 'in-system' management measures to reduce runoff volumes and peak flows (for example, maximise infiltration from leaky pipes and stormwater pits installed above pollutant retentive material)

- Retain and restore existing elements of the natural drainage system, including waterway, wetland and groundwater features and processes, and integrate these elements into the urban landscape, possibly through a multiple use corridor.

- Minimise pollutant inputs through implementation of appropriate non-structural source controls (such as town planning controls, strategic planning controls, pollution prevention procedures, education and participation programs and regulatory controls) and structural controls (that manage the quantity and quality of stormwater runoff and prevent or treat stormwater pollution)

- Maximise water use efficiency, reduce potable water demand, and maximise the re-use of water harvested from impermeable surfaces

Water quantity management principles and objectives are provided based on post-development discharges being maintained relative to predevelopment levels. Criteria are provided for both ecological protection (1 in 1 year events), and flood protection (1 in 100 year events). Water quality management principles and objectives are based on maintaining or improving water quality relative to existing conditions.

Specific water quality guidelines are provided in the document including limitations on developments where average input rates of nutrients exceed 15 kg/phosphorus/ha per annum or 150 kg/nitrogen/ha per annum.

In addition, stormwater management is stated as having to provide (as compared to a development that does not actively manage stormwater quality):

- 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

The policy is consistent with the *Decision Process for Stormwater Management in WA* (DoE and Swan River Trust 2005) which is appended to the policy and is consistent with the objectives of the Environmental Protection Policy (Peel Inlet – Harvey Estuary) 1992.

This policy is stated as holding no legal standing and envisages each local government in the Peel Harvey catchment will customise the model policy to suite its own specific requirements.

At the time of preparing this LWMS, it is understood no customisation of this policy has been undertaken by the Shire of Serpentine -Jarrahdale.

1.2.2 Stormwater Management Manual for Western Australia (2007)

The Water and Rivers Commission (now Department of Water, DoW) released *A Manual for Managing Urban Stormwater Quality in Western Australia* in 1998 to define and practically describe Best Management Practices (BMP's) to reduce pollutant and nutrient inputs to stormwater drainage systems. The Manual also aimed to provide guidelines for the incorporation of water sensitive design principles into urban planning and design, which would enable the achievement of improved water quality from urban development.

The document was released to provide a guideline for best planning and management practices and was intended for use by Water and Rivers Commission, but also by other State and Local Government Authorities and sectors of the urban development industry.

DoW has recently completed a major review of the manual in consultation with a working team comprising industry and government representatives. The revised manual was officially launched in August 2007.

DoW's current position on Urban Stormwater Management in Western Australia is outlined in Chapter 2: Understanding the Context of the Stormwater Management Manual for Western Australia (DoW 2007), which details the management objectives, principles and a stormwater delivery approach for WA. Principle objectives for managing urban water in WA are stated as:

- Water Quality: To maintain or improve the surface and groundwater quality within development areas relative to pre-development conditions
- Water Quantity: To maintain the total water cycle balance within development areas relative to the pre-development conditions
- Water Conservation: To maximise the reuse of stormwater
- Ecosystem Health: To retain natural drainage systems and protect ecosystem health
- Economic Viability: To implement stormwater systems that are economically viable in the long term
- Public Health: To minimise the public risk, including risk of injury or loss of life to the community
- Protection of Property: To protect the built environment from flooding and waterlogging
- Social Values: To ensure that social aesthetic and cultural values are recognised and maintained when managing stormwater
- Development: To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles

To provide a decision framework for planning and design of stormwater management systems and assist in meeting the objectives specified above, the Department of Environment (now Department of Environment and Conservation / DoW) and Swan River Trust released the Decision Process for Stormwater Management in WA in 2005. An update of the decision process is in progress, but a review of the draft indicates no significant changes are proposed.

1.2.3 Better Urban Water Management (2008)

The guideline document Better Urban Water Management (WAPC, 2008), focuses on the process of integration between land use and water planning by specifying the level of investigations and documentations required at various decision points in the planning process.

This LWMS complies with the BUWM process.

1.2.4 Byford Townsite Drainage and Water Management Plan (2008)

In 2005 the Byford District Structure Plan was endorsed by the Shire of Serpentine-Jarrahdale. In support of the DSP was the Byford Urban Stormwater Management Strategy (Parsons Brinkerhoff, 2003) which was later simplified to the Byford Urban Stormwater Management Plan Developer Guidelines in 2005 (Parsons Brinkerhoff, 2005).

In 2007 the Department of Water nominated to prepare the Byford Townsite Drainage and Water Management Plan (DWMP) to address the DSP. The DWMP was completed in 2008, and according to the document, now supersedes the Byford Urban Stormwater Management Strategy previously adopted by the Shire.

The DWMP provides a district scale assessment of the hydrological relevant to the implementation of the Byford DSP. The DWMP includes:

- Regional groundwater contour mapping based on regional groundwater modelling by Cymod.

- Hydrological modelling (flows, flood levels) of the main tributaries through the DSP area for both the pre-development and post-development condition.

- Post-development 5yr and 100 yr ARI peak runoff compensation volumes for sub-catchments discharging to the Oakland Main Drain and the hydraulic backwater conditions. Modelling allows discharge at pre-development peak discharge rates and assumes 1yr ARI is infiltrated.

- Alternative definitions of groundwater terms (CGL, MGL, phreatic line) and groundwater management requirements to determine the CGL and phreatic line. Fill requirements for finished lot levels are 1.2m above the MGL or phreatic line where sub surface drainage is installed at or above regional CGL contours. No guidance is provided in the document on how such CGL or MGL calculations should be carried out.

- Sub surface drainage design criteria.

- Groundwater and surface water quality management objectives.

This LWMS addresses the water management criteria presented in the DWMP and provides a refinement of the hydrology to a local scale, appropriate for the implementation of The Glades LSP.

TABLE 1: SUMMARY OF LWMS DESIGN PRINCIPLES AND OBJECTIVES

<table>
<tr><th colspan="3">Key Guiding Principles</th></tr>
<tr><td colspan="3">• Facilitate implementation of sustainable best practice in urban water management
• Encourage environmentally responsible development
• Provide integration with planning processes and clarity for agencies involved with implementation
• Facilitate adaptive management responses to the monitored outcomes of development
• To minimise public risk, including risk of injury or loss of life
• To maintain the total water cycle</td></tr>
<tr><th>Category</th><th>DWMP Criteria</th><th>LWMS Objective</th></tr>
<tr><td>Water Balance</td><td>• To minimise changes to the water balance to prevent negative impacts on water courses and wetlands</td><td>• To minimise changes to the water balance to prevent negative impacts on water courses and wetlands</td></tr>
<tr><td>Water Conservation and Sustainability</td><td>• The State Water Plan target for water use of 100 kL/person/yr with no more than 60 kL/person/yr of scheme water.</td><td>• The State Water Plan target for water use of 100 kL/person/yr with no more than 60 kL/person/yr of scheme water.</td></tr>
<tr><td>Village Centre Lake</td><td>• Constructed Lakes are not recommended by the Department of Water.</td><td>• To demonstrate that a well designed and maintained constructed lake, providing aesthetic, recreational and health benefits to the Glades community, is feasible at the Village Centre site.</td></tr>
<tr><td>Watercourse restorations and alignments</td><td>• Restoration or waterways with channel realignments and profile modifications is permitted provide the cross-sectional area of the channel is maintained.</td><td>• Restoration or waterways with channel realignments and profile modifications is permitted provide the flow capacity of the channel is maintained.</td></tr>
<tr><td>Stormwater Management</td><td>• All 1 yr 1 hr ARI event runoff be infiltrated at sources where possible
• Post-development critical 1 yr ARI peak flow and volume and the 100 yr ARI peak flow shall be consistent with pre-development peak flow at the discharge point of each sub-catchment and discharge points of all subdivisions into waterways</td><td>• All 1 yr 1 hr ARI event runoff treated prior to discharge.
• Post-development critical 1 yr ARI peak flow and volume and the 100 yr ARI peak flow shall be consistent with pre-development peak flow at the discharge point of each sub-catchment and discharge points of all subdivisions into waterways</td></tr>
<tr><td>Groundwater Management</td><td>• Protection of infrastructure and assets from flooding and inundation by high seasonal groundwater levels, perching and/or soil moisture.
• Managing and minimising changes in groundwater levels and groundwater quality following development.</td><td>• Protection of infrastructure and assets from flooding and inundation by high seasonal groundwater levels, perching and/or soil moisture.
• Managing and minimising changes in groundwater levels and groundwater quality following development.</td></tr>
<tr><td>Water Quality</td><td>• To develop site specific targets for the area. In the interim when compared to a development that does not actively manage water quality a 60% reduction in Total Phosphorus and 45% reduction in Total Nitrogen should be achieved.</td><td>• To develop site specific targets for the area. In the interim when compared to a development that does not actively manage water quality a 60% reduction in Total Phosphorus and 45% reduction in Total Nitrogen should be achieved.
• To minimise and manage Total Phosphorus and Total Nitrogen inputs consistent with the targets of the Peel Harvey WSUD Local Planning Policy (2006).</td></tr>
<tr><td>Wetlands</td><td>• To maintain the pre-development hydrological regime of the wetlands
• Protect wetlands from the impacts of urban runoff</td><td>• To maintain the pre-development hydrological regime of the wetlands
• Protect wetlands from the impacts of urban runoff</td></tr>
</table>

1.3 Statutory Framework

1.3.1 Regional Planning

The Glades at Byford is zoned urban under the Metropolitan Regional Scheme (WAPC, 2007).

1.3.2 District Planning

The Glades at Byford development lies within the Byford District Structure Plan area. The Byford District Structure Plan was prepared by the Shire of Serpentine Jarrahdale in 2005. Following a revision in 2006 the plan was adopted in February 2007.

A regional Byford Urban Stormwater Management Strategy (BUSMS) initiated by the Shire was prepared for the Byford Structure Plan area by Parsons Brinkerhoff and Ecological Engineering (2003) along with the subsequent BUSMS Guidelines for Developers (2005). The BUSMS Guidelines for Developers (2005) includes guidance on water reuse options, sizing stormwater treatment measures, water-quality related monitoring and vegetation treatments for stormwater structures.

The Department of Water released the Drainage and Water Management Plan (DWMP) for the Byford area in September 2008 which includes revised hydraulic modelling of major water courses.

1.3.3 Local Structure Plan

This LWMS is presented in support of the Local Structure Plan.

The LWMS addresses the LWP Property Group landholding and provides a refinement of the flood modelling, surface water management strategy and groundwater management strategy to a local scale. This LWMS is consistent with the DWMP and water sensitive urban design practices as described in the Stormwater Management Manual of WA (DoW, 2007).

2. PROPOSED DEVELOPMENT

The subject land is 328 ha and is situated within the south eastern corridor of the Perth Metropolitan Region and is located approximately 25km south of the Perth CBD.

The site is bounded by Hopkinson Rd to the west, Abernethy Road to the north, Soldiers Rd to the east and Cardup Brook to the south (Figure 1). The subject land starts approximately 500 m west of the existing Byford Town site.

The proposed land use is for residential development consistent with the Byford Structure Plan. The structure plan for The Glades is shown in Figure 7.

Major existing hydrological features within the study area include Cardup Brook and 3 minor unnamed watercourses which pass through the site.

Key elements of the Structure Plan related to urban water management include:

- The use of Multiple Use Corridors (MUC) to retain and enhance the natural water courses passing through the study area.
- Use of bio-retention treatment systems for detention and treatment of stormwater.
- All drainage infrastructure located outside of CCW's and associated buffers.
- The extensive use of local native species in open spaces, streetscapes and wetland buffers to reduce nutrient input and conserve water resources.
- The creation of a feature lake in the Village Centre precinct providing amenity to this community area.

3. PREDEVELOPMENT ENVIRONMENT

3.1 Location and Existing Land Use

The subject site was historically utilised for rural purposes, predominately horse agistment and therefore has been previously cleared.

Existing land use of the site is shown in Figure 2. The Study Area is approximately 95% cleared pasture with some pockets of trees in around existing rural dwellings.

3.2 Topography

The existing topography of the Study Area is shown in Figure 3. The site features several small sand dunes but in generally slopes gently to the west with the most elevated land along the eastern boundary at 56 m AHD and the lowest portion of the site along the western boundary at 27 m AHD.

3.3 Climate

The Perth region is characterised by a Mediterranean climate comprising hot dry summers and cool wet winters. The closest rainfall station to the study area is Cardup, Bureau of Meteorology Station No 009137, which has an annual mean of 871.5 mm recorded from 1970 to 2005.

The average annual pan evaporation is approximately 1898 mm (Luke et al, 1988).

3.4 Aboriginal Heritage

An Aboriginal Heritage assessment of The Glades was undertaken in 2006.

Two Aboriginal sites are listed on the Register of Aboriginal Sites in the Glades at Byford:

Cardup Brook (Site ID 16108), listed on the Interim Register of Aboriginal Sites as a mythological site and encompasses the entire brook and a buffer zone of 30m on either side.

Cardup (Site ID 3310), listed on the Interim Register of Aboriginal Sites as an artefact scatter is reportedly located approximately 50m from the north bank of Cardup Brook and roughly 400m southwest of the intersection of the Orton and Doley roads.

As a result of the 2006 assessment three new archaeological sites, stone artefact scatters (BAS-001, BAS-002 and BAS-005) and four isolated artefacts (BAS/ISO-003-BAS/ISO-006) were recorded in the vicinity of The Glades at Byford. These sites comprise small clusters of flaked stone artefacts (34, 6 and 22 respectively) and are of low-moderate archaeological significance. All are located on Bassendean Sands or on Bassendean Sands overlying the Guildford Formation. There is also potential for further artefacts to be present in sub-surface sands in the immediate vicinity of the sites.

The field survey could not locate the previously recorded Cardup site (Site ID 3310) and it is possible that either the spatial information recorded by DIA is incorrect or that the site has been destroyed by previous land use.

Apart from Cardup Brook (site 16108) no ethnographic surveys were identified during the 2006 consultation with indigenous families.

A section 18 Notice has been granted by the Department of Indigenous Affairs that allow development of The Glades at Byford.

3.5 Geology and Soils

The soils are classified by Jordan (1986) as Colluvium with sandy clays dominant (Figure 5). The soils are variable with lenses of silt, rounded gravels and quartz sands.

A preliminary geotechnical investigation has been completed for the site by Coffey Geotechnical in September 2005. The investigation included 30 test pits where sampling and pocket penetrometer readings were recorded. Dynamic Cone Penetrometer test were also conducted at 30 locations varying in depth from 1.05 m to 2.10 m below existing ground surface. The location of the test pits are shown on Figure 3.

The results of the preliminary geotechnical assessment generally agree with the mapping by Jordan (1986)

3.6 Acid Sulphate Soils

Regional Acid Sulphate Soil (ASS) risk mapping from Planning Bulletin no 64 (WAPC, 2003), is shown in Figure 5. The risk mapping is associated with geology as the ASS mapping was derived on the basis of geological origin and depth to groundwater. Mapping identifies the sandy clay areas in the Study Area as Class 2; moderate to high risk of ASS or PASS occurring >3 m of natural soil surface, but no risk < 3 m from soil surface, the maximum depth that most development activates would disturb. A portion of land in the south east corner of the site is classified as Class 3; No risk of ASS of PASS.

Most of the development activity will not disturb soils greater than 3 m below natural surface and as such no further ASS investigations have been undertaken to date. Construction of the main sewer line from the pump station located in the eastern side of the Study Area requires excavation in excess of 3 m below natural surface. An ASS assessment was completed for the sewer line. The results of the testing, assessed against the *Water Corporation Acid Sulphate Soil and Dewatering Management Strategy* found the level of ASS risk to be low (Level 1 Management Ranking). This is consistent with the regional ASS mapping.

3.7 Surface Water Hydrology

3.7.1 Existing Surface Drainage

The Byford area drains east to west, with catchments of the major tributaries extending back into the Darling Scarp. Naturally these tributaries would have dissipated to the west where the flow moves out onto the sandy soils of the Swan Coastal Plain and infiltrates, but historically the construction of a series of open drains west of Hopkinson Rd now connects these tributaries to the Serpentine River which ultimately flows to the Peel-Harvey Estuary. West of Hopkinson Rd the watercourses flow into the Water Corporation main drainage network, referred to as Oakland Drain.

Beenyup Brook

Beenyup Brook is a major tributary located just north of Abernethy Rd, with a catchment of approximately 1350 ha extending east of South Western Hwy into the Darling Scarp. Beenyup Brook does not flow through the Study area, but the development of the Byford District Structure plan influences the flow route of Beenyup Brook in major flood events which has implication for The Glades development. This is discussed further in Section 4.4.

Cardup Brook

Cardup Brook marks the southern boundary of the study area, just south or Orton Rd. The Brook flows east to west with a catchment extending into the Darling Scarp. The catchment east of South Western Hwy is approximately 1286 ha.

Minor Tributaries

A series of minor tributaries are present over the study area. These tributaries are local drainage commencing at the foot of the hills and flowing west. The tributaries are generally quite degraded as they pass through open paddocks where livestock can access the creek line.

The minor tributaries passing through the Study area have no official title and are referred to as Tributary 6, 7 and 10 in the DWMP. For consistency these names have been adopted in this report.

3.7.2 Peak Flow Estimates

Pre-development peak flow estimates for each of the tributaries are presented in the Byford Townsite DWMP (DoW, 2008). The flows for the relevant tributaries at the upstream and downstream boundaries of the study area are summarised in Figure 9.

3.7.3 Surface Water Quality

Surface water sampling from four surface water monitoring sites commenced in August 2006 and is ongoing (Figure 6). Samples were analysed for physical parameters and nutrients.

A summary of the surface water quality results are shown in Table 2 in relation to ANZECC (2000) guideline values, as well as Australian Runoff Quality mean stormwater concentrations (IEA, 2006) and the Phosphorus targets presented in the Peel-Harvey WQIP (EPA, 2008).

All of the sites flow seasonally, generally from May to December each year depending on rainfall.

TABLE 2: PRE-DEVELOPMENT AVERAGE SURFACE WATER QUALITY VALUES

Parameter and unit of measurement	ANZECC Guide-line Values	Mean ARQ Urban Stormwater Concentration	Peel-Harvey Estuary WQIP Target for the Upper Serpentine	Monitoring Sites					
				S1	S2	S3	S4	S5	S6
Electrical conductivity (mS/cm)	0.12 – 0.30	-	-	0.52	0.43	0.53	0.51	0.44	0.54
pH	6.5 – 8.0	6.80	-	7.09	6.92	7.15	6.75	6.75	6.92
Total Nitrogen (mg/L)	1.20	2.70	-	1.02	1.02	1.26	0.53	0.55	0.69
Nitrate/Nitrite NOx as N (mg/L)	0.15	-	-	0.46	0.24	0.84	0.23	0.24	0.41
Total Kjeldahl Nitrogen (mg/L)	-	-	-	0.60	0.83	0.43	0.29	0.31	0.32
Total Phosphorus (mg/L)	0.06	0.29	0.1	0.07	0.09	0.02	0.05	0.03	0.03
Filterable Reactive Phosphorus (mg/L)	0.040	-	-	0.050	0.026	0.003	0.012	0.003	0.002

Note: Average values derived from at least 6 samples at each site.

3.8 Groundwater Hydrology

The geological formations have been grouped into two distinct aquifers, each being assigned the name of the major geological unit contributing to it. In descending order of depth from natural surface they are:

- Superficial Aquifer (unconfined)
- Cattamarra Coal Measures (confined)

3.8.1 Superficial Aquifer

The Superficial Aquifer in this region is referred to as the Byford Area, and extends approximately 166 km^2. The aquifer has a maximum thickness of 20 m and consists of clayey sediments of the Guildford Clay with an average transmissivity of about 100 m^2/day.

Due to the poor hydraulic conductivity of the clayey soils the area is characterised by extensive surface flow. The Superficial Aquifer is directly underlain by the Cattamarra Coal Measures in the Study Area.

3.8.2 Cattamarra Coal Measures Aquifer

The Cattamarra Coal Measures formation extends beneath all of the coastal plain between Gingin Brook and South Dandalup River, but it is present at a relatively shallow depth only in the southern area where the Yarragadee Formation is absent (Davidson, 1995). The formation is made up of fluvial sandstones, siltstones and shales with minor coal seams. In the Perth region the sandstone are pale in colour, often clayey, mostly medium to course grained and in beds up to 50 m thick. The shales are dark grey, sometimes carbonaceous, often laminated and occur in beds up to 30 m thick. The upper section of the formation is often weathered to a yellow, reddish brown colour.

Drilling in The Glades development area has encountered the top of the formation at approximately 60 m below natural surface level. The Cattamarra Coal Measures represents the most feasible source of non-potable water supply in this area.

3.8.3 Seasonal Variation in the Watertable

The Superficial Formation in the Byford area is characterised by a high clay content in the sediments which ensures only a low percentage of rainfall migrates through the soil profile to recharge the watertable. Davidson and Yu (2008) estimate the average recharge in this area to be 10% or equivalent of 87 mm per year.

The low rate of infiltration and the presence of hardpan layers in the soil profile mean that a ‘perched watertable’ can form locally. In average and above average rainfall years the rate of recharge will be sufficient that any perched layers will be seasonal, with the regional watertable rising up over the course of winter to incorporate the perched layers into a continuous saturated column. In below average rainfall years the rainfall recharge may not be sufficient to cause the regional watertable to rise significantly and the ‘perched watertable’ will remain above the regional watertable. Given the location of the study area to the Darling Scarp, a significant proportion of recharge to the regional watertable will be via groundwater throughflow in the Superficial Formations, rather than vertical recharge over the Study area.

Depending on the specific yield of the local soils, fluctuations in the regional watertable may vary 2 to 5m seasonally.

3.8.4 Estimated Regional Watertable Design Levels

Over parts of the study area the seasonal fluctuation in the regional watertable results in the watertable being close to the natural surface level for a few months of the year. This generally occurs in August/September consistent with the seasonal rainfall pattern of Perth. Where construction occurs in these areas a watertable design level needs to be specified in order to provide adequate separation of building levels from the average winter maximum watertable level. As documented in the Byford Townsite DWMP a separation of 1.2 m from the average winter maximum level is considered appropriate, achieved by importing sand fill to the site.

The winter maximum watertable varies from year to year consistent with the variation in the amount and intensity of rainfall and evapotranspiration; therefore the watertable design level needs to allow for this natural variation.

To determine the regional watertable design levels over the study area local groundwater investigations were conducted by JDA. In summary, 12 groundwater monitoring bores were installed across the study area (Figure 6), with water levels first measured in all of the bores on 13 September 2005, then measured monthly from August 2006. To date the highest level in all of the bores was recorded on 13 September 2005.

Details of the bores are provided in Table 3. The lithological logs for the bores are provided in Appendix A and a time series plot of water levels recorded in the bores is included as Appendix B.

TABLE 3: DETAILS OF GROUNDWATER MONITORING BORES

Bore ID	GDA Coordinates		Ground Level (m AHD)	Top of Casing (m AHD	Screened Interval (m BNS)	Estimated watertable design level (m AHD)
	Easting	Northing				
BDM1	404525	6434630	34.88	35.45	3.5-7.5	33.47
BDM2	404621	6433858	37.34	38.07	5.0-7.0	35.56
BDM3	404835	6432861	42.37	42.98	4.0-6.0	40.46
BDM5	403901	6432978	31.98	32.63	3.5-5.5	31.84
BDM6	403447	6432498	29.12	29.63	3.0-5.0	28.46
BDM7	404075	6433783	32.73	33.39	3.0-5.0	32.58
BDM8	403891	6434720	30.62	31.30	3.0-5.0	30.57
BDM9	405222	6434091	42.06	42.72	3.5-5.5	42.13
BDM10	405398	6433455	47.00	47.00	4.0-6.0	45.18
BDM11	405012	6433364	41.88	41.88	4.0-6.0	41.69
BDM12	406253	6433849	56.07	56.06	5.5-7.5	55.99
BDM13	405383	6432380	50.88	51.57	7.0-9.0	42.76

To correlate the water levels recorded in the JDA bores on 13 September 2005 to long-term groundwater measurements, water levels were also recorded in 4 Department of Water (DoW) monitoring bores on the 13 September 2005. Four monitoring bores were located within 1 km of The Glades development area. These bores are T170, T220, SES20 and SES21. Bores T170 and T220 have long-term records spanning from 1975 to present. Bores SES20 and SES21 were originally installed by Rockwater in 1995, with DoW taking custody of the bores following completion of the Rockwater study. These bores have only been measured on 5 occasions since 1997. Water levels recorded in the DoW bores on 13 September are presented in Table 4.

TABLE 4: DETAILS OF DOW MONITORING BORES

Bore ID	Record Period	Top of Casing (m AHD)	Water Level 13/9/05 (m AHD)	Calculated average of peaks (m AHD)	Difference (m)
T170	1975- 2008	26.94	24.96	26.08	+1.12
T220	1975- 2008	21.44	19.57	19.57	0.00
SES20	1995- 1998	39.03	37.57	-	-
SES21	1995-	60.74	59.65	-	-
				Average	**+0.56**

The average of the annual groundwater peaks over the period 1975 – 2005 was calculated to determine the watertable design level. The calculation was undertaken as a two stage process:

- ❑ An initial estimate of the AAMGL (1975 – 2005) made by applying an adjustment of +0.56 m to 13 September 2005 readings for all monitoring bores and contouring this data over The Glades development area. This adjustment was based on an average of the 2 DoW bores measured on the same day.
- ❑ Adjusting the initial AAMGL (1975 – 2005) contours to include the local groundwater drawdown effect due to Cardup Brook and the creeks. The drawdown in the creeks was based on an estimated baseflow depth of 0.5 m within the creeks.

3.8.5 Groundwater Quality

Groundwater quality monitoring of the Superficial Aquifer was done by JDA monthly for all 12 bores from August 2006 and is ongoing. Samples were analysed for physical parameters and nutrients. A time series plot for each of the parameters measured is provided in Appendix B, with a summary of average values presented in Table 5.

Key results from the monitoring are as follows:

- The average Total Nitrogen (TN) concentration varied between bores indicating local affects from different land uses.
- The average dissolved Phosphorus (FRP) concentrations are below detection limit which indicates a large proportion of Phosphorus is held in sediments and organics.

TABLE 5: PRE-DEVELOPMENT AVERAGE GROUNDWATER QUALITY

	Parameter and Unit of Measure						
Site	**EC (mS/cm)**	**pH**	**Total Nitrogen (mg/L)**	**NOx (as N) (mg/L)**	**Total Kjeldahl Nitrogen (mg/L)**	**Total Phosphorus (mg/L)**	**Filterable Reactive Phosphorus (mg/L)**
BDM1	0.11	5.34	3.80	2.44	1.34	0.40	<0.005
BDM2	0.30	6.42	6.40	5.14	1.29	0.13	<0.005
BDM3	0.21	6.25	8.22	5.90	2.25	0.04	<0.005
BDM5	0.37	5.13	4.26	4.47	0.55	0.53	<0.005
BDM6	1.60	6.49	2.18	1.66	0.67	0.05	<0.005
BDM7	0.28	5.99	0.93	0.69	0.27	0.04	<0.005
BDM8	0.29	5.65	3.84	3.96	0.76	0.05	<0.005
BDM9	0.63	6.39	2.04	1.30	0.39	0.05	<0.005
BDM10	0.21	5.74	0.51	0.19	0.37	0.40	<0.005
BDM11	0.59	5.81	0.97	0.74	0.45	0.47	<0.005
BDM12	1.28	5.05	1.20	0.75	0.43	0.12	<0.005
BDM13	0.15	5.51	1.93	1.50	0.56	0.07	<0.005

3.9 Wetlands

Several wetlands occur on and adjacent to the study area. A large portion of the study area is mapped in the DEC’s *Geomorphic Wetlands Swan Coastal Plain* dataset as palusplain (a seasonally waterlogged flat) (UFI 13500; 13912). Throughout the Swan Coastal Plain, areas of palusplain have historically been extensively cleared for rural pursuits (grazing and horse agistment) as is the case in the study area. The management category of the majority of these wetlands has been evaluated as Multiple Use (MU) wetlands. Wetlands that support native vegetation are identified as Conservation (CCW) or Resource Enhancement (RE) wetlands (Coffey Environments, 2009).

A CCW was previously located on Lot 3 Abernethy Road (UFI 7829, 7866 and 7829). As part of the site investigations undertaken by ATA Environmental, a site visit was conducted in September 2005 to ‘groundtruth’ the appropriateness of the CCW management category of the wetland. It was concluded that due to the degraded nature of the wetland, along with other environmental characteristics of the site (discussed in further detail in Section 3), the DEC’s CCW classification should be revised to a MU management category. The Wetlands Branch of the Department of Environment agreed to revaluate the wetland category of Conservation Category to Multiple Use in February 2006.

CCWs (UFI 8005; 7844; 13911; 13901) were previously located along parts of the Cardup Brook that support native riparian vegetation. Following site investigations by ATA Environmental in 2004 it was concluded that the degraded nature of the wetland and other environmental characteristics that the DEC classification should be revised to REW. The Wetlands Branch of the Department of Environment agreed to revaluate the wetland category of CCW to REW in July 2004.

One CCW (UFI 15452) is located on land directly abutting the study area and is within the Bush Forever Site 321 to the east of the study area.

3.10 Water Resources

3.10.1 Groundwater availability

The Study Area is located within the Serpentine groundwater area and the Perth – Cattamarra Coal Measure North groundwater sub-area. Department of Water has advised that there was 1,000,000 kL/yr available for allocation as of 19 June 2007.

Opportunities for utilising this aquifer as a non-potable supply are discussed in Section 4.2.1.

4. LOCAL WATER MANAGEMENT STRATEGY

4.1 Water Balance

Design Criteria (from DWMP):

To minimise changes to the water balance to prevent negative impacts on watercourses and wetlands

No guidance is provided in the Byford Townsite DWMP on changes to the water balance as a result of the land use changes proposed in the Byford DSP. In the absence of a district water balance model a simplistic water balance has been developed to enable assessment of the Study Area as a result of implementing The Glades LSP.

As rainfall is the primary input to the local environment, scheme water has not been considered in the water balance which aims to assess the impacts of urban development on wetlands and watercourses. As the most reliable estimates of rainfall, evaporation, transpiration and recharge are at regional scales, for the purposes of this water balance assessment, annual average values have been assumed for the site as a whole, without further detailed breakdowns.

As discussed in section 3.7.3 the site is characterised by limited recharge due to the clay sediments with a high proportion for rainfall runoff.

TABLE 6: ESTIMATED RAINFALL WATER BALANCE

	Area (ha)	mm	Abstractions	Discharge	ML/yr
Pre-Development					
Input Rainfall	328	872			2860
Water Use					
Native Bush	-	570[1]			
Rural	319	600[2]			- 1914
Watercourses + Buffers	9	800[2]		572	- 644
Balance (Recharge)					**+ 302**
Post-Development					
Input Rainfall	328	872			2860
Water Use					
Urban (Residential)	190	260[1]			- 494
Urban (Commercial)	51	175[1]			- 90
Parks	59	600[2]			- 354
Watercourses + Buffers	27	800[2]		1520	- 1734
Village Centre Lake	0.6	1700			-10
Rainwater Tanks Initiative	190	30			- 57
Balance (Recharge)					**+ 235**

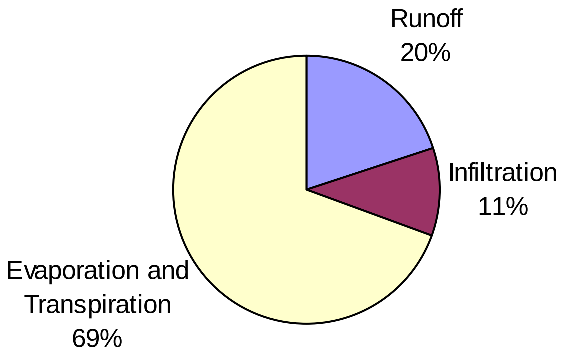
Notes: 1. Based on recharge estimates provided in Davidson and Yu (2006)

2. Based on evaporation and transpiration estimates provided in Silberstein *et al* (2007)

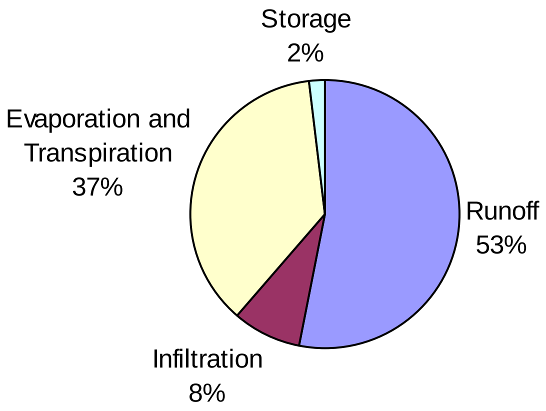
Table 6 shows that recharge to the watertable is likely to be in the order of 10% under the existing predominately rural land use. This is governed largely by the limited infiltration rate of the local soils, with only a slight reduction post-development. Following residential development evaporation and transpiration is reduced due to the reduction in vegetative cover and more ready infiltration into the imported sandy fill. The surplus recharge into the fill is collected and discharged by the subsoil pipes laid at the base of the fill. This is shown in the water balance as additional discharge from the watercourses, the discharge points for the subsoil system.

The overall outcome is likely to be an increased baseflow in the watercourses passing through the development, a similar rate of recharge to the watertable and a small proportion retained as storage within rainwater tanks as a result of the rainwater tank initiative (see section 4.2.2). The impacts of this change are discussed in Section 4.5 and 4.6.

Pre-development rainfall distribution



Post-development rainfall distribution



4.2 Water Sustainability Initiatives

Design Criteria (from DWMP):

The State Water Plan (Government of Western Australia, 2007) target for water use of 100kL/person/yr with no more than 60kL/person/yr of scheme water.

4.2.1 Water Supply

Public Open Spaces

Considering the fit for purpose strategy, the water supply for the public open spaces is proposed to be from local groundwater resources. There are still significant groundwater allocation volumes available from the confined aquifer.

Currently, one licence of 50 000 kL/yr is held for the Glades development, GWL 164628(1) which is valid to March 2010. On renewal of this licence a Staged Development Licence will be applied for consistent with the Department of Water's guidance on Staged Development licences to secure an allocation suitable to supply the complete development proposal.

Residential Lots

Water supply to households is to be scheme water via extension of the existing system. This is supported by Water Corporation.

4.2.2 Water Efficiency measures

Public Open Spaces

The estimated irrigated POS area for the development is 30 ha which will require an approximate 200 000 kL/yr. This water should be sourced from the confined groundwater reserves consistent with a fit for purpose strategy.

Landscaped Public Open Space areas are to be at least 50% native plants, with water wise irrigation system design.

Residential Lots

To achieve water efficiency targets, households are to be built consistent with current BCA water efficiency standards and the State Governments 5 Star Plus scheme. To further improve the water efficiency of residential lots LWP commit to a sustainability contract with each lot owner. A copy of the contract is included in Appendix D as an example. As part of the contract LWP will provide the following waterwise initiatives;

- A waterwise front landscaping package to each home, designed by a certified waterwise landscaper.
- Provision of a 2 kL rainwater tank for each home plumbed to the toilet and laundry, with an overflow to the stormwater drainage system (Appendix D). Please note that the contract shown in Appendix D is a blank contract. On the contract provided to purchasers the option for the rain tank is already ticked by LWP. This format is used to help educate lot purchasers about water conservation options.

4.3 Village Centre Lake

Design Criteria (proposed by LWP);

To demonstrate that a well designed and maintained constructed lake, providing aesthetic, recreational and health benefits to the Glades community, is feasible at the Village Centre site.

4.3.1 Lake Benefits to the Village Centre

A constructed lake is proposed as part of the Village Centre precinct. The lake is intended as a community asset providing:

- Aesthetic functions which make the village centre an active hub for commercial and social activities.
- A focus for recreational activity, supported by the network of paths and boardwalks that provide access to the lake for residents.
- Structural benefits which include increased flexibility in the design of the POS irrigation system by providing storage and;
- Additional stormwater detention storage in major flood events.

The Village Centre Masterplan including the lake concept is shown in Figure 8.

4.3.2 Physical Lake Design Characteristics

Proposed Construction

The proposed lake will be approximately 6000 m^2 in area, with an approximate total volume of 8000 m^3. To account for the fall over the site of approximately 1: 100 (v:h) the lake will be split into 2 levels, with the top level smaller in area than the bottom level.

The upper level will be located on the east side and overflow into the lower level on the west side adjacent to Doley Rd via a broad weir structure. The weir can be landscape for a more natural appearance and to improve access to the lake for residence a boardwalk could be constructed along the weir.

The lake will be a total depth of 2-3m on both sides with the upper level approximately 1 m higher than the lower level.

The lake will be designed to circulate water between the two levels. For water quality management purposes, the residence time for the water in either tier of the lake should ideally be less than 30 days. Based on the indicative volume of the lake, an average circulation rate of approximately 12 m^3/hour (3.5 L/s) is required to achieve the required residence time.

Lake Water Levels

The lake will have a proposed constant water level of 34.5 m AHD in the bottom lake, with a top water level in the 100 yr ARI of approximately 35.0 m AHD. This level is largely controlled by Doley Rd adjacent, which needs to be maintained at its existing level of approximately 35.3 m AHD to retain the roadside avenue of existing trees. The upper lake will be set higher than the lower lake, but the top water level should not exceed 36.20 m AHD in the 100 yr ARI to remain hydraulically disconnected from the bio-retention storage located immediately to the east.

The watertable in the location of the proposed Village Centre Lake is 1 to 1.5 m below natural surface at the average seasonal maximum recorded level, but fluctuates in excess of 5 m. The lake will be designed so that the lake water level remains relatively constant (±0.30 m). In order to achieve this it will be necessary to line the lake, hydraulically separating the lake from the highly fluctuating watertable. The lake liner can be a natural clay based product or a PVC liner, so long as the base of the lake is sufficiently sealed to ensure minimal water loss from the lake via leakage.

<u>Bore Water Top-Up</u>

To maintain water levels in the lake it is proposed to top-up the lake using an artesian bore located on the west side of Doley Rd. The location of the bore can be seen in Figure 7. The bore was constructed in January 2008 and is currently licensed for abstraction of 50 000kL/annum.

The submersible pump fitted to the bore is a variable speed pump with a maximum pump rate of 25 L/s, but a sustainable pump rate of 20 L/s. Preliminary testing of the water shows the water to have moderate levels of Total Iron (0.16 mg/L), low levels of Total Nitrogen (<0.005 mg/L), moderate levels of Total Phosphorus (0.02 mg/L), with low levels of dissolved Phosphorus (<0.005 mg/L).

Table 7: Bore Water Quality Analysis

Parameter and unit of measurement	ANZECC Guideline Trigger Values	Bore Water
Electrical conductivity (mS/cm)	0.12 – 0.30	1.40
pH	6.5 – 8.0	5.75
Total Nitrogen (mg/L)	1.2	<0.05
Ammonia N (mg/L)	0.8	<0.005
Nitrate/Nitrite NOx as N (mg/L)	0.15	<0.10
Total Phosphorus (mg/L)	0.065	0.02
Filterable Reactive Phosphorus (mg/L)	0.04	<0.005

This water is considered to be of appropriate quality for the lake, which will be further improved by the addition of rainfall recharge falling on the lake over the winter period.

To enhance circulation between the 2 lake levels, pumping from the bore should be delivered to the upper lake, with abstraction for irrigation taken from the lower lake.

Evaporation Management

The existing bore's sustainable pump rate is 20L/s or 72 m^3/hr. Assuming an irrigation depth of 10 mm for parkland areas, this equates to 100 m^3/ha, so the bore has capacity to fill the lake for irrigation at a rate of approximately 0.72 ha per hour.

The lake surface area is proposed as 6000 m^2. Table 6 shows the estimated evaporation loss from the lake as 10 ML (10 000 kL) per annum. This represents 5% of the total groundwater abstraction estimated for the development of 200 000 KL/annum.

This evaporation loss is based on a Class A Pan evaporation for Byford of 1898 mm/yr and a waterbody evaporation coefficient of 0.9 (Luke et al, 1988).

Flood Risk

In order to manage the water quality of the lake, the lake should be 'offline' of the minor drainage system (rainfall events up to the 5 yr ARI), as these rainfall events vary significantly in water quality and include catchment 'first flush' events. Separate bio-retention storage is proposed immediately east of the lake within the MUC to receive flows up to the 5 yr ARI. It is proposed that the outflow from the bio-retention storage be monitored as part of the relevant UWMP, and if it can be demonstrated that the water quality from the bio-retention storage is of suitable quality, outflow from the bio-retention storage could be (partially) diverted into the lake to increase the rainfall harvest of the lake.

For events in excess of the 5 yr ARI, the runoff will be conveyed overland via the road network and flow directly into the lake to utilise the lake for additional flood detention storage. The lake is proposed to be designed with an additional 0.8 m of freeboard above the constant water level, with 0.5 m utilised for flood detention storage in the 100 yr ARI. This provides for 0.3 m freeboard to infrastructure outside of the lake in the 100 yr ARI flood event. For the lower lake this means a constant water level of approximately 34.5 m AHD, a 100 yr ARI peak water level of 35.0 m AHD, providing 0.30 m of freeboard to Doley Rd at 35.3 m AHD.

Soil Acidity

The calculated average winter maximum watertable level in the proposed location for the lake is approximately 34.5 m AHD. The proposed minimum constant water level in the lake of 34.5 m AHD is consistent with the watertable in this location, and therefore should not disturb any potentially acidic soils in this location.

The lake liner will separate the lake water from any potential acidity in the surrounding natural soils. Preliminary ASS testing in the area indicates low risk of ASS for soils less than 3 m below natural surface.

Fire Fighting Water Supply

The lake may be used as a water supply for fire fighting purposes in the vicinity of The Glades development. Any abstractions from the lake for fire fighting purposes should be limited to a total volume of 1500 m^3 in a 24 hour period to ensure that water levels in the lake are not excessively impacted.

4.3.3 Lake Management

To document the design details of the lake, maintenance and management requirements a Lake Management Plan should be stipulated as a condition of subdivision for the Village Centre Precinct.

The Lake management plan should address the following issues as a minimum;

- Control of nuisance algae
- Control of nuisance insects and disease vectors
- Control of feral fish and exotic plant invasions
- Management of gross pollutants
- Management schedule
- Maintenance schedule

4.4 Stormwater Management

4.4.1 District Stormwater Management

Beenyup Brook (Abernethy Rd)

Beenyup Brook is located just north of Abernethy Rd and flows east to west with the catchment commencing in the Darling Scarp. The district flood analysis presented in the DWMP indicates that the peak flow in Beenyup Brook at the Abernethy Rd crossing is 32 m^3/s, but constraints exist in the flow path north of Abernethy Rd which result in a significant amount of flooding in the location of the new town centre. To alleviate the potential flooding problem, the DWMP provides guidance on a swale to be built in the Abernethy Rd reserve to convey flow away from Beenyup Brook in rainfall events greater than the 50 yr ARI. The flow from Beenyup Brook diverted down Abernethy Rd is estimated in the DWMP to be 11.5 m^3/s (DWMP ref: Table 6-2) in the 100 yr ARI.

The DWMP flood route also shows some of the flow along Abernethy Rd being diverted down Warrington Rd and Doley Rd to Tributary 6. The diverted flow is estimated to be 1.3 m^3/s (DWMP ref: Table 6-2 and Figure A-8).

The Glades development will not be adopting these diversions, but will instead provide for the full flow (11.5 m^3/s) to continue down Abernethy Rd in the drainage design of Abernethy Rd. This negates the need to provide a drainage swale in Warrington Rd and Doley Rd, allowing a significant number of trees to be preserved.

The Shire has recently provided advice to JDA that the following design provisions need to be made for Abernethy Rd fronting the Glades development for consistency with the Town Centre design currently being prepared for the Shire (Appendix C). The 3 requirements are as follows

- The Abernethy Rd reserve will have a final width of 40 m along the full frontage of the Glades development

- Outflow to Abernethy Rd from The Glades estate will be consistent with the Byford Townsite DWMP.
- Any point of outflow from the estate should be designed such that they can be connected to a median swale at a time when the road upgrade design is finalised.

Under the pre-development scenario, the land fronting Abernethy Rd drains unattenuated into the Abernethy Rd drainage system. Given the low density (R10) of the lots proposed in the Glades LSP along Abernethy Rd (Figure 7), this land will continue to discharge unattenuated into Abernethy Rd. This approach is consistent with the direction provided for sub-catchments 5C and 5D in the Byford Townsite DWMP (DoW, 2008).

Cardup Brook

A foreshore reserve will be provided along the Cardup Brook to accommodate the Bush Forever and Conservation Category Wetland mapping shown over the brook. The reserve will be located between the wetland boundary and the northern edge of the proposed Byford by the Brook subdivision. The width of the reserve will range from 10 m to 60 m, averaging 32 m.

The intention is to retain the character of the Brook, with some rehabilitation by slashing grass and supplementary plantings of additional indigenous trees.

Flood conveyance in Cardup Brook will not be altered by development in the study area (the northern side).

Minor Tributaries

The minor tributaries passing through the Study area are labelled Tributary 6, 7 and 10 in the Byford Townsite DWMP. For consistency these names have been adopted in this report. The minor tributaries are generally very degraded. Consistent with the DWMP these watercourses can be modified to restore a living stream. In modifying the watercourse the DWMP stipulates that the cross sectional area of the tributary must be maintained, such that the upstream and downstream flood levels and flows at the boundary of the study are remain consistent with the levels and flows provided in the DWMP.

Tributaries 6 and 7 have catchments commence at the foot of the Darling Scarp, with flows entering the study area at the Warrington Rd crossing (Figure 9). The district inflows from east of Warrington Rd must be considered in the restoration of the tributaries through the study area and the location of flood detention storages.

The catchment of Tributary 10 commences within the study area (Figure 9). Therefore only a downstream flood level and flow criteria applies.

4.4.2 Watercourse Restoration and Alignments

Design Criteria (from DWMP):

Restoration of waterways with channel realignments and profile modifications is permitted provided the flow capacity of the channel is maintained.

4.4.2.1 Watercourse Restoration

The watercourses passing through The Glades development have been highly degraded by stock access to the channel. The structure plan for The Glades provides a series of multiple use corridors (MUC's) that take in the tributaries and preserve the general alignment of the watercourses.

Within the MUC's the watercourses will be restored with areas of passive landscaping and rehabilitation to provide a mix of natural, aesthetic and recreational landscapes. Where rehabilitation is undertaken to improve the environmental value of the watercourse this will generally include weed removal and a basic level of re-vegetation with local native plant species.

4.4.2.2 Watercourse Realignments

The development will retain the natural watercourse alignments wherever possible, but relatively minor realignments of the tributary will be required in some locations to allow additional facilities to be included within the MUC.

Key criteria for any channel realignments are as follows;

- The realigned channel must maintain the flow capacity of the original channel. Flow capacity is considered a more appropriate design criterion to cross-sectional area, as specified in the DWMP, as adjustments to the channel grade can vary the flow velocity, which in turn alters the cross sectional area required to accommodate the design flow.
- Any reconstructed banks will have a 1:6 batter.
- The realigned channel must include a baseflow channel and broader 'floodway' consistent with the 'floodway' widths provided in Figures 10 to 15. An example cross section showing the tributary "floodway" taken from the DWMP is provided in Figure 17.

4.4.3 Floodway Corridors

The Byford Townsite DWMP provides indicative 'floodway' corridor widths for each of the tributaries to ensure provision is made within the local structure planning for conveyance for district flood flows.

As part of this LWMS the 'floodway' corridor widths have been refined based on the additional information and design undertaken as part of this LWMS. The revised 'floodway' corridor widths are shown in Figures 10, 12 and 14 and include provision for the district flood flows. This included utilising hydrographs from the district Infoworks model at the upstream boundaries of the study area provided by GHD. Further details of the local scale refinement and design are discussed in section 4.4.4.

4.4.4 Local Stormwater Management

Design Criteria (from DWMP);

All 1yr 1hr ARI event runoff treated prior to discharge;

Post-development critical one year ARI peak flow and volume and the 100 year ARI peak flow shall be consistent with pre-development peak flow at the discharge points of each sub-catchment and discharge points of all subdivisions into waterways.

The Local Stormwater Management system has been designed in consonant with the following constraints:

- The multiple district flood pathways through the structure plan area.
- Wetlands
- Low soil infiltration rates

The stormwater drainage system will be designed using a major/minor approach. The major drainage system is defined as the arrangement of roads, drainage reserves, detention or infiltration areas and open space planned to provide safe passage of stormwater runoff from extreme events which exceeds the capacity of the minor system. The locations of key features of the drainage system are shown in Figures 10 to 14.

The minor drainage system is defined as the series of pipes, kerbs, gutters etc designed to carry runoff generated by low frequency ARI storms, typically less then 5 year ARI. The minor drainage incorporates a treatment train of best management practice (BMP) water quality structural controls such as GPT's and bio-retention systems that provide water quality treatment from the proposed development.

4.4.4.1 Major Drainage System

The major drainage system is designed to manage rainfall events greater than the 5yr ARI, up the 100yr ARI. The design strategy is consistent with the objectives provided in the District DWMP. Key points of the major drainage system strategy are as follows:

- Roads graded to direct flow to the lowest point in the catchment.
- Detention storage to be provided in the lowest point of the catchment to control outflows from the catchment.
- Flush kerbing or kerb breaks at the low point, graded to drain flows off the street into the detention storage.
- Discharge from the detention storages consistent with pre-development outflows for the 5yr and 100 yr ARI's.

Due to the low permeability of the soils over the site it is not possible to infiltrate large volumes of water. Therefore the major drainage system makes use of detention storages to control major runoff events to outflows consistent with pre-development flow rates.

To enhance the use of the tributaries located within MUC's as 'living streams', discussions were held with the Department of Water about the option to store part of the 100 yr ARI flood water within the MUC. This concept is not consistent with the general guidance provided within the Byford Townsite DWMP, which specifies that all 100yr ARI detention must be achieved outside (offline) of the watercourse ‘floodway’.

From the discussion with DoW it was agreed that some storage could occur within the ‘floodway’ provided the flowing requirements were achieved;

1. Flood detention storage for the subdivision should be provided offline to the floodway corridor for all events up to the 5 yr ARI.

2. The ‘floodway’ corridor for each Tributary as defined in the DWMP can be utilised for detention storage for events greater than the 5yr ARI provided it is demonstrated that this will not adversely affect the conveyance of the district flood flow.

3. Flood detention in the floodway for events greater than the 5 yr ARI is permissible provided the peak flow and HGL at Hopkinson Rd for each tributary is consistent with the values presented in the DWMP.

A copy of the correspondence with the Department of Water is included as Appendix C.

Based on these outcomes the key design criteria for the major detention storages are as follows;

- Where storage is located near a tributary the detention storage will be designed with capacity to hold at least the 5 yr ARI.

- Where controls points along the main tributary exist (e.g. a road crossing) the detention storage can be designed to overflow into the tributary with the additional storage for the 100 yr ARI provide at the control point.

- Where no control point exists the 100 yr ARI storage volume must be provided outside of the tributary.

- All storages are designed to dry out between storms.

- The minimum building floor levels will comply with DoW requirements for a 0.5 m clearance above the estimated 100yr ARI flood level in the storages.

POS Detention Storages

The detention storages to control outflow from the development in major storm events are located in the lowest point of the catchment. This is typically within POS areas. To achieve the required storage volumes, it is intended that the POS is shaped to provide low points with sufficient capacity as opposed to any formal drainage structure. Landscape treatments are appropriate to accommodate the frequency of drainage inundation. The key design elements of the detention storages are as follows;

- Due to the natural fall of the site it may be necessary to tier the storage areas to achieve the required volumes. The tiers should be arranged such that the low area in the storage is smaller and opens out to a broader higher level storage. This allows the more frequent inflow to be stored in a smaller area, with the larger less frequent rainfall events stored over the broader area.

- The POS detention storage is independent of the minor event storage. There should be no overflow to or from the adjacent minor event storage. See section 4.4.2.2 for further discussion of this point.

- The DWMP specifies that detention basins should be dry with a minimum clearance of 0.3 m above the design watertable level. We acknowledge that this criteria generally offers improved serviceability and reduces maintenance within the storage, however there may be catchments were the optimal design is compromised by this requirement and therefore the separation to the watertable design level should be considered on a case by case basis with consideration for the proposed landscape treatment.

Catchment Mapping

The internal study area catchment boundaries were based on structure plan design, topography and site inspections. The devised sub-catchments and areas are presented in Figure 9, consistent with the proposed structure plan. It should be noted that the refinement of the sub-catchments mapping has resulted in some variations in catchments from those shown in the DWMP. Where appropriate, this refinement has taken into consideration the upstream and downstream catchments and these external catchments were validated by site inspection and culvert surveys.

A total of 53 sub-catchments were considered, with 42 sub-catchments identified within the Glades LSP area.

Sub-Catchment Peak Outflow Criteria

With the refined sub-catchment boundaries differing from the sub-catchments shown in the DWMP it was not possible to utilise the peak flows for each sub-catchment presented in Table 6.2 of the DWMP. Following discussions with DoW it was agreed that sub-catchment discharge rates could be developed for the refined catchment mapping provided the following 2 criteria was satisfied;

1. The overall post-development peak flow and flood level at Hopkinson Rd for each Tributary remained consistent with the values shown in the DWMP.

2. Provision is made through the Glades LSP for upstream catchments and district flows as specified in the DWMP.

Further discussions were also held with GHD regarding the DWMP modelling to clarify the link on the eastern side of Hopkinson Rd, allowing flow from Tributary 6 down to Tributary 7. It was confirmed that the major flow at Tributary 6 in the 100 yr ARI is over Hopkinson Rd and as the flow backs up behind Hopkinson Rd a portion of the flow is able to breach south to the Tributary 7 culvert crossing under Hopkinson Rd. To maintain the pre-development flow balance the outflow rates for Tributary 6 and 7 were considered as a combined flow. A summary of this strategy is as follows;

Tributary	100yr ARI Peak Outflow (m^3/s)	
	Byford Townsite DWMP	The Glades LWMS
Tributary 6	6.7	11.8
Tributary 7	5.1	
Cardup Brook	33.2	33.9
Tributary 10	1.4	1.4

On this basis, the 5 yr and 100 yr pro-rata peak flood detention criteria for the revised sub-catchments is presented in Table 8.

TABLE 8: SUB-CATCHMENT DRAINAGE PLANNING CRITERIA - ULTIMATE DEVELOPMENT

Sub-catchment	**Area (ha)**	**5yr ARI**		**100 yr ARI**	
		Peak Flow (m^3/s)	**Detention Volume (m^3)**	**Peak Flow (m^3/s)**	**Detention Volume (m^3)**
Tributary 6					
US Inflow provided from DWMP		1.28	-	2.29	-
6A	10.48	0.16	-	0.28	-
6B	11.21	0.25	2898	0.30	4324
6C	9.58	0.19	2689	0.26	3804
6D	3.98	0.17	444	0.19	764
6E	1.37	0.03	227	0.07	206
6F	6.30	0.13	1025	0.17	1831
6G	9.42	0.13	1340	0.18	1910
6H	5.14	0.06	730	0.09	1040
6I	1.68	0.04	202	0.05	384
6J	9.38	0.19	2064	0.25	2521
6K	1.30	0.03	175	0.04	306
6L	5.52	0.10	982	0.15	1502
6M	10.17	0.11	1957	0.27	2830
6N	3.74	0.08	512	0.10	1002
6O	5.57	0.12	917	0.15	1594
6P	9.35	0.18	1751	0.25	2773
6Q	8.60	0.17	1506	0.23	2395
6R	8.91	0.20	1313	0.24	2452
6S	2.96	0.06	403	0.08	789
6T	2.42	0.05	309	0.07	646
6U	7.92	0.18	1063	0.21	2132
6V	7.29	0.15	1200	0.20	2011
6W (DS)	27.53	0.42	-	0.74	-
6MUC1	4.15	0.07	-	0.11	-
6MUC2	0.96	0.02	-	0.03	-
6MUC3	2.83	0.05	-	0.08	-
6MUC4	0.97	0.02	-	0.03	-
6MUC5	1.20	0.02	-	0.03	-
Sum of peak flows (6)		**4.65**		**7.14**	
Tributary 7					
7A	31.26	0.55	-	0.84	-
7B	52.86	0.93	-	1.43	-
7C	7.48	0.13	-	0.20	-
7D	5.54	0.12	494	0.15	1339
7E	10.53	0.22	1362	0.28	2242
7F	5.89	0.12	560	0.16	1447
7G	5.57	0.12	366	0.15	1200
7H	2.11	0.04	160	0.06	524
7I	9.27	0.21	1505	0.25	2567
7J	34.82	0.61	-	0.94	-
7MUC1	1.54	0.02	-	0.04	-
7MUC2	1.78	0.03	-	0.05	-
7MUC3	2.99	0.04	-	0.06	-
Sum of peak flows (7)		**3.14**		**4.61**	
Sum of peak flows (6 & 7)		**7.78**		**11.75**	
Cardup Brook					
Orton Rd Inflow		1.30	-	2.00	-
8A	5.81	0.14	-	0.21	-
8B	19.56	0.47	-	0.72	-
8C	8.59	0.20	-	0.31	-
8D	7.08	0.17	-	0.26	-
8E	5.55	0.13	-	0.20	-
Cardup Brook Inflow		5.80		23.53	
9A	25.30	0.78	2780	0.83	5530
9B	21.15	0.66	1973	0.75	4400
9C	16.68	0.46	2054	0.61	3900
9D&E	12.31	0.32	1835	0.45	2980
Sum of peak flows (CB)		**10.43**		**29.88**	
Tributary 10					
10A + 10B + 10C	34.29	0.93	3473	1.40	5760
10D	6.82	-	-	-	-

Sizing Detention Storages

To size the detention storages the XP-SWMM model was used. Storage areas were designed to contain runoff from the 100 year ARI storm event, with discharge for the 100 year ARI event designed not to exceed the ultimate development flow criteria as specified in Table 8.

Storage locations were determined based on existing topographic contours, depth to groundwater mapping, and local structure plan constraints. Side slopes of 1 in 6 (v:h) have been adopted for all storages.

The design storms modelled in XP-SWMM were calculated according to the methodology in Australian Rainfall & Runoff (AR&R) (Institution of Engineers, Australia 2000). The rainfall temporal pattern was assumed to be spatially uniform across the catchment. Storm durations modelled ranged from 10 minutes to 72 hours.

The catchment runoff parameters applied for the various land uses were consistent with the parameters provided in the DWMP, as follows;

Land Use	**Surface Roughness (Mannings n)**		**Initial Loss (mm)**		**Infiltration Loss (mm/hr)**	
	Perv.	Imperv.	Perv.	Imperv.	Perv.	Imperv.
Rural Pasture	0.050	0.015	10	1.5	4	0
Existing Urban	0.025	0.015	10	1.5	4	0
Constructed Urban	0.025	0.015	10	15	4	0

Land Use Category	**Pervious Area (%)**	**Impervious Area (%)**
Roads	30	70
Mixed business	25	75
Neighbourhood centre	45	55
Residential (R20-R60)	50	50
Schools	50	50

There is insufficient information provided in the DWMP to reconcile the peak outflows and sub-catchment detention storages for the 5 yr ARI based on the runoff parameters described. As such the for the revised sub-catchments the detention storage volumes for the 5 yr ARI were calculated based on achieving similar detention volumes to those provided in the DWMP using the DWMP runoff parameters. In most cases this results in higher peak outflow in the 5 yr ARI than shown in the DWMP.

The results for the detention storage are presented in Figures 10, 12 and 14. Long-sections of each tributary post-development are provided in Figures 11, 13 and 15.

A long section of Cardup Brook is not provided in the figures. Due to the complexity of modelling the large 100 yr ARI flow in Cardup Brook we have not tried to reproduce the DWMP modelling. Instead, the basins proposed by JDA (shown in Figure 14) were added to the district Infoworks model by GHD and checked for compliance with the DWMP flood management strategy. Compliance was confirmed and this advice is included in Appendix C.

Note that storage shapes and volumes shown in the figures are indicative and appropriate at a local planning scale only. The final configuration (side slopes etc) and exact location of storage areas will be dependent on final earthworks, drainage, and road design levels for the development, and catchment areas shown in this report may change as a result. The details will be refined at the sub-division stage and reported in the relevant Urban Water Management Plan (UWMP).

100yr Flood Emergency Access Routes

The Byford Townsite DWMP identifies Abernethy Rd, Kardan Boulevard, Thomas Rd and South West Hwy as major arterial roads that should remain passable in the 100 yr ARI.

Within The Glades structure plan area, if the design is achievable without affecting the existing trees, Doley Rd should also be designed to remain passable in the 100 yr ARI, providing a link to Abernethy Rd through the sub-division.

4.4.4.2 Minor Drainage System

The minor drainage system is designed to manage rainfall events up to the 5yr ARI and includes GPT's, swales, bio-retention structures, lot connection pits and the pipe drainage system. The minor drainage system is designed to also provide the structural controls for water quality treatment.

The minor drainage system for The Glades has been designed with the intention of separating the flow paths of major and minor rainfall events. Separating the flow paths of the major and minor rainfall events provides many benefits to the water quality structures incorporated into the minor drainage system which include;

- Limits potential erosion and scour of bio-retention structures by large flows.
- Reduced potential re-mobilisation of pollutants captured during minor flows.
- Reduced maintenance requirements as a result of the above 2 points.

Due to the local soils, infiltration of stormwater at the lot scale via soakwells is problematic. Geotechnical advice to LWP Property Group is that implementing such a strategy would result in a significant additional cost to new home builders by way of increased footing specifications for the building. As such a conscious decision has been made to provide a lot connection point to the street drainage network and treat the 1 yr ARI 1 hour duration event (16.9 mm rainfall) at the neighbourhood catchment scale. For this solution to be effective, the minor drainage system for The Glades incorporates the following design elements;

- Residential lots will be connected to the road pipe drainage system with a connection capacity of 5 yr ARI.
- The road drainage system is via roadside pipe network with capacity for a 5yr ARI.
- Bio-retention swales and bio-retention storages provided require a minimum treatment capacity of the 1yr ARI 1 hour event.
- For all outlets to minor stormwater detention storages, stormwater will be treated by Gross Pollutant Traps prior to discharge.
- A diversion structure will be located immediately downstream of the GPT to separate the major runoff events from the minor runoff events and protect the minor event detention storage (typically a bio-retention storage structure) from excess flooding and scour.

The key design principles for the diversion structure and bio-retention systems are discussed in more detail below.

Drainage Diversion Structure

The key design principle to the separation of the major and minor drainage system is the use of the diversion structure located upstream of the stormwater storage structures. A typical design for the diversion structure is shown in Figure 17

The function of the diversion structure is as follows;

- The bio-retention storage downstream of the diversion structure is sized to treat a 1yr ARI 1hr duration event (16.9 mm/hr). For rainfall events up to this intensity the pipe outlets from the diversion structure provide sufficient capacity for the flows to continue downstream to the bio-retention storage.
- For rainfall events in excess of 16.9 mm/hr the outlet pipes will be full. The diversion structure has been designed with minimal cover over the outlet obvert so that once the outlet pipes are full any hydraulic head that builds up behind the pipes is released via an open grate in the top of the manhole (bubble up). This excess water is then diverted away from the diversion structure via an overland flow path to the major detention storage.
- To ensure that the diversion structure operates correctly the top water level in the bio-retention storage is designed as the same level as the overflow level in the diversion structure. With the design levels matching, once the bio-retention storage is full it creates a backwater in the pipes that matches the diversion structure overflow level which further ensures that any additional inflow to the diversion structure will bubble out rather than flow down the pipes.

Bio-retention Swales

Bio-retention swales will typically be located within the central median of roads, but can be located on either side of the road reserve where the design dictates this as a preferred location. A typical section of a bio-retention swale is shown in Figure 17. The key design elements to the function of the swale are as follows;

- The central median is an inverted crown with flush kerbing so that rainfall runoff can flow directly from the paved road surface into the swale by sheet flow. Sheet flow minimises potential scour of the swale banks that would be caused by concentrating this flow in a pipe.

- The swale in underlain by a minimum of 0.5 m thick permeable soil material to encourage water to soak into the swale rather than continue to flow along the swale. Water soaking into the permeable soil is improved by a combination of chemical and biological process. Water soaking into the permeable soil is available to vegetation for evapotranspiration, which reduces the outflow from the system.

- If the wetting front of the infiltrated water reaches the base of the permeable soil material the emerging treated water is collected in the subsoil pipe system located at the base of the swale.

- In major rainfall events, when the capacity of the swale storage is reached overflow gullies connected to the pipe system will collect the excess stormwater overflow. The invert of the overflow gullies is set at the designed top water level of the swale.

Mead St is the main road identified for a bio-retention swale, but swales should be incorporated into other roads wherever possible. To protect the stands of existing trees it is not possible to construct swales in Doley Rd or Warrington Rd,

Bio-retention Storages

The bio-retention storages have been included in the design of the minor drainage system to provide treatment of excess stormwater runoff from both the road network and residential housing lots in minor rainfall events up to the 1 yr ARI 1 hour duration (16.9mm/hr intensity). A typical section of a bio-retention storage is shown in Figure 17. The key design elements to the function of the bio-retention storages are as follows;

- Stormwater inflow is limited to the capacity of the pipe system from the diversion structure to minimise the maintenance requirements of the storage.

- The design top water level is the same level (m AHD) as the overflow level of the diversion structure to create a backwater effect that assists the operation of the diversion structure.

- Outflow from the storage is via soakage through a layer of permeable material under the storage, which is to be a minimum of 0.5 m thick. Water soaking into the permeable soil is improved by a combination of chemical and biological processes. Water soaking into the permeable soil is available to vegetation for evapotranspiration, which reduces the outflow from the system.

- If the wetting front of the infiltrated water reaches the base of the permeable soil material the emerging treated water is collected in the subsoil pipe system located at the base of the storage.

- If the intended function of the storage fails for any reason a high level overflow spillway is provided to control the maximum water level in the storage. The overflow discharges directly to the receiving tributary and is not in anyway connected to the POS detention storage area located adjacent. The spillway should not flow under normal operating conditions, only as an emergency failsafe in large rainfall events.

Specific details of 1 in 1 year treatment measures will be documented in the relevant UWMP.

4.5 Groundwater Management

Design Criteria (from DWMP);
Protection of infrastructure and assets from flooding and inundation by high seasonal groundwater levels, perching and/or soil moisture;

Managing and minimising changes in groundwater levels and groundwater quality following development.

4.5.1 Managing Groundwater levels to protect infrastructure

To protect infrastructure from high seasonal groundwater levels the watertable design level has been calculated by measurement of the watertable as described in Section 3.7.4. The watertable design level contours are presented in Figure 6 and the depth of the contours below existing natural surface level in Figure 16. With reference to Figures 6 and 16, the criteria for the installation of subsoil pipes will be as follows;

- Where a perched watertable exists or the predicted watertable design level is at or within 1.2 m of natural surface, clean fill and/or the provision of subsoil drainage will be provided. In such instances subsoil pipes will be placed at or above the watertable design level.

- Unless otherwise negotiated with the Shire, development should ensure finished lot levels are a minimum of 0.5 m above the level of any groundwater mounding between subsoil pipes.

- Subsoil pipe systems must be designed with free draining outlets.

Based on these criteria and the presence of clay soils over the site that will cause a perched watertable to form, subsoil pipes will be required for all significant building sites as part of this development.

4.5.2 Managing changes to groundwater levels

Shallow groundwater in the area is limited and currently used only for domestic water supply purposes. The estimated water balance for the site presented in Table 6 indicates that as a result of urban development the recharge to the Superficial Aquifer will be reduced slightly. This is not considered to be a significant negative impact for 3 reasons;

1. The Superficial Aquifer is a limited resource in this area and does not support significant abstraction.

2. There are no REW or CCW wetlands located within the study area dependant on the watertable. Wetlands adjacent to the study area are located up-gradient and changes to groundwater recharge at The Glades are unlikely to impact up-gradient areas.

3. Base flows will be maintained in the watercourses, maintaining the hydrology of the watercourses, in particular Cardup Brook.

The abstraction from the confined aquifer for irrigation of the parks is significant in the context of the sites overall water balance, but this abstraction is unlikely to alter the watertable levels evident over the site as this deeper aquifer is hydraulically disconnected from the overlying Superficial Aquifer.

4.6 Wetland Management

Design Criteria (from DWMP);
To maintain the pre-development hydrological regime of the wetlands;

Protect wetlands from the impacts of urban runoff.

4.6.1 Maintaining the hydrological regime

As discussed in Section 4.1 the natural condition of the site is limited recharge due to the clay sediments, with a high proportion for rainfall runoff. The hydrology of the wetlands are therefore characterised by rainfall recharge directly onto the surface of the wetland and surface runoff into the wetland. This is supported by the high seasonal fluctuation in the watertable shown in the groundwater monitoring data (Appendix B).

The hydrological regime of the wetlands will be maintained post-development by the following measures;

- The wetland areas will be preserved. The surface area for rainfall recharge directly onto the wetland will therefore remain unchanged.
- The watertable design level has been determined to allow the watertable to fluctuate up to the average annual maximum level in low lying areas where the seasonal maximum level is close to the existing natural surface level.
- Drainage inverts will be set at or above the watertable design level, although existing inverts below may remain.

There are no water level criteria for significant wetlands in the region presented in the Byford Townsite DWMP.

4.6.2 Protection of wetlands and watercourses from the impacts of urban runoff

For the five watercourses located within the Study Area, all runoff up to the 1 yr ARI 1 hour duration event will be treated prior to discharge into the waterways. Peak flows will be maintained to pre-development rates for 1yr, 5yr and 100 yr ARI with scour protection included as part of the restoration works of the waterways within the study area.

4.7 Water Quality Management

Design Criteria (from DWMP):

Compared to a development that does not actively manage water quality a 60% reduction in TP and 45% reduction in TN should be achieved.

To minimise and manage TP and TN inputs consistent with the targets of the Peel Harvey WSUD Local Planning Policy (2006).

4.7.1 Nutrient Source Controls

The effective implementation of the structural and non-structural controls as part of the urban development will enhance the improvements in water quality from this site as a result of the land use change.

4.7.1.1 Non Structural Controls

Non structural source controls to reduce nutrient export from the site need to focus on reducing the need for nutrient inputs into the landscape. The following strategies are proposed;

- Local native plants make up a minimum 50% of the landscape and streetscape treatments.
- Street sweeping and GPT education, co-ordinated with the Shire of Serpentine-Jarrahdale.
- Promotion of local native plants and drought tolerant gardens to lot purchasers via a landscape package.
- Promotion of Fertilise Wise practices to new residents coordinated with the Shire of Serpentine-Jarrahdale.

4.7.1.2 Structural Controls

Structural source controls are proposed to compliment the non-structural source controls and provide a complete treatment train for stormwater movement through the development. The following structural controls are considered appropriate for the development area;

- The use of bio-retention swales preferentially over pipe systems where design constraints permit. The swale should have capacity to treat the 1 yr ARI 1 hr flow and convey the 5 yr ARI critical flow.
- The use of bio-retention systems to treat road runoff. A minimum treatment capacity of approximately 2% of connected impervious area should be provided.
- A GPT will be installed upstream of any outlets to detention/bio-retention storages sized to treat the 3 month ARI but with capacity to bypass the 5 yr ARI.

The minimum specifications for all bio-retention systems (swales and storages) will be as follows;

Item	Specification
Amended soil media	Minimum 500 mm thick PRI > 5 Hydraulic Conductivity (sat) > 6 m/day pH 5.5-7.5 Total clay and silt fraction < 3% in total (w/w) Organic matter content <5% (w/w) Phosphorus content <100 mg/kg Light compaction only. Infiltration testing of material prior to installation and again once construction is complete. Ongoing testing as per the monitoring program. Where insufficient depth is not available for a Transition soil layer, soil layers should be separated by shade cloth.
Plant selection	Tolerant of periodic inundation and extended dry periods. Spreading root system. Preferential selection of endemic and local native species. Planting to provide 70-80% coverage at plant maturity.
Planting density and distribution	Planting density appropriate for species selection. Even spatial distribution of plant species.

The bio-retention systems should be sized to function correctly with a Ksat of 3, so a factor of 2 is provided for clogging that will occur in the first few years. Recent research conducted by the Facility for Advancing Water Biofiltration (FAWB, 2008) indicates that the desired Ksat is in the range of 2.5 to 7 m/day, to fulfil the drainage requirements as well as retain sufficient moisture to support the vegetation. The FAWB (2008) research also specifies that for vegetated systems some clogging will occur in the first few years until the vegetation is established. Once the plants are established, the roots and associated biological activity maintain the conductivity of the soil media over time.

It should be recognised that data currently guiding the design of bio-retention systems is only recent and largely based on laboratory testing. Details of plant selection, maintenance and likely nutrient uptake in the Byford environment are not well known at this stage. The specifications provided in this document should be considered as the best available information at the time. Some flexibility in the specifications will be required as the knowledge base increases.

4.7.2 Land Use Change Nutrient Impacts

To assess the likely impact of the change in land use to the proposed urban landscape the NiDSS model has been used to help quantify the nutrient inputs for the pre-development and post-development scenarios. The NiDSS model measures inputs only for Total Phosphorus and Total Nitrogen on the premise that ‘prevention is better than a cure’ i.e. nutrients that are not put into the system cannot be transported through the system as a contaminant.

The NiDSS analysis shows that the changes in land use from rural (pasture) to a built urban environment will result in an increase in the nutrient load on the catchment. This increase needs to be reduced using WSUD principles. With the implementation of the proposed structural and non-structural controls, a reduction of 53% for Phosphorus and 34% for Nitrogen is achieved compared to urban development without WSUD. Compared to the pre-development nutrient inputs, this is a reduction of 51% for Phosphorus and no change for Nitrogen. The modelled input rates of 10 kg/ha/yr for Phosphorus and 63 kg/ha/yr for Nitrogen are within the targets of the Peel Harvey WSU Planning Policy (2006) which specifies input rates of 15 kg/ha/yr for Phosphorus and 150 kg/ha/yr for Nitrogen.

5. IMPLEMENTATION

5.1 Urban Water Management Plan (Subdivision)

Processes defined in Better Urban Water Management (WAPC, 2008) are referred to in the Byford Townsite DWMP (2008), which requires an Urban Water Management Plan (UWMP) at subdivision stage. With an approved LWMS, a UWMP is required as a condition of subdivision and prior to any ground disturbing activities.

Specific issues raised in this LWMS that need to be addressed by the relevant UWMP include;

- Details of 1 yr ARI water quality treatment designs (BMP's).
- Monitoring of Village Centre 5 yr ARI bio-retention storage outflow water quality. A conclusion on the suitability of the treated stormwater runoff for the lake should be reported as part of the UWMP post-development monitoring reporting.
- Monitoring of specific BMP structures performance to be included as part of the post-development monitoring programme within the relevant UWMP. The long-term impacts of urban development are included as the post-development monitoring within this LWMS (see section 5.3), therefore only development stages with new design concepts or alternative BMP structures will require post-development monitoring specified within the UWMP.

5.2 Construction Management

5.2.1 Dewatering

Dewatering will be required for some elements of subdivision construction given the depth of construction, dewatering will only be in the Superficial Aquifer. Site conditions dictate that construction is limited over the winter period, so that the majority of major earthworks will occur in the summer period when the watertable is naturally lower.

Prior to the commencement of any dewatering, the construction contractor will apply for and obtain from DoW a “Licence to Take Water”. All dewatering will be carried out in accordance with the conditions of this licence. Where possible, construction will be timed to minimise impacts on groundwater and any dewatering requirement.

5.2.2 Acid Sulphate Soils

Management of Acid Sulphate Soils (ASS) will be addressed as a separate process to the urban water management document approvals process (LWMS/UWMP).

ASS will be investigated and managed in accordance with the applicable DEC Acid Sulphate Soil Guideline Series and requirements of dewatering licences as they arise.

5.2.3 Construction of MUC's

The MUC's will be constructed with capacity to convey flood flows for ultimate development of the catchment, including upstream catchments. Where online flood storage is proposed for a sub-catchment, the control point within the MUC tributary should be constructed prior to the development of the sub-catchment, otherwise addition offline storage must be provided for the sub-catchment in the interim.

5.3 Stormwater System Operation and Maintenance

The operation and maintenance of the drainage system will initially be the responsibility of the developer, ultimately reverting to the local authority, Shire of Serpentine-Jarrahdale.

The surface and subsoil drainage system will require regular maintenance to ensure its efficient operation. It is considered the following operating and maintenance practices will be required periodically:

- Removal of debris to prevent blockages
- Street sweeping to reduce particulate build up on road surfaces and gutters
- Maintenance of vegetation in Bio-retention Systems/ Storages as outlined in the UWMP
- Cleaning of sediment build up and litter layer on the bottom of Storages as specified in the UWMP
- Mowing of grassed open channel sections monthly and grassed clippings removed
- Application of slow release/low phosphorus fertilisers for maintenance of swales
- Undertake education campaigns regarding source control practices to minimise pollution runoff into stormwater drainage system
- Checks on subsoil drainage function

5.4 Monitoring Programme

The monitoring program has been designed to allow a quantitative assessment of hydrological impacts of the proposed development within the Study Area. The monitoring programme will complement the district water quality monitoring program currently proposed by the Shire, which indicates monthly water quality grab sampling at 12 surface water sites. The period of the district monitoring program is not yet defined.

The post-development monitoring program for the Glades LSP area will commence in October 2009 and is designed to operate until completion of the development to allow for time lags of impacts on the receiving environment to occur. This is likely to be a period of 12 years based on current projections. The program will be periodically reviewed to ensure suitability and practicality.

All water quality sample testing will be conducted by a NATA approved laboratory.

A summary of the proposed monitoring program and reporting schedule is shown in Table 9, with the frequency of water quality target review and the contingency action plan detailed in Table 10.

It is proposed that post-development monitoring for groundwater and surface will continue to monitor the sites established for the pre-development monitoring program. The locations of the monitoring sites are shown in Figure 6.

5.4.1 Reporting Mechanisms

The preparation of monitoring reports is to be co-ordinated by the developer and submitted to the Department of Water/Shire of Serpentine Jarrahdale for review. The report will compare the monitoring results with the design criteria and performance objectives and determine what, if any, further actions are necessary consistent with contingency planning measures detailed in Table 10.

The proposed reporting schedule is detailed in Table 9.

TABLE 9: POST-DEVELOPMENT MONITORING SCHEDULE AND REPORTING

Monitoring Type	Location	Method	Frequency & Timing	Responsibility	Parameter	Reporting
Groundwater Level	12 Bores	Electrical depth probe or similar	2 times/year, April and October to coincide with the annual high and low water levels. Commence October 2009 and continue until completion of the final stage of development	Developer	Water Level (m AHD)	Reports to be provided by the developer every 3 years until completion of the monitoring program. Reports will be submitted to DoW/SSJ within 3 months of completion of the reporting period.
Surface Water Quantity	4 Locations	Continuous logger	Downloaded 2 times/year (April and October). Commence October 2009 and continue until completion of the final stage of development	Developer	Stage (flow inferred)	
Groundwater Quality	12 Bores	Pumped bore samples	2 times/year (April and October). Commence October 2009 and continue until completion of the final stage of development.	Developer	In-situ: pH, EC, temp Lab: TN, TKN, NO_X, TP, FRP	
Surface Water Quality	4 Locations	Collected grab samples	2 times/year (April and October). Commence October 2009 and continue until completion of the final stage of development	Developer	In-situ: pH, EC, temp Lab: TN, TKN, NO_X, TP, FRP, TSS	

TABLE 10: CONTINGENCY PLANNING

Monitoring Type	Criteria for Assessment	Criteria Assessment Frequency	Contingency Action 1. Assess if an isolated, development area or regional occurrence. 2. Determine if due to the development or other external factors. 3. Perform appropriate contingency action as required (examples provided below) 4. Record and report in the annual report any breach and action taken. 5. If necessary, inform residents of any required works and their purpose.
Groundwater Level	Groundwater levels not to exceed design water level plus 0.7m.	After monitoring occasion	1. Review annual rainfall total 2. Review design and operation of subsoil and stormwater drainage system. 3. Perform maintenance as required.
Surface Water Quantity	Hydrograph to be within range of pre-development monitoring.		1. Review recent rainfall ARI's 2. Review design and construction of detention storage areas 3. Perform maintenance as required
Groundwater Quality	Nutrient concentrations in shallow bores to be similar or better than predevelopment values on an annual average basis.	Annual review of water quality targets	1. Identify and remove any point sources. 2. Reinforce Community Education/Awareness program. 3. Review operational and maintenance (e.g. fertilising) practices. 4. Consider alterations to POS areas including landscape regimes and soil amendment. 5. Consider modifications to the stormwater system. 6. Consider initiation of community based projects.
Surface Water Quality	Nutrient concentrations in tributaries to be similar or better than predevelopment values on an annual average basis.		

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Western Australian Planning Commission (2007) *Metropolitan Regional Scheme, 1:100,000 series Map*. Amended to 8 August 2008. Available online.

Western Australian Planning Commission. (2008) *Better Urban Water Management*.

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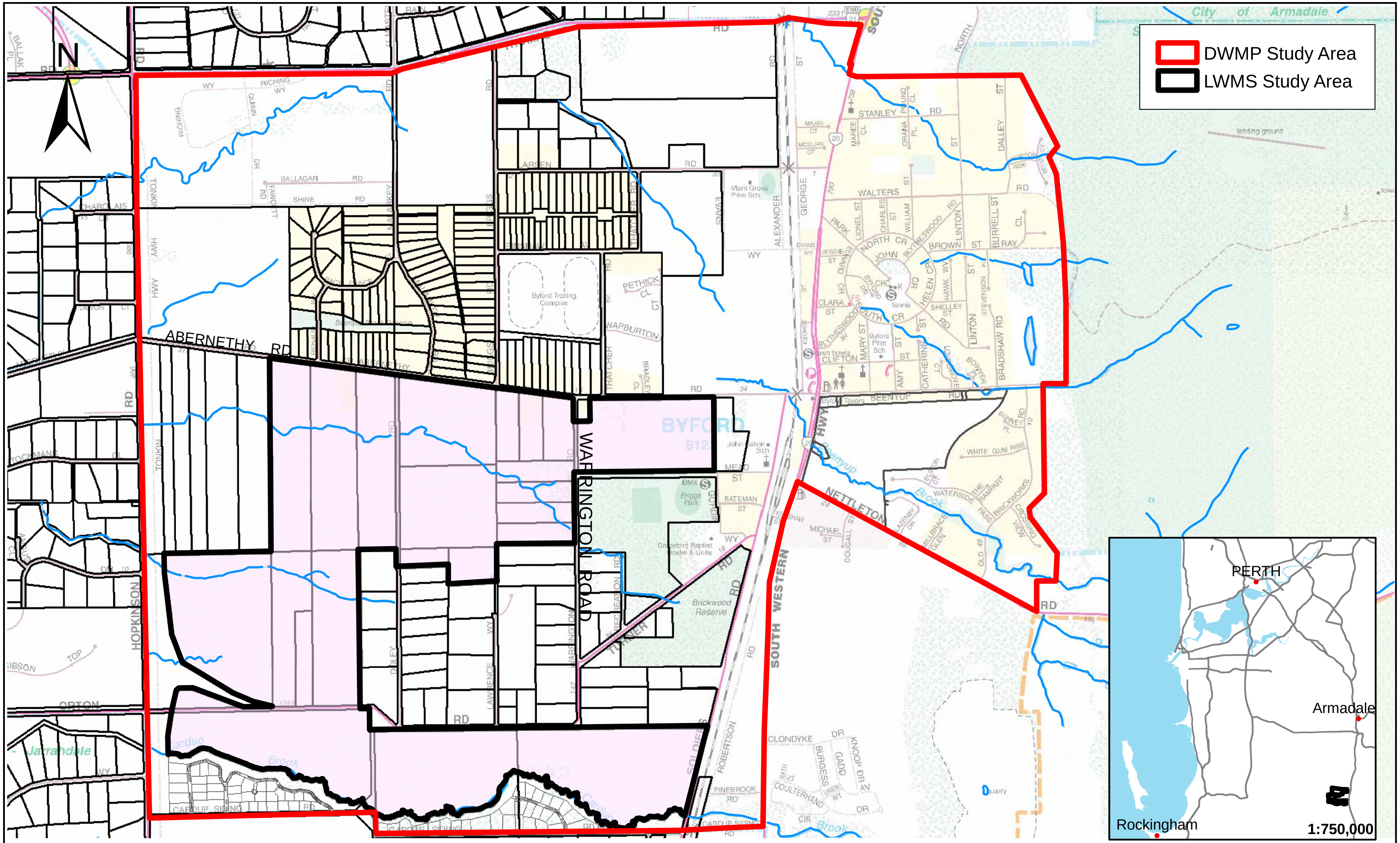
JDA Consultant Hydrologists

ISO 9001
BUREAU VERITAS
Certification

FIGURES



Data Source: DoW (2008) Byford townsite drainage and water management plan.

Job No. J4320

Scale:1:26,000

0 200 400 600 800 1,000 Meters

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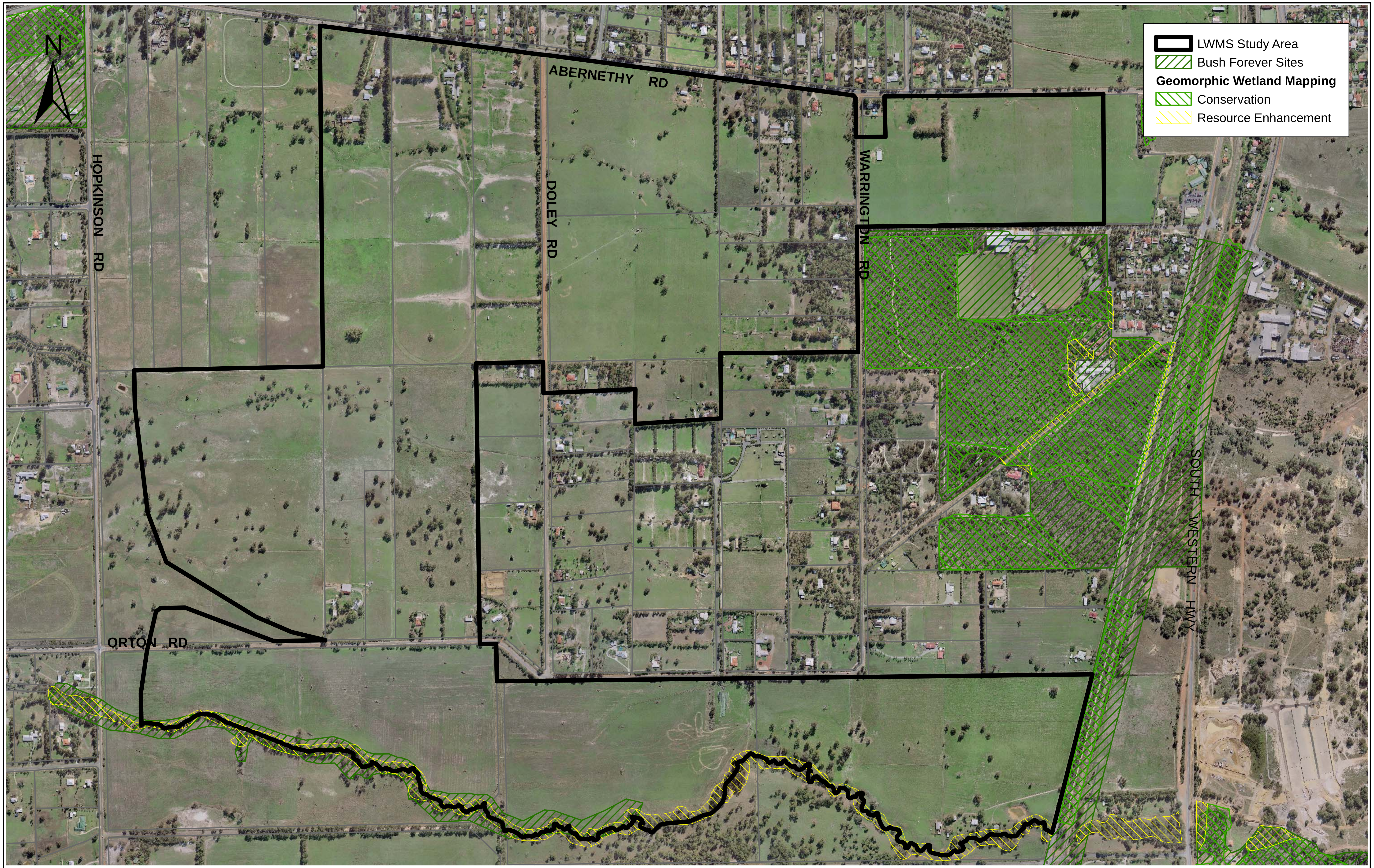
The Glades at Byford LWMS

Figure 1: Location Plan



Data Source: DEC (2009) Geomorphic Wetlands of the Swan Coastal Plain

Job No. J4320
Scale: 1:10,000
0 100 200 300 400 500 Meters

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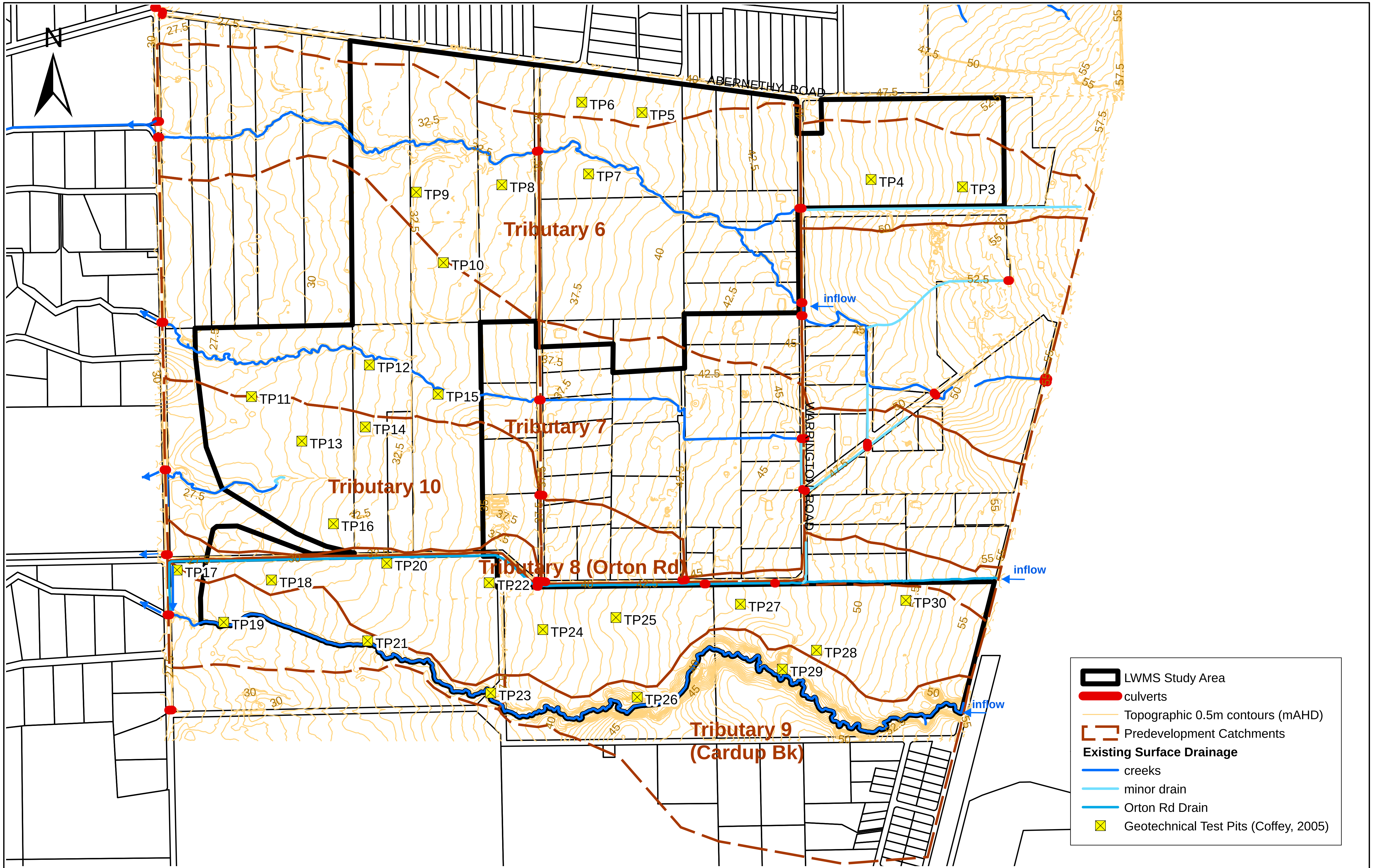
Figure 2: Existing Land Use, Bush Forever and Geomorphic Wetland Mapping.



Data Source: MAPS (2007) Topographic Contours; Coffey (2005) Proposed Subdivision Byford Main Precinct - Preliminary Geotechnical Investigation.

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Job No. J4320
Scale: 1:12,000
0 200 400 600 800 1,000 Meters

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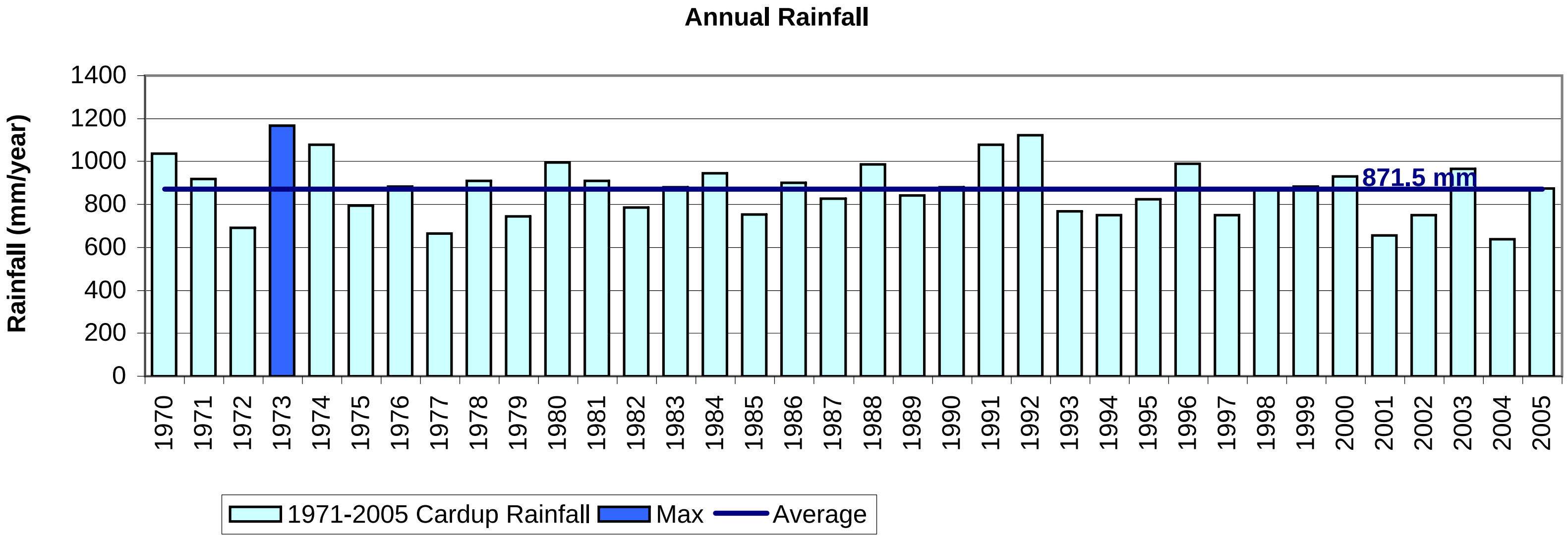
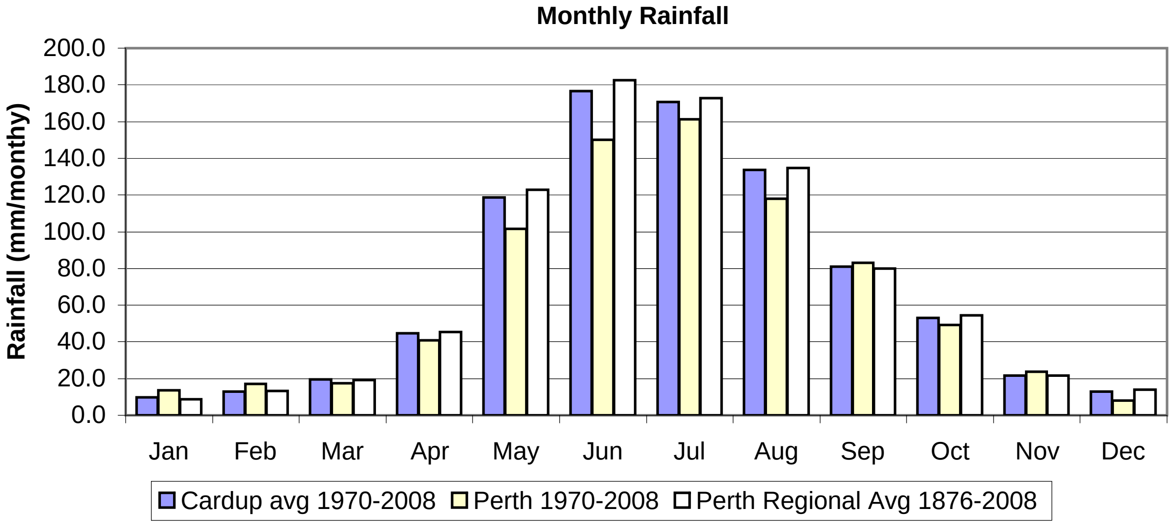
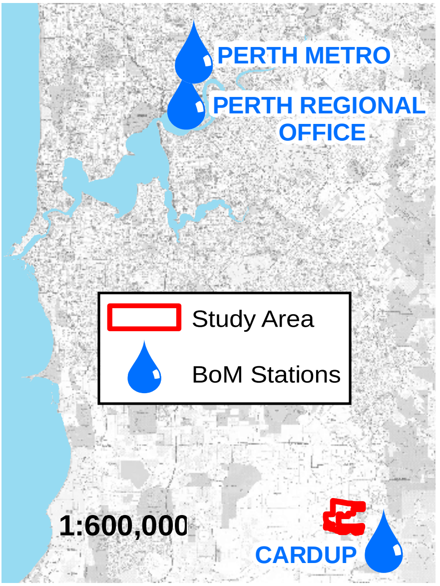
Figure 3: Topography, Existing Surface Drainage and Geotechnical Test Pit locations







Data Source: Bureau of Meterology (2009)

Job No. J4320

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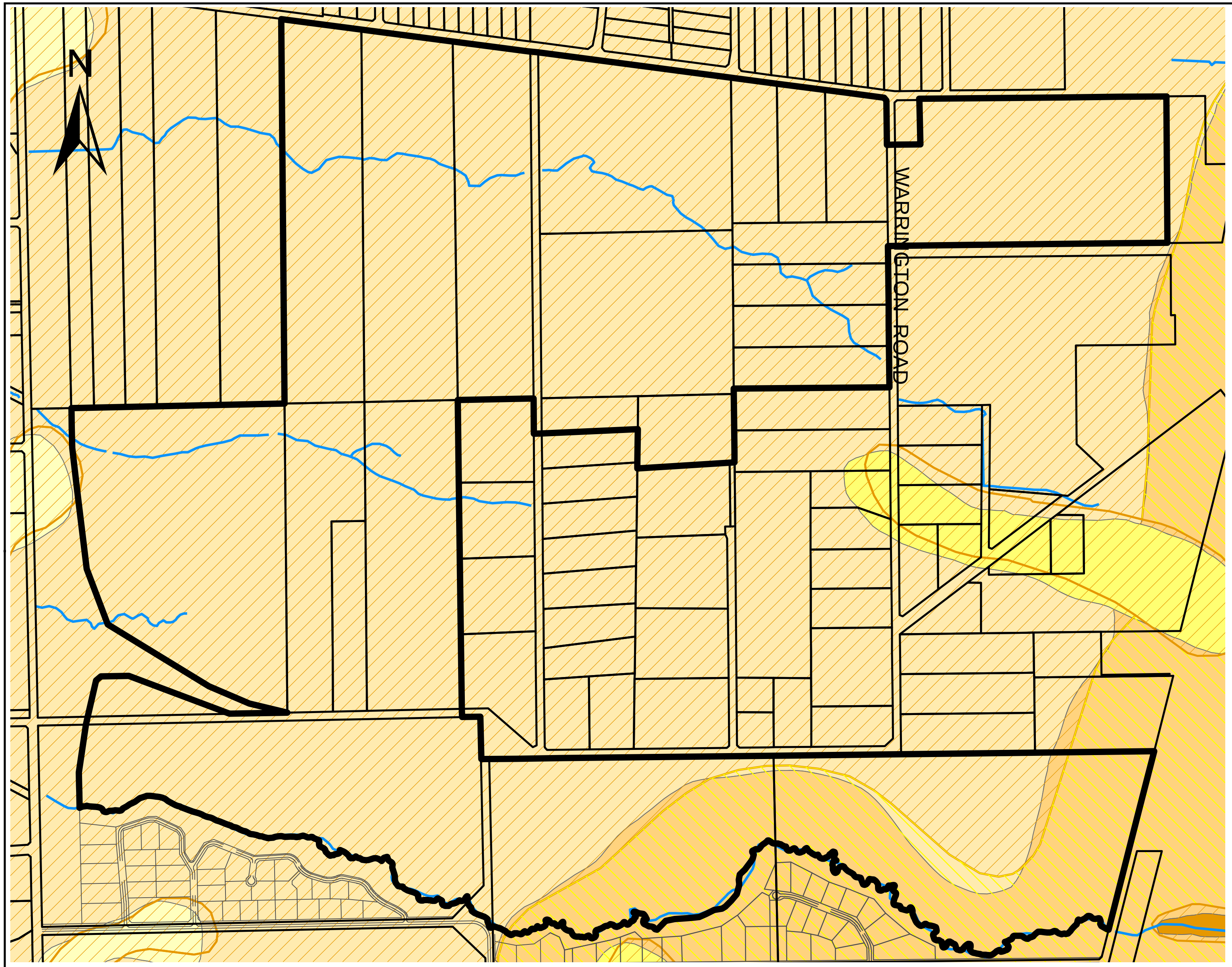
Tht Glades at Byford LWMS

Figure 4: Annual and Average Monthly Rainfall Data



▭ LWMS Study Area

Acid Sulphate Soils

▨ Class 2 Risk

▨ Class 3 Risk

Surface Geology

🟨 S8 - Sand

🟨 S10 - Sand

🟨 Cs - Sandy Clay

🟧 Csg - Sandy gravely Clay

🟧 Msc1 - Clayey Sandy Silt

Notes:

ASS Class 2 - Moderate to high risk of ASS or PASS occurring >3 m from soil surface; no risk of occurrence <3m from soil surface

ASS Class 3 - Low to nil risk of ASS or PASS occurring >3 m from soil surface; no risk of occurrence <3m from soil surface

Data Source: Jordan J.E. (1986) Armadale part Sheets 2033 I and 2133 IV, Perth Metropolitan Region, Environmental Geology Series, GSWA.

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Job No. J4320

Scale: 1:15,000

0 250 500 750 1,000 Meters

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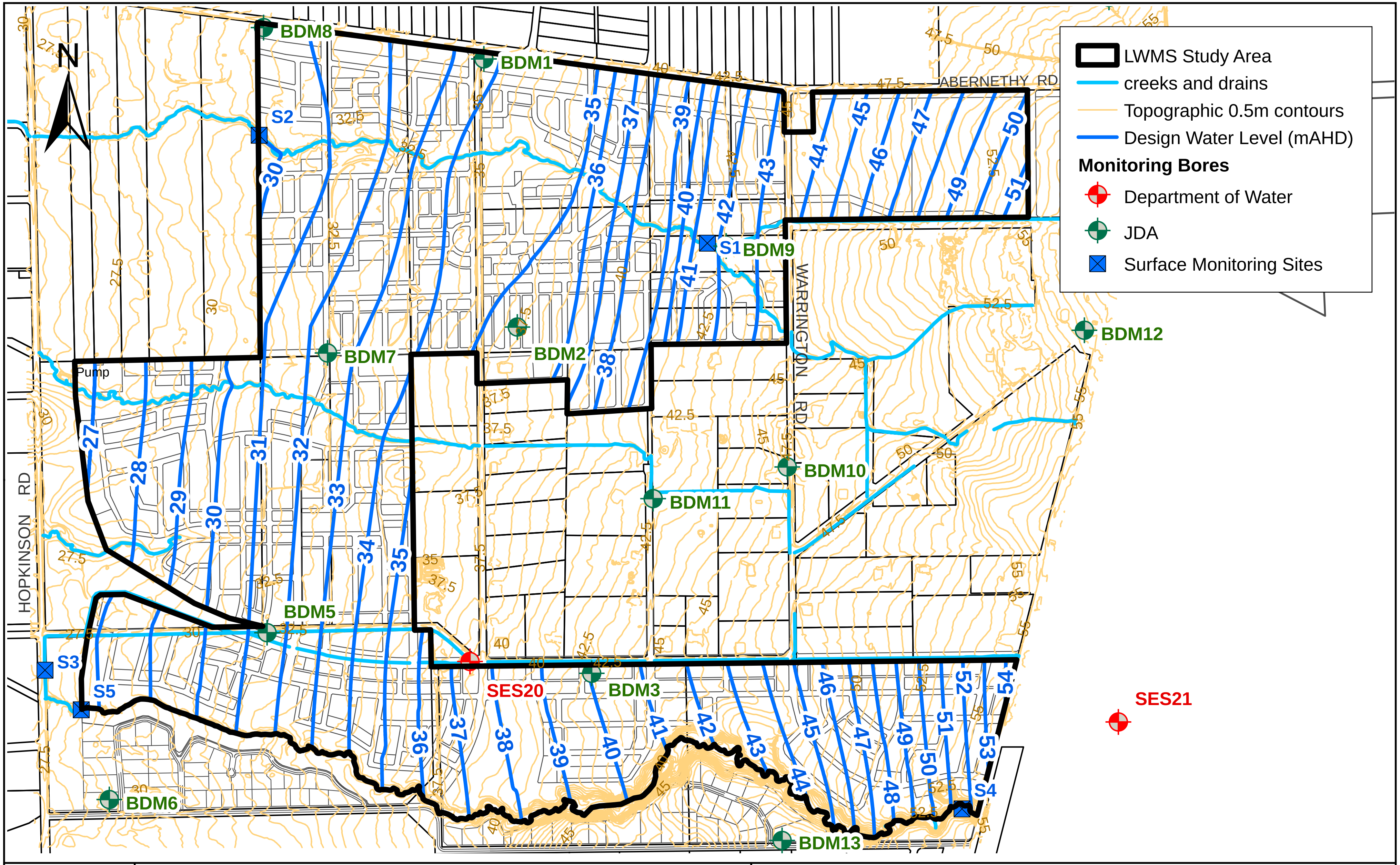
Figure 5: Surface Geology and ASS Risk Mapping



Job No. J4320

Scale:1:15,000

0 250 500 750 1,000 Meters

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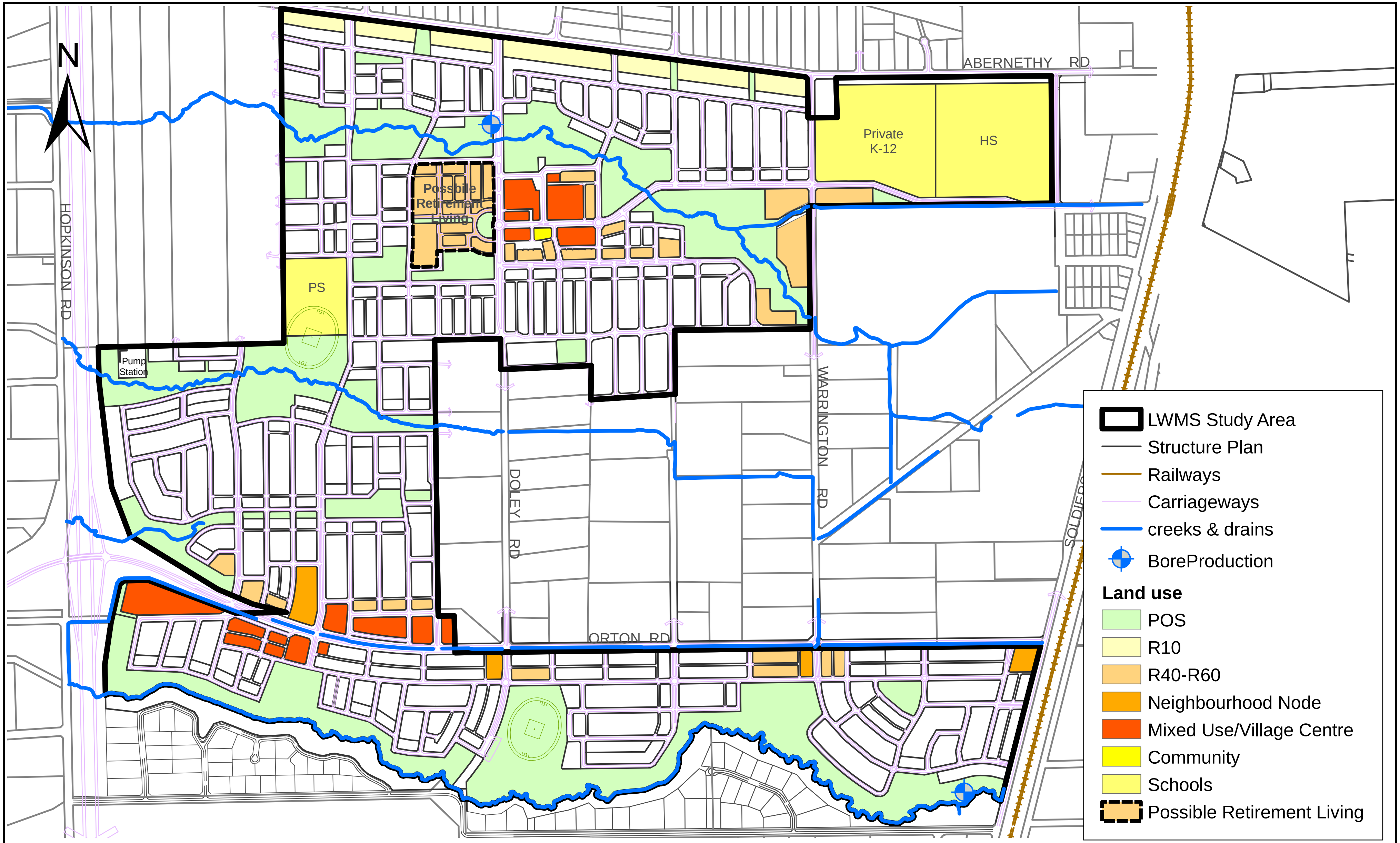
The Glades at Byford LWMS

Figure 6: Estimated Watertable Design Levels and JDA Monitoring Locations



Data Source: TBB (2009) Byford Main Precinct Local Structure Plan. Ref Plan 06/014/012F.

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Job No. J4320
Scale:1:15,000

0 250 500 750 1,000 Meters

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Figure 7: Proposed Structure Plan and Land Uses

Data Source: Plan E (2009)

Job No. J4320

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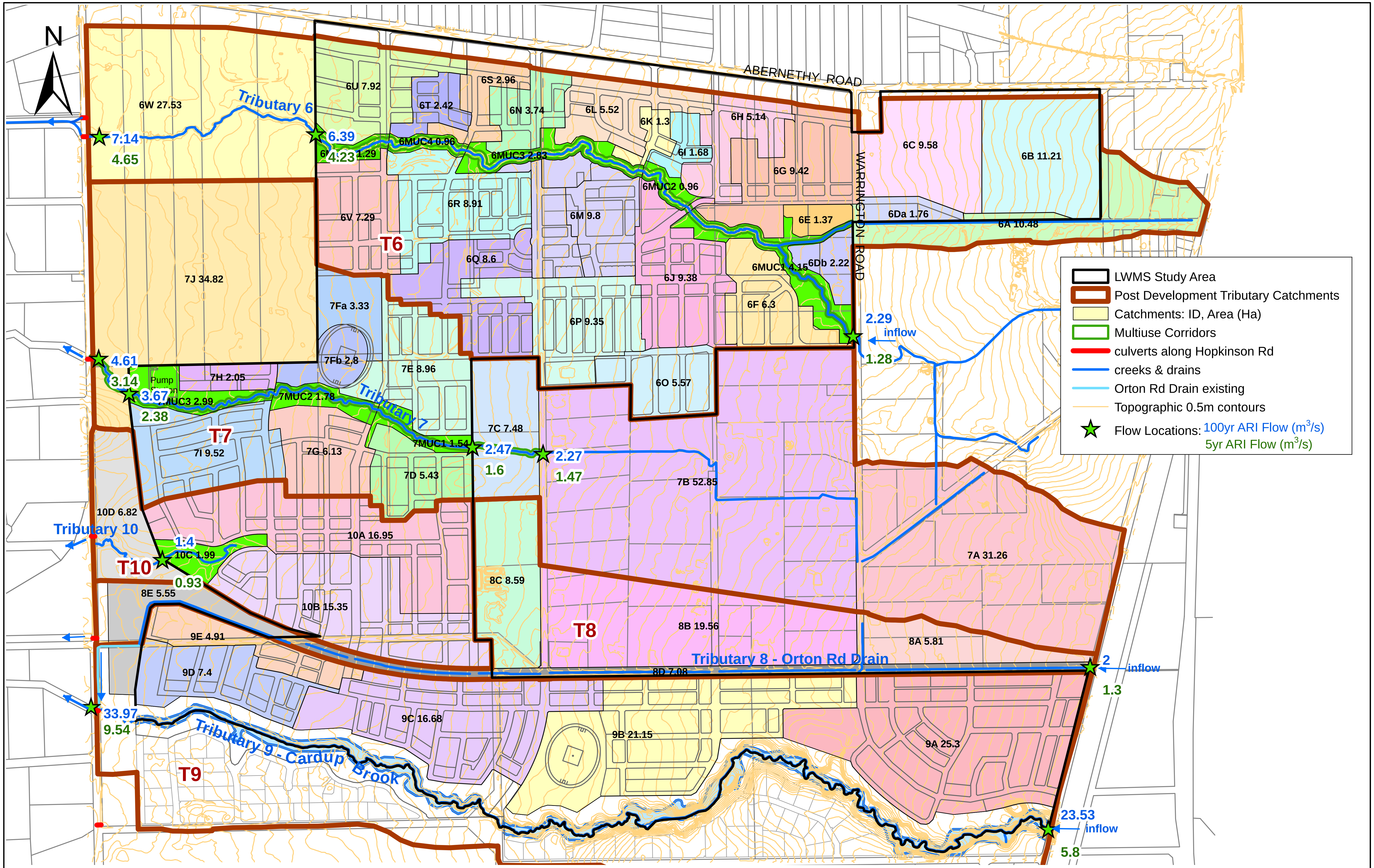
The Glades at Byford LWMS

Figure 8: Village Centre Masterplan



Data Source: TBB (2009) Structure Plan; MAPS (2007) Topographic 0.5m Contours.

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Scale: 1:10,000
0 250 500 750 1,000 Meters

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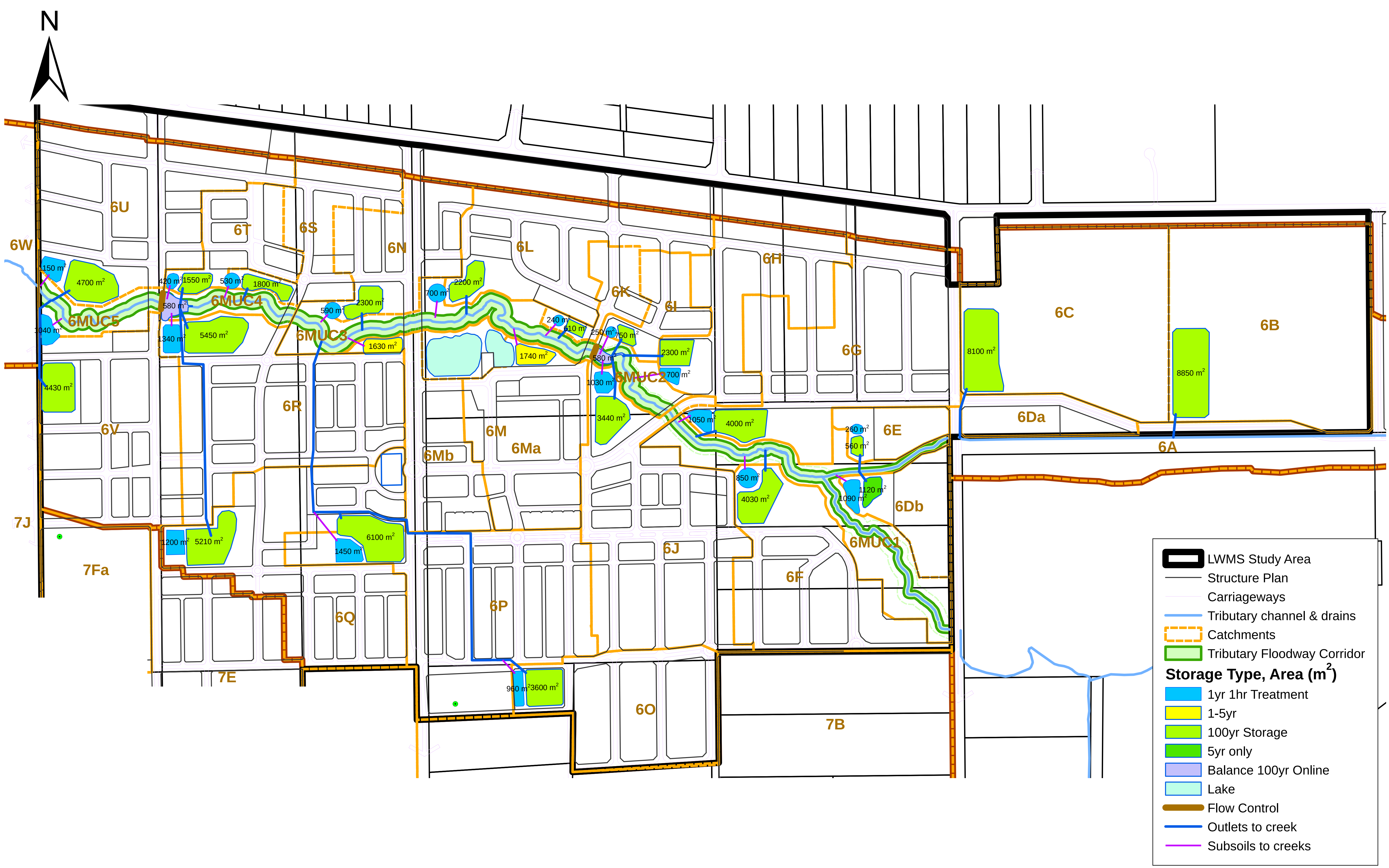
Figure 9: Catchment Plan and Multiple Use Corridors (MUC)



Data Source: TBB (2009) Structure Plan & Carriageways

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Job No. J4320
Scale: 1:6,000

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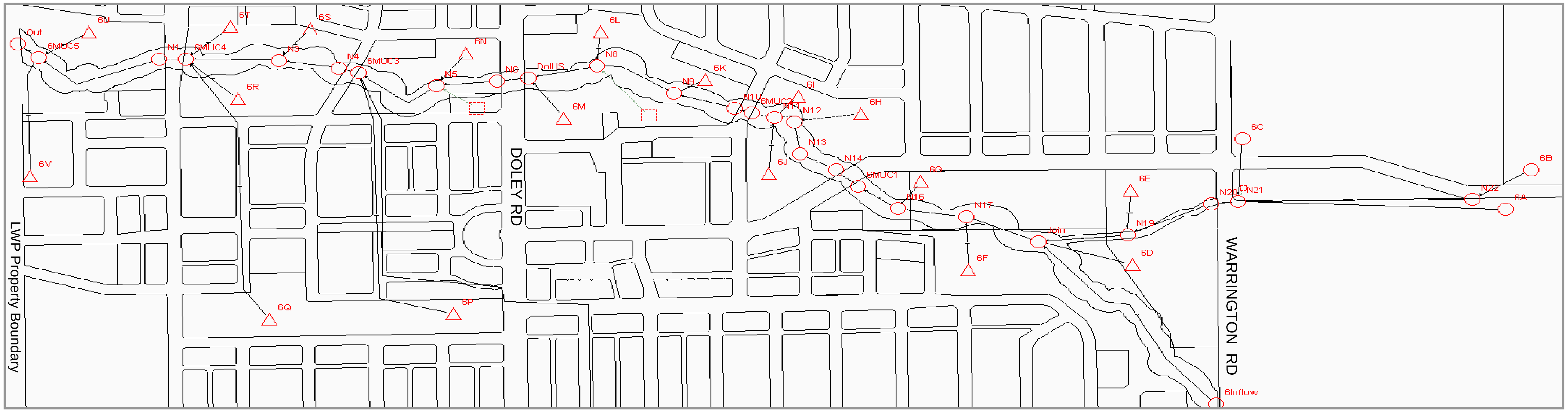
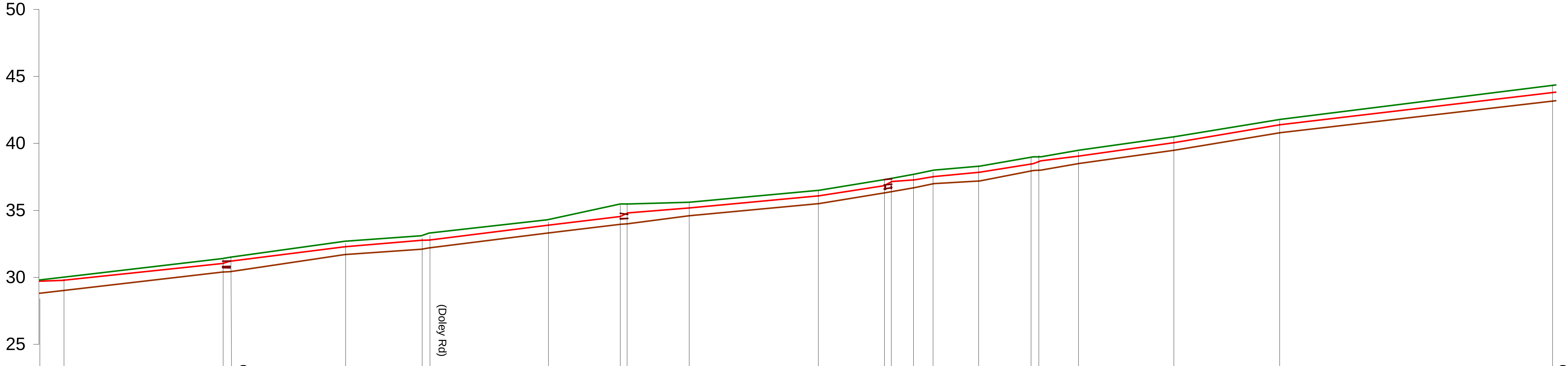
Figure 10: Proposed Tributary 6 Stormwater Management Concept





	Out	6MUC5	N	6MUC4	N3	N4	6MUC3	N5	N6	DolU	N8	N9	N10	6MUC2	N11	N12	N13	N14	6MUC1	N16	N17	Join	6Inflow
Chainage (m)	0	30	240	250	400	500	510	665	760	770	850	1020	1105	1115	1145	1170	1230	1300	1310	1360	1485	1623	1983
Ground Level (m)	29.8	30	31.4	31.5	32.7	33.1	33.3	34.3	35.5	35.5	35.6	36.5	37.3	37.4	37.	38	38.3	39	39	39.5	40.5	41.8	44.4
Maximum water Elevation (m)	29.8	31	31.2	31.2	32.3	32.8	32.8	33.9	34.8	34.8	35.2	36.1	36.8	37.1	37.3	37.5	37.8	38.5	38.7	39.1	40.1	41.4	43.8
Invert Elevation (m)	28.8	29	30.4	30.4	31.7	32.1	32.2	33.3	33.96	34	34.6	35.5	36.3	36.4	36.7	37	37.2	38	38	38.5	39.5	40.8	43.2

Maximum 100yr Flow (m^3/s)	5.68	5.3	0.14 5.18	4.81	4.74	4.75	4.37	4.29	0.14 4.1	4.01	3.88	3.84	0.1 3.71	3.82	3.53	3.42	3.42	3.42	3.33	3.18	3.03	2.29
Maximum 100yr Velocity (m/s)	0.6	0.78	2.06 0.98	0.8	0.66	1.07	0.76	0.76	2.02 1.07	0.67	0.74	0.79	1.85 1.6	0.81	0.8	0.61	0.78	3.85	0.77	0.78	0.86	0.74

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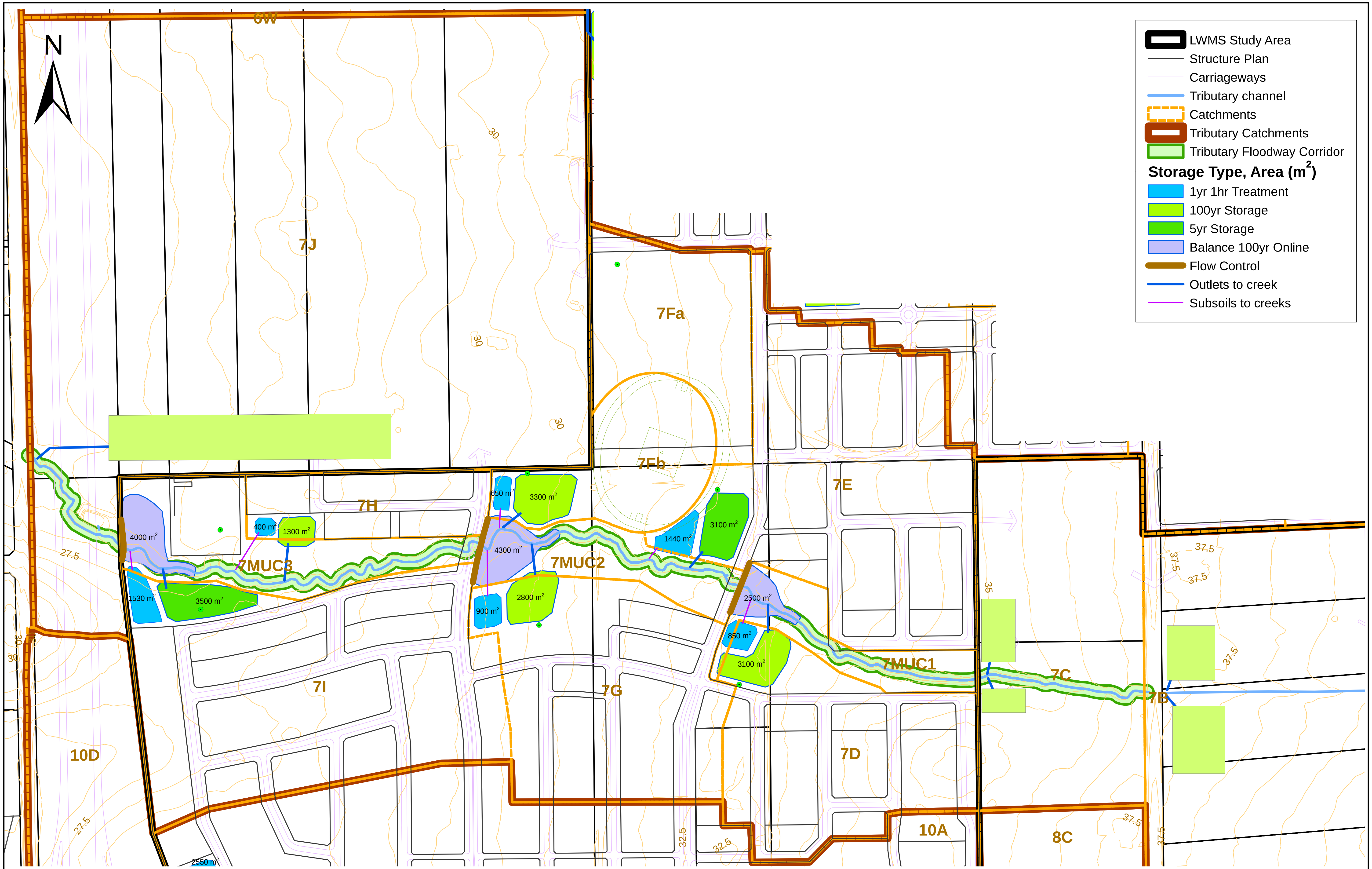
Figure 11: Tributury 6 Longsection and Hydraulic Grade Line Concept



Data Source: TBB (2009) Structure Plan & Carriageways

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Job No. J4320
Scale: 1:4,000

0 100 200 300 400 500 Meters

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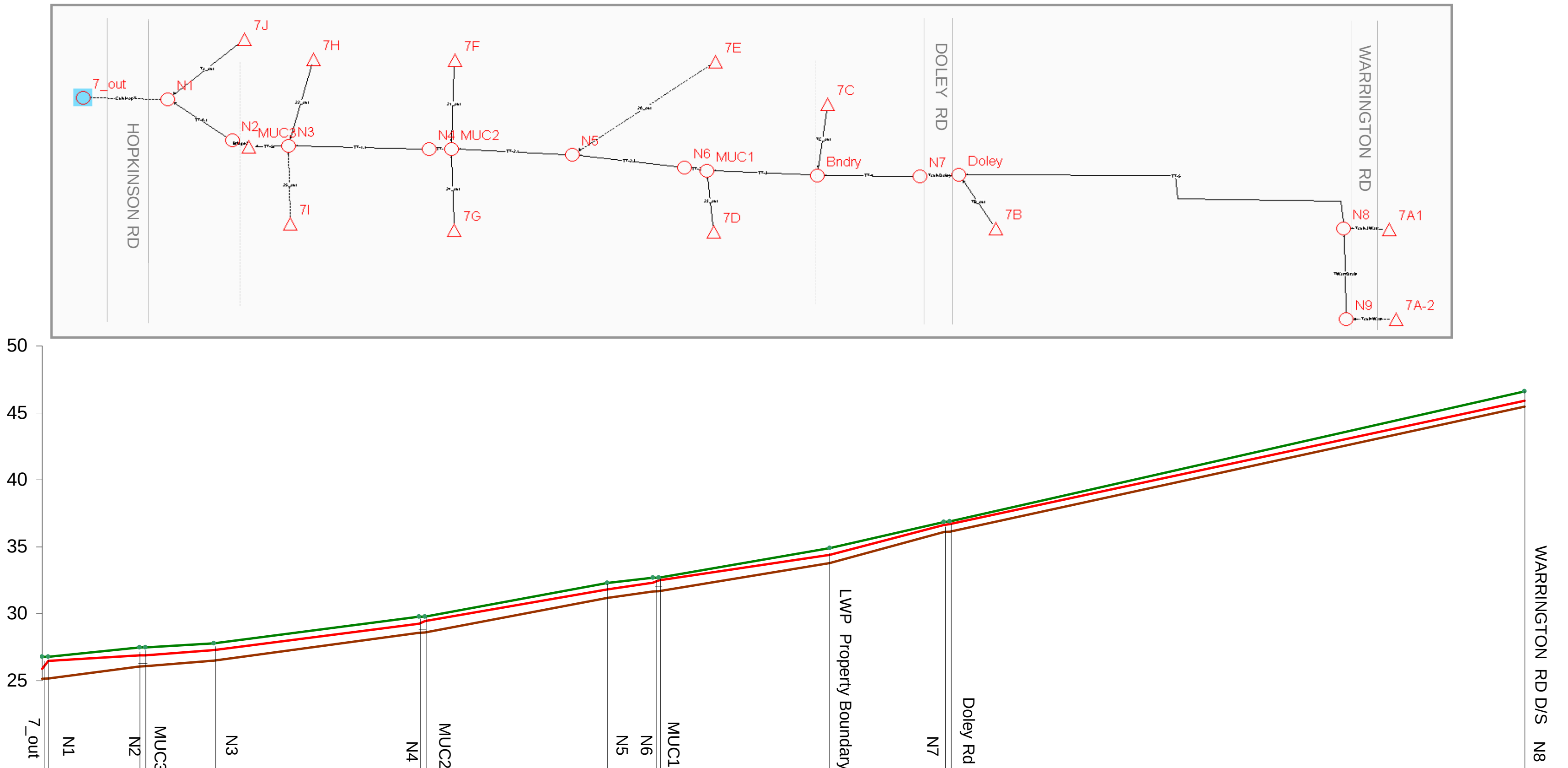
The Glades at Byford LWMS

Figure 12: Proposed Tributary 7 Stormwater Management Concept



	7_out	N1	N2	MUC3	N3	N4	MUC2	N5	N6	MUC1	LWP Property Boundary	N7	Doley Rd	WARRINGTON RD D/S N8
Chainage (m)	0	11	171	181	181	671	671	761	1071	1081	1381	1581	1591	2599
Ground Level (m)	26.8	26.8	27.5	27.5	27.8	29.8	29.8	32.3	32.7	32.7	34.9	36.85	36.9	46.2
Maximum water Elevation (m)	25.9	26.49	26.9	26.9	27.3	29.27	29.46	31.82	32.32	32.51	34.40	36.64	36.70	45.91
Invert Elevation (m)	25.15	25.18	26.08	26.1	26.5	28.58	28.6	31.2	31.68	31.7	33.8	36.11	36.14	45.47

Maximum 100yr Flow (m^3/s) OvRd 0.33 culvert: 4.09 3.58 3.59 0.11 3.52 3.2 3.07 0.15 2.86 2.64 2.51 0.13 2.47 2.27 2.27 0.84

Maximum 100yr Flow (m^3/s) 0.99 5.65 0.63 weir 1.4 0.66 0.76 weir 2.06 0.79 0.75 weir 1.8 0.73 0.88 1.4 0.66

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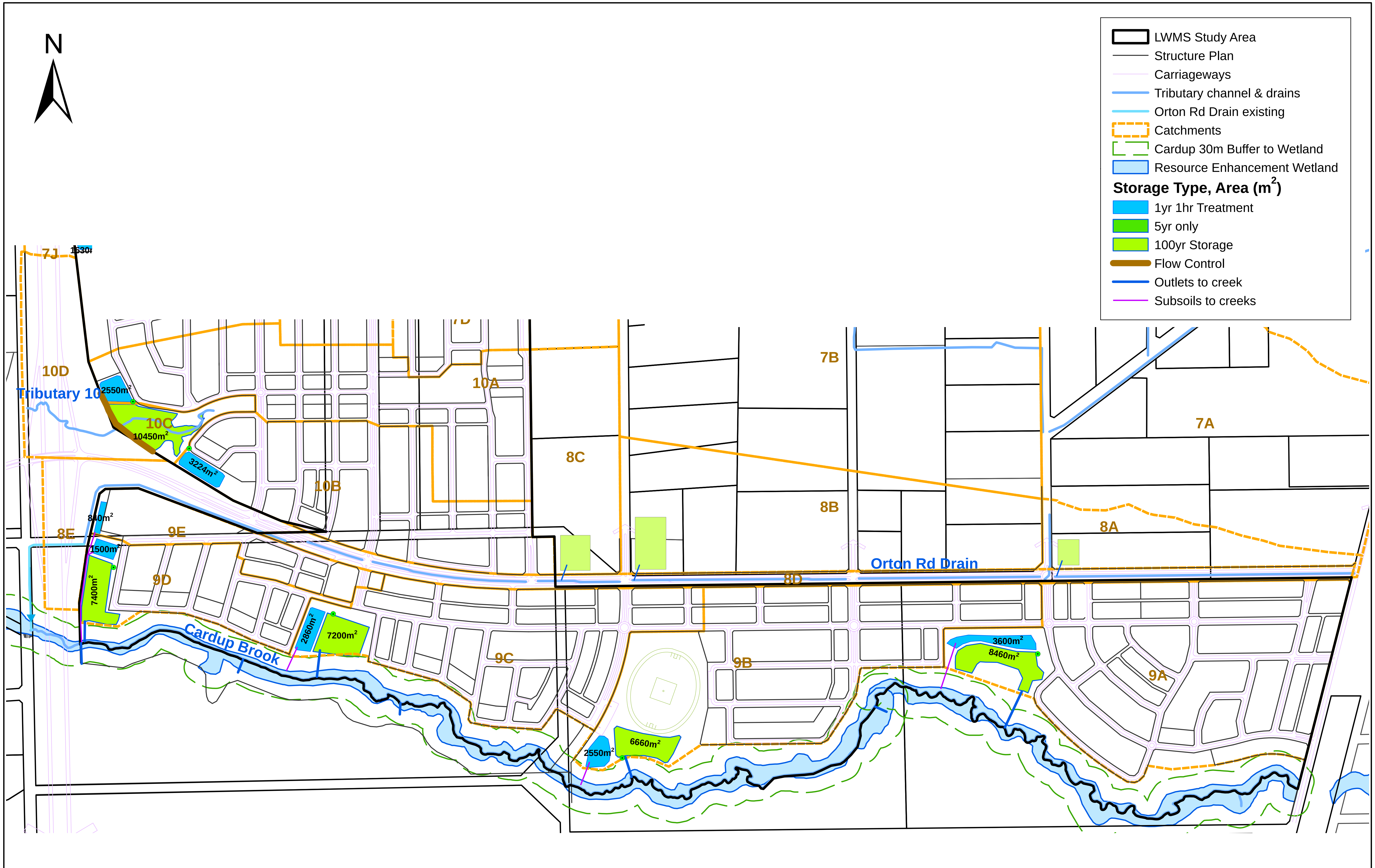
Figure 13: Tributary 7 Long Sections and Hydraulic Grade Line Concept



Data Source: TBB (2009) Structure Plan & Carriageways

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Scale: 1:7,500

0 200 400 600 800 1,000 Meters

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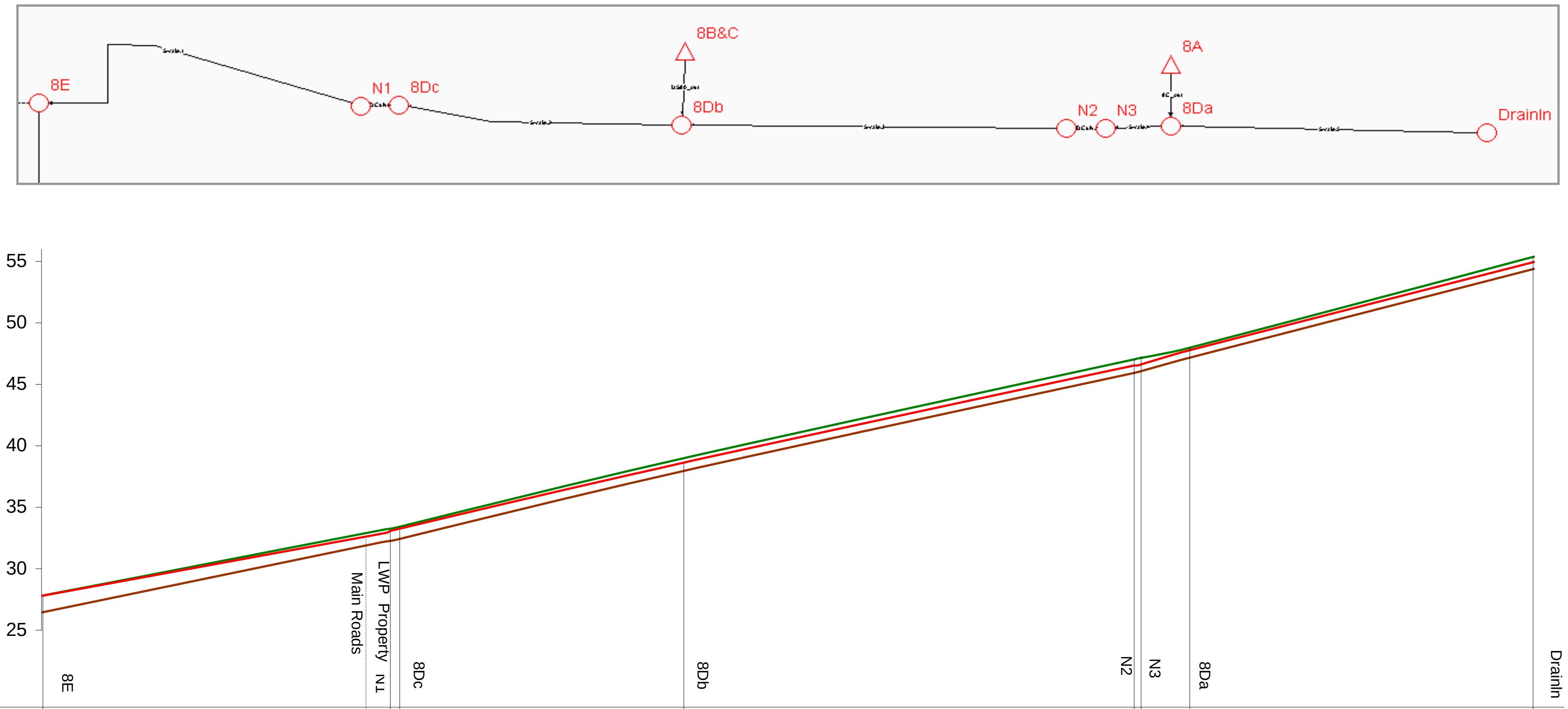
The Glades at Byford LWMS

Figure 14: Proposed Tributary 10 & Cardup Brook Stormwater Management Concept



	8E	N1	8Dc	8Db	N2	N3	8Da	DrainIn
Chainage (m)	0	660	665	1215	2065	2075	2175	2825
Ground Level (m)	27.8	33.2	33.3	39	47	47.	48	55.4
Maximum water Elevation (m)	27.8	32.91	33.12	38.63	46.51	46.53	47.8	54.96
Invert Elevation (m)	26.45	32.2	32.3	37.95	45.9	46	47.2	54.4

Maximum 100yr Flow (m^3/s)	3.2	3.2	3.18	2.34	2.34	2.34	2.0
Maximum 100yr Velocity (m^3/s)	0.92	3.3	0.98	0.89	1.81	0.96	0.92

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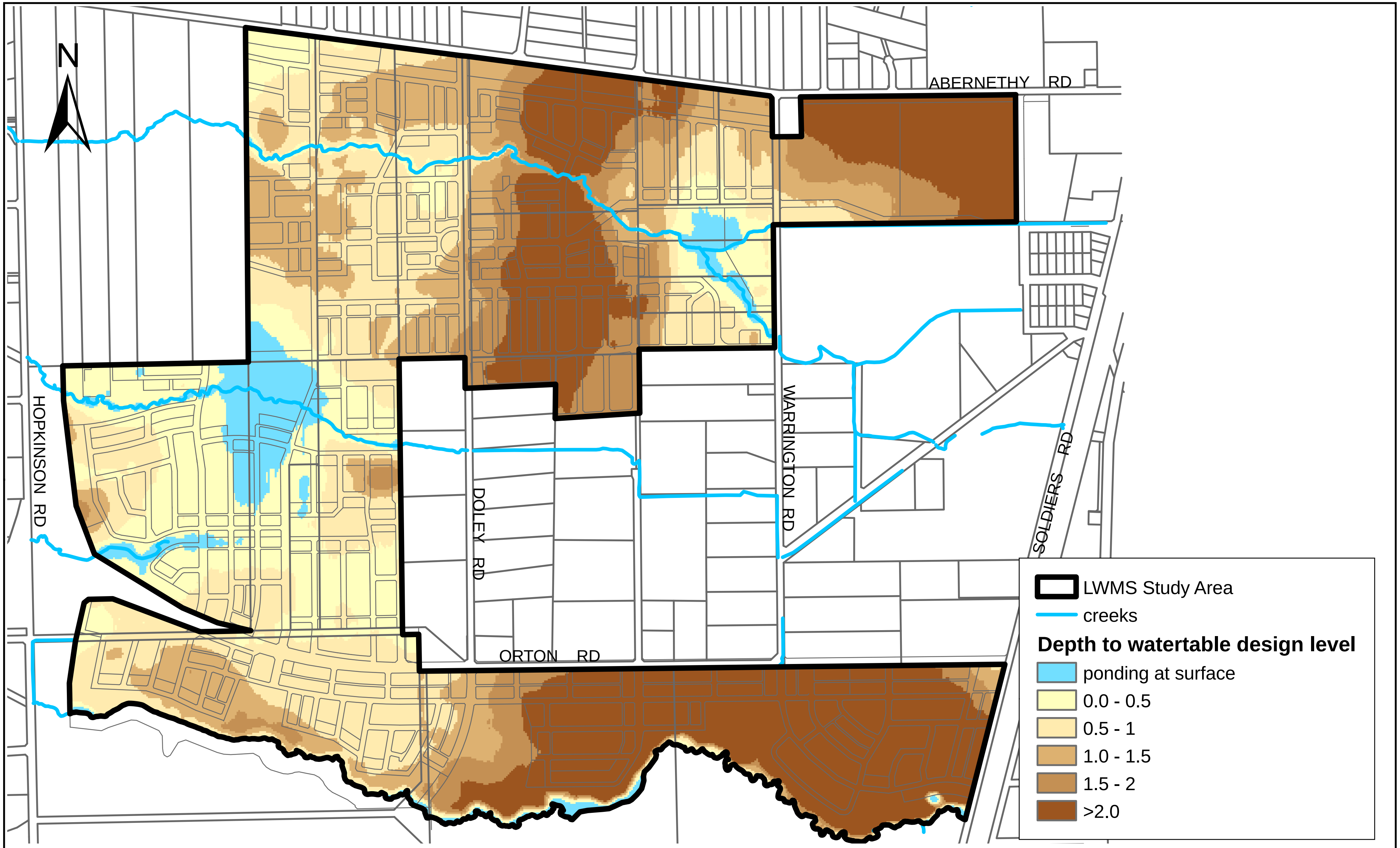
Figure 15: Orton Rd Long Sections and Hydraulic Grade Line Concept



Data Source: based on Maps (2007) Topographic 0.5 m interval Contours, and JDA estimated watertable design level

JDA Consultant Hydrologists

Job No. J4320

Scale:1:15,000

0 100 200 300 400 500 Meters

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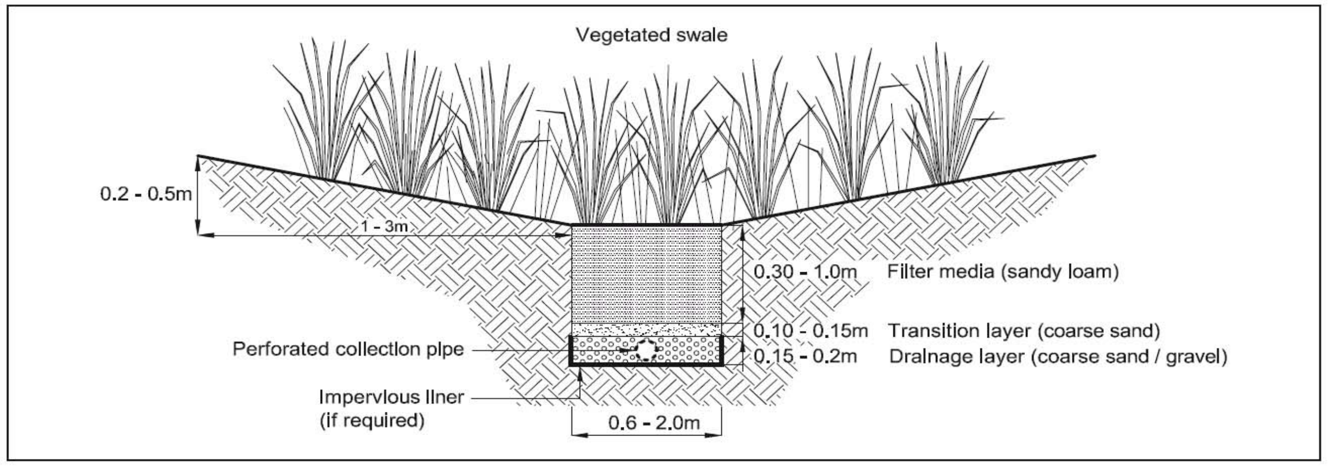
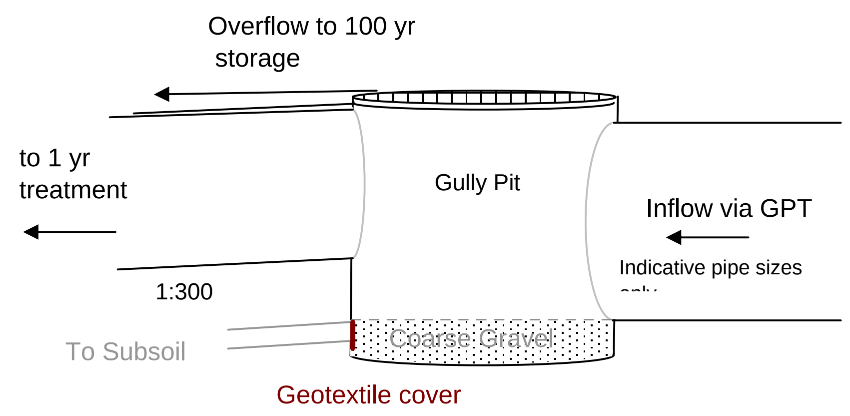
The Glades at Byford LWMS

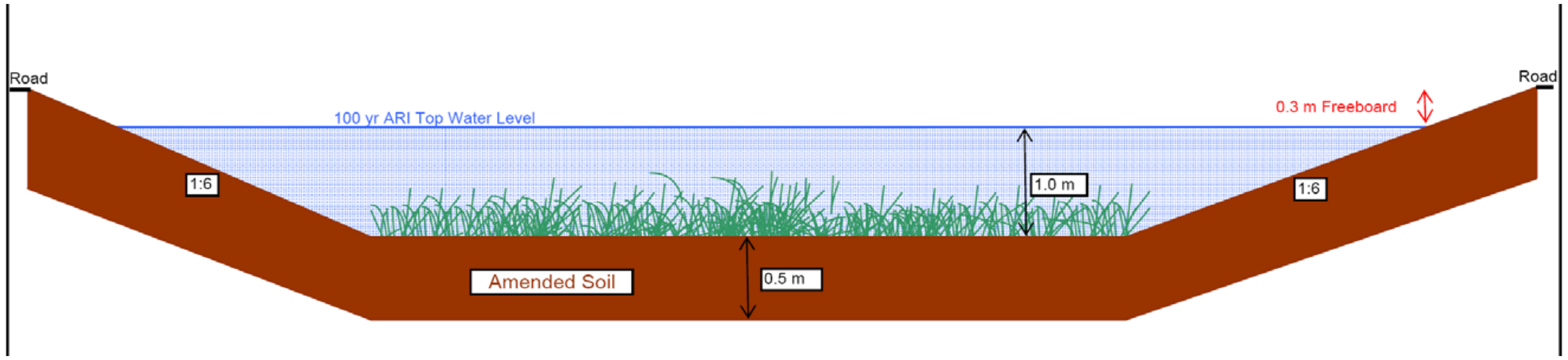
Figure 16: Depth to Groundwater Mapping



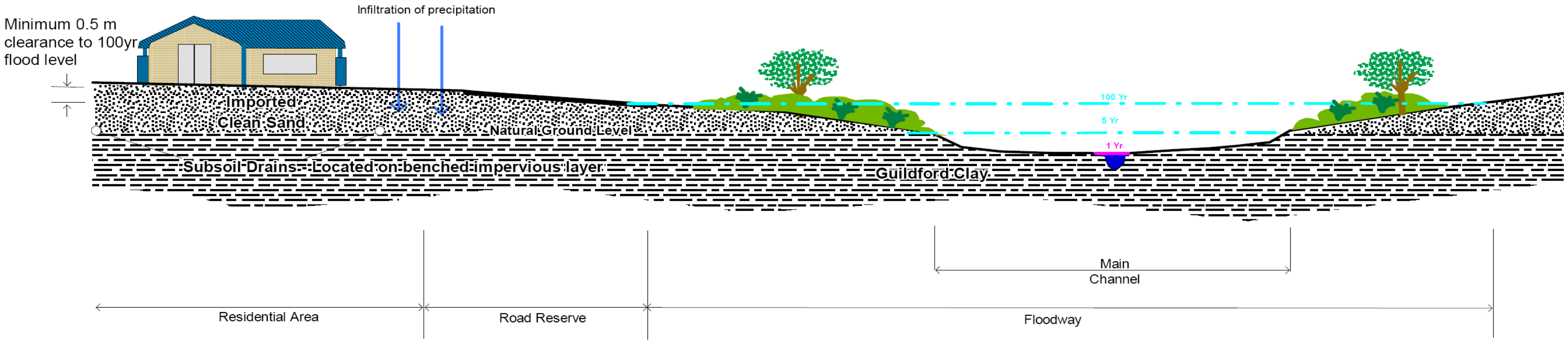
Typical bio-retention swale arrangement for impervious soils. (Source: DoW, 2007)

Diversion Structure Schematic





Example arrangement of bio-retention storage.



Indicative section of a tributary channel and floodway

Source: Byford Townsite DWMP (DoW, 2008)

Not to scale, all dimensions vary

Job No. J4320

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The Glades at Byford LWMS
Figure 17: Typical Sections for Water Management Structures

APPENDIX A

Lithological Logs

JDA Consultant Hydrologists
Suite 1, 27 York Street
Subiaco WA 6008
Tel: 9388 2436
Fax: 9381 9279

JDA Consultant Hydrologists

LITHOLOGICAL LOG

Client:	LWP Property Group	Job No:	J3690
Project:	Byford by the Glade	Hole commenced:	06/09/05
Bore location:	404522, 6434630	Hole completed:	06/09/05
Datum:	MGA94/AHD	Logged by:	SW
Bore Name:	BDM 1	Total Depth:	7.5 m BNS
Drill type:	Air Core	R.L. TOC:	35.45 m AHD
Hole diameter:	100 mm	Natural Surface:	34.88 m AHD

method	penetration 1 2 3	support	water	Slot / Screen Depth	Depth (metres)	SOIL CHARACTERISTICS					
						COLOUR	PARTICLE SIZE	TEXTURE	ORGANIC CONTENT	MOISTURE	COMMENTS
AC		PVC (Class 9)				Light grey to cream	Medium	Sand	Low	Slightly moist	
					1 m	Light grey and red	Coarse to fine	Gravelly clay			Gravel to 30 mm size
					2 m 3 m	Red	Fine			Dry	Well cemented. Gravel content decreasing with depth
				▤	4 m 5 m 6 m	Light grey to cream. Blue/grey mottling		Clay			
			▽							Moist	
					7 m					Saturated	*End of Hole*
					8 m 9 m 10 m						

NOTES ON BORELOG

COLOURS: Solid colours are BLACK, WHITE, BEIGE

		Tones : solid colour, blemish or mottle
Dark :	Brown, Red, Orange, Yellow, Grey, Blue	
Medium :	Brown, Red, Orange, Yellow, Grey, Blue	
Light :	Brown, Red, Orange, Yellow, Grey, Blue	

PARTICLE SIZE : Particles are either FINE, MEDIUM or COARSE

TEXTURE : Sand, Loamy Sand, Clayey Sand
Silt, Loam, Sandy Loam, Clay Loam
Clay, Sandy Clay

ORGANIC CONTENT: VOLUME: High, Medium, Low
SIZE: Fine, Medium, Coarse

MOISTURE: Soil Moisture can be either: DRY, SLIGHTLY MOIST, MOIST or SATURATED

STATIC WATER LEVEL

Date: ……………………………

WL below TOC ……………..……

Stickup above NS: ………….m

WL …………….. m below NS

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Fax: 9381 9279

LITHOLOGICAL LOG

Client:	LWP Property Group	Job No:	J3690
Project:	Byford by the Glade	Hole commenced:	06/09/05
Bore location:	404622, 6433850	Hole completed:	06/09/05
Datum:	MGA94/AHD	Logged by:	SW
Bore Name:	BDM 2	Total Depth:	7.0 m BNS
Drill type:	Air Core	R.L. TOC:	38.07 m AHD
Hole diameter:	100 mm	Natural Surface:	37.34 m AHD

method	penetration 1 2 3	support	water	Slot / Screen Depth	Depth (metres)	SOIL CHARACTERISTICS					
						COLOUR	PARTICLE SIZE	TEXTURE	ORGANIC CONTENT	MOISTURE	COMMENTS
AC		PVC (Class 9)				Light grey	Medium to fine	Sandy Clay	Low	Moist	
					1 m	Light brown to yellow	Fine	Clay			
					2 m						
					3 m						
					4 m						
				▤	5 m	Light grey to cream		Sandy Clay			
										Very moist	
					6 m						
			▽							Saturated	
					7 m						*End of Hole*
					8 m						
					9 m						
					10 m						

NOTES ON BORELOG

COLOURS: Solid colours are BLACK, WHITE, BEIGE

Dark :	Brown,	Red,	Orange,	Yellow,	Grey,	Blue	Tones : solid colour, blemish or mottle
Medium :	Brown,	Red,	Orange,	Yellow,	Grey,	Blue	
Light :	Brown,	Red,	Orange,	Yellow,	Grey,	Blue	

PARTICLE SIZE : Particles are either FINE, MEDIUM or COARSE

TEXTURE : Sand, Loamy Sand, Clayey Sand
Silt, Loam, Sandy Loam, Clay Loam
Clay, Sandy Clay

ORGANIC CONTENT: VOLUME: High, Medium, Low
SIZE: Fine, Medium, Coarse

MOISTURE: Soil Moisture can be either: DRY, SLIGHTLY MOIST, MOIST or SATURATED

STATIC WATER LEVEL

Date: ………………………………

WL below TOC ………………

Stickup above NS: ………….m

WL …………….. m below NS

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Tel: 9388 2436
Fax: 9381 9279

JDA Consultant Hydrologists

LITHOLOGICAL LOG

Client:	LWP Property Group	Job No:	J3690
Project:	Byford by the Glade	Hole commenced:	06/09/05
Bore location:	404834, 6432867	Hole completed:	06/09/05
Datum:	MGA94/AHD	Logged by:	SW
Bore Name:	BDM 3	Total Depth:	6.0 m BNS
Drill type:	Air Core	R.L. TOC:	42.98 m AHD
Hole diameter:	100 mm	Natural Surface:	42.38 m AHD

method	penetration 1 2 3	support	water	Slot / Screen Depth	Depth (metres)	SOIL CHARACTERISTICS COLOUR	PARTICLE SIZE	TEXTURE	ORGANIC CONTENT	MOISTURE	COMMENTS
AC		PVC (Class 9)				Light grey to cream	Medium	Sand	Low	Slightly moist	
					1 m	Light grey to yellow	Medium to fine	Clayey Sand		Moist	
					2 m	Light brown to yellow	Coarse to fine	Gravelly clay			
				▤	3 m 4 m	Orange	Fine	Clay			
			∇	▤	5 m	Yellow	Fine	Sandy clay		Very moist Saturated	*End of Hole*
					6 m 7 m 8 m 9 m 10 m						

NOTES ON BORELOG

COLOURS: Solid colours are BLACK, WHITE, BEIGE

Dark :	Brown, Red, Orange, Yellow, Grey, Blue	Tones : solid colour, blemish or mottle
Medium :	Brown, Red, Orange, Yellow, Grey, Blue	
Light :	Brown, Red, Orange, Yellow, Grey, Blue	

PARTICLE SIZE : Particles are either FINE, MEDIUM or COARSE

TEXTURE : Sand, Loamy Sand, Clayey Sand
Silt, Loam, Sandy Loam, Clay Loam
Clay, Sandy Clay

ORGANIC CONTENT: VOLUME: High, Medium, Low
SIZE: Fine, Medium, Coarse

MOISTURE: Soil Moisture can be either: DRY, SLIGHTLY MOIST, MOIST or SATURATED

STATIC WATER LEVEL

Date: ……………………………

WL below TOC ……………..…

Stickup above NS: ………….m

WL …………….. m below NS

JDA Consultant Hydrologists

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LITHOLOGICAL LOG

Client:	LWP Property Group	Job No:	J3690
Project:	Byford by the Glade	Hole commenced:	06/09/05
Bore location:	406320, 6434804	Hole completed:	06/09/05
Datum:	MGA94/AHD	Logged by:	SW
Bore Name:	BDM 4	Total Depth:	8.5 m BNS
Drill type:	Air Core	R.L. TOC:	52.84 m AHD
Hole diameter:	100 mm	Natural Surface:	52.17 m AHD

	1 2 3					SOIL CHARACTERISTICS					
method	penetration	**support**	**water**	**Slot / Screen Depth**	**Depth (metres)**	**COLOUR**	**PARTICLE SIZE**	**TEXTURE**	**ORGANIC CONTENT**	**MOISTURE**	**COMMENTS**
AC		PVC (Class 9)			1 m	Light brown	Medium to fine	Sandy clay	Low	Slightly moist	
					2 m	Yellow/Orange	Coarse to fine	Gravelly clay			
						Dark Orange					
					3 m	Very hard laterite layer					
					4 m	Red	Coarse to fine	Gravelly clay	Low	Dry	Well cemented
					5 m 6 m		Fine	Clay			
				▤	7 m	Light grey to cream with grey/blue mottling				Moist	Stiff clay
			▽	▤	8 m					Saturated	*End of hole*
					9 m 10 m						

NOTES ON BORELOG

COLOURS: Solid colours are BLACK, WHITE, BEIGE

Dark :	Brown,	Red,	Orange,	Yellow,	Grey,	Blue
Medium :	Brown,	Red,	Orange,	Yellow,	Grey,	Blue
Light :	Brown,	Red,	Orange,	Yellow,	Grey,	Blue

Tones : solid colour, blemish or mottle

PARTICLE SIZE : Particles are either FINE, MEDIUM or COARSE

TEXTURE :
Sand, Loamy Sand, Clayey Sand
Silt, Loam, Sandy Loam, Clay Loam
Clay, Sandy Clay

ORGANIC CONTENT:
VOLUME: High, Medium, Low
SIZE: Fine, Medium, Coarse

MOISTURE: Soil Moisture can be either: DRY, SLIGHTLY MOIST, MOIST or SATURATED

STATIC WATER LEVEL

Date: ……………………………

WL below TOC ……………..….

Stickup above NS: ………….m

WL …………….. m below NS

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LITHOLOGICAL LOG

Client:	LWP Property Group	Job No:	J3690
Project:	Byford by the Glade	Hole commenced:	07/09/05
Bore location:	403901, 6432972	Hole completed:	07/09/05
Datum:	MGA94/AHD	Logged by:	SW
Bore Name:	BDM 5	Total Depth:	5.5 m BNS
Drill type:	Air Core	R.L. TOC:	32.63 m AHD
Hole diameter:	100 mm	Natural Surface:	31.97 m AHD

method	penetration 1 2 3	support	water	Slot / Screen Depth	Depth (metres)	SOIL CHARACTERISTICS COLOUR	PARTICLE SIZE	TEXTURE	ORGANIC CONTENT	MOISTURE	COMMENTS
AC		PVC (Class 9)				Grey	Fine	Sandy silty clay	Medium	Very moist	
						Cream		Sandy clay	Low	Saturated	
			▽		1 m	Red/Orange				Moist	
					2 m	Orange to yellow	Coarse to fine	Gravelly clay		Saturated	Ironstone and feldspar gravel 3 mm size
					3 m	Yellow	Fine	Clay			
				▤	4 m	Red with white peds					
				▤	5 m	White with blue/grey mottling					*End of Hole*
					6 m 7 m 8 m 9 m 10 m						

NOTES ON BORELOG

COLOURS: Solid colours are BLACK, WHITE, BEIGE

Dark :	Brown, Red, Orange, Yellow, Grey, Blue	Tones : solid colour, blemish or mottle
Medium :	Brown, Red, Orange, Yellow, Grey, Blue	
Light :	Brown, Red, Orange, Yellow, Grey, Blue	

PARTICLE SIZE : Particles are either FINE, MEDIUM or COARSE

TEXTURE : Sand, Loamy Sand, Clayey Sand
Silt, Loam, Sandy Loam, Clay Loam
Clay, Sandy Clay

ORGANIC CONTENT: VOLUME: High, Medium, Low
SIZE: Fine, Medium, Coarse

MOISTURE: Soil Moisture can be either: DRY, SLIGHTLY MOIST, MOIST or SATURATED

STATIC WATER LEVEL

Date: ……………………………

WL below TOC ……………..……

Stickup above NS: ………….m

WL …………….. m below NS

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LITHOLOGICAL LOG

Client:	LWP Property Group	Job No:	J3690
Project:	Byford by the Glade	Hole commenced:	07/09/05
Bore location:	403449, 6432502	Hole completed:	07/09/05
Datum:	MGA94/AHD	Logged by:	SW
Bore Name:	BDM 6	Total Depth:	5.0 m BNS
Drill type:	Air Core	R.L. TOC:	29.63 m AHD
Hole diameter:	100 mm	Natural Surface:	29.12 m AHD

method	penetration 1 2 3	support	water	Slot / Screen Depth	Depth (metres)	COLOUR	PARTICLE SIZE	TEXTURE	ORGANIC CONTENT	MOISTURE	COMMENTS
						SOIL CHARACTERISTICS					
AC		PVC (Class 9)				Dark brown	Medium to fine	Sandy clay	Low	Moist	
			▽		1 m	Yellow	Fine	Clay			
							Coarse to fine	Gravelly clay		Saturated	
				▤	2 m 3 m		Fine	Clay			
				▤	4 m	Yellow to light brown	Coarse to fine	Gravelly clay			Ironstone gravel 3 mm size
				▤	5 m	Cream with blue/grey mottling	Medium to fine	Sandy clay			*End of Hole*
					6 m 7 m 8 m 9 m 10 m						

NOTES ON BORELOG

COLOURS: Solid colours are BLACK, WHITE, BEIGE

Dark :	Brown, Red, Orange, Yellow, Grey, Blue	Tones : solid colour, blemish or mottle
Medium :	Brown, Red, Orange, Yellow, Grey, Blue	
Light :	Brown, Red, Orange, Yellow, Grey, Blue	

PARTICLE SIZE : Particles are either FINE, MEDIUM or COARSE

TEXTURE : Sand, Loamy Sand, Clayey Sand
Silt, Loam, Sandy Loam, Clay Loam
Clay, Sandy Clay

ORGANIC CONTENT: VOLUME: High, Medium, Low
SIZE: Fine, Medium, Coarse

MOISTURE: Soil Moisture can be either: DRY, SLIGHTLY MOIST, MOIST or SATURATED

STATIC WATER LEVEL

Date: ……………………………

WL below TOC ……………..…

Stickup above NS: ………….m

WL …………….. m below NS

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LITHOLOGICAL LOG

Client:	LWP Property Group	Job No:	J3690
Project:	Byford by the Glade	Hole commenced:	07/09/05
Bore location:	404080, 6433782	Hole completed:	07/09/05
Datum:	MGA94/AHD	Logged by:	SW
Bore Name:	BDM 7	Total Depth:	5.0 m BNS
Drill type:	Air Core	R.L. TOC:	33.38 m AHD
Hole diameter:	100 mm	Natural Surface:	32.73 m AHD

method	penetration 1 2 3	**support**	**water**	**Slot / Screen Depth**	**Depth (metres)**
AC		PVC (Class 9)			
					1 m
					2 m
			▽		
				▤	3 m
				▤	4 m
				▤	5 m
					6 m
					7 m
					8 m
					9 m
					10 m

SOIL CHARACTERISTICS

COLOUR	**PARTICLE SIZE**	**TEXTURE**	**ORGANIC CONTENT**	**MOISTURE**	**COMMENTS**
Cream	Medium to fine	Loamy sand	Medium	Moist	
		Sandy clay	Low		
		Gravelly clay			
Yellow to light brown	Coarse to fine				Well cemented. Ironstone anfd feldspar gravel
Pink/Red				Saturated	
Cream with blue/grey mottling	Fine	Clay			*End of Hole*

NOTES ON BORELOG

COLOURS: Solid colours are BLACK, WHITE, BEIGE

Dark :	Brown,	Red,	Orange,	Yellow,	Grey,	Blue	Tones : solid colour, blemish or mottle
Medium :	Brown,	Red,	Orange,	Yellow,	Grey,	Blue	
Light :	Brown,	Red,	Orange,	Yellow,	Grey,	Blue	

PARTICLE SIZE : Particles are either FINE, MEDIUM or COARSE

TEXTURE : Sand, Loamy Sand, Clayey Sand
Silt, Loam, Sandy Loam, Clay Loam
Clay, Sandy Clay

ORGANIC CONTENT: VOLUME: High, Medium, Low
SIZE: Fine, Medium, Coarse

MOISTURE: Soil Moisture can be either: DRY, SLIGHTLY MOIST, MOIST or SATURATED

STATIC WATER LEVEL

Date: ……………………………

WL below TOC ………….……

Stickup above NS: ………….m

WL …………….. m below NS

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LITHOLOGICAL LOG

Client:	LWP Property Group	Job No:	J3690
Project:	Byford by the Glade	Hole commenced:	07/09/05
Bore location:	403890, 6434716	Hole completed:	07/09/05
Datum:	MGA94/AHD	Logged by:	SW
Bore Name:	BDM 8	Total Depth:	5.5 m BNS
Drill type:	Air Core	R.L. TOC:	31.30 m AHD
Hole diameter:	100 mm	Natural Surface:	30.62 m AHD

method	penetration 1 2 3	support	water	Slot / Screen Depth	Depth (metres)	COLOUR	PARTICLE SIZE	TEXTURE	ORGANIC CONTENT	MOISTURE	COMMENTS
						SOIL CHARACTERISTICS					
AC						Grey	Medium to fine	Clayey sand	Low	Moist	
		PVC (Class 9)	▽		1 m 2 m	Cream	Coarse to fine	Gravelly clay			Ironstone and feldspar gravel
				▤	3 m 4 m	Pink/Red				Saturated	
				▤		Red with grey blue mottling	Fine	Clay			
				▤	5 m	Cream to light grey with grey/blue mottling					*End of Hole*
					6 m 7 m 8 m 9 m 10 m						

NOTES ON BORELOG

COLOURS: Solid colours are BLACK, WHITE, BEIGE

Dark :	Brown,	Red,	Orange,	Yellow,	Grey,	Blue	Tones : solid colour, blemish or mottle
Medium :	Brown,	Red,	Orange,	Yellow,	Grey,	Blue	
Light :	Brown,	Red,	Orange,	Yellow,	Grey,	Blue	

PARTICLE SIZE : Particles are either FINE, MEDIUM or COARSE

TEXTURE : Sand, Loamy Sand, Clayey Sand
Silt, Loam, Sandy Loam, Clay Loam
Clay, Sandy Clay

ORGANIC CONTENT: VOLUME: High, Medium, Low
SIZE: Fine, Medium, Coarse

MOISTURE: Soil Moisture can be either: DRY, SLIGHTLY MOIST, MOIST or SATURATED

STATIC WATER LEVEL

Date: ……………………………

WL below TOC ……………..……

Stickup above NS: ………….m

WL …………….. m below NS

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LITHOLOGICAL LOG

Client:	LWP Property Group	Job No:	J3690
Project:	Byford by the Glade	Hole commenced:	07/09/05
Bore location:	405218, 6434087	Hole completed:	07/09/05
Datum:	MGA94/AHD	Logged by:	SW
Bore Name:	BDM 9	Total Depth:	5.5 m BNS
Drill type:	Air Core	R.L. TOC:	42.72 m AHD
Hole diameter:	100 mm	Natural Surface:	42.06 m AHD

method: AC

penetration 1 2 3

support: PVC (Class 9)

water: ▽

Slot / Screen Depth: ▤

Depth (metres): 1 m, 2 m, 3 m, 4 m, 5 m, 6 m, 7 m, 8 m, 9 m, 10 m

SOIL CHARACTERISTICS

COLOUR	PARTICLE SIZE	TEXTURE	ORGANIC CONTENT	MOISTURE	COMMENTS
Light brown to grey	Coarse to fine	Gravelly clay	Low	Very moist	
Red				Slightly moist	
				Moist	
Cream with grey/blue mottling	Fine	Clay		Saturated	*End of Hole*

NOTES ON BORELOG

COLOURS: Solid colours are BLACK, WHITE, BEIGE

Dark :	Brown,	Red,	Orange,	Yellow,	Grey,	Blue	Tones : solid colour, blemish or mottle
Medium :	Brown,	Red,	Orange,	Yellow,	Grey,	Blue	
Light :	Brown,	Red,	Orange,	Yellow,	Grey,	Blue	

PARTICLE SIZE : Particles are either FINE, MEDIUM or COARSE

TEXTURE : Sand, Loamy Sand, Clayey Sand
Silt, Loam, Sandy Loam, Clay Loam
Clay, Sandy Clay

ORGANIC CONTENT: VOLUME: High, Medium, Low
SIZE: Fine, Medium, Coarse

MOISTURE: Soil Moisture can be either: DRY, SLIGHTLY MOIST, MOIST or SATURATED

STATIC WATER LEVEL

Date: ……………………………

WL below TOC ………………

Stickup above NS: …………m

WL …………….. m below NS

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LITHOLOGICAL LOG

Client: LWP Property Group
Project: Byford by the Glade
Bore location: 405400, 6433458
Datum: MGA94/AHD

Job No: J3690
Hole commenced: 08/09/05
Hole completed: 08/09/05
Logged by: SW

Bore Name: BDM 10
Drill type: Air Core
Hole diameter: 100 mm

Total Depth: 6.0 m BNS
R.L. TOC: 47.00 m AHD
Natural Surface: 47.00 m AHD

method: AC
penetration: 1 2 3
support: PVC (Class 9)
water: ∇
Slot / Screen Depth
Depth (metres): 1 m, 2 m, 3 m, 4 m, 5 m, 6 m, 7 m, 8 m, 9 m, 10 m

SOIL CHARACTERISTICS

COLOUR	PARTICLE SIZE	TEXTURE	ORGANIC CONTENT	MOISTURE	COMMENTS
Yellow	Medium to fine	Sand	Low	Moist	
	Coarse to fine	Gravelly sand			Gravel to 5 mm size
Yellow to light brown		Gravelly sandy clay			Ironstone and feldspar gravel
Red with mix of red/yellow and grey/blue mottling				Saturated	
Light brown with grey/blue mottling	Fine	Clay			*End of Hole*

NOTES ON BORELOG

COLOURS: Solid colours are BLACK, WHITE, BEIGE

Dark :	Brown, Red, Orange, Yellow, Grey, Blue	Tones : solid colour, blemish or mottle
Medium :	Brown, Red, Orange, Yellow, Grey, Blue	
Light :	Brown, Red, Orange, Yellow, Grey, Blue	

PARTICLE SIZE : Particles are either FINE, MEDIUM or COARSE

TEXTURE : Sand, Loamy Sand, Clayey Sand
Silt, Loam, Sandy Loam, Clay Loam
Clay, Sandy Clay

ORGANIC CONTENT: VOLUME: High, Medium, Low
SIZE: Fine, Medium, Coarse

MOISTURE: Soil Moisture can be either: DRY, SLIGHTLY MOIST, MOIST or SATURATED

STATIC WATER LEVEL

Date: ……………………………

WL below TOC ……………..…

Stickup above NS: ………….m

WL …………….. m below NS

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LITHOLOGICAL LOG

Client:	LWP Property Group	Job No:	J3690
Project:	Byford by the Glade	Hole commenced:	08/09/05
Bore location:	405008, 6433362	Hole completed:	08/09/05
Datum:	MGA94/AHD	Logged by:	SW
Bore Name:	BDM 11	Total Depth:	6.0 m BNS
Drill type:	Air Core	R.L. TOC:	41.88 m AHD
Hole diameter:	100 mm	Natural Surface:	41.88 m AHD

method	penetration 1 2 3	support	water	Slot / Screen Depth	Depth (metres)	SOIL CHARACTERISTICS					
						COLOUR	PARTICLE SIZE	TEXTURE	ORGANIC CONTENT	MOISTURE	COMMENTS
AC		PVC (Class 9)				Cream	Medium to fine	Sandy clay	Low	Moist	
			▽		1 m 2 m 3 m	Light brown	Coarse to fine	Gravelly clay			Very gravelly 2.5 to 3.0m depth
				▤	4 m 5 m	Orange	Fine	Clay		Saturated	
				▤	6 m	Red with grey blue mottling					Stiff clay *End of Hole*
					7 m 8 m 9 m 10 m						

NOTES ON BORELOG

COLOURS: Solid colours are BLACK, WHITE, BEIGE

Dark :	Brown, Red, Orange, Yellow, Grey, Blue	Tones : solid colour, blemish or mottle
Medium :	Brown, Red, Orange, Yellow, Grey, Blue	
Light :	Brown, Red, Orange, Yellow, Grey, Blue	

PARTICLE SIZE : Particles are either FINE, MEDIUM or COARSE

TEXTURE : Sand, Loamy Sand, Clayey Sand
Silt, Loam, Sandy Loam, Clay Loam
Clay, Sandy Clay

ORGANIC CONTENT: VOLUME: High, Medium, Low
SIZE: Fine, Medium, Coarse

MOISTURE: Soil Moisture can be either: DRY, SLIGHTLY MOIST, MOIST or SATURATED

STATIC WATER LEVEL

Date: ……………………………

WL below TOC ………….……

Stickup above NS: ………….m

WL …………….. m below NS

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LITHOLOGICAL LOG

Client:	LWP Property Group	Job No:	J3690
Project:	Byford by the Glade	Hole commenced:	08/09/05
Bore location:	406254, 6433850	Hole completed:	08/09/05
Datum:	MGA94/AHD	Logged by:	SW
Bore Name:	BDM 12	Total Depth:	7.5 m BNS
Drill type:	Air Core	R.L. TOC:	56.06 m AHD
Hole diameter:	100 mm	Natural Surface:	56.07 m AHD

method	penetration 1 2 3	support	water	Slot / Screen Depth	Depth (metres)	SOIL CHARACTERISTICS					
						COLOUR	PARTICLE SIZE	TEXTURE	ORGANIC CONTENT	MOISTURE	COMMENTS
AC		PVC (Class 9)				Grey	Medium to Fine	Clayey sand	Low	Moist	
					1 m 2 m 3 m	Light brown to yellow	Coarse to fine	Gravelly clay			Ironstone and feldspars gravel < 3 mm
					4 m	Light grey to cream					
				▤	5 m	Green claystone with feldspar grains					
			▽	▤	6 m 7 m	Olive with grey blue clay mottling	Coarse to fine	Gravelly clay	Low	Saturated	*End of Hole*
					8 m 9 m 10 m						

NOTES ON BORELOG

COLOURS: Solid colours are BLACK, WHITE, BEIGE

Dark :	Brown, Red, Orange, Yellow, Grey, Blue	Tones : solid colour, blemish or mottle
Medium :	Brown, Red, Orange, Yellow, Grey, Blue	
Light :	Brown, Red, Orange, Yellow, Grey, Blue	

PARTICLE SIZE : Particles are either FINE, MEDIUM or COARSE

TEXTURE : Sand, Loamy Sand, Clayey Sand
Silt, Loam, Sandy Loam, Clay Loam
Clay, Sandy Clay

ORGANIC CONTENT: VOLUME: High, Medium, Low
SIZE: Fine, Medium, Coarse

MOISTURE: Soil Moisture can be either: DRY, SLIGHTLY MOIST, MOIST or SATURATED

STATIC WATER LEVEL

Date: ……………………………

WL below TOC ……………..…

Stickup above NS: ………….m

WL …………….. m below NS

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LITHOLOGICAL LOG

Client:	LWP Property Group	Job No:	J3690
Project:	Byford by the Glade	Hole commenced:	08/09/05
Bore location:	405380, 6432373	Hole completed:	08/09/05
Datum:	MGA94/AHD	Logged by:	SW
Bore Name:	BDM 13	Total Depth:	9.0 m BNS
Drill type:	Air Core	R.L. TOC:	51.57 m AHD
Hole diameter:	100 mm	Natural Surface:	50.88 m AHD

method	penetration 1 2 3	support	water	Slot / Screen Depth	Depth (metres)	SOIL CHARACTERISTICS COLOUR	PARTICLE SIZE	TEXTURE	ORGANIC CONTENT	MOISTURE	COMMENTS
AC		PVC (Class 9)			1 m 2 m	Yellow	Medium	Sand	Low	Moist	
					3 m 4 m 5 m	Light brown	Coarse to fine	Gravelly clay			
					6 m	Red with white mottling	Fine	Clay		Dry	
					7 m	Pink	Coarse to fine	Gravelly clay		Moist	Feldspar gravel <1 mm
						Red with grey mottling	Fine	Clay		Dry	Very stiff clay
			▽		8 m					Moist	
					9 m					Saturated	*End of Hole*
					10 m						

NOTES ON BORELOG

COLOURS: Solid colours are BLACK, WHITE, BEIGE

Dark :	Brown, Red, Orange, Yellow, Grey, Blue	Tones : solid colour, blemish or mottle
Medium :	Brown, Red, Orange, Yellow, Grey, Blue	
Light :	Brown, Red, Orange, Yellow, Grey, Blue	

PARTICLE SIZE : Particles are either FINE, MEDIUM or COARSE

TEXTURE : Sand, Loamy Sand, Clayey Sand
Silt, Loam, Sandy Loam, Clay Loam
Clay, Sandy Clay

ORGANIC CONTENT: VOLUME: High, Medium, Low
SIZE: Fine, Medium, Coarse

MOISTURE: Soil Moisture can be either: DRY, SLIGHTLY MOIST, MOIST or SATURATED

STATIC WATER LEVEL

Date: ……………………………

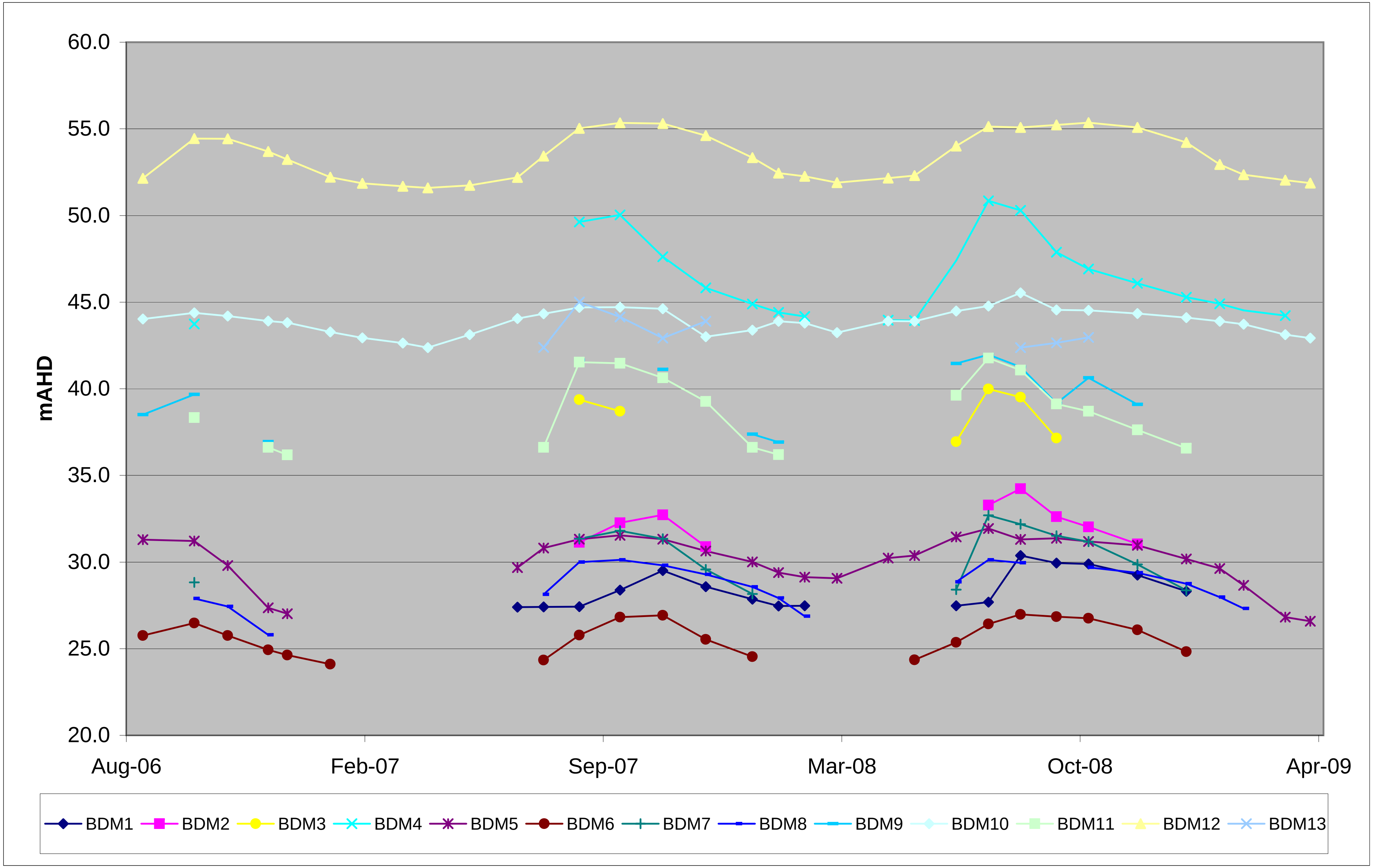
WL below TOC ………………

Stickup above NS: ………….m

WL …………….. m below NS

APPENDIX B

Groundwater Monitoring Bore Hydrographs and Nutrient Concentrations



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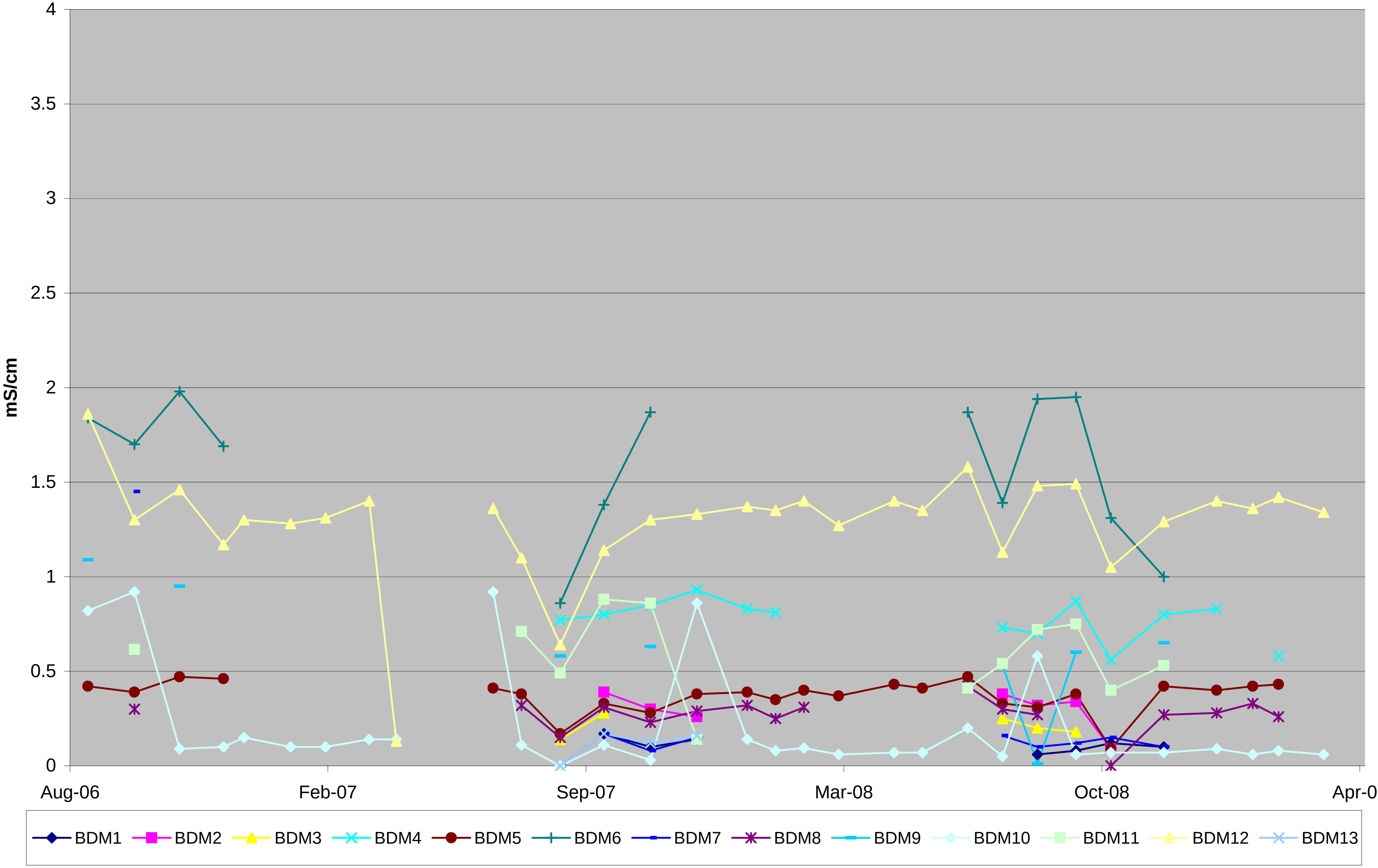
Appendix B1: Time Series Plot of water levels in JDA Bores



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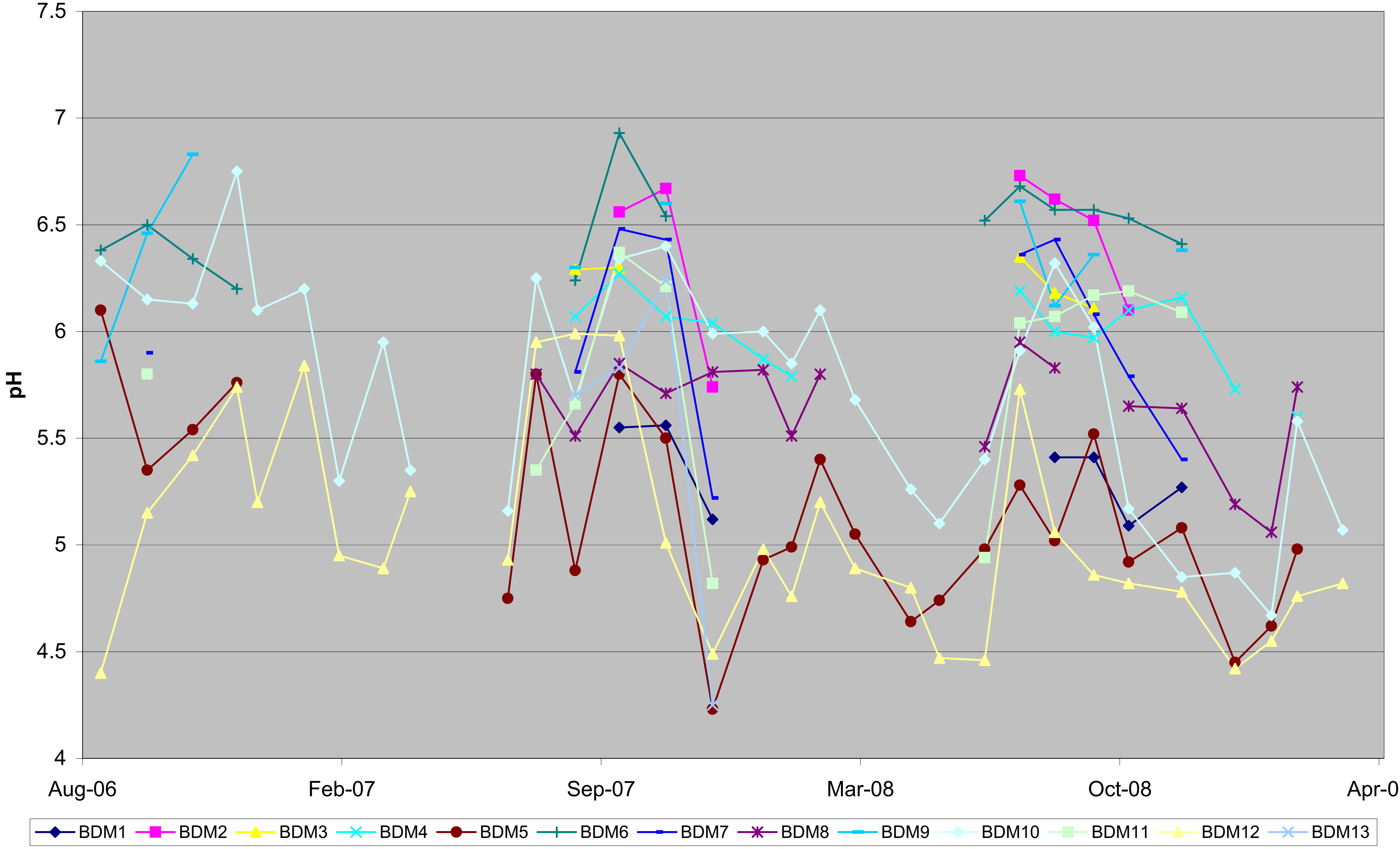
Appendix B2: Electrical Conductivity for JDA Bores



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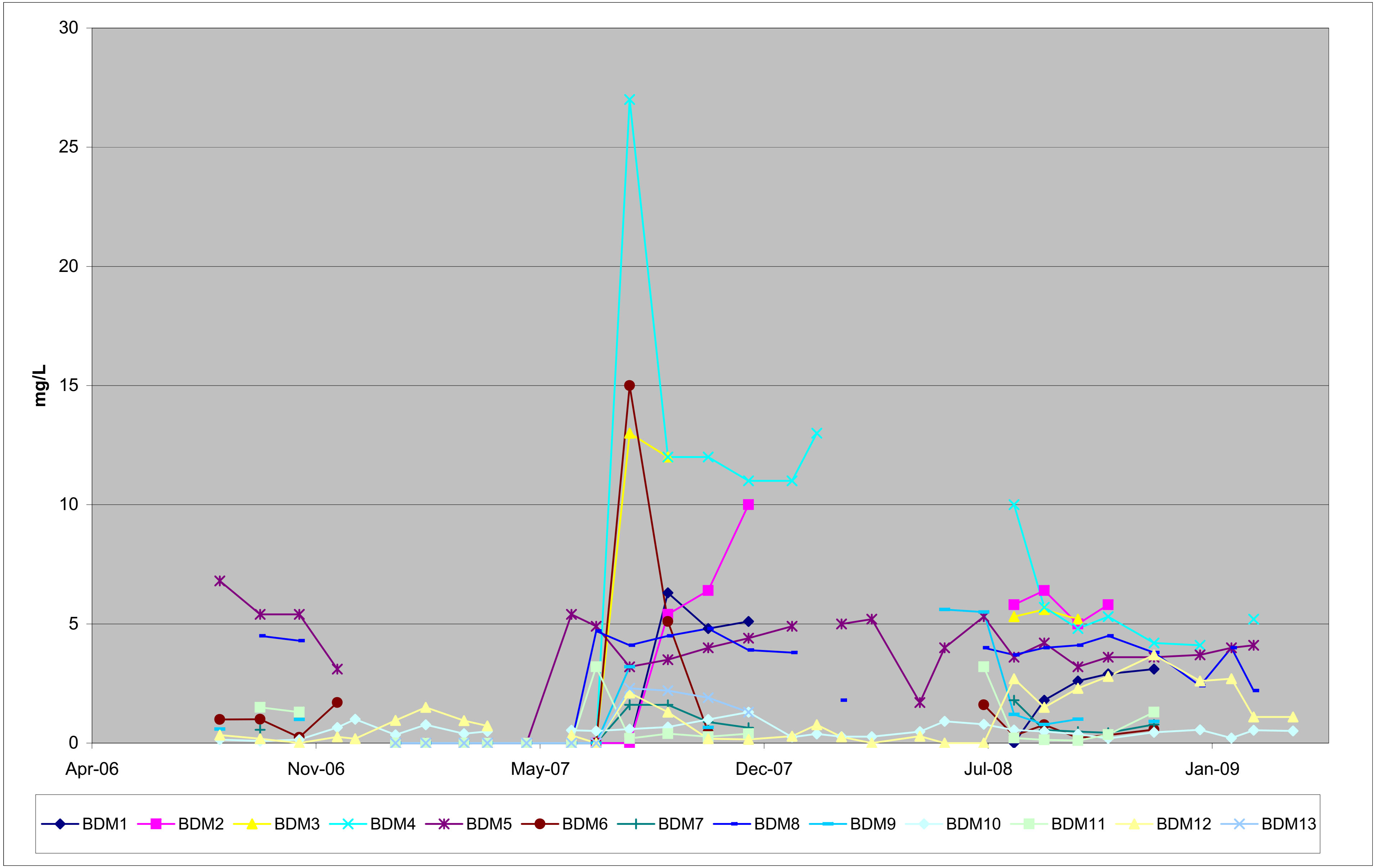
Appendix B3: pH for JDA Bores



Job No. J4320

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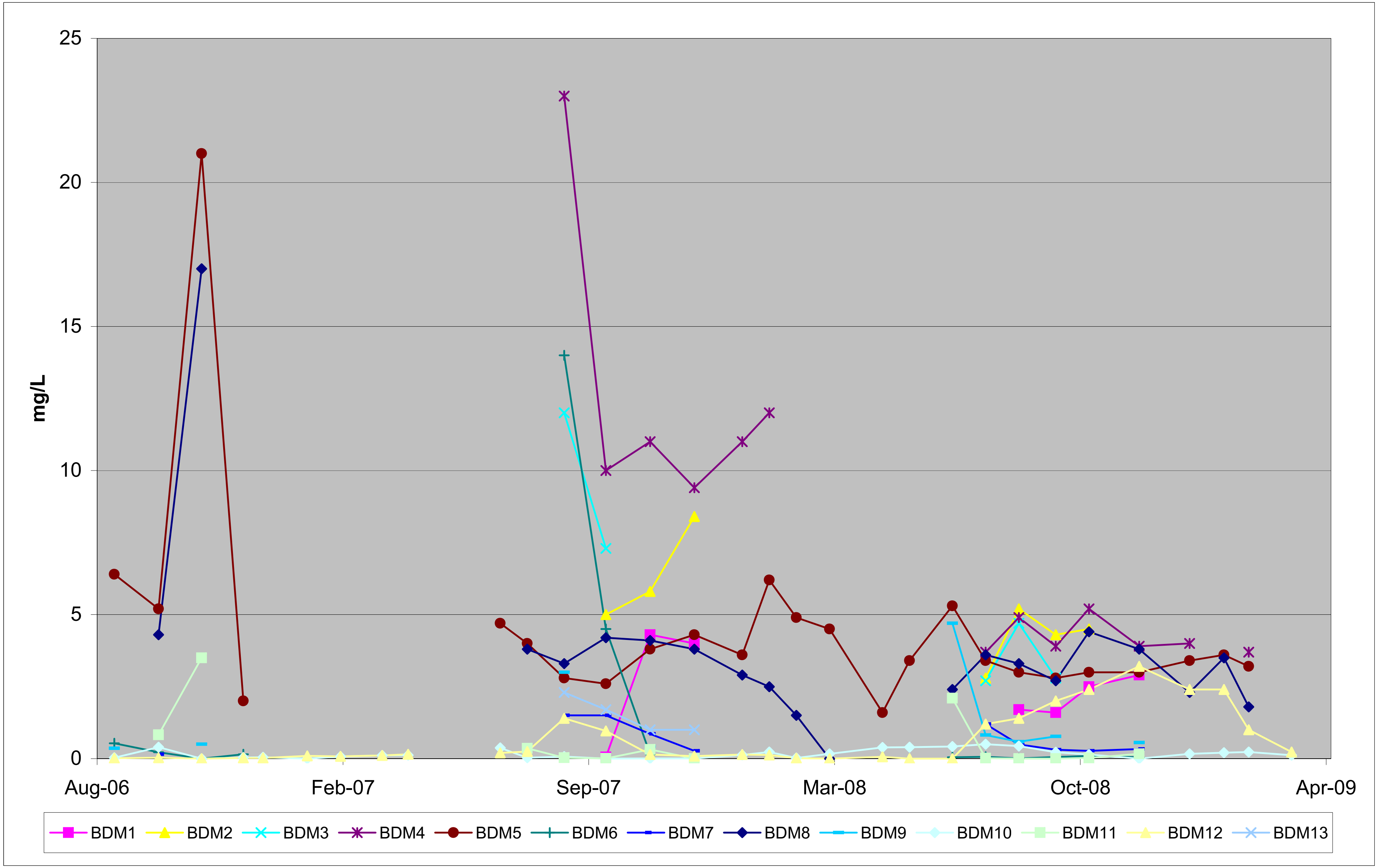
Appendix B4: Total Nitrogen Concentrations for JDA Bores



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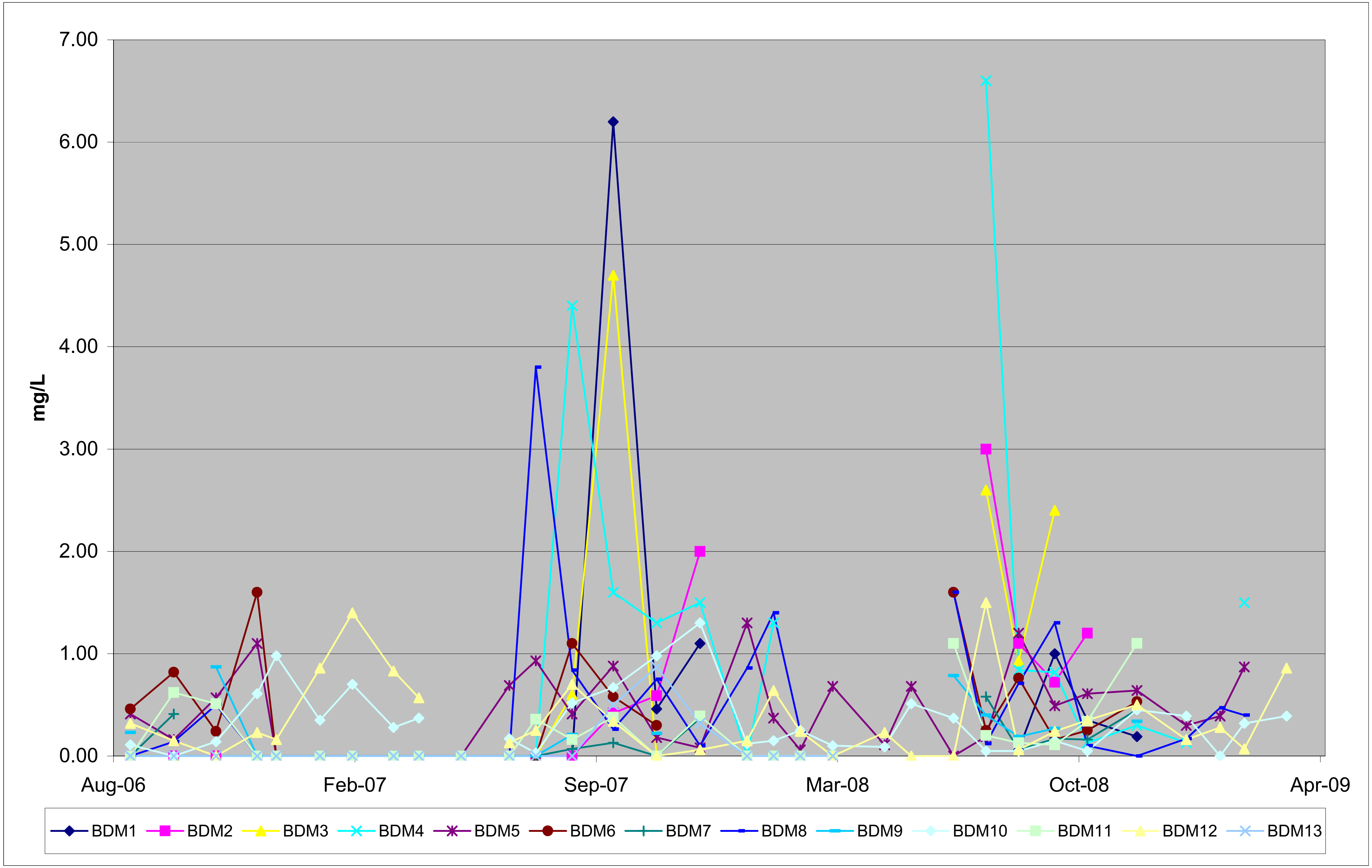
Appendix B5: Nitrate/Nitrite Concentrations for JDA Bores



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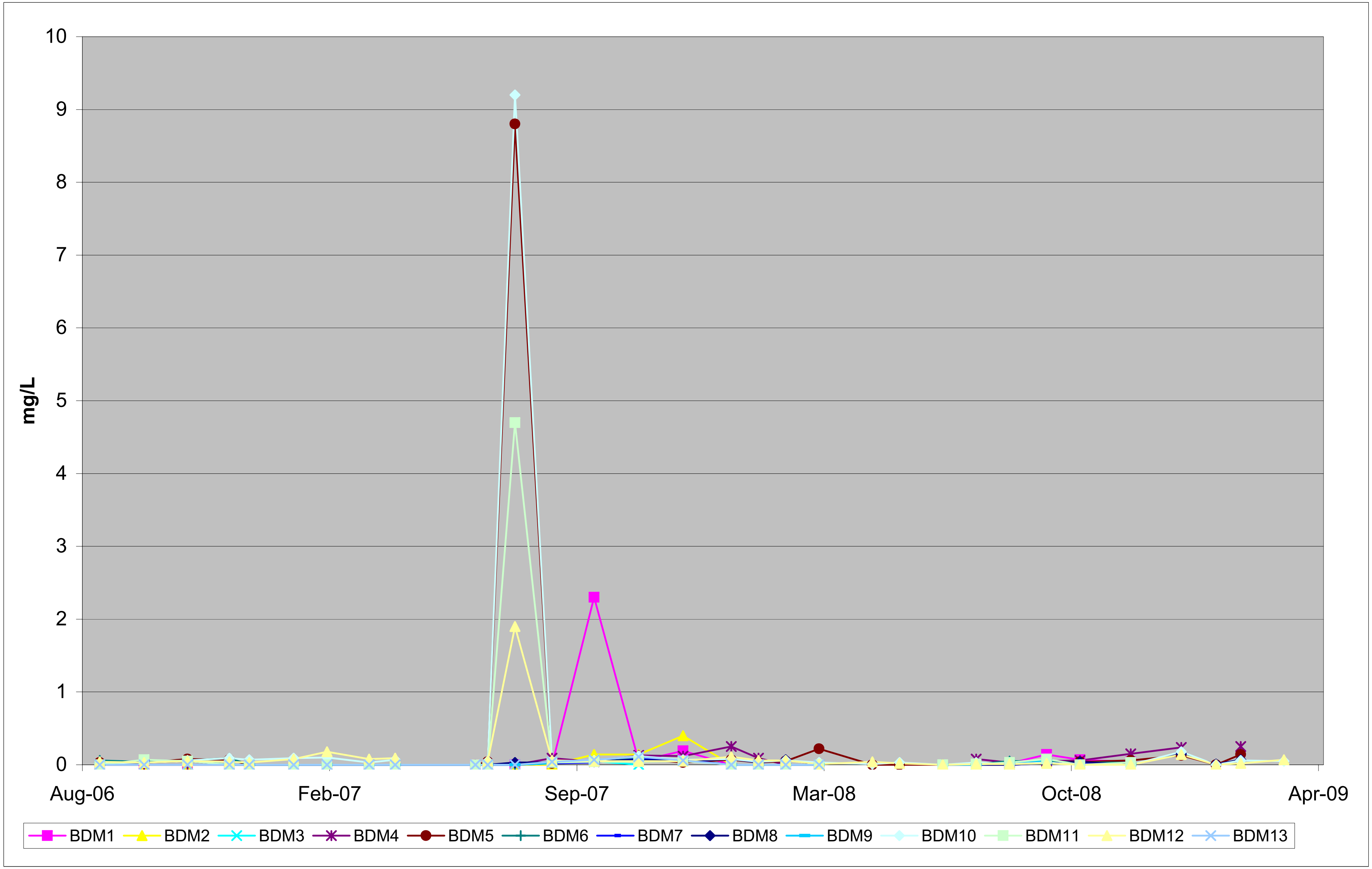
Appendix B6: Total Kjeldahl Nitrogen Concentrations for JDA Bores



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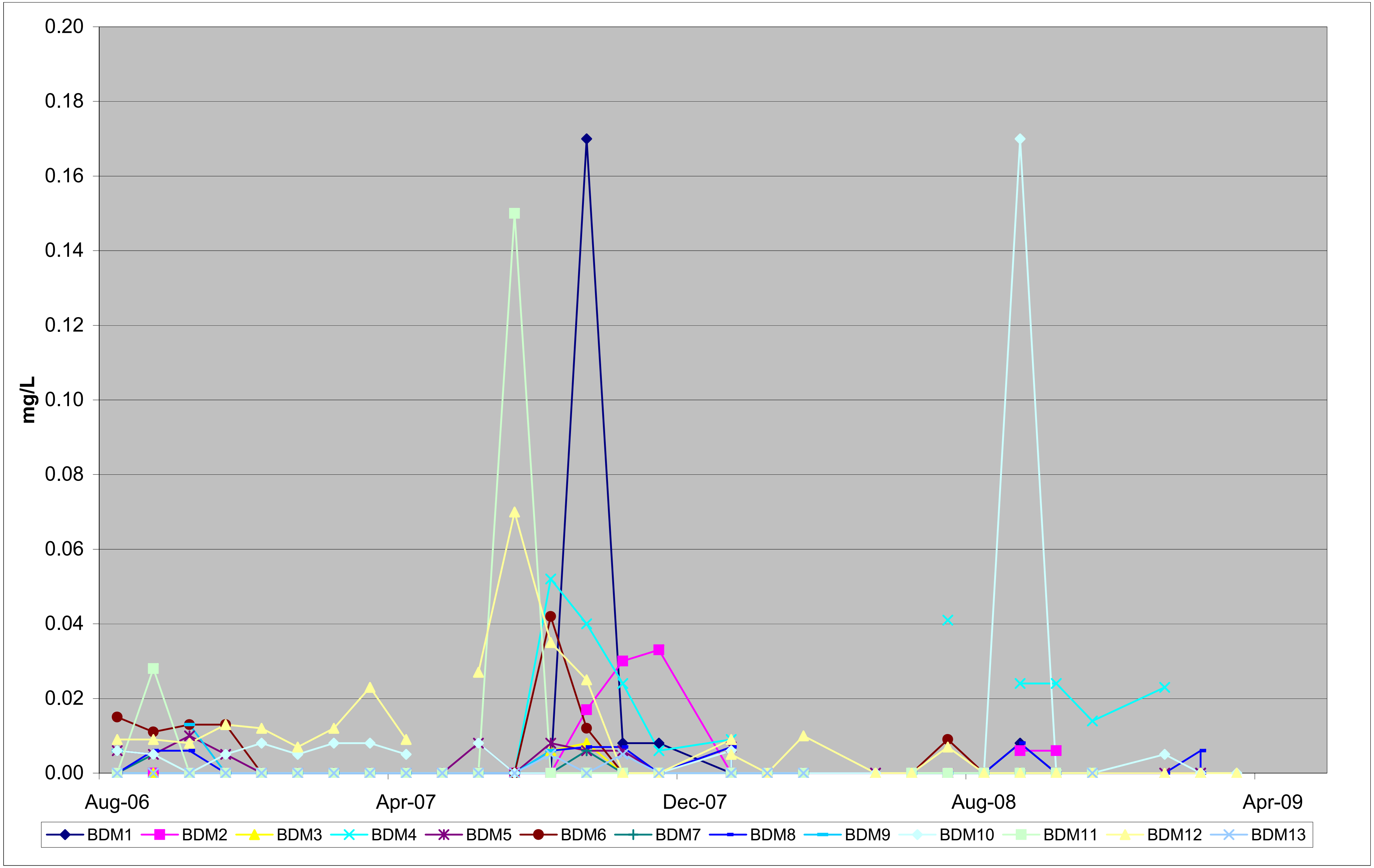
Glades at Byford LWMS

Appendix B7: Total Phosphorus Concentrations for JDA Bores



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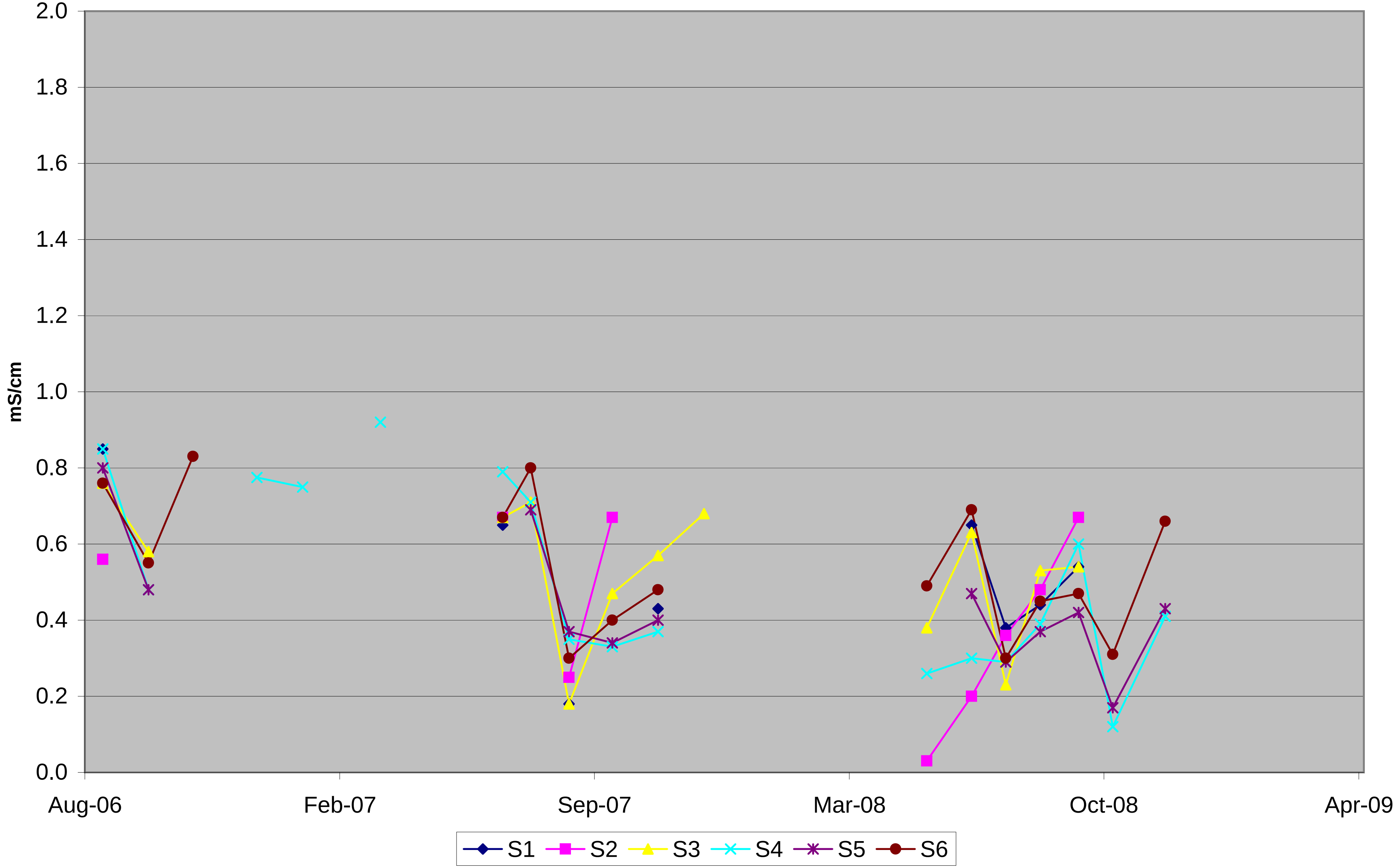
Appendix B8 Filterable Reactive Phosphous Concentrations for JDA Bores



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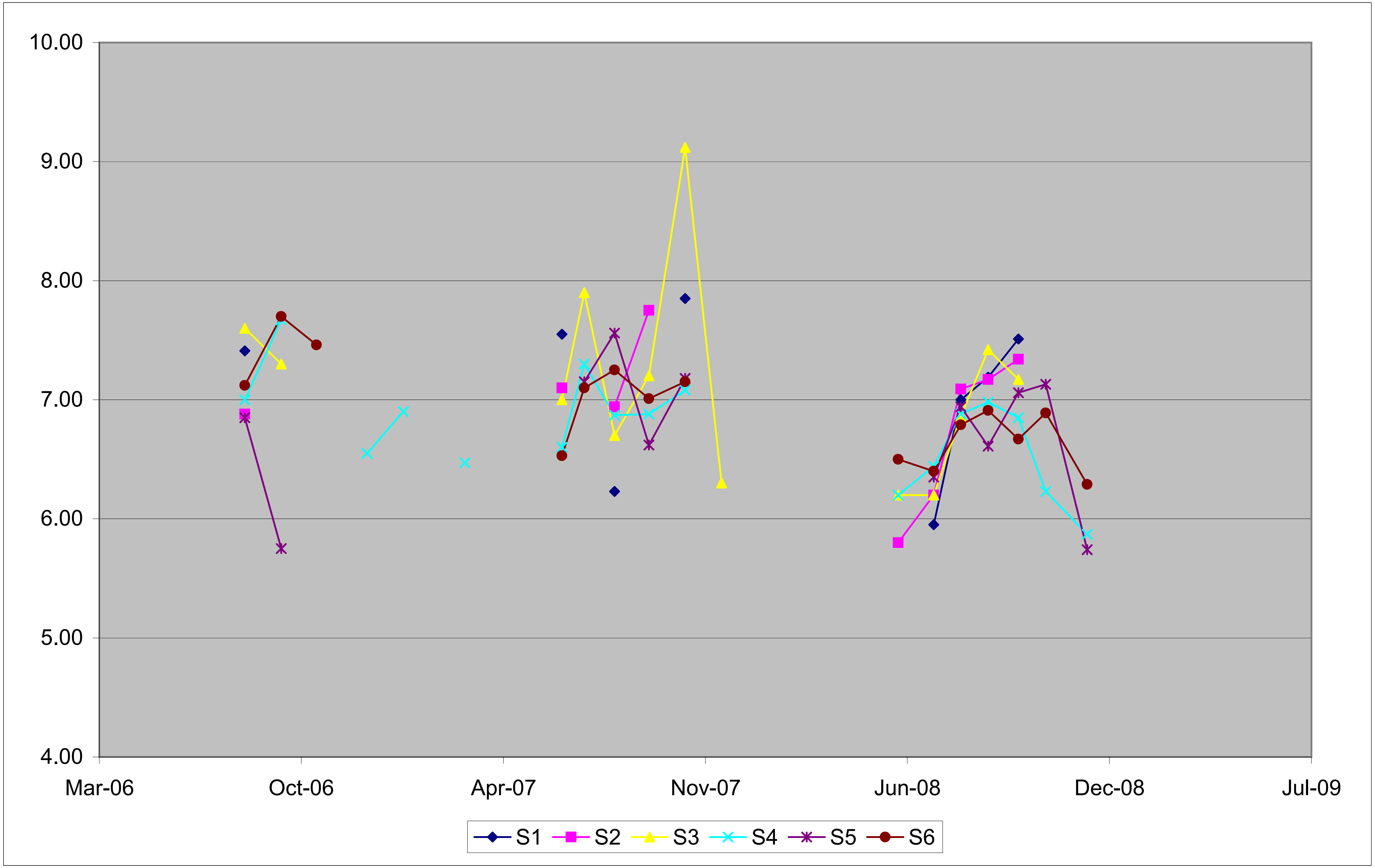
Appendix B9: Electrical Conductivity for Surface Water Sites



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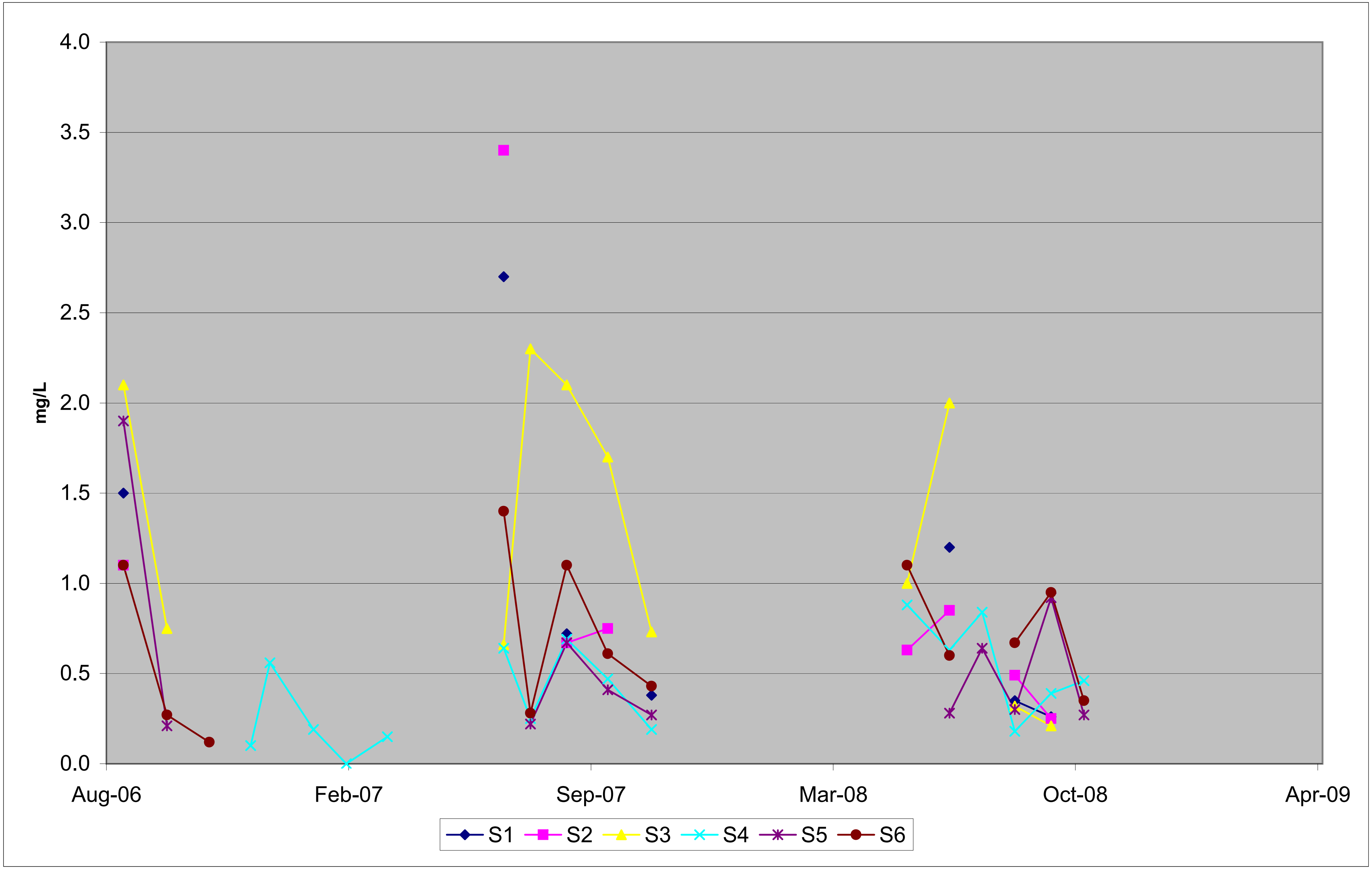
Appendix B10: pH for Surface Water Sites



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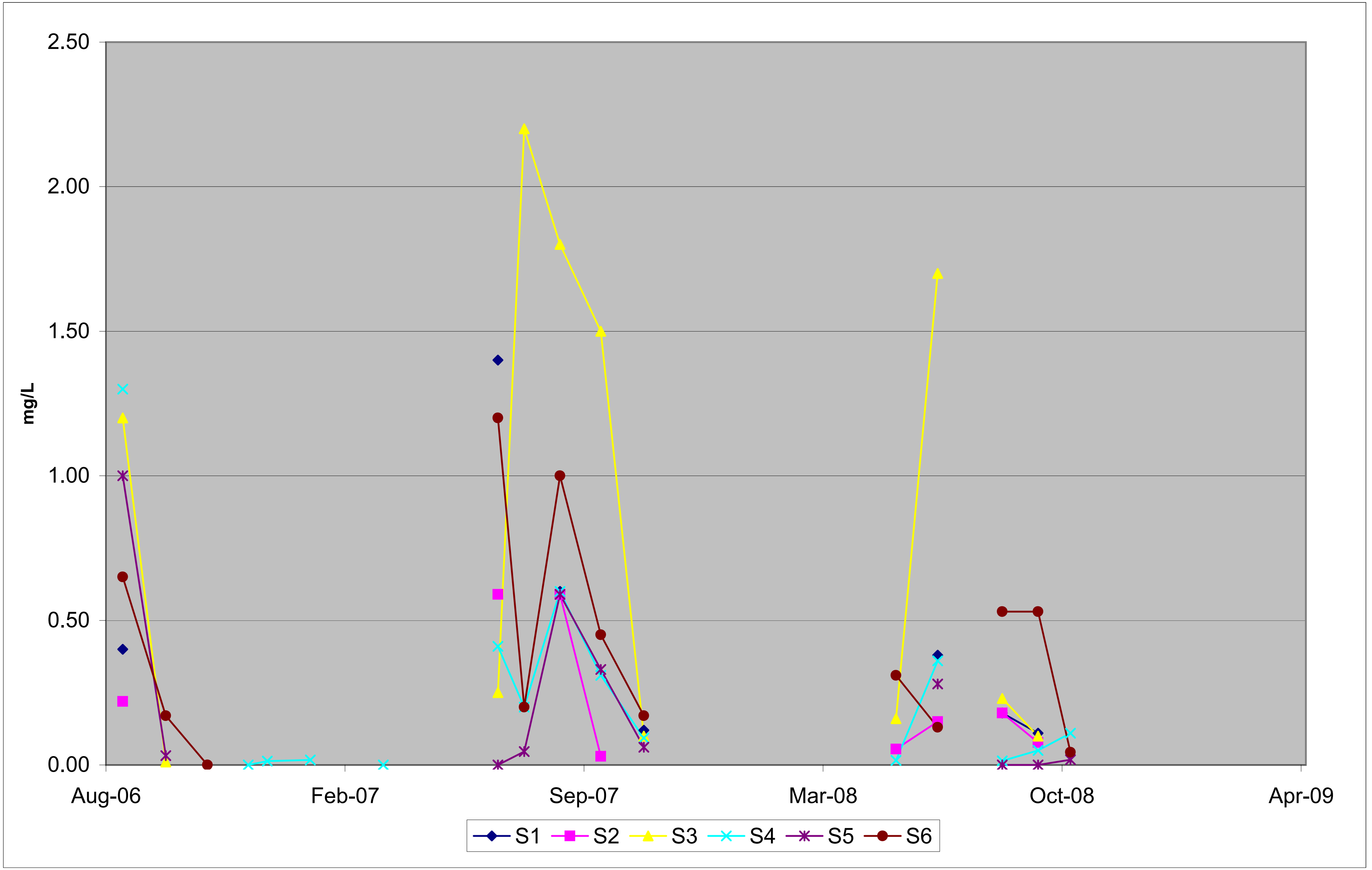
Glades at Byford LWMS
Appendix B11: Total Nitrogen Concentrations for Surface Water Sites



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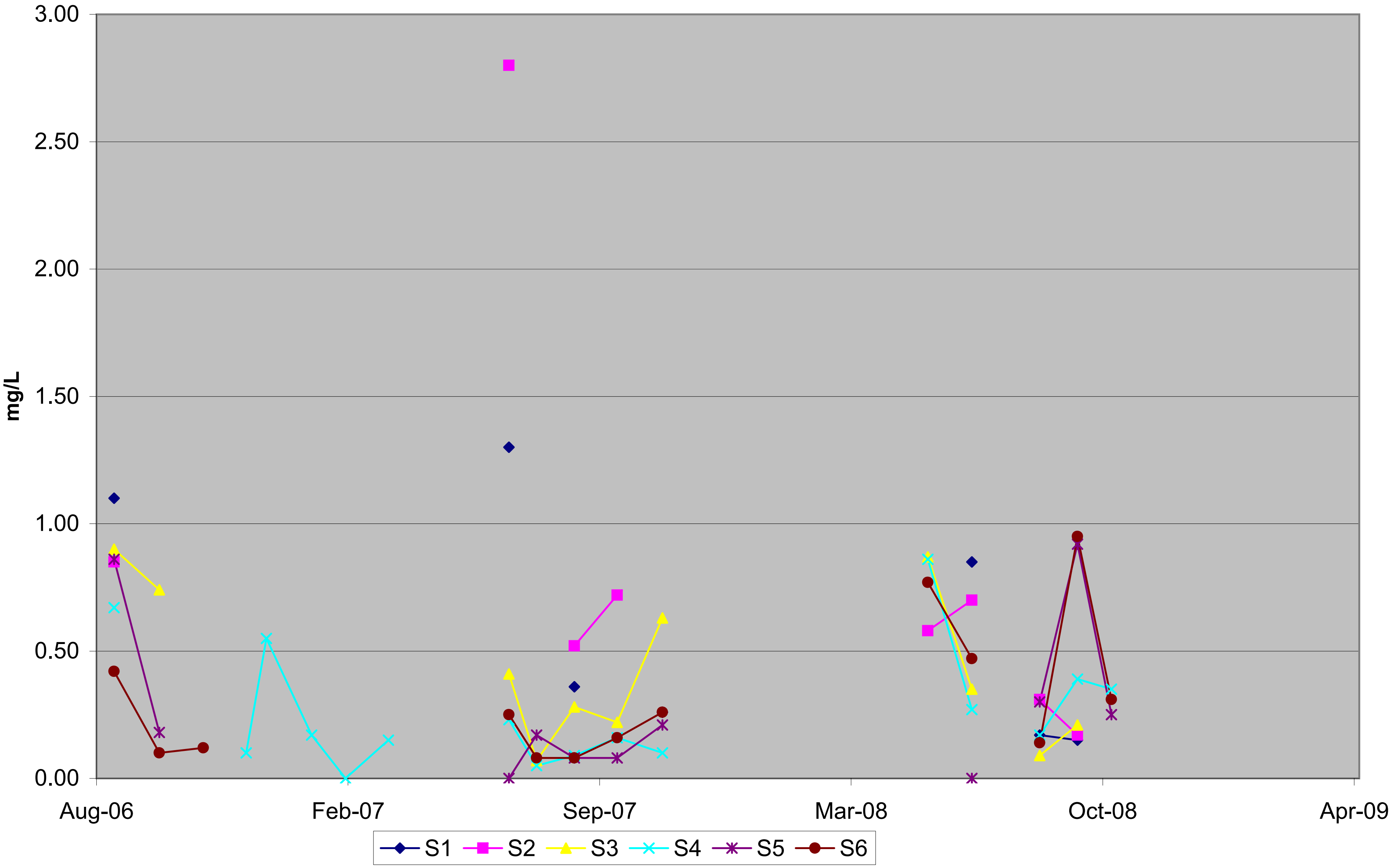
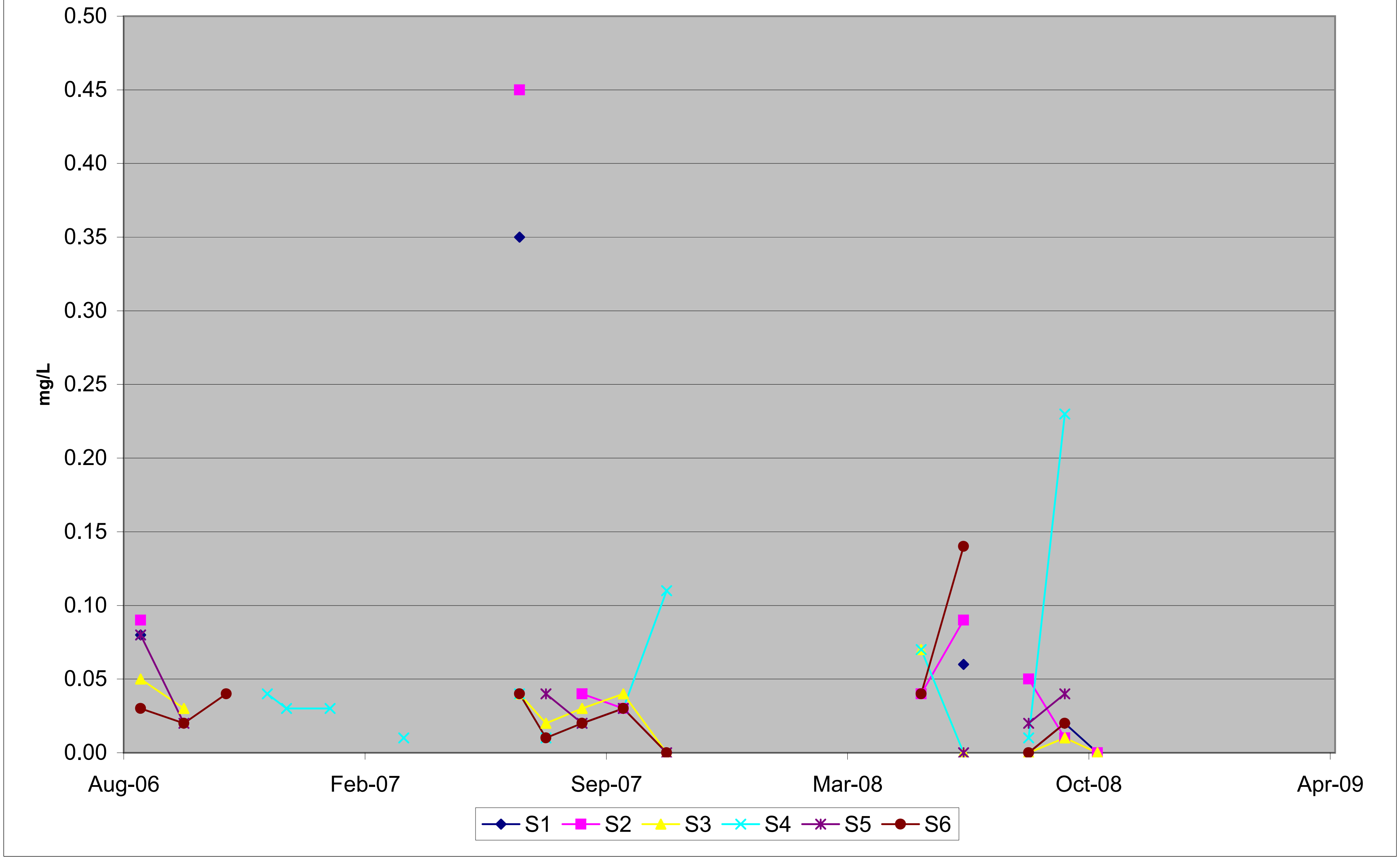
Glades at Byford LWMS
Appendix B12: Nitrate/Nitrite Concentrations for Surface Water Sites



Job No. J4320

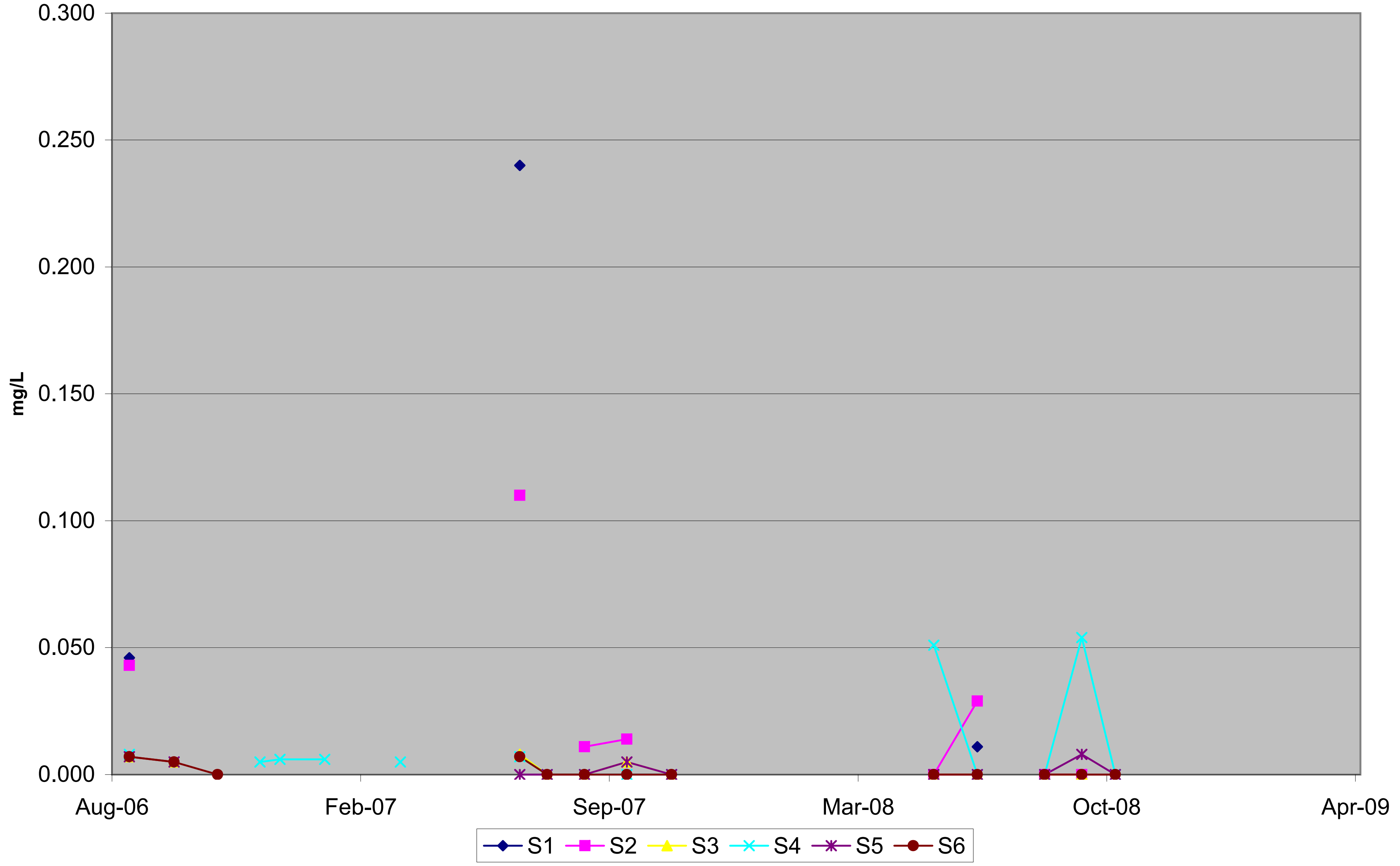
LWP Property Group Pty Ltd
Glades at Byford LWMS

Appendix B13: Total Kjeldahl Nitrogen Concentrations for Surface Water Sites



Job No. J4320

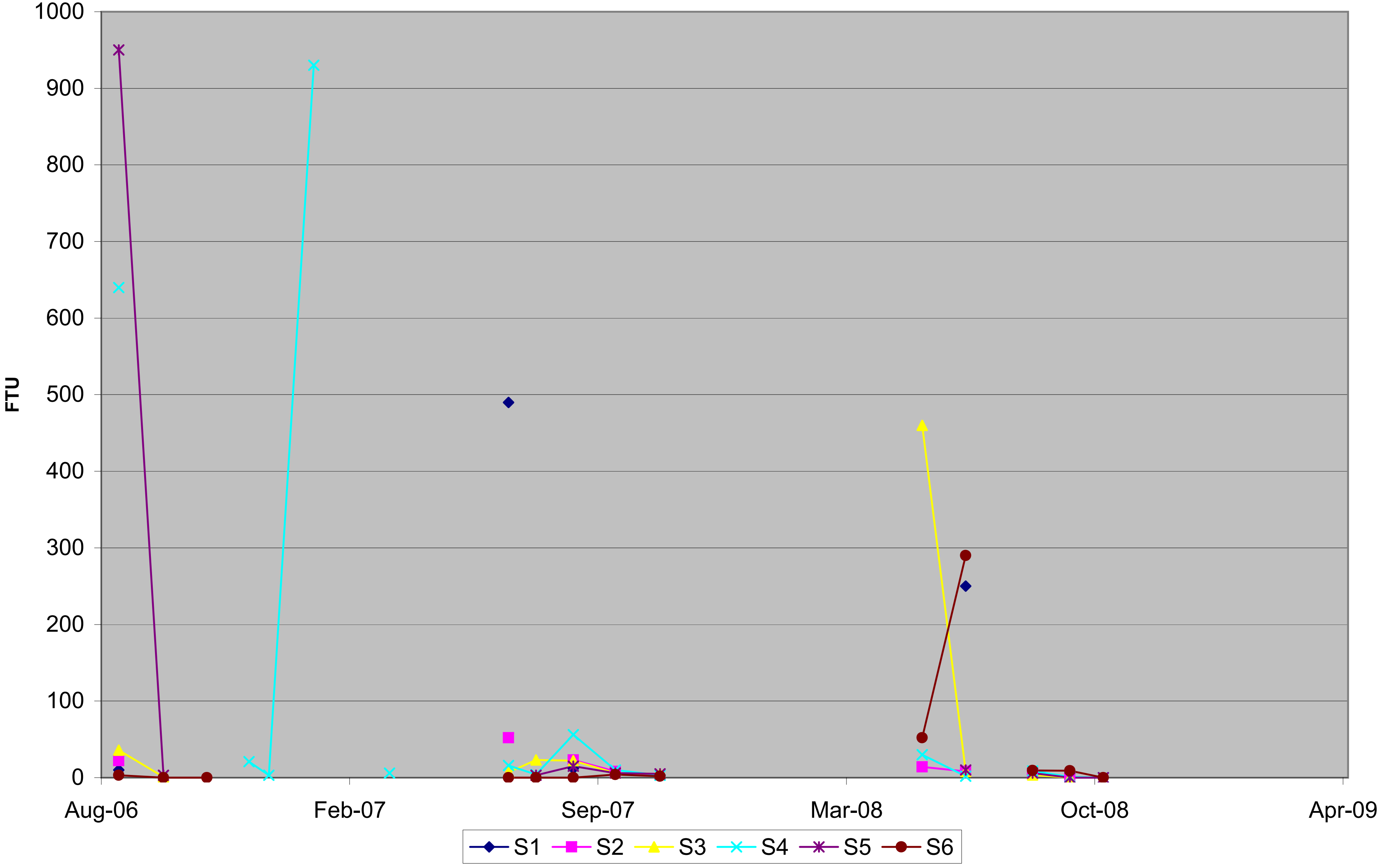
LWP Property Group Pty Ltd
Glades at Byford LWMS
Appendix B14: Total Phosphorus Concentrations for Surface Water Sites



Job No. J4320

LWP Property Group Pty Ltd
Glades at Byford LWMS

Appendix B15: Filterable Reactive Phosphorus Concentrations for Surface Water Sites



Job No. J4320

LWP Property Group Pty Ltd
Glades at Byford LWMS
Appendix B16: Total Suspended Solids for Surface Water Sites

APPENDIX C

Correspondence

Jim Davies & Associates Pty Ltd
ACN 067 295 569
Suite 1, 27 York Street, Subiaco
PO Box 117, Subiaco WA 6008
Telephone (08) 9388 2436
Facsimile (08) 9381 9279
Email info@jdahydro.com.au
www.jdahydro.com.au

JDA CONSULTANT HYDROLOGISTS

Our Ref: J4320a

19 February 2009

Bill Till
Drainage and Waterways Branch
Department of Water
168 St Georges Terrace
PERTH WA 6000

Dear Bill,

BYFORD TOWNSITE LOCAL STORMWATER MANAGEMENT

Further to our meeting on Tuesday 16 February 2009 to discuss the progress of the LWMS covering the LWP Property Group land in Byford, based on the discussions of the meeting it is my understanding that in addition to the design criteria provided in the DWMP DoW will support the following design strategies;

1) Flood detention storage for the subdivision should be provided offline to the floodway corridor for all events up to the 5 yr ARI.

2) The floodway corridor for each Tributary as defined in the DWMP can be utilised for detention storage for events greater than the 5yr ARI provided it is demonstrated that this will not adversely affect the conveyance of the district flood flow.

3) Flood detention in the floodway for events greater than the 5 yr ARI is permissible provided the peak flow and HGL at Hopkinson Rd for each tributary is consistent with the values presented in the DWMP.

Can you please confirm that these strategies will be acceptable to DoW if proposed in the LWMS we are currently preparing.

If you have any queries, please do not hesitate to contact Scott Wills

Yours sincerely,

JDA Consultant Hydrologists

cc. Craig Wansbrough (Shire of Serpentine-Jarrahdale)

Scott Wills

From: TILL Bill [Bill.TILL@water.wa.gov.au]
Sent: Monday, 9 March 2009 9:58 AM
To: 'Scott Wills'
Cc: 'Phil Cuttone'; DUNN Brett; Craig Wansbrough
Subject: Byford - The Glades Development
Attachments: J4320a.pdf; ATT00004.txt

Scott

Further to our meeting and subsequent emails it is confirmed that the strategies outlined in the attached letter are acceptable for further development/refinement in the updated LWMS for this development.

Regards

Bill Till
Supervising Engineer
Drainage and Waterways Branch
Department of Water
168 St Georges Terrace Perth Western Australia 6000
PO Box K822 Perth Western Australia 6842
Phone:(08) 6364 6626
Fax: (08) 6364 6516
Mobile:0409 106 438
Email: bill.till@water.wa.gov.au

From: Scott Wills [mailto:scott@jdahydro.com.au]
Sent: Friday, 20 February 2009 3:38 PM
To: TILL Bill
Cc: Craig Wansbrough; 'Phil Cuttone'
Subject:

Hi Bill,

Further to our meeting Tuesday regarding local flood management design in Byford, please find attached a letter summarising the outcomes of our discussions for your response.

Regards,

Scott Wills | Senior Environmental Hydrologist

JDA CONSULTANT HYDROLOGISTS
Suite 1/27 York St, Subiaco WA 6008 | PO Box 117, Subiaco WA 6904 |
Direct: (08) 6380 3425 | Reception: (08) 9388 2436 | Fax: (08) 9381 9279 | www.jdahydro.com.au

serpentine jarrahdale shire

All enquiries to Richard Gorbunow on 9526 1111
Our ref: A1305/10 CW:jm
Electronic Ref: OC09/3103

1 May 2009

RECEIVED
4 MAY 2009

Scott Wills
JDA Consultant Hydrologist
PO Box 117
SUBIACO WA 6904

Dear Mr Wills

RE THE GLADES LOCAL WATER MANAGEMENT STRATEGY - ABERNETHY ROAD & DRAINAGE DESIGN

The final road cross-sectional designs for the major east-west distributor roads in the Byford District Structure Plan area (i.e. Thomas Road, Abernethy Road and Orton Road) are not yet finalised, nor are they approved by either the Shire's Leadership Team or Council, both steps which is required prior to us releasing any information providing details to developers in the District. This is not a desirable position for Shire Officers at this late stage in the new District Structure Plan Review process, but further issues have recently (this week) been identified, which means that we need to undertake a bit of additional detailed investigation before the designs can be finalised.

For the purposes of preparing the Local Water Management Strategy for the Glades estate, there are only three points that need to be considered for inclusion in your calculations and design. These are:

1. The Abernethy Road Reserve will have a final width of 40.0 metres along the full frontage of The Glades Estate;
2. The drainage requirements for the estate, with respect to outflow to Abernethy Road will be the same as those stipulated in the Byford Townsite Drainage and Water Management Plan (DWMP). That is, all stormwater in the estate must be contained, treated for nutrient stripping, and detained sufficiently *within the Estate* to ensure that all outflows to Abernethy Road (or Orton Road) do not exceed pre-development rates. As this is a Local Water Management Strategy (as opposed to an Urban Water Management Plan) further detailed design will not be required. May we recommend you be guided by the Byford Townsite DWMP checklist for preparation of a Local Water Management Strategy for the Byford urban area.
3. Any points of outflow should be designed such that they can be connected to a median swale at a time when the road upgrade design is finalised and the construction undertaken. It is unlikely that there will be any roadside table drain along the southern side of Abernethy Road into which discharge can be directed (beyond what is currently there to cater for existing flows, but this may change with the ultimate road upgrade design).

You should also note that the Shire has not engaged any consultants to prepare draft road designs for any roads through the town centre beyond the works being undertaken to prepare the Byford Townsite Structure Plan, a project which is being managed by the Shire's Strategic Community Planning Directorate. The Shire may, however, decide to engage consultants to undertake such works, but until after the finalisation and formal adoption and WAPC approval of that Structure Plan, as any design works prior to that time would be premature.

Yours sincerely

Uwe Striepe
EXECUTIVE MANAGER ENGINEERING

Scott Wills

From: Craig Wansbrough [cwansbrough@sjshire.wa.gov.au]
Sent: Tuesday, 26 May 2009 5:31 PM
To: Scott Wills
Cc: Helen.Brookes@ghd.com.au
Subject: Cardup Brook Flows

Hi Scott,

As discussed, Helen has provided the following advice with regard to Cardup Brook:

I have now completed adding the JDA provided storage volumes and revised subcatchment arrangements for Cardup Brook and can confirm that the proposed design as built into the InfoWorks model does result in maintaining the predevelopment flow rates predicted by the current InfoWorks model and in accordance with the DWMP. Whilst a direct comparison of the volumes against those published in the DWMP is impossible given the extensive redistribution of subcatchments, the overarching principle, to maintain predevelopment flow rates for the 5 and 100 year ARI events, is complied with.

From the meeting we had at GHD on 16/4/2009 a longitudinal cross section of Cardup Brook was also required. Scott, please liaise with Helen to progress this work and Cc me into correspondence.

Kind regards,

Craig Wansbrough | Project Manager - Water Sensitive Urban Design
Serpentine Jarrahdale Shire
ph: (08) 9526 1178
fax: (08) 9525 5441
Mob: 0448 795 864
cwansbrough@sjshire.wa.gov.au
6 Paterson Street, Mundijong 6123
'we're delivering the vision'

www.sjshire.wa.gov.au

APPENDIX D

LWP Sustainability Contract

Annexure G
Sustainability Checklist

Lot __________________________________BYFORD WA 6122

NB: This form is to be completed in full and attached to building plans for prior approval by LWP Property Group Pty Ltd. Please send to LWP Property Group Pty Ltd. 34 Main Street Ellenbrook 6069

5.1 Social Sustainability

Compulsory Items– INCLUDE ALL

☐ The main living area and at least one bedroom and bathroom are located at ground level and can be accessed from the garage, carport or front boundary.

☐ Secure connections to rear laneways through the installation of lockable garage doors and gateways have been provided. (Compulsory for laneway homes only.)

☐ A legible and welcoming entry with clear pedestrian pathways, driveways and good external lighting is provided.

Optional Items – SELECT ONE

☐ The home is designed to have good surveillance over the street. For double storey homes, include a balcony with views over the street.

☐ Front gardens and rear outdoor areas at laneways are well lit; possibly incorporating motion activated light fittings.

5.2 Energy Efficiency

Compulsory Items – INCLUDE ALL

☐ Eaves to a minimum of 450mm have been included throughout. (Refer to section 3.9.1 “Eaves” for excepted areas.)

☐ A minimum of 50% of all light fixtures are fitted with fluorescent lighting either in the form of tubes or compact, fluorescent globes. [1]

☐ At least one internal living area has a major opening facing north.

☐ Glazing that faces east or west is shaded by awnings, louvres or similar.

☐ Where an air conditioner is installed it has a minimum energy rating of 4 stars and permits separate thermostat controls for living and sleeping areas.

Optional Items – SELECT FOUR

☐ A very light coloured roofing material is selected. (Colorbond¨ Surfmist, Shale Grey, Classic Cream, Dune, Zincalume or corresponding roof tile colours.)

☐ Outdoor living areas are located to the north.

☐ The north facade has a solar pergola or a pergola with deciduous vines growing on it.

☐ Roof ventilation is provided (rotary or static ventilators) to cool the home.

☐ Any mechanical heating or cooling system is sized to match the affected spaces and has a minimum energy efficiency rating of 5 stars.

☐ The home is zoned to maximise the efficiency of heating and cooling. Different living areas are capable of being closed off from one another to create easily heated or cooled zones. E.g. doors to close off living areas from hallways and bedrooms.

☐ Chimneys are fitted with dampers to prevent warm air escaping from the house when the fireplace is not in use.

☐ Cavities within double brick areas are fitted with insulation to east and west walls.

☐ Reverse Brick Veneer 3 construction has been used for north facing walls.[2]

☐ Installation of Photovoltaic panels to the roof as a supplementary source of electricity.

☐ If a new refrigerator is installed it should have a high energy efficiency rating (above 3.5 stars). [3]

Annexure G
Sustainability Checklist continued………

5.3 Sustainable Water Usage

Optional Items – SELECT ONE

- ☐ Opportunities for grey-water recycling internally and externally have been provided. (Provide details.)
- ☐ A rainwater tank(s) is installed and fitted to provide an alternative water source for laundry and toilet areas. (please refer to section 3.11.3 of this document for more detail relating to the tank provided to you by LWP)
- ☐ Dishwashers and clothes washing machines have a minimum waterwise rating of AAA.

5.4 Sustainable Landscape Design – Backyard (for information only)

Optional Items - If you would like to reduce water and nutrient requirements for your backyard landscaping and assist the passive heating and cooling of your home, you may consider the following suggestions;

- ☐ Subterranean and rain sensor irrigation systems to reduce water evaporation are included. (Irrigation systems installed must meet Irrigation Association of Australia standards.)
- ☐ Landscaping with plants to complement the passive solar requirements of the home, e.g. shading to east/west and deciduous creepers or solar pergolas to the north is included.
- ☐ More than 50% of all plants used in the backyard are selected from the list located within Appendix 2 of this document.

---

1 Installing compact fluorescent light fittings in lieu of incandescent and halogen down-lights can equate to annual savings in the hundreds of dollars every year.

2 "Reverse Brick Veneer"' refers to the construction of external walls where the internal leaf of brickwork is complemented by an external stud framed wall rather than traditional 'double brick' construction. For areas with a direct solar load this form of construction can contribute to energy efficiency. Insulated wall framing clad in a reflective material can provide more satisfactory insulating characteristics than double brick walls which tend to store heat during hot days and radiate it into the home at night. Reverse brick veneer can also have the added advantage of introducing an element of variety to the elevations through the use of an additional wall material.

3 The refrigerator is the most energy hungry appliance in the home. It operates 24 hours per day, 7 days per week and hence it is important to select a high star rating to cut costs and energy use.

Rain Water Tanks

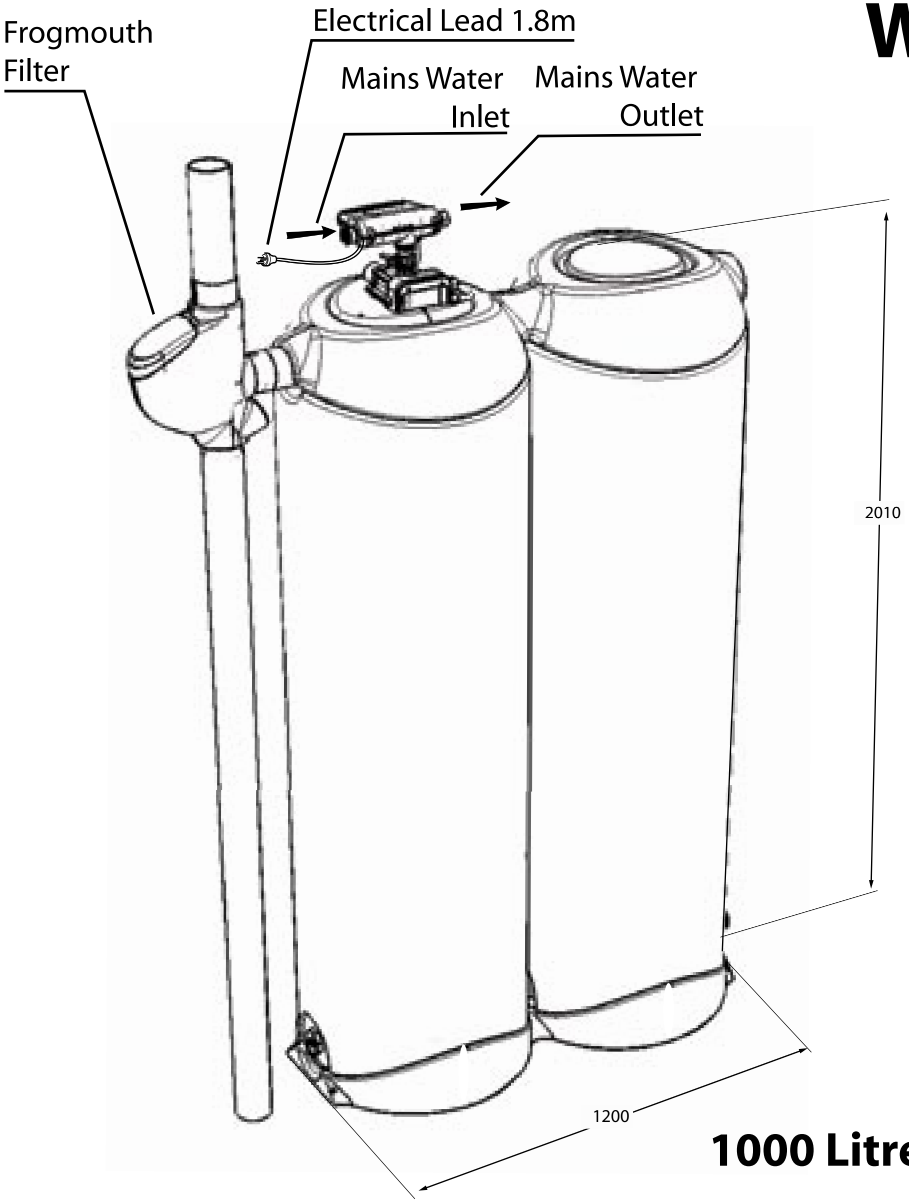
Building Provisions

Installation of the 2,000 litre under eaves rain water tanks will be carried out by the Seller's contractor at completion of the home subject to the Buyer making provision, via the builder, to ensure the following is allowed for in the design and construction of the home:

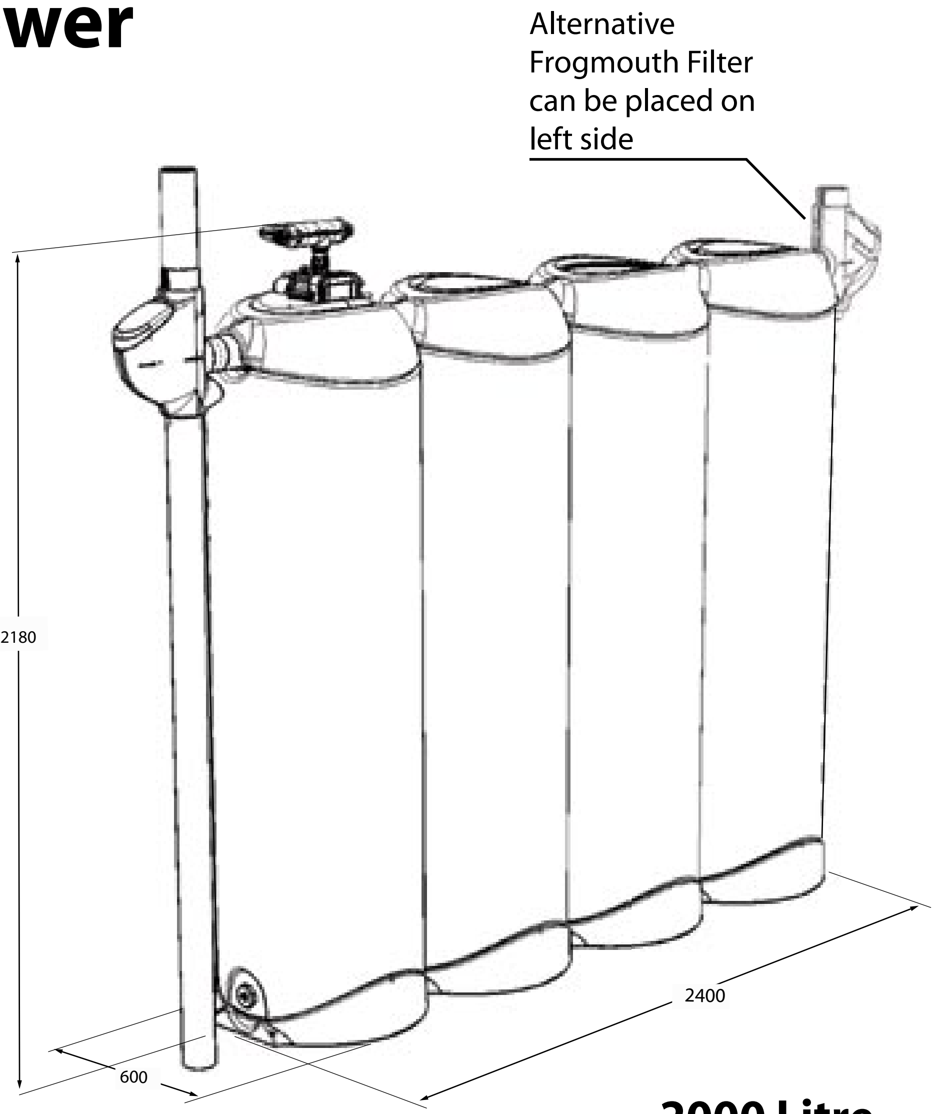
- A minimum of wall length of 2,500mm with no openings located in close proximity to the Laundry and Toilet;
- A minimum floor to under eaves height of 2,200mm;
- Builder's plumber to separately connect from the rainwater tank to the toilet cistern and cold laundry washing machine during roughin stage of construction;
- Provide at the tank location a mains water supply (refer to attached plans for the location of the water inlet and outlet to the toilet and washing machine on the rainwater tank);
- A roof water minimum catchment area of 40sqm is required;
- Provide a 10AMP water proof GPO outside (refer to attached plans for location);
- Provide a hardstand for the rainwater tanks prior to installation of the rainwater tanks. Paved or slabs are adequate.

Please note that the above provisions should be read in conjunction with the rain water tank plans and details provided.

Water Tower

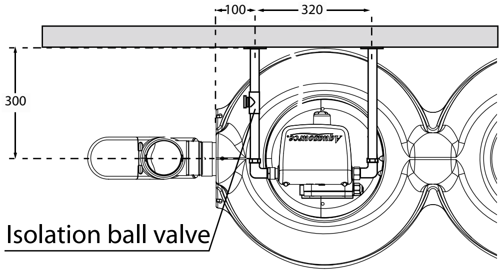


1000 Litre



2000 Litre

Note:
Layout shown with 3/4 MF elbow each side (not supplied).

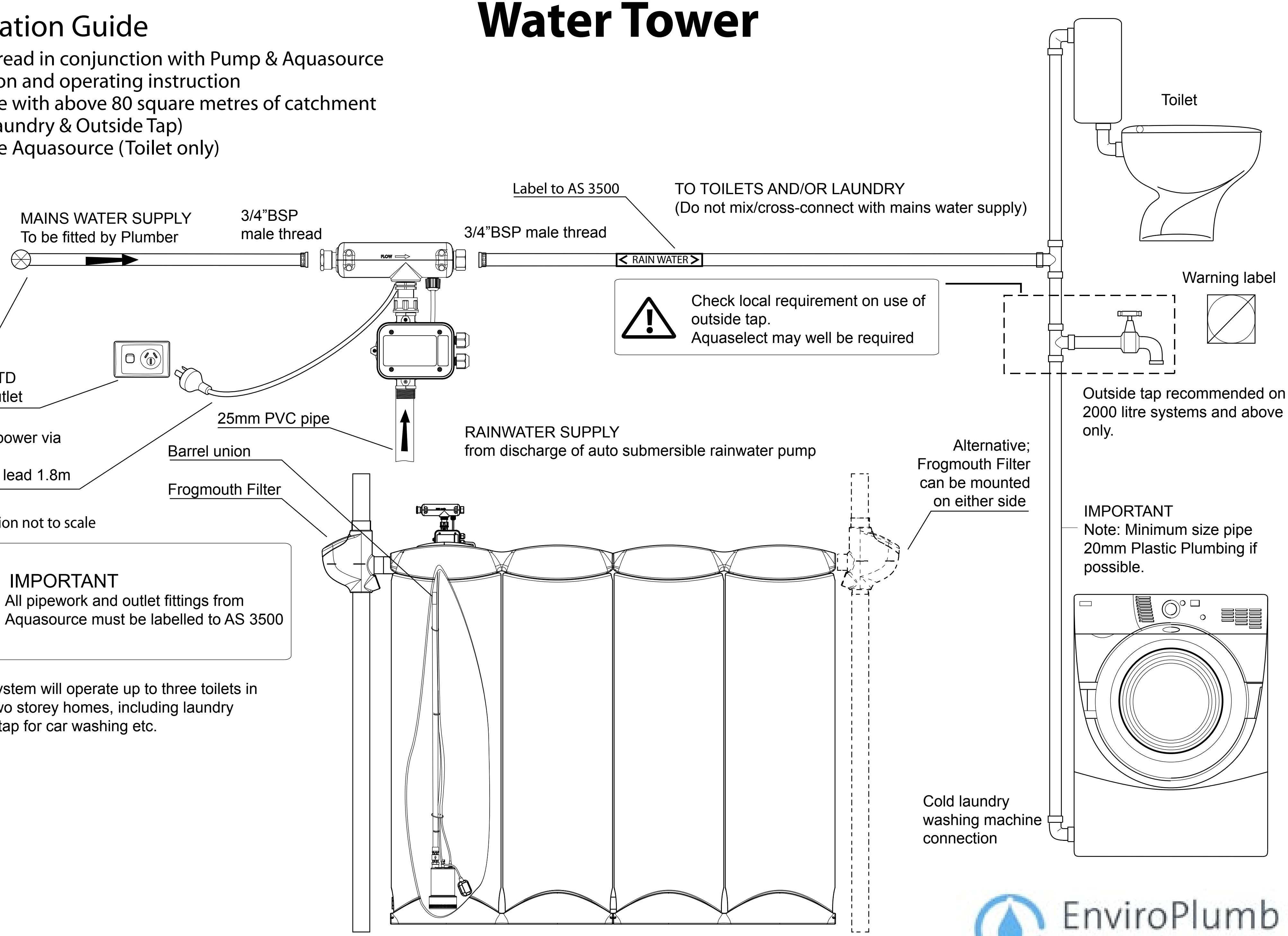


EnviroPlumb
Water recycling systems

Water Tower

Installation Guide

Must be read in conjunction with Pump & Aquasource installation and operating instruction
2000 Litre with above 80 square metres of catchment
(Toilet, Laundry & Outside Tap)
1000 Litre Aquasource (Toilet only)



Check local requirement on use of outside tap.
Aquaselect may well be required

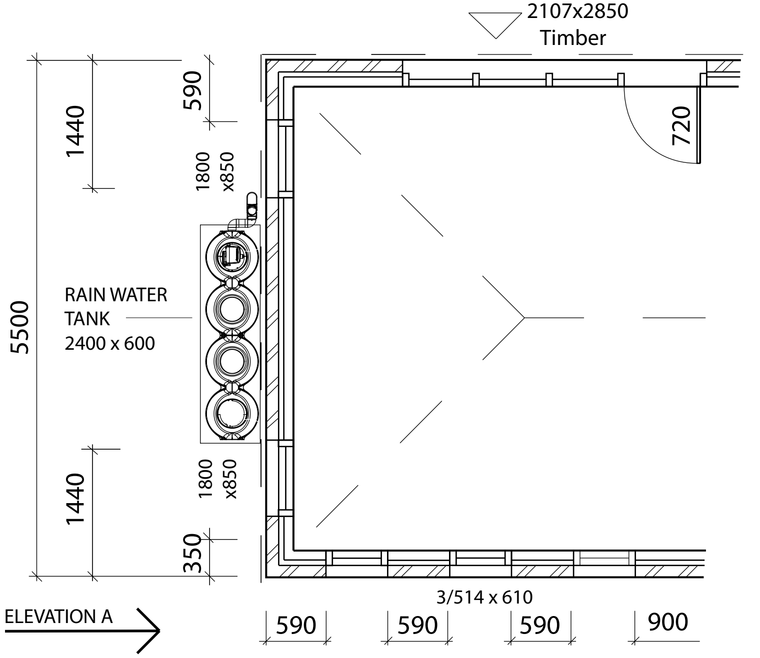
Note Illustration not to scale

IMPORTANT
All pipework and outlet fittings from Aquasource must be labelled to AS 3500

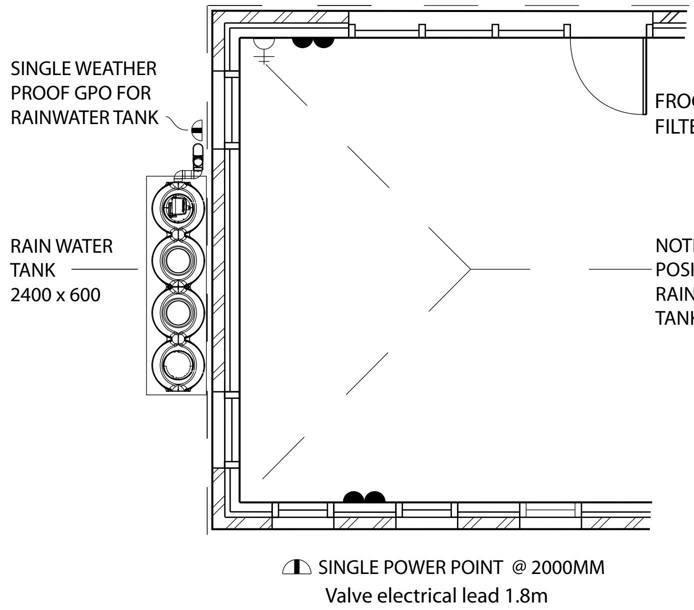
The pump system will operate up to three toilets in single and two storey homes, including laundry and outside tap for car washing etc.

EnviroPlumb
Water recycling systems

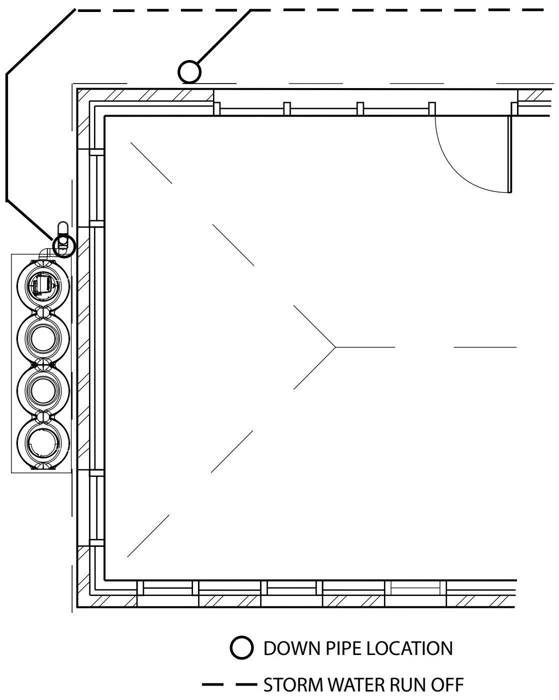
Water Tower



SITE PLAN



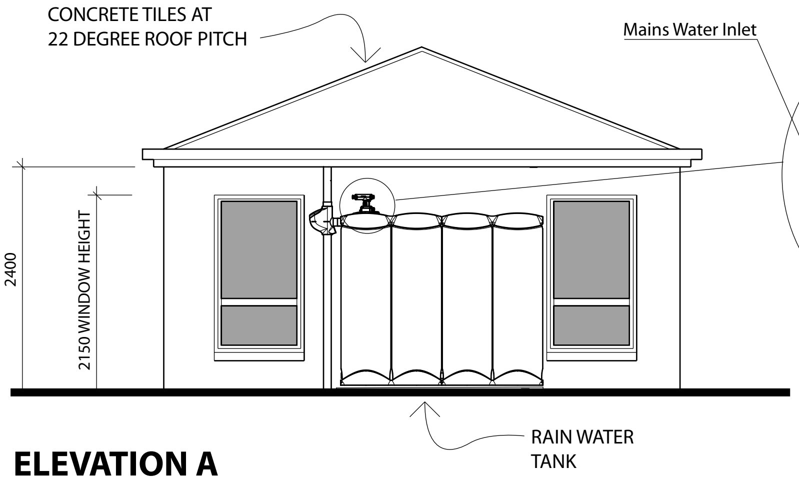
WIRING PLAN



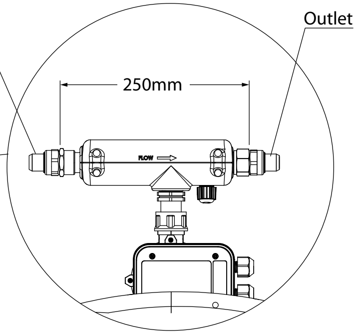
DRAINAGE PLAN

Our preferred method of providing the concrete slab is to detail it on the site plan and pour as part of the house slab.

Overflow socket is provided for connection to stormwater drainage and inlet from Frogmouth Filter.



ELEVATION A



Aquasource Pump Controller

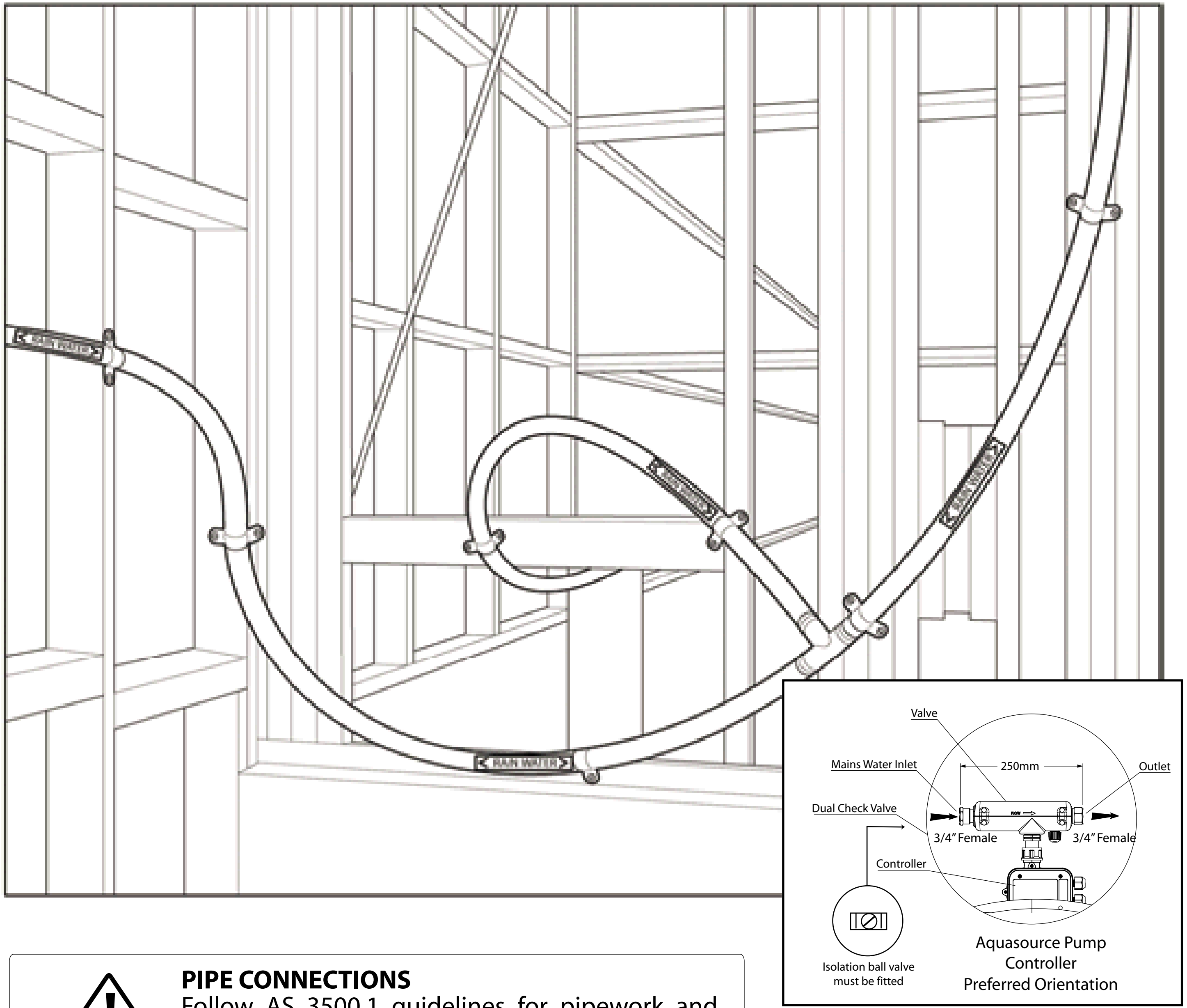
Aquasource requires your plumber to separately connect from the toilet cisterns to tank location at roughing in stage. A mains water supply is also required at the tank location.

The modular system is very easy to handle at fit out, each unit weighing only 35kg and fitting through a normal doorway.

Examples of site plan, electrical wiring main building plan and drainage plan
showing rainwater tank position, wiring requirements and rainwater drainage.

EnviroPlumb
Water recycling systems

Water Tower



Aquasource Pump Controller
Preferred Orientation

Aquasource requires your plumber to separately connect from the rainwater tank to the toilet cisterns during the roughin stage. Also required at the tank location is a mains water supply. Please see separate drawing for the location of mains water inlet and outlet to the toilet on the rainwater tank.

A separate instruction sheet is given for final connection at the time of fitting out.

Aquasource comes complete with a 3/4 "BSP female threaded dual check valve on the incoming mains connection. This is the side that is connected to the mains water supply.

Note: It is highly recommended that an isolation valve is installed on this pipe to facilitate easier servicing if required.

Aquasource has a 3/4" female connection to supply water to the toilet and/or laundry outlet.

EnviroPlumb recommends the use of REHAU green piping for designated rainwater lines.

PIPE CONNECTIONS
Follow AS 3500.1 guidelines for pipework and tapware markings for rainwater.

EnviroPlumb
Water recycling systems

APPENDIX E

Nutrient Input (NiDSS) Results

NiDSS

Nutrient Input Decision Support System
Version 2.0 March 2005
JDA Consultant Hydrologists
Report Date : 20-May-09

The Glades, Byford	
Total Nutrient Input - No WSUD (kg/yr)	**6,455**
Reduction due to WSUD (kg/yr)	**0**
Percentage Overall Reduction	**0.0%**
Pecentage Development Reduction	**0.0%**
Cost of Selected Program ($/kg/yr)	**$0**

● Total Phosphorus
○ Total Nitrogen

Catchment Name The Glades, Byford
Option Description Pre-Development Scenario
Catchment Area 328 ha

Land Use Breakdown

Residential : ~R15	0.0%	lower density residential areas (excludes road reserve area)
Residential : ~R35	0.0%	higher density residential areas (excludes road reserve area)
Road Reserves : Minor	1.0%	maintainance of verge by landowners
Road Reserves : Major	0.0%	maintainance of verge by local authority
POS : Active	0.0%	grassed areas
POS : Passive / Basins	0.0%	native vegetation
Rural : Pasture	97.0%	general pasture
Rural : Residential ~R2.5/R5	2.0%	low density
Rural : Poultry	0.0%	specific high nutrient input land use
Commercial/Industrial	0.0%	town centre etc

Total Residential **0.0%**
Total Area **100.0%**

Nutrient Input Without WSUD

Residential	Garden	0.00	kg/net ha/yr	0.00	kg/gross ha/yr	0	kg/yr	0.0%
	Lawn	0.00		0.00		0		0.0%
	Pet Waste	0.00		0.00		0		0.0%
	Car Wash	0.00		0.00		0		0.0%
	Sub Total			0.00		0		0.0%
POS	Garden/Lawn	2.60	kg/ha POS/yr	0.00	kg/gross ha/yr	0	kg/yr	0.0%
	Pet Waste	0.00		0.00		0		0.0%
	Sub Total			0.00		0		0.0%
Road Reserve	Major Roads	1.04	kg/ha RR/yr	0.00	kg/gross ha/yr	0	kg/yr	0.0%
	Minor Roads	20.00		0.20		66		1.0%
	Sub Total			0.20		66		1.0%
Rural	Pasture	20.00	kg/ha Rural/yr	19.40	kg/gross ha/yr	6,363	kg/yr	98.6%
	Poultry Farms	75.00		0.00		0		0.0%
	Residential (R2.5/R5)	4.00		0.08		26		0.4%
	Sub Total			19.48		6,389		99.0%
			Total	**19.68**	kg/gross ha/yr	**6,455**	kg/yr	**100.0%**

Residential Areas (R15-R35) : Nutrient Removal via Source Control

☐ Native Gardens (Lots - Garden)
☐ Native Gardens (Lots - Lawn)
☐ Native Gardens (POS)
☐ Street Sweeping
☐ Community Education : Fertiliser
☐ Community Education : Pet Waste
☐ Community Education : Car Wash

Education Effectiveness 0%

	% Area of Influence	Removal kg/gross ha/yr	Removal kg/yr	Removal %	Capital Cost $	Operating Cost $/yr	Cost $/kg/yr
Native Gardens (Lots - Garden)	0%	0.00	0	0.0%	$0	$0	$0.0
Native Gardens (Lots - Lawn)	0%	0.00	0	0.0%	$0	$0	$0.0
Native Gardens (POS)	0%	0.00	0	0.0%	$0	$0	$0.0
Community Education : Fertiliser	0%	0.00	0	0.0%	$0	$0	$0.0
Community Education : Pet Waste	0%	0.00	0	0.0%	$0	$0	$0.0
Community Education : Car Wash	0%	0.00	0	0.0%	$0	$0	$0.0
Street Sweeping	0%	0.00	0	0.0%	$0	$0	$0.0
Totals		**0.00**	**0**	**0.0%**	**$0**	**$0**	**$0.0**

Residential Areas (R15-R35) : Nutrient Removal via In-Transit Control

☐ Gross Pollutant Trap
☐ Water Pollution Control Pond

	% Area of Influence	Removal kg/gross ha/yr	Removal kg/yr	Removal %	Capital Cost $	Operating Cost $/yr	Cost $/kg/yr
Gross Pollutant Traps	0%	0.00	0	0.0%	$0	$0	$0.0
Water Pollution Control Ponds	0%	0.00	0	0.0%	$0	$0	$0.0
Total		**0.00**	**0**	**0.0%**	**$0**	**$0**	**$0.0**

Net Nutrient Input

	kg/gross ha/yr	kg/yr	%	Capital Cost $	Operating Cost $/yr	Cost $/kg/yr
Nutrient Input : Residential Area without WSUD	0.20	66	1.0%			
Nutrient Input : Rural Area	19.48	6,389	99.0%			
Removal via Source Control	0.00	0	0.0%	$0	$0	$0.0
Removal via In-Transit Control	0.00	0	0.0%	$0	$0	$0.0
Total Removal	0.00	0	0.0%	$0	$0	$0.0
Net Nutrient Input	**19.68**	**6,455**	**100.0%**			

NiDSS

Nutrient Input Decision Support System
Version 2.0 March 2005
JDA Consultant Hydrologists
Report Date : 20-May-09

The Glades, Byford	
Total Nutrient Input - No WSUD (kg/yr)	**19,622**
Reduction due to WSUD (kg/yr)	**0**
Percentage Overall Reduction	**0.0%**
Pecentage Development Reduction	**0.0%**
Cost of Selected Program ($/kg/yr)	**$0**

○ Total Phosphorus
● Total Nitrogen

Catchment Name	The Glades, Byford	
Option Description	Pre-Development Scenario	
Catchment Area	328	ha

Land Use Breakdown

Residential : ~R15	0.0%	lower density residential areas (excludes road reserve area)
Residential : ~R35	0.0%	higher density residential areas (excludes road reserve area)
Road Reserves : Minor	1.0%	maintainance of verge by landowners
Road Reserves : Major	0.0%	maintainance of verge by local authority
POS : Active	0.0%	grassed areas
POS : Passive / Basins	0.0%	native vegetation
Rural : Pasture	97.0%	general pasture
Rural : Residential ~R2.5/R5	2.0%	low density
Rural : Poultry	0.0%	specific high nutient input land use
Commercial/Industrial	0.0%	town centre etc

Total Residential	**0.0%**
Total Area	**100.0%**

Nutrient Input Without WSUD

Residential	Garden	0.00	kg/net ha/yr	0.00	kg/gross ha/yr	0	kg/yr	0.0%
	Lawn	0.00		0.00		0		0.0%
	Pet Waste	0.00		0.00		0		0.0%
	Car Wash	0.00		0.00		0		0.0%
	Sub Total			0.00		0		0.0%
POS	Garden/Lawn	73.40	kg/ha POS/yr	0.00	kg/gross ha/yr	0	kg/yr	0.0%
	Pet Waste	0.00		0.00		0		0.0%
	Sub Total			0.00		0		0.0%
Road	Major Roads	29.36	kg/ha RR/yr	0.00	kg/gross ha/yr	0	kg/yr	0.0%
Reserve	Minor Roads	132.00		1.32		433		2.2%
	Sub Total			1.32		433		2.2%
Rural	Pasture	60.00	kg/ha Rural/yr	58.20	kg/gross ha/yr	19,090	kg/yr	97.3%
	Poultry Farms	175.00		0.00		0		0.0%
	Residential (R2.5/R5)	15.20		0.30		100		0.5%
	Sub Total			58.50		19,189		97.8%
			Total	**59.82**	kg/gross ha/yr	**19,622**	kg/yr	**100.0%**

Residential Areas (R15-R35) : Nutrient Removal via Source Control

☐ Native Gardens (Lots - Garden) ☐ Native Gardens (Lots - Lawn) ☐ Native Gardens (POS) ☐ Street Sweeping
☐ Community Education : Fertiliser ☐ Community Education : Pet Waste ☐ Community Education : Car Wash

Education Effectiveness 0%

	% Area of Influence	Removal kg/gross ha/yr	Removal kg/yr	Removal %	Capital Cost $	Operating Cost $/yr	Cost $/kg/yr
Native Gardens (Lots - Garden)	0%	0.00	0	0.0%	$0	$0	$0.0
Native Gardens (Lots - Lawn)	0%	0.00	0	0.0%	$0	$0	$0.0
Native Gardens (POS)	0%	0.00	0	0.0%	$0	$0	$0.0
Community Education : Fertiliser	0%	0.00	0	0.0%	$0	$0	$0.0
Community Education : Pet Waste	0%	0.00	0	0.0%	$0	$0	$0.0
Community Education : Car Wash	0%	0.00	0	0.0%	$0	$0	$0.0
Street Sweeping	0%	0.00	0	0.0%	$0	$0	$0.0
Totals		**0.00**	**0**	**0.0%**	**$0**	**$0**	**$0.0**

Residential Areas (R15-R35) : Nutrient Removal via In-Transit Control

☐ Gross Pollutant Trap ☐ Water Pollution Control Pond

	% Area of Influence	Removal kg/gross ha/yr	Removal kg/yr	Removal %	Capital Cost $	Operating Cost $/yr	Cost $/kg/yr
Gross Pollutant Traps	0%	0.00	0	0.0%	$0	$0	$0.0
Water Pollution Control Ponds	0%	0.00	0	0.0%	$0	$0	$0.0
Total		**0.00**	**0**	**0.0%**	**$0**	**$0**	**$0.0**

Net Nutrient Input

	kg/gross ha/yr	kg/yr	%
Nutrient Input : Residential Area without WSUD	1.32	433	2.2%
Nutrient Input : Rural Area	58.50	19,189	97.8%

				Capital Cost $	Operating Cost $/yr	Cost $/kg/yr
Removal via Source Control	0.00	0	0.0%	$0	$0	$0.0
Removal via In-Transit Control	0.00	0	0.0%	$0	$0	$0.0
Total Removal	0.00	0	0.0%	$0	$0	$0.0

Net Nutrient Input	**59.82**	**19,622**	**100.0%**

NiDSS

Nutrient Input Decision Support System
Version 2.0 March 2005
JDA Consultant Hydrologists
Report Date : 20-May-09

The Glades, Byford	
Total Nutrient Input - No WSUD (kg/yr)	**7,087**
Reduction due to WSUD (kg/yr)	**3,763**
Percentage Overall Reduction	**53.1%**
Pecentage Development Reduction	**53.1%**
Cost of Selected Program ($/kg/yr)	**$13**

● Total Phosphorus
○ Total Nitrogen

Catchment Name	The Glades, Byford	
Option Description	Post-Development Scenario	
Catchment Area	328	ha

Land Use Breakdown

Residential : ~R15	32.0%	lower density residential areas (excludes road reserve area)
Residential : ~R35	19.0%	higher density residential areas (excludes road reserve area)
Road Reserves : Minor	15.0%	maintainance of verge by landowners
Road Reserves : Major	7.0%	maintainance of verge by local authority
POS : Active	12.0%	grassed areas
POS : Passive / Basins	5.0%	native vegetation
Rural : Pasture	0.0%	general pasture
Rural : Residential ~R2.5/R5	0.0%	low density
Rural : Poultry	0.0%	specific high nutient input land use
Commercial/Industrial	10.0%	town centre etc

Total Residential	**51.0%**
Total Area	**100.0%**

Nutrient Input Without WSUD

Residential	Garden	21.65	kg/net ha/yr	11.04	kg/gross ha/yr	3,622	kg/yr	51.1%
	Lawn	10.09		5.15		1,688		23.8%
	Pet Waste	2.81		1.43		469		6.6%
	Car Wash	0.13		0.07		22		0.3%
	Sub Total			17.69		5,801		81.9%
POS	Garden/Lawn	2.60	kg/ha POS/yr	0.31	kg/gross ha/yr	102	kg/yr	1.4%
	Pet Waste	4.47		0.54		176		2.5%
	Sub Total			0.85		278		3.9%
Road Reserve	Major Roads	1.04	kg/ha RR/yr	0.07	kg/gross ha/yr	24	kg/yr	0.3%
	Minor Roads	20.00		3.00		984		13.9%
	Sub Total			3.07		1,008		14.2%
Rural	Pasture	20.00	kg/ha Rural/yr	0.00	kg/gross ha/yr	0	kg/yr	0.0%
	Poultry Farms	75.00		0.00		0		0.0%
	Residential (R2.5/R5)	4.00		0.00		0		0.0%
	Sub Total			0.00		0		0.0%
			Total	**21.61**	kg/gross ha/yr	**7,087**	kg/yr	**100.0%**

Residential Areas (R15-R35) : Nutrient Removal via Source Control

☑ Native Gardens (Lots - Garden) ☐ Native Gardens (Lots - Lawn) ☑ Native Gardens (POS) ☑ Street Sweeping
☐ Community Education : Fertiliser ☐ Community Education : Pet Waste ☐ Community Education : Car Wash

Education Effectiveness 0%

	% Area of Influence	Removal kg/gross ha/yr	Removal kg/yr	Removal %	Capital Cost $	Operating Cost $/yr	Cost $/kg/yr
Native Gardens (Lots - Garden)	100%	11.04	3,622	51.1%	$0	$0	$0.0
Native Gardens (Lots - Lawn)	0%	0.00	0	0.0%	$0	$0	$0.0
Native Gardens (POS)	100%	0.31	102	1.4%	$0	$0	$0.0
Community Education : Fertiliser	0%	0.00	0	0.0%	$0	$0	$0.0
Community Education : Pet Waste	0%	0.00	0	0.0%	$0	$0	$0.0
Community Education : Car Wash	0%	0.00	0	0.0%	$0	$0	$0.0
Street Sweeping	50%	0.08	27	0.4%	$0	$14,883	$546.5
Totals		**11.44**	**3,752**	**52.9%**	**$0**	**$14,883**	**$4.0**

Residential Areas (R15-R35) : Nutrient Removal via In-Transit Control

☑ Gross Pollutant Trap ☑ Water Pollution Control Pond

	% Area of Influence	Removal kg/gross ha/yr	Removal kg/yr	Removal %	Capital Cost $	Operating Cost $/yr	Cost $/kg/yr
Gross Pollutant Traps	19%	0.02	6	0.1%	$105,445	$4,038	$1,766.9
Water Pollution Control Ponds	19%	0.02	6	0.1%	$310,012	$4,306	$3,911.8
Total		**0.04**	**12**	**0.2%**	**$415,458**	**$8,344**	**$2,838.4**

Net Nutrient Input

	kg/gross ha/yr	kg/yr	%	Capital Cost $	Operating Cost $/yr	Cost $/kg/yr
Nutrient Input : Residential Area without WSUD	21.61	7,087	100.0%			
Nutrient Input : Rural Area	0.00	0	0.0%			
Removal via Source Control	11.44	3,752	52.9%	$0	$14,883	$4.0
Removal via In-Transit Control	0.04	12	0.2%	$415,458	$8,344	$2,838.4
Total Removal	11.47	3,763	53.1%	$415,458	$23,227	$12.8
Net Nutrient Input	**10.13**	**3,324**	**46.9%**			

NiDSS

Nutrient Input Decision Support System
Version 2.0 March 2005
JDA Consultant Hydrologists
Report Date : 20-May-09

The Glades, Byford	
Total Nutrient Input - No WSUD (kg/yr)	**31,679**
Reduction due to WSUD (kg/yr)	**10,957**
Percentage Overall Reduction	**34.6%**
Pecentage Development Reduction	**34.6%**
Cost of Selected Program ($/kg/yr)	**$5**

○ Total Phosphorus

● Total Nitrogen

Catchment Name The Glades, Byford
Option Description Post-Development Scenario
Catchment Area 328 ha

Land Use Breakdown

Residential : ~R15	32.0%	lower density residential areas (excludes road reserve area)
Residential : ~R35	19.0%	higher density residential areas (excludes road reserve area)
Road Reserves : Minor	15.0%	maintainance of verge by landowners
Road Reserves : Major	7.0%	maintainance of verge by local authority
POS : Active	12.0%	grassed areas
POS : Passive / Basins	5.0%	native vegetation
Rural : Pasture	0.0%	general pasture
Rural : Residential ~R2.5/R5	0.0%	low density
Rural : Poultry	0.0%	specific high nutient input land use
Commercial/Industrial	10.0%	town centre etc

Total Residential	**51.0%**
Total Area	**100.0%**

Nutrient Input Without WSUD

Residential	Garden	47.32	kg/net ha/yr	24.13	kg/gross ha/yr	7,915	kg/yr	25.0%
	Lawn	66.58		33.96		11,138		35.2%
	Pet Waste	11.14		5.68		1,864		5.9%
	Car Wash	0.04		0.02		6		0.0%
	Sub Total			63.79		20,923		66.0%
POS	Garden/Lawn	73.40	kg/ha POS/yr	8.81	kg/gross ha/yr	2,889	kg/yr	9.1%
	Pet Waste	17.76		2.13		699		2.2%
	Sub Total			10.94		3,588		11.3%
Road Reserve	Major Roads	29.36	kg/ha RR/yr	2.06	kg/gross ha/yr	674	kg/yr	2.1%
	Minor Roads	132.00		19.80		6,494		20.5%
	Sub Total			21.86		7,169		22.6%
Rural	Pasture	60.00	kg/ha Rural/yr	0.00	kg/gross ha/yr	0	kg/yr	0.0%
	Poultry Farms	175.00		0.00		0		0.0%
	Residential (R2.5/R5)	15.20		0.00		0		0.0%
	Sub Total			0.00		0		0.0%
			Total	**96.58**	kg/gross ha/yr	**31,679**	kg/yr	**100.0%**

Residential Areas (R15-R35) : Nutrient Removal via Source Control

☑ Native Gardens (Lots - Garden) ☐ Native Gardens (Lots - Lawn) ☑ Native Gardens (POS) ☑ Street Sweeping

☐ Community Education : Fertiliser ☐ Community Education : Pet Waste ☐ Community Education : Car Wash

Education Effectiveness 0%

	% Area of Influence	Removal kg/gross ha/yr	Removal kg/yr	Removal %	Capital Cost $	Operating Cost $/yr	Cost $/kg/yr
Native Gardens (Lots - Garden)	100%	24.13	7,915	25.0%	$0	$0	$0.0
Native Gardens (Lots - Lawn)	0%	0.00	0	0.0%	$0	$0	$0.0
Native Gardens (POS)	100%	8.81	2,889	9.1%	$0	$0	$0.0
Community Education : Fertiliser	0%	0.00	0	0.0%	$0	$0	$0.0
Community Education : Pet Waste	0%	0.00	0	0.0%	$0	$0	$0.0
Community Education : Car Wash	0%	0.00	0	0.0%	$0	$0	$0.0
Street Sweeping	50%	0.25	81	0.3%	$0	$14,883	$183.6
Totals		**33.19**	**10,885**	**34.4%**	**$0**	**$14,883**	**$1.4**

Residential Areas (R15-R35) : Nutrient Removal via In-Transit Control

☑ Gross Pollutant Trap ☑ Water Pollution Control Pond

	% Area of Influence	Removal kg/gross ha/yr	Removal kg/yr	Removal %	Capital Cost $	Operating Cost $/yr	Cost $/kg/yr
Gross Pollutant Traps	19%	0.11	36	0.1%	$105,445	$4,038	$286.1
Water Pollution Control Ponds	19%	0.11	36	0.1%	$432,374	$6,005	$883.5
Total		**0.22**	**72**	**0.2%**	**$537,820**	**$10,044**	**$584.6**

Net Nutrient Input

	kg/gross ha/yr	kg/yr	%	Capital Cost $	Operating Cost $/yr	Cost $/kg/yr
Nutrient Input : Residential Area without WSUD	96.58	31,679	100.0%			
Nutrient Input : Rural Area	0.00	0	0.0%			
Removal via Source Control	33.19	10,885	34.4%	$0	$14,883	$1.4
Removal via In-Transit Control	0.22	72	0.2%	$537,820	$10,044	$584.6
Total Removal	33.41	10,957	34.6%	$537,820	$24,927	$5.2
Net Nutrient Input	**63.18**	**20,722**	**65.4%**			