FINAL

MKSEA Surface Water and Groundwater Monitoring and Investigation Report

Prepared for

City of Gosnells

by

Endemic Pty Ltd

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1. Introduction

The Maddington Kenwick Strategic Employment Area (MKSEA) is approximately 10km south-east of the Perth CBD in the City of Gosnells. The MKSEA covers approximately 575 hectares and contains the Greater Brixton Street Wetland (GBSW) complex covering 90 hectares. The site is bordered by Tonkin Highway to the east, Roe Highway to the west, Bickley Road to the south and Welshpool Road to the north (Figure 1).

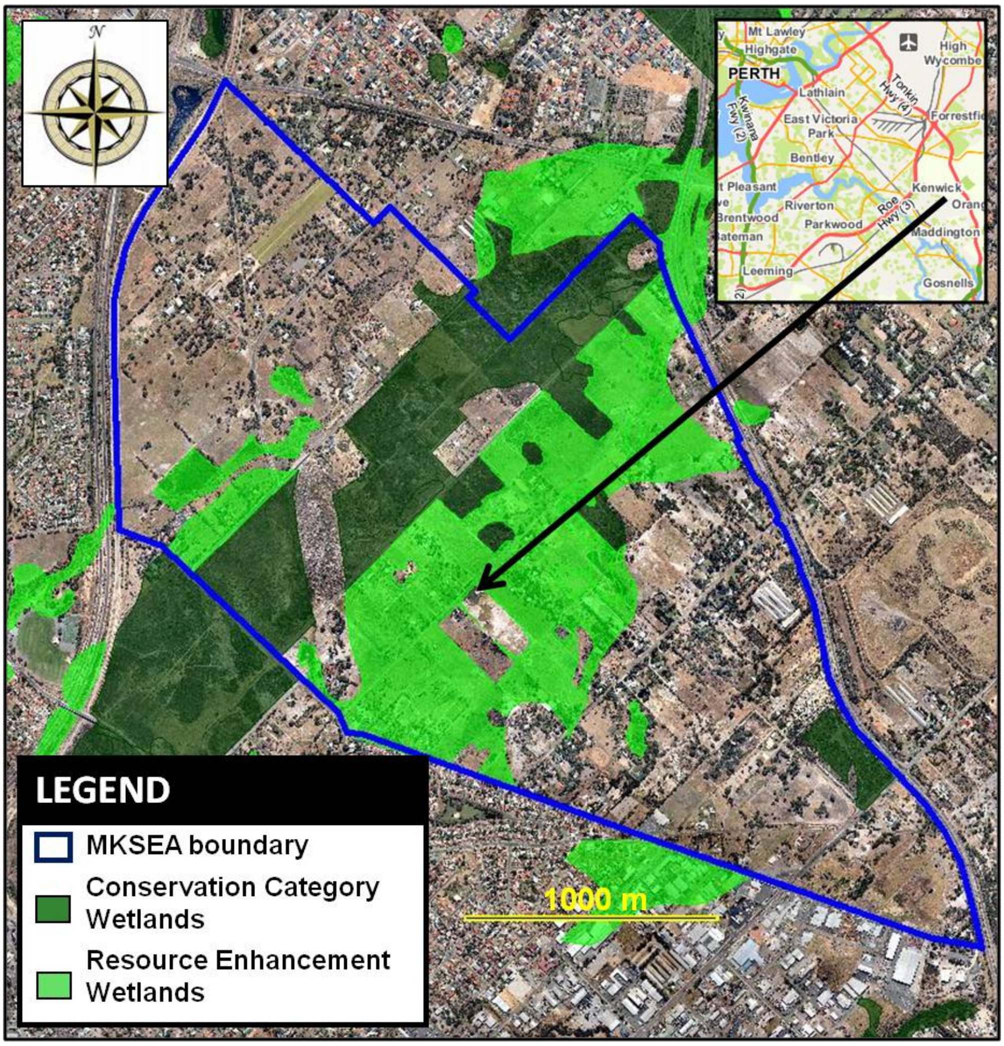


Figure 11: MKSEA site with Conservation Category and Resource Enhancement wetlands.

The Brixton Street Wetland (proper) contains over 320 plant species representing more than 20% of Perth's floristic biodiversity contained within an area of 19 hectares (or a meagre 0.005% of Perth's area).

The Brixton Street Wetland was entered into the Directory of Important Wetlands in Australia in 1992 and placed on the Register of the National Estate of the Australian Heritage Commission in November, 2000. The wetland system is protected under the EPBC Act (Commonwealth) and has been identified for conservation within Bush Forever Site No. 387 (Govt of WA, 2000). The wetland has also been identified as a Conservation Category Wetland (palusplain) within the DEC's Wetland Database.

1.1 Background

The MKSEA was identified within *Metroplan* in 1990 as a future strategic industrial area. The City of Gosnells (the City), through the Maddington Kenwick Sustainable Communities Partnership with the State Government, has embarked on an intensive planning exercise to deliver a framework for the future subdivision and development of the area. To date, a number of technical studies have been completed by the City, including transport, community engagement, environmental, servicing and drainage. A current concept plan is included as Appendix A.

The work to date has identified a number of challenges in progressing the planning for this area including:

- areas of environmental significance, including the Greater Brixton Street Wetlands and associated biodiversity conservation requirements;
- the interaction between both local and district water management regimes;
- the interaction between groundwater and surface water;
- high levels of fragmented land ownership, with in excess of 200 landowners; and
- potential delays and costs in providing servicing infrastructure.

In April 2007, the City engaged a consultant to scope the information requirements for a District Water Management Strategy (DWMS) for the MKSEA. A key information requirement identified from the scoping study included the need for an investigation that addresses both surface water and groundwater to improve the understanding of the hydrological regime and water quality dynamics in the project area.

Arising from this study, the City engaged a hydrological consultant to prepare a Surface Water and Groundwater Investigation and Monitoring Program (the Program). The Program was completed in August 2008 (Aquaterra, 2008) and the City subsequently engaged Endemic to implement the recommended Program.

The Surface Water and Groundwater Investigation and Monitoring Program was initiated in May 2009. An Interim report was prepared following the completion of the first 12 months of ground and surface water monitoring, which summarised the data to date and provided recommendations to enhance the quality of the monitoring program. Changes to the monitoring program included removal of BOD and COD from analysis parameters as they were considered surplus to requirements, and a change in NATA accredited laboratory. This Water Quality Monitoring Report summarises the findings of the completed 18 month monitoring program.

1.2 Aim and Objectives

The aim of the Surface Water and Groundwater Investigation and Monitoring Program is to gather data suitable for integration into future modelling (to be undertaken by others) to address future water quality and drainage management issues within the MKSEA.

The objective of this report is to collect baseline datasets (groundwater level/quality, wetland water level and surface water flow/quality) for the site in its pre-urbanised condition. In accordance with the Aquaterra *MKSEA Surface Water and Ground Water Investigation and Monitoring Program*, the aims of this hydrological and hydrogeological monitoring program are to determine:

- baseline environmental conditions;
- the interaction between groundwater and surface water;
- groundwater / surface water hydrological interactions with areas of environmental significance (including the Greater Brixton Street Wetlands);
- groundwater / surface water hydrological divide in regard to Precinct 1 and Precinct 2; and
- the interaction between local and district water regimes.

These final datasets that will be collated at the end of the two year monitoring program can be used, where required, to facilitate the:

- Establishment and calibration of a model of the site's groundwater hydrological system;
- Determination of seasonal groundwater level fluctuations and the Maximum Groundwater Level;
- Determination of seasonal wetland water level fluctuations to develop the Ecological Water Requirements (EWRs) for the Conservation Category Wetlands within the site; and
- Integration of surface water quality data with water level / flow rates (collected by others) to enable the calculation of flow-weighted nutrient loads within the hydrologic and hydraulic surface water models.
- Determination of Maximum Groundwater Level and aquifer characteristics to investigate the potential for flooding, and inform decisions about developable land area and potential drainage and fill requirements.
- Establishment of a baseline dataset to characterise the surface inflows and outflows of the site as the basis for impact assessment and an ongoing monitoring programme to monitor the impact of future development on surface water flows and quality.

The above matters can be addressed in a future DWMS prepared for the MKSEA.

1.3 Scope of Works

The scope of work for this project entails implementation of the surface water and groundwater quality and quantity monitoring program for a period of two years as defined by the Aquaterra *MKSEA Surface Water and Ground Water Investigation and Monitoring Program*. Due to delays in gaining site access, the monitoring program could not commence before June 2009 and thus constitutes 18 months' monitoring over two winter periods. The program comprised the following sub-tasks:

1. Surface Water Monitoring

The objective of the Program is to provide an understanding of the quality of surface water and the nature and quantity of surface water movement together with the spatial and temporal variation in water quality, as well as providing a characterisation of depth and period of inundation of specific seasonal wetlands.

1.1 Surface Water (Streamflow) Monitoring

- Establishment and operation of 2 streamflow gauging stations (M1 and M2).
- An additional 4 stream water level recorders at sites to be selected
- Collection of stage height/discharge measurements to determine instantaneous streamflow for the above monitoring sites.

1.2 Surface Water Quality Monitoring

- Establishment and operation of up to 14 surface monitoring stations. Eight of the above monitoring stations coincide with wetland monitoring stations and stream gauging stations.

1.3 Wetland Water Level Monitoring

- Surface water quality monitoring to follow general principles and guidance provided in Section 3.5 of the Program, and to specifically address water quality parameters and sampling regime (reproduced below in Table 1).
- Establishment and operation of up to 6 wetland surface water level monitoring stations as per Section 3.2 of the Program (M8 and up to 5 other sites to be selected).

2. Groundwater Monitoring

The objective of the groundwater monitoring program is to understand the level and quality of groundwater and nature of subsurface water movement, together with the spatial and temporal variation in those parameters.

2.1 Groundwater Level Monitoring

- Establishment and operation of 11 groundwater monitoring bores, as advised in Section 3.6, and located as per Figure 5 of the Program.

2.2 Groundwater Quality Monitoring

- Utilising the 11 monitoring bores, groundwater quality data is to be collected as advised in Section 3.6 of the Program, and to specifically address water quality parameters and sampling regime provided in the Program (reproduced below in Table 1 below).

Table 11: Water Quality Sampling.

Sampling Suite	Parameters Analysed	Groundwater Sampling Regime	Surface Water Sampling Regime
Physical Characteristics	(pH, TDS, TSS, EC, DO, BOD & COD)	Quarter yearly**	Monthly May-November (all sites) and Weekly for 6 weeks (creeks and drains only)*
Nutrients	(TN,KN,NO_3,NO_2, TP, OP)	Quarter yearly**	Monthly May-November (all sites) and Weekly for 6 weeks (creeks and drains only)*
Metals	(Cd, Co, Cr, Cu, Mn, Ni, Pb, Zn. Fe, As, Hg. Se, Al)	Quarter yearly**	Once per year after flow commences
BTEX	(Benzene, Toluene, Ethylbenzene and Xylene compounds)	Half yearly	Once per year after flow commences
TRH	(Total recoverable hydrocarbon compounds)	Half yearly	Once per year after flow commences
PAH	(Polycyclic aromatic hydrocarbons)	Half yearly	Once per year after flow commences
Major Pesticides	Multiple pesticides	Half yearly	Once per year after flow commences

* Monthly May-November (within 6 hours of high flow / storm event) plus for a 6 week “high flow” period in July/August each year.

** There are potentially seasonal variations in nutrient levels in superficial aquifers. Physical Characteristics and Nutrients are to be sampled on a quarterly basis.

Following an initial site inspection, a high level of tampering and vandalism was anticipated given the proximity of the Yule Brook upstream gauge station (M1) to a school and relative isolation of the downstream (M2) station (being located alongside a railway line). These sites were considered ‘high risk’ and unsuitable for deployment of automatic water samplers. Endemic has employed an alternative (tamperproof) method to measure streamflows/contaminant loads which achieves the projects objectives and also increased the temporal and spatial resolution of the flow monitoring for the purposes of future development and drainage design. Specific construction details are presented in the next section.

The surface and groundwater monitoring network utilised for the study area is summarised in Table 2.

Table 22: Summary of 2009-2010 Monitoring Program.

Site	Tender Scope	Actual	Site Codes
Surface water (creek) sites	4 sites (staff readings)	6 sites (continuous levels/flow logging)	SW1-3, SW5-7
Groundwater sites	11 sites (level readings)	11 sites (continuous level logging)	GW1-9, GW11-13
Wetland sites	6 sites (staff readings)	7 sites	WET2-WET8
Gauge Stations	Yule Brook Upper & Lower (continuous level/flow)	Yule Brook Upper & Lower (continuous level/flow)	M1, M2

Note: Groundwater monitoring sites GW2-5 and GW9 also coincide with Conservation Category Wetland habitats.

3. Reporting

The objective of the final reporting stage is to provide a basis for impact assessment of the proposed development on surface water levels and quality, and ongoing monitoring needs. The final report summarises the work done and applies it to the key objectives of the monitoring program over the 18 month period, and presents the results obtained from monitoring works. The report collates, analyses and evaluates all collected data in conjunction with longer period datasets and other available information from previously prepared reports and literature. The analysis is utilised to describe and characterise the surface and sub-surface hydrology of the site, relationship between the two, and hydrological linkages between wetlands within and outside the MKSEA boundary. Finally, the report concludes with comments on the threats and opportunities with respect to the goal of future development, and considers data gaps and future monitoring that may be required.

Environmental conditions extrapolated from this data set may be used to gauge the impact of future changes to local land use patterns, by providing suitable guidelines and indicators of disturbance in the Bickley Brook/ Yule Brook catchments and GBSW. It will provide the City of Gosnells a scientifically justifiable understanding of the current baseline hydrological conditions in the MKSEA and, as such, forms part of a District Water Management Strategy (DWMS, the recommended approach for total water cycle management within the redevelopment area consistent with sustainability principles.)

2. Site Characteristics and Literature Review

The Maddington Kenwick Strategic Employment Area comprises four distinct areas within the City of Gosnells, Precincts 3A (~90 ha) and 3B (~62 ha) in the north western portion of the site, Precinct 2 (~290 ha including ~90 ha of the GBSW) in the central portion of the site, between Brook Road and Victoria Road, and Precinct 1 (~125 ha) in the south eastern portion of the site. The site is currently zoned rural (excluding Bush Forever sites), with the primary land use since initial settlement in 1832 being farming (Aquaterra Consulting, 2008). Before the 1960s, surrounding land uses were similar, with a minor role for industrial activity until the development of the Maddington Industrial Area. Light rural industry, horticulture, sand mining, transport and biodiversity conservation land uses are also characteristic of the general area. Two Bush Forever sites lie within the MKSEA, The Greater Brixton Street Wetlands (Bush Forever Site 387) and Clifford Street Bushland (Bush Forever Site 53).

A proposed amendment to the Metropolitan Region Scheme has been submitted to the Western Australian Planning Commission to rezone Precinct 1 of the MKSEA, immediately north of the Maddington Industrial Area, from Rural to Industrial. The majority of the MKSEA is proposed for future industrial land uses, however the post-development site will also house wetlands of Conservation, Resource Enhancement and Multiple Use management categories. These management categories provide guidance on the nature of the management and protection needs of wetlands of the Swan Coastal Plain. The City of Gosnells has undertaken detailed evaluation of the wetlands in the MKSEA and proposed modifications to wetland management categories and/or boundaries may result.

The geology and hydrogeology of the MKSEA project area impact the hydrological system and relationships at the site. Detail on the site's geological, hydrogeological characteristics is presented in the following section. This chapter also includes a brief review of existing literature and reports relevant to the site's hydrological and environmental constraints and opportunities.

2.1 Geology

Regional geology information was obtained from the Geological Survey of Western Australia, Perth Metropolitan Region 1:50,000 Environmental Geology Series, Armadale, part map sheets 2033 (I) and 2133 (IV) (GSWA, 1986). The lots that make up the MKSEA project area were identified as being within the Quaternary Guildford formation and comprises areas of Sandy Clays (Cs) overlain in parts by thin Bassendean sands (S10 and S8) (Figure 2). Thicker Bassendean Dune deposits are represented by a low dune running northward from the intersection of Brentwood and Bickley Roads. Endemic also suspects a band of subcropping Leederville formation limestone and calcrete through the section of the site supporting the GBSW that warrants further investigation.

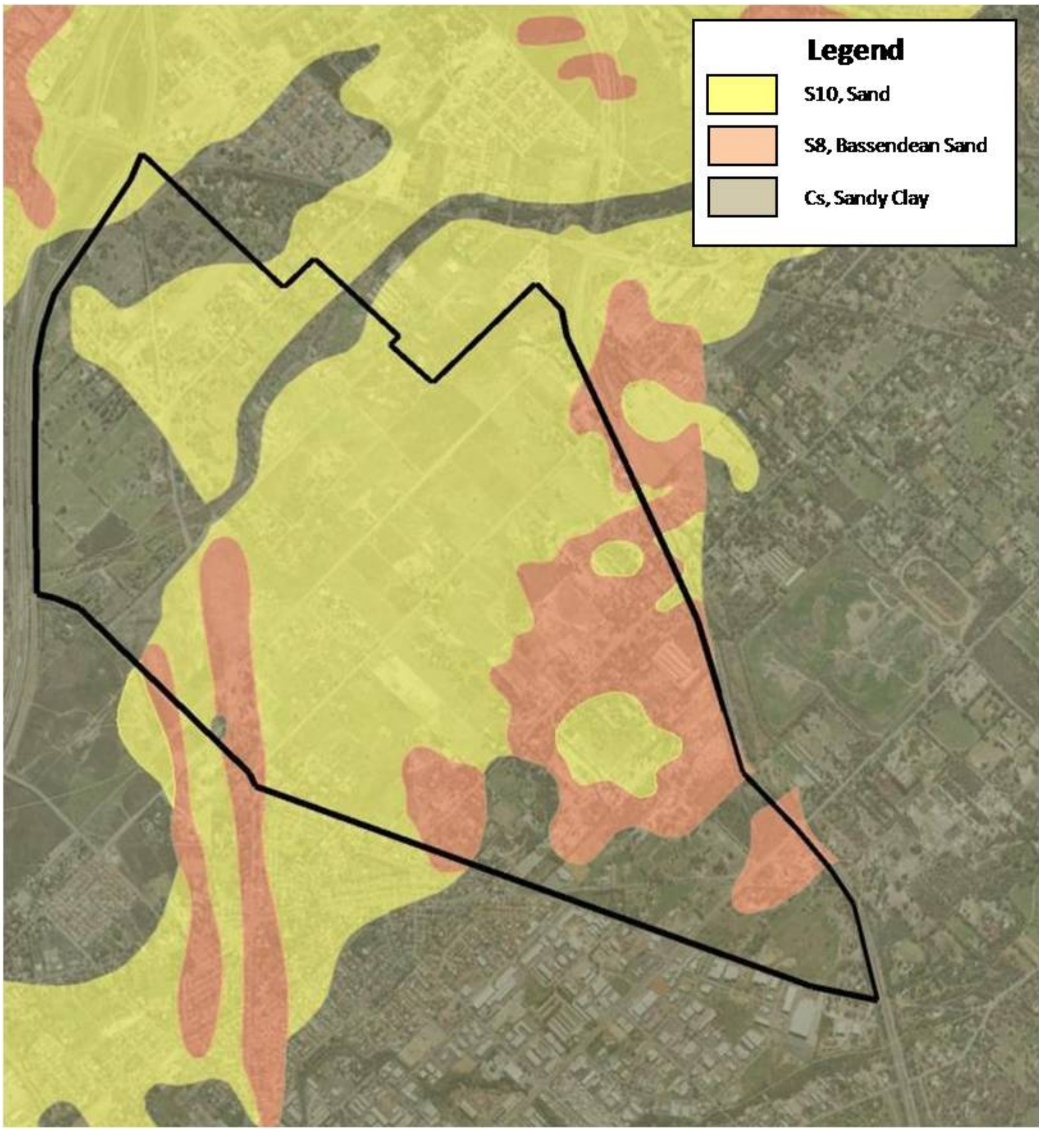


Figure 22: Soil types within the MKSEA project area (GSWA, 1986)

2.2 Hydrology

The aquifers of the MKSEA area include the superficial Perth Swan unconfined aquifer which is a shallow aquifer formed from surficial sediments. The Perth Groundwater Atlas (DEC, 2004) reports groundwater elevation varying from 5m AHD to 15m AHD, with flow generally in a westerly direction toward the Canning River (GHD, 2005). The geological age of the site is Quaternary over a confined aquifer associated with the Perth Leederville Formation.

Wetlands are a significant hydrological feature of the MKSEA with a large proportion of the site located on palusplain, and comprising the Greater Brixton Street Wetland Complex as well as several separate patches of wetland, several of which support Threatened Ecological Communities. The interactions between ground and surface waters within these wetlands is varied and complicated by the existence of a subcropping calcrete horizon within, and possibly outside of, the GBSW Complex.

GHD's Engineering Feasibility Study Report suggests a significant difference in groundwater depth between the north western and south eastern portions of the site, with the north west supporting vast wetland areas, and groundwater further from the surface in the south east. Surface Water drainage is reported to comprise a series of open, unlined drains, and varies in direction across the site. GHD notes that surface water north and west of the Yule Brook drains through unlined open road drains into the Yule Brook, while surface runoff north of Bickley Road, between Boundary and Victoria Roads drains south west towards Bickley Road and discharges into Binley Brook. GHD reported that the land east of the Yule Brook, to Victoria Road drains through unlined open drains traversing the GBSW Reserve, however minimal flow has been noted during monitoring rounds conducted for this investigation.

2.3 Literature Review

Several previous investigations have been conducted in the vicinity of the MKSEA project area, including:

- Hydrological Study of the Greater Brixton Street Wetlands, V & C Semeniuk Research Group (2001)
- Environmental Review for the MKSEA, Cardno BSD (2005)
- Engineering Review for the MKSEA, GHD (2005)
- Maddington Kenwick Sustainable Communities Partnership – Action and Implementation Plan
- Yule Brook Report Card, Swan River Trust (2009)
- MKSEA project area preliminary Acid Sulfate Soils Screening and SPOCAS Assessment, Endemic Pty Ltd (2009)
- The flora, vegetation and wetlands of the Maddington-Kenwick Strategic Employment Area, Tauss and Weston (2010)

2.3.1 Hydrological Study of the Greater Brixton Street Wetlands

The V & C Semeniuk Research Group undertook a study of the Greater Brixton Street Wetlands during 1999-2000, covering wetlands both inside and outside the proposed MKSEA. The objective was to 'investigate the hydrological mechanisms of recharge, flow, and discharge, within these remnant wetlands areas, and to identify inter-related water/sediment/plant responses, where possible.'

The study involved drilling 6 holes from 6-17m depth, placement of 34 piezometers along 8 transects and vegetation surveys. The wetlands were found to be maintained by 'surface and near surface perching of direct precipitation, and by infiltration, most commonly via root cavities', with minimal interaction from the regional aquifer. For most of the area the groundwater was found to be semi-confined.

The study found that the major effect of drains adjacent to the Greater Brixton Street Wetlands area is upon the surface water in the wetlands, and that 'the draining of the wetlands has the effect of reducing the hydroperiod of innundation and waterlogging in the surface sediments, and of reducing the potential for infiltration. Alteration of water levels through drainage was found to be having a serious impact on some of the vegetation.

2.3.2 Environmental Review for the MKSEA

Cardno BSD undertook field-based assessments of the flora, vegetation, fauna and wetlands at the Maddington Kenwick Strategic Industrial Area over one day in October, 2004. The Environmental Review report was subsequently submitted to the City of Gosnells in July, 2005, and detailed the flora and vegetation, fauna and wetland survey methodology and results as well as recommendations for future studies and management.

The Environmental Review identified a total of 199 taxa, comprising 53 families, and 145 genera within the project area. The greatest species representations were among the Myrtaceae, Papilionaceae (now Fabaceae), and Cyperaceae families, with sixty introduced species collected most commonly within the Poaceae, Iridaceae, and Papilionaceae (now Fabaceae) families. The Environmental Review recorded two Declared Rare Flora species, one Priority 1 species, and one Priority 3 species as well as five Threatened Ecological Communities out of the 22 local vegetation communities described in the area.

The fauna study reported the MKSEA's fauna as depauperate due to habitat loss and degradation of remaining habitat. However the study did acknowledge the existence of seasonal wetlands on the site which, although degraded in many areas, may be important for linkages between habitat corridors on the coastal plain and along the Darling Escarpment. The Environmental Review reported that the Department of Environment (now Department of Environment and Conservation) has mapped the majority of the study area as wetlands. Excluding the two Bush Forever sites, there also exist four Conservation Category Wetlands, and large areas of Resource Enhancement Category Wetland. The Environmental Review recommended five wetlands for referral for reclassification from their existing management category, as well as suggesting further studies that could possibly result in recommendations for reclassification of some areas of REW.

2.3.3 Maddington Kenwick Sustainable Communities Partnership

The Maddington Kenwick Sustainable Communities Partnership is a coalition between the City of Gosnells and the State Government of Western Australia with the aim of establishing a model for sustainable community regeneration in the urban middle ring which can be applied throughout Australia's metropolitan areas. The Action and Implementation Plan is based on the 2005 20-year community vision that:

"*In the year 2025, Maddington Kenwick has realised its full potential and become a leading community in sustaining itself socially, environmentally and economically. Maddington Kenwick has a high quality of life, strong sense of place and positive identity. It is an innovator and model for other communities. Maddington Kenwick is a place where people choose to be.*"

The Action and Implementation Plan identifies the area's European heritage as beginning in the 1830s when the two suburbs of Maddington and Kenwick were centres of agricultural development around the Canning River. The area's Aboriginal Heritage lies with the Beeliar and Beeloo groups of Noongar people. The plan identified 14,000 residents with a mix of residential, rural, commercial and industrial land uses. The area also contains natural assets including the Canning River and the GBSW.

The Plan sets out implementation actions for each of the sub-vision goals such as investigating a possible business hub in the employment area as an economic improvement action and working with agencies to improve water-wise and fertiliser-wise gardening practices and environmental asset inventories as environmental improvement actions.

2.3.4 Yule Brook Report Card

The Yule Brook is a 6.8km watercourse that runs from Lesmurdie Reserve to its discharge point into the Canning River. It is a natural watercourses at its headwaters, and a network of deeply incised drains in its lower reaches. The Swan River Trust maintains a monitoring site in the lower reaches of the Yule Brook, near Mills Park. The purpose of this monitoring site is to monitor nutrients leaving the Yule Brook catchment and flowing into the Canning River. As such the monitoring data obtained by the Swan River Trust does not accurately represent nutrients present in upstream areas.

The Swan River Trust reported in 2009 that the Yule Brook has met the Short Term target median TN concentration (mg/L) in all years of monitoring between 1994 and 2006 as well as meeting the Long Term target median TN concentration (mg/L) in 2006. The Yule Brook has met the Short and Long Term target median TP concentrations in all monitoring years between 1994 and 2006. The highest median TN concentration observed at the Mills Park monitoring site was 1.4 mg/L in 1996 and the lowest was 0.83 mg/L in 2002 (prior to revision of the Short and Long Term target median TN concentrations). The highest median TP concentration observed at the Mills Park monitoring site was 0.155 mg/L in 2006, and the lowest was 0.04 mg/L in 1994.

The Swan River Trust have identified that TN concentrations appear to have remained fairly constant during the 1994-2006 monitoring period, whereas TP concentrations appear to have been increasing during this monitoring period. TN in the Yule Brook is made up of approximately two thirds organic nitrogen, with the remainder made up of dissolved inorganic nitrogen consisting of ammonium (about 14%) and N oxides (about 25%). TP in the Yule Brook is made up of approximately two thirds particulate P, with the remainder made up of Soluble Reactive P. The Swan River Trust assessed the Yule Brook as showing positive signs in passing the Short and Long Term TN and TP targets, and reserves concern over the increasing short and long term trends in TP concentrations.

The information obtained from this document can be used to compare the TN and TP concentrations in the section of the Yule Brook that passes through the MKSEA site, to the north of the GBSW.

2.3.5 MKSEA project area preliminary Acid Sulfate Soils Screening and SPOCAS Assessment

In response to the WAPC’s Acid Sulfate Soils Self Assessment Form and in accordance with the DEC’s requirements (DEC, 2009a), a preliminary site investigation for Acid Sulfate Soils was undertaken in 2009. The purpose of the investigation was to confirm the regional ASS mapping, investigate the occurrence and extent of acid sulfate soils on the site and determine the need for further investigation and management. The MKSEA project area was screened against the acid sulfate soils risk map outlined in the Acid Sulfate Soils Planning Bulletin (WAPC, 2009), map 23. The MKSEA project area is listed as having predominately a moderate to low risk of ASS occurring within 3 m of natural soil surface (Figure 3). There are two high to moderate ASS risk areas associated with Yule Brook and a small Resource Enhancement wetland (Kenwick Swamp; UFI 15418). The preliminary acid sulfate soil investigation identified five lithologies with varying degrees of acid generating potential – the BASSENDEAN SAND, WHITE SANDY CLAY, WHITE CLAY, ORANGE / WHITE CLAY and BLUE / GREY CLAY.

The BASSENDEAN SAND, WHITE SANDY CLAY, WHITE CLAY and ORANGE / WHITE CLAY lithologies were found to be not acid generating, with zero samples exhibiting a net acidity greater than the assessment criteria of 0.03% S. The BLUE / GREY CLAY lithology was generally moderately acid generating, with 100% of the samples (2 of 2 samples from these soil types tested for SPOCAS) exhibiting a net acidity greater than the assessment criteria of 0.03%S. The BLUE / GREY CLAY soil unit has been given a HIGH RISK of acid generation due to its low to moderate total sulfur concentration and presence at or below the water table. The BLUE / GREY CLAY soil unit occurs in discrete areas across the site and excavation volumes will be minimal, although there may be areas around the pump stations and localised sections of the sewer lines that intersect volumes that exceed 100 m3. The greatest risk for the oxidation of the BLUE / GREY CLAY is associated with the planned soil excavations and potential dewatering of this unit.

Therefore, based upon the limited sampling undertaken, a moderate actual risk of ASS is generally associated with the BLUE / GREEN CLAY soil type, however, this is likely to be a localised impact. Endemic believes that the ASS onsite does not provide a significant impediment to development and appropriate management strategies for handling these moderate risk soils could be defined in accordance with DEC guidance (DEC 2009a; DEC 2009b).

2.3.6 The flora, vegetation and wetlands of the Maddington-Kenwick Strategic Employment Area

This Level 2 flora, vegetation and wetlands survey of the MKSEA was commissioned by the City of Gosnells in early September 2007 to provide detailed guidance to the MKSEA planning process, superseding the results of Cardno BSD (2005). Tauss and Weston identified nationally significant conservation values including threatened flora and threatened ecological communities (TECs). They found that most of the flora and vegetation of high conservation significance found in the MKSEA are highly dependent on surface waters and/or groundwater

The Tauss and Weston report identified significant constraints to development within the MKSEA, requiring further detailed study of the hydrogeology across the site as a basis for long-term sustainable planning. In particular, they recommended further hydrological investigation of the interface between the Bassendean sands and Pinjarra Plain.

3. Monitoring Methodology

The following section details the construction details and sampling methodology used to implement the Surface Water and Groundwater Investigation and Monitoring Program for MKSEA.

3.1 Groundwater Bore installation

In accordance with the approved scope of works, 11 groundwater monitoring bores were installed at the site on the 18-19th June, 2009 (Figure 2). Bores were installed up to a depth of 6m Below Ground Level (BGL), with individual bore depths varying depending on the superficial geology and groundwater depth encountered at each location. The shallowest bore depths were between 1m to 2.5m BGL, observed in bores GW12, GW2, GW4, and GW5, all within the GBSW. It is suspected that refusal was reached due to the presence of underlying calcrete.

Figure 33: Location of Groundwater Monitoring Bores.

It should be noted that the bore numbering includes 12 bores (GW1-GW12), however during the installation program, site access was problematic and bore GW10 was not utilised. Therefore, the groundwater bore series includes GW1, GW2, GW3, GW4, GW5, GW6, GW7, GW8, GW9, GW11 and GW12.

Due to winter waterlogging, groundwater bores GW2, GW4 and GW9 also serve as wetland water level monitoring sites.

3.1.1 *Bores outside of wetland boundaries*

Details of the specific bore construction parameters outside of wetland areas are as follows:

- The bores were installed with a Geoprobe 6620 drill rig using the continuous push tube Macro-core sampling system. All bore hole locations were marked using a handheld GPS with an accuracy of ±5 meters. Cores were extracted within the plastic macro-core tubes and split in half to provide a clean and intact core. No auguring was required during the drilling program;
- The continuous push tube Macro-core sampling system provides intact cores of approximately 1.2 m in length within a disposable plastic casing. The soil cores were split in half and geotechnical logging performed according to the USGS classification system (AS/NZS 4452.1997), with all soil horizons and the water table depth recorded;
- Bore cases and screens were constructed using 50 mm diameter, class 18 threaded PVC with end caps. Screens and casings were joined using the pre-cut thread, no solvents or glues were used in bore construction to minimise the risk of sample contamination;
- Bore casing and screened segments were pre-washed with an organic based detergent and arrived in sealed bags.
- During monitoring bore installation, the direct push tube was inserted until a significant aquitard (well developed ‘hardpan’ or clay horizon) was encountered. The tube was then backed out 20cm and the PVC slotted bore casing installed. The remainder of the annular space was sand-packed and the annulus sealed with bentonite and allowed to settle for at least 1 month prior to water quality sampling.
- The bores were constructed with standpipes at least 0.5 m above ground, casing to 0.5 m below ground level (BGL) depth and followed by a slotted PVC screen which covered the intercepted groundwater level. Standpipe elevation above the ground level was surveyed using an RTK device to allow for future correction to mAHD and groundwater contour calculations;
- All bores were developed following construction. This is the process of removing fines such as sand, silt and clay from the aquifer around the bore screen to maximises the hydraulic connection between the bore and the formation;
- Each bore was sealed using an EnviroCap tamperproof well cap to secure the bores and provide an air-tight seal for hydrocarbon sampling; and

- A continuous water level logger (Insitu Level Troll 100) was suspended by a stainless steel wire attached to the post end-cap. The loggers automatically recorded average water levels each hour and with an accuracy of 1cm. Loggers were downloaded at approximately 3 month intervals.

3.1.2 *Bores within wetland boundaries*

Due to the sensitivities of installing monitoring bores within a Conservation Category wetland, bores located within the Brixton Street Wetland Reserve were installed using a hand auger to minimise vegetation disturbance. The need for vehicle access during bore construction and routine water quality sampling was averted in order to reduce the potential for the spread of weeds and pathogens (in particular, dieback disease) within conservation areas.

The bore construction and sampling details were identical to those outlined in 2.1.1, with the following variations:

- The bores were installed using a hand auger taking care not to disturb surrounding vegetation;
- Soil cores were extracted from the hand auger in 15cm segments and laid out onto a core tray for soil logging. Once the water table was reached the installation technique was changed (the auger does not retain slurry) and the PCV casing was placed into the hole and the soil water mixture removed. The sludger was then emptied onto the core tray and allowed to drain prior to soil logging. The PVC bore casing was sludged into the groundwater until a significant aquitard (well developed 'hardpan' or clay horizon) was encountered. In some locations calcrete was encountered and was identified by a hard 'pinging' on refusal, a lack of clay and the presence of milky-white material on the auger or within the sludger;
- During monitoring bore installation, the Dormer was hand augured down to the water table, sludged until refusal and installed. The remainder of the annular space was gravel packed and the annulus sealed with bentonite and allowed to settle for at least 1 month prior to water quality sampling.
- A continuous water level logger (Insitu Level Troll 100) was suspended by a stainless steel wire attached to the post end-cap. The loggers automatically recorded average wetland water levels each hour and with an accuracy of 1cm. Loggers were downloaded at approximately 3 month intervals.

3.1.3 *Groundwater monitoring program*

The groundwater monitoring network was installed in July 2009, with the first round of the water quality monitoring commencing in September 2009.

Groundwater Levels

Water level loggers (Insitu Troll 100) were deployed in all groundwater monitoring bores and were barometrically corrected to provide (continuous) hourly monitoring of groundwater levels.

The use of automated groundwater level monitoring improves the temporal resolution of groundwater level datasets compared with the original scope (which required monthly groundwater level dipping). This is likely to be advantageous given the 'flashy' nature and responsiveness of the catchment to rainfall. The loggers were downloaded on a quarterly basis, immediately prior to manual water level measurement (for calibration) and water quality sampling of each bore.

Groundwater Quality

Groundwater quality was monitored on a quarterly basis, with individual sampling being conducted on the 9th September, 25th November, 2009 and 23rd March, 24th June, 23rd September, and 15th December 2010. During the February 2010 sampling event all groundwater bores were dry, hence water quality sampling was not possible on this occasion. An additional water quality sampling round was undertaken in March as replacement, however only one bore, GW06 contained enough water to produce a water quality sample for analysis.

Details of the specific groundwater purging and sampling methods are as follows:

- The bores were allowed to equalise with the surrounding groundwater for one month prior to sampling;
- The bores were installed (in part) to detect Light Non-Aqueous Phase Liquids (LNAPLs i.e. petrol, diesel and other petroleum products). As such, each bore was sealed using an airtight EnviroCap tamperproof well plug to allow for retention of volatile compounds within the bore.
- Prior to purging, an intrinsically safe electronic oil/water interface dipper with graduated measuring tape was used to measure groundwater levels, as well as floating hydrocarbons (LNAPLs). A positive result on the dipper would result in a groundwater sample being taken from the top of the water column to provide NATA accredited laboratory confirmation analysis.
- A hand bailer was used to purge at least 5 volumes of bore water (in accordance with AS/NZS 5667.1-1998) immediately prior to obtaining the groundwater sample for analysis.
- Physical parameters were measured onsite using a multi-parameter water probe;
- In accordance with the scope, unfiltered samples were collected in laboratory provided bottles containing the appropriate preservative and placed into an esky with freezer blocks. In addition to the unfiltered samples, during the September 2009 sampling event duplicate samples were taken, filtered to 0.5µm and placed in sample bottles provided by the laboratory (with preservatives, where required) and placed into an esky with freezer blocks. This filtered / unfiltered round of sampling was undertaken to verify the suspicion that high proportion of analytes being detected were indeed associated with clay particulates. This information has been used during the formulation of future monitoring recommendations.

- All equipment (that is routinely reused) and in contact with bore water was decontaminated between the sampling locations in accordance with Endemic's decontamination procedures (phosphate free detergent, 10% nitric acid wash and rinsed 3 times with Deionised Water); and
- Groundwater samples were stored frozen at the Endemic office in Subiaco and forwarded to a NATA accredited laboratory for analyses. A chain of custody form accompanied samples during each transport and delivery. Table 3 outlines adherence to groundwater sampling procedures and methodology.

Table 33: Groundwater Sampling Methods.

Activity	Details
Well Purging and Sampling	Purging and sampling according to AS/NZS 5667.1-1998 "Water quality – Sampling, Part 1: Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples.
Well Gauging	Water levels gauged using a standard water / oil interface level probe.
Disposal of Groundwater	Purged groundwater was disposed of on-site.
Quality Assurance	1:20 duplicate samples sent to the NATA accredited laboratory.
Sample Acquisition and Storage	Samples collected using disposable Enviroquip Clearview bailers and stored in laboratory provided bottles (with preservative as required) and prepared according to AS/NZS 5667.1:1998.
Sample Preservation	Samples were stored on freezer blocks while on-site, frozen at Endemic offices and on ice whilst in transit to the laboratory.
Sample Handling	Samples were sent to the lab accompanied by a Chain of Custody.
Sample analytes	As per Table 1.

3.2 Wetland Water Level Monitoring

In accordance with the approved scope of works, 6 wetland water level monitoring sites were selected and installed within the project area. Upon inspection during Winter 2010, an additional (7^{th}) wetland monitoring site was added by Endemic to improve the spatial coverage of the groundwater/wetland network.

The wetland water level monitoring stations were installed by hand on the 13^{th} August (WET4 and WET8), 3^{rd} September (WET5, WET6 and WET7), 8^{th} September (WET3) and 11^{th} September (WET2), 2009 (note, WET1 was a spare site that was not installed).

Therefore, the wetland water level monitoring sites included WET2, WET3, WET4, WET5, WET6, WET7 and WET8 (Figure 3).

Details of the installation of the wetland monitoring stations are as follows:

- A series of 10 inlet holes were drilled into the lower half of a 3.0 m long, 50 mm diameter galvanised steel poles.
- The poles were installed into the nominated wetland monitoring site using a hand held auger in order to minimise soil and vegetation disturbance. Once the

water table was reached, the steel poles were installed using the sludger (same as per bores within the wetlands) until refusal was reached;

- A continuous water level logger (Insitu Level Troll 100) was then suspended by a stainless steel wire attached to the post end-cap. The loggers automatically recorded average wetland water levels each hour and with an accuracy of 10mm;
- A barometric logger (Insitu Baro Troll 100) was installed at Site SW5 to provide barometric correction for the water level loggers. This is required to calibrate the readings of the loggers for background fluctuations in atmospheric pressure and is accurate to a 5 km radius;
- All wetland water level monitoring stations were secured within the steel housing with a tamperproof envirocap to reduce the likelihood of tampering and vandalism; and
- Loggers were downloaded at approximately 3 month intervals.

Figure 44: Location of Wetland Monitoring Bores.

Due to site access restrictions and the need to locate specific monitoring sites during elevated groundwater conditions, many of the wetland monitoring sites were only installed in August/September 2009.

3.3 Surface Water Monitoring

The surface water monitoring network is designed to provide detailed information on the flows of surface water together with the spatial and temporal variation in water quality at MKSEA. The surface water monitoring stations were installed by hand on the 29th May (M1 and M2), 8th July (SW3 and SW5), 12th July (SW1), 20th July (SW7), 26th July (SW2 and SW6), 2009. SW4 was a spare site that was not installed.

In line with the approved scope of works, a total of 8 surface water monitoring sites were installed along drainage lines within the MKSEA site and included M1, M2, SW1, SW2, SW3, SW5, SW6 and SW7 (Figure 4).

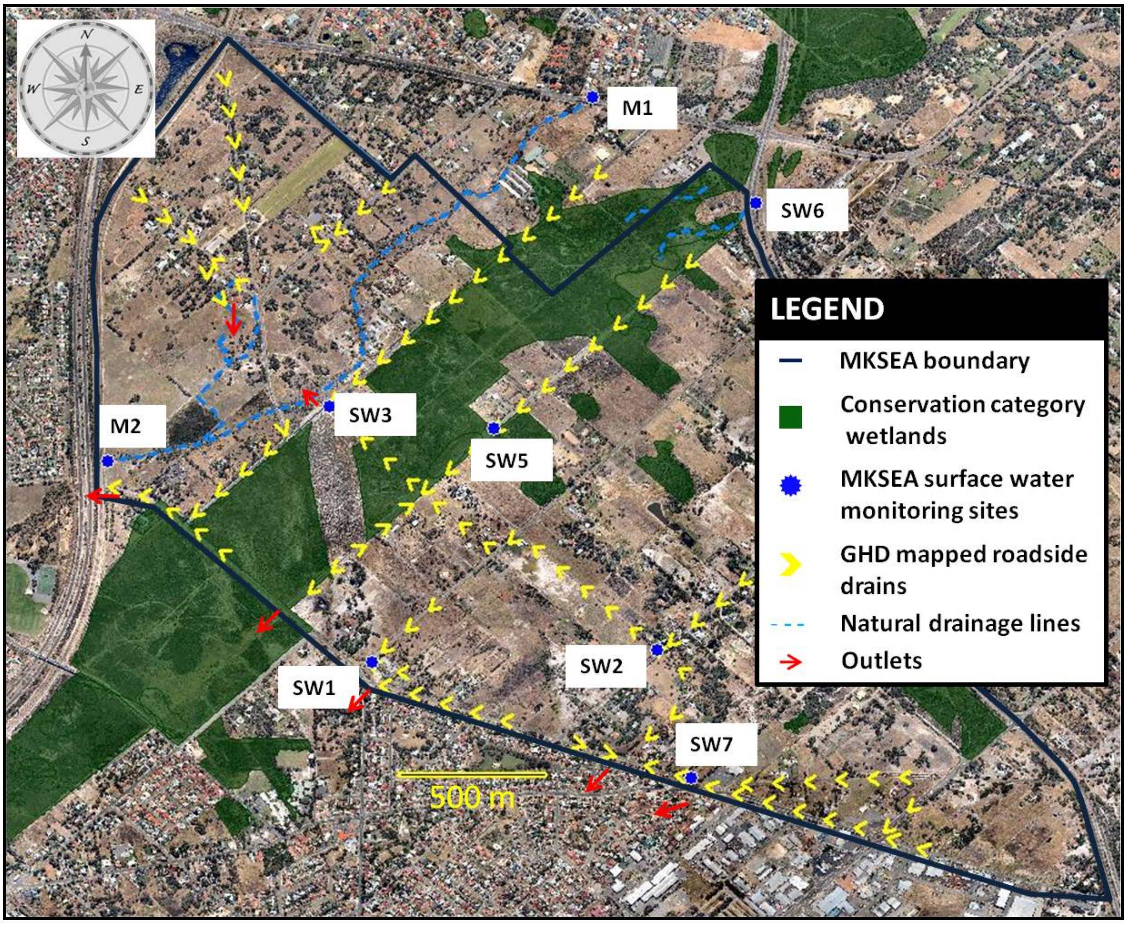


Figure 55: Location of Surface Water Monitoring Stations.

The scope required the establishment and operation of 2 automated stream gauging stations, being M1 and M2. However, due to high levels of tampering and vandalism evident, both sites were considered to be high risk and unsuitable for deployment of auto samplers. Instead, Endemic used an alternative method to measure stream flows / loads, which was extended to cover the six additional surface water monitoring sites. Details of the installation of the surface water monitoring stations are as follows:

- Gauge plates were installed on all 8 sites;
- Automatic water level monitoring stations were installed:
  - A series of 10 inlet holes were drilled into the lower half of a 3.0 m long, 50 mm diameter galvanised steel poles.
  - The poles were installed into the surface water monitoring site using a hand held auger in order to minimise disturbance. Once the water table was reached, the steel poles were installed using the sludger until refusal was reached;
  - A continuous water level logger (Insitu Level Troll 100) was suspended by a stainless steel wire attached to the post end-cap. The loggers automatically recorded average water levels each hour and with an accuracy of 10 mm. Loggers were downloaded at approximately 3 month intervals;
  - A barometric logger (Insitu Baro Troll 100) was installed to provide barometric correction for the water level loggers. This is required to calibrate the readings of the loggers for background fluctuations in atmospheric pressure and is accurate to a 5 km radius; and
  - All water level monitoring stations were secured within the steel housing with a lockable steel lid to reduce the likelihood of tampering / vandalism;
- Preliminary rating curves were developed for each of the 8 sites using a Flowmate 2000 electromagnetic flow meter and following USGS methodologies (DEP, 2008). Up to 5 rating points were collected for each of the 8 sites, however due to the nature of the dry seasons experienced, high flow events captured over the monitoring period were not sufficient for development of reliable rating curves.
- The Flowmate 2000 has no moving parts, water resistant electronics and fixed period averaging (accuracy of ±2% of reading, range of -0.15 to 6 m / sec) and is superior over conventionally used OTT propeller-based current velocity meters (which have calibration and fouling issues).
- Surface water sampling was undertaken on a monthly basis through the 24 month monitoring program, dependent on sufficient flow, with further opportunistic sampling conducted during the winter months in times of significant stream flow.
- Prior to each sampling event, the gauge reading was noted and will be used (subsequent to further development of rating curves) to calculate stream flow records and flow weighted nutrient / contaminant loads for the MKSEA site.
- Surface water quality samples for nutrient and physicochemical characteristic analysis were collected manually during wetter months, during higher flows,

and to gather data on the water quality associated with the first flush contaminant signature.

- The sampling protocol was in accordance with the Australian Standards (AS/NZS 5667:1998) and followed methodology appropriate for each parameter as outlined by the laboratory. Each batch of sampling was accompanied by a Chain of Custody form and included 1:20 duplicate and 1:20 triplicate samples for QA/QC purposes.
- For safety reasons, surface water grab samples were collected using a glass container suspended from a rope. Samples were collected (unfiltered samples) and stored in laboratory provided bottles containing the appropriate preservative (sampling methods are further detailed in Table 4). All water samples were stored on ice while on-site or in-transit. A chain of custody form accompanied samples during transport and delivery to the NATA Accredited laboratory.
- Physical parameters were measured onsite using a multi-parameter water probe; and
- All equipment (that is routinely reused) and in contact with the water was decontaminated between the sampling locations in accordance with Endemic's decontamination procedures (phosphate free detergent, 10% nitric acid wash and rinsed 3 times with deionised water).

Table 44: Surface Water Sampling Methods.

Activity	Details
Sampling	Purging and sampling according to AS/NZS 5667.1-1998 "Water quality – Sampling, Part 1: Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples.
Quality Assurance	1:20 duplicate samples sent to the NATA accredited laboratory.
Sample Acquisition and Storage	Samples collected using clean glass jars and stored in laboratory provided bottles (with preservative as required) and prepared according to AS/NZS 5667.1:1998.
Sample Preservation	Samples were stored on freezer blocks while on-site, frozen at Endemic offices and on ice whilst in transit to the laboratory.
Sample Handling	Samples were sent to the lab accompanied by a Chain of Custody.
Sample analytes	As per Table 1.

3.4 Assessment Criteria

The trigger values adopted in this report are defined as a 'first pass' assessment of analytical results to determine if a substance presents a potential risk to environmental or human health. Where analytical results exceed the trigger value, a management response is 'triggered' by way of further investigation in support of the risk assessment for the site.

Under the NWQMS framework, primacy is given to the use of locally-derived trigger values, where these exist (ANZECC/ARMCANZ, 2000). For example, primacy has been given to meeting site specific nutrient targets identified by the Swan River Trust for Yule Brook in the Swan Canning Water Quality Improvement Plan (SCWQIP) (SRT, 2009) over the more general trigger values contained within the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000).

Wetland

The National Water Quality Management Strategy (NWQMS paper no. 4) describes how stakeholders for a water body can assess change in its quality by collecting monitoring data at test site(s) and comparing the median from the test site with guideline trigger values derived from reference sites. The hydrological monitoring undertaken during this investigation will contribute to the establishment of baseline water quality data to inform locally-derived trigger values relevant to wetland ecosystem health at the site, though wetland water quality monitoring will likely be required pre-development. With regard to wetland water levels, the aim should be to ensure the water balance at the site is maintained and that post-development flow rates are similar to the pre-development flow rates. DEC currently recommends water level changes for CCW sumplands post-urbanisation should ideally be sustained at ±10% of pre-development levels.

Surface Water

The trigger values adopted for surface water are in accordance with the default values contained within the AWQGs and the DEC's Assessment Levels for Soil, Sediment and Water (DEC, 2010). The downstream receptor for MKSEA site is the Swan Canning Estuary ecosystem.

The marine ecosystem protection levels (95th percentile) have been selected as trigger values to screen the surface water quality for the potential for downstream toxicant impacts for this receptor.

For total phosphorus and total nitrogen, SCWQIP 'long term water quality objectives' have been adopted as assessment criteria. The MKSEA is located within the Yule Brook sub-catchment of the Swan Canning River system. The Long Term target median TN concentration for the Yule Brook Catchment is 0.75 mg/L. The Long Term target median TP concentration for the Yule Brook Catchment is 0.075 mg/L.

Groundwater

The trigger values adopted for groundwater are in accordance with the default values contained within the AWQGs and the DEC's Assessment Levels for Soil, Sediment and Water (DEC, 2010).

The long-term irrigation water levels have been selected as the most likely future use of surficial groundwater within the MKSEA site. Results have also been screened against DEC guidelines for Domestic non-potable use.

A direct comparison between the SCWQIP long term water quality targets for Yule Brook and MKSEA groundwater concentrations is not strictly valid. However, comparison with these values provides some insight into the potential for groundwater impacts on downstream receptors following discharge to onsite drainage.

The adopted trigger values for groundwater are presented in Table 5 below.

Table 55: Adopted surface and groundwater trigger values for the MKSEA.

Group	Analyte	Units	Long term Irrigation Guidelines, mg/L 1	Domestic non-potable Guidelines, mg/L 2	Marine waters Guidelines at 95th percentile, mg/L 3
Physicals	pH	-	-	6.5 - 8.5 (groundwater) 6.5-9.0 (surface)	8.0 – 8.4
Nutrients	TN*	mg/L	-	-	-
	NOx_N	mg/L	-	-	-
	NO2_N	mg/L	-	30	-
	Nitrate-NO3	mg/L	-	500	-
	TKN	mg/L	-	-	-
	TP*	mg/L	-	-	-
	FRP	mg/L	-	-	-
Metals	Aluminium	mg/L	5	2	-
	Arsenic	mg/L	0.1	0.07	-
	Cadmium	mg/L	0.01	0.02	0.0007
	Cobalt	mg/L	0.05	-	0.001
	Chromium	mg/L	0.1**	0.5**	0.0044***
	Copper	mg/L	0.2	20	0.0013
	Iron	mg/L	0.2	3	1
	Mercury	mg/L	0.002	0.01	0.0001
	Manganese	mg/L	0.2	5	-
	Nickel	mg/L	0.2	0.2	0.007
	Lead	mg/L	2	0.1	0.0044
	Selenium	mg/L	0.02	0.1	-
	Zinc	mg/L	2	30	0.015
Hydrocarbons	TRH, C6-9, C15-28, C29-36	mg/L	-	-	-
	Benzene	mg/L	-	0.01	0.5
	Toluene	mg/L	-	0.025	-
	Ethylbenzene	mg/L	-	0.003	-
	Xylene	mg/L	-	0.02	-
	Napthalene	mg/L	-	-	0.05
	Benzo(a)pyrene	mg/L	-	0.0001	-
OC Pesticides	Aldrin plus Dieldrin	mg/L	-	0.003	-
	Chlordane	mg/L	-	0.01	-
	Endosulfan	mg/L	-	0.03	0.00001
	DDT	mg/L	-	0.2	-
	Heptachlor + epoxide	mg/L	-	0.003	-
	Endrin	mg/L	-	-	0.000008
OP Pesticides	Chlorpyrifos	mg/L	-	0.01	0.000009
	Diazinon	mg/L	-	0.001	-
	Fenitrothion	mg/L	-	0.01	-
	Methyl Parathion	mg/L	-	0.0003	-
	Parathion	mg/L	-	0.01	-

1. Long Term Irrigation Guidelines Values (ANZECC/ARMCANZ, 2000 / DEC, 2010)
2. Domestic Non-Potable Groundwater Use (DEC, 2010)
3. Marine waters Guidelines values (ANZECC/ARMCANZ, 200 / DEC, 2010)

* Whilst there are no adopted trigger values for TN or TP, results will be compared to SCWQIP long term median concentration targets for the Yule Brook sub-catchment as a measure of assessment (TP = 0.075 mg/L; TN = 0.75 mg/L)

** Un-speciated Chromium trigger value (DEC, 2010)

*** Chromium, CR (VI) selected as lowest trigger value (DEC, 2010)

4. Results

Six groundwater sampling events and 14 surface water sampling events have been conducted during the course of the monitoring program. Low rainfall during the winters of 2009 and 2010 (for example September 2010 was the driest September on record), meant that several monitoring rounds could not be conducted due to insufficient water to obtain credible samples after bore purging, and inadequate base flow in surface water. Water level loggers have been monitoring groundwater and wetland surface water levels on an hourly basis since their installation date. The following section details the water level and water quality data collected, including a comparison against the adopted trigger values.

4.1 Groundwater Levels

Endemic has been conducting water level monitoring at the MKSEA site using automatic water level loggers (Insitu Troll 100s) set at hourly intervals. Groundwater levels were recorded within the study area at a 1 hour frequency using continuous data loggers (Insitu Level Troll 100).

During May 2010 all Insitu Level Troll 100s were subject to an Australia wide product recall due to an unacceptably high rate of seal failure. As a result some of the trolls failed during the monitoring period and some data is missing. Fortunately, most of these failures occurred during summer months following the drying out of the bores and the winter peak water level datasets remain intact. All groundwater loggers at the MKSEA site were removed and replaced with newly designed Insitu Level Troll 500 loggers, which have a higher accuracy and do not suffer from seal failure in the field. Notwithstanding, staff level readings have been recorded at all surface water sites during routine sampling visits.

Endemic does not believe this event impacts on the quality of the datasets over the ‘whole of the project’ and has completed a logger replacement program in May 2010 to ensure the second year has complete hydrographs through the summer period.

Hydrographs for groundwater bores are presented as Figures 6 to 9 below. The hydrographs extend from June or July 2009 to the end of December 2010.

The following groundwater level trends were observed during the monitoring period:

- Groundwater appears to be highly responsive to rainfall due to the shallow impervious calcrete horizon in some areas. A coincidence of shallow depth to refusal and highly responsive groundwater levels was noted in bores GW02, GW04, GW05 and GW12, all in close vicinity of the GBSW.
- Bore GW09 contained little water during only the wettest months of 2009, and was completely dry throughout 2010;
- Peak groundwater levels for the MKSEA site typically occurred during September in 2009, and occurred earlier, in August or July during 2010. 2010

recorded the driest September on record, which could explain the variation in peak groundwater levels;

- Peak groundwater levels encountered in 2009 varied from 0.03 m BGL at bore GW12 to 3.54 at bore GW06, and in 2010 peak groundwater varied from 0.09 m BGL at bore GW01 to 4.28 m BGL at bore GW06;
- Minimum Groundwater levels encountered in 2009 varied from 3.9 m BGL at bore GW06 to 0.85 m BGL at bore GW04, and in 2010 minimum groundwater varied from to 0.98 m BGL at bore GW04 to 5.06 at bore GW06; and
- Groundwater levels were significantly lower across the site during 2010, compared to 2009. This is reflective of the lower rainfall encountered during 2010, and indicates the high responsiveness of groundwater at the site to rainfall.

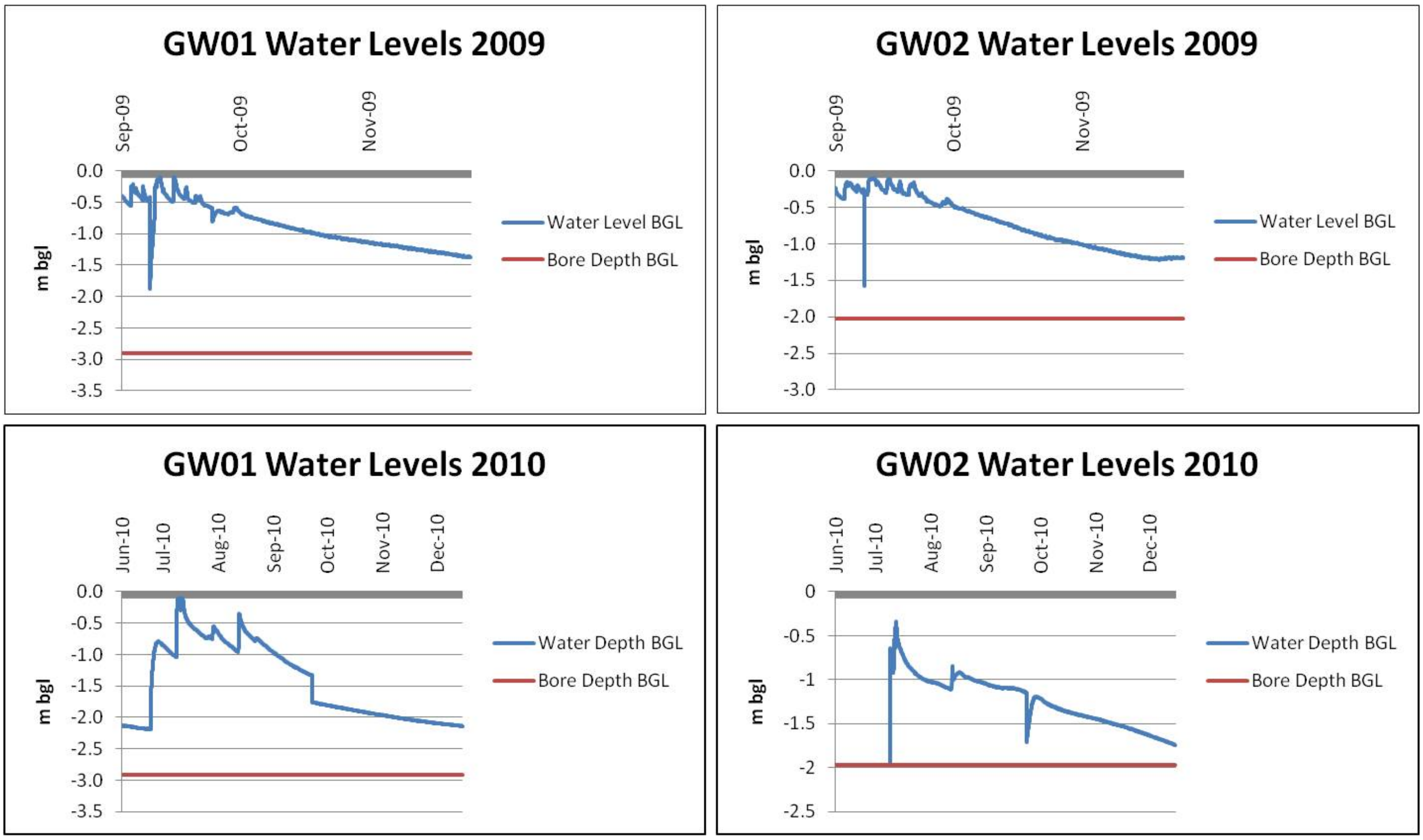


Figure 66: Uncorrected groundwater hydrographs for bores GW 1 - 2 (blue) with the base of the bore screen (red) and ground surface (grey) highlighted (2009 and 2010 datasets).

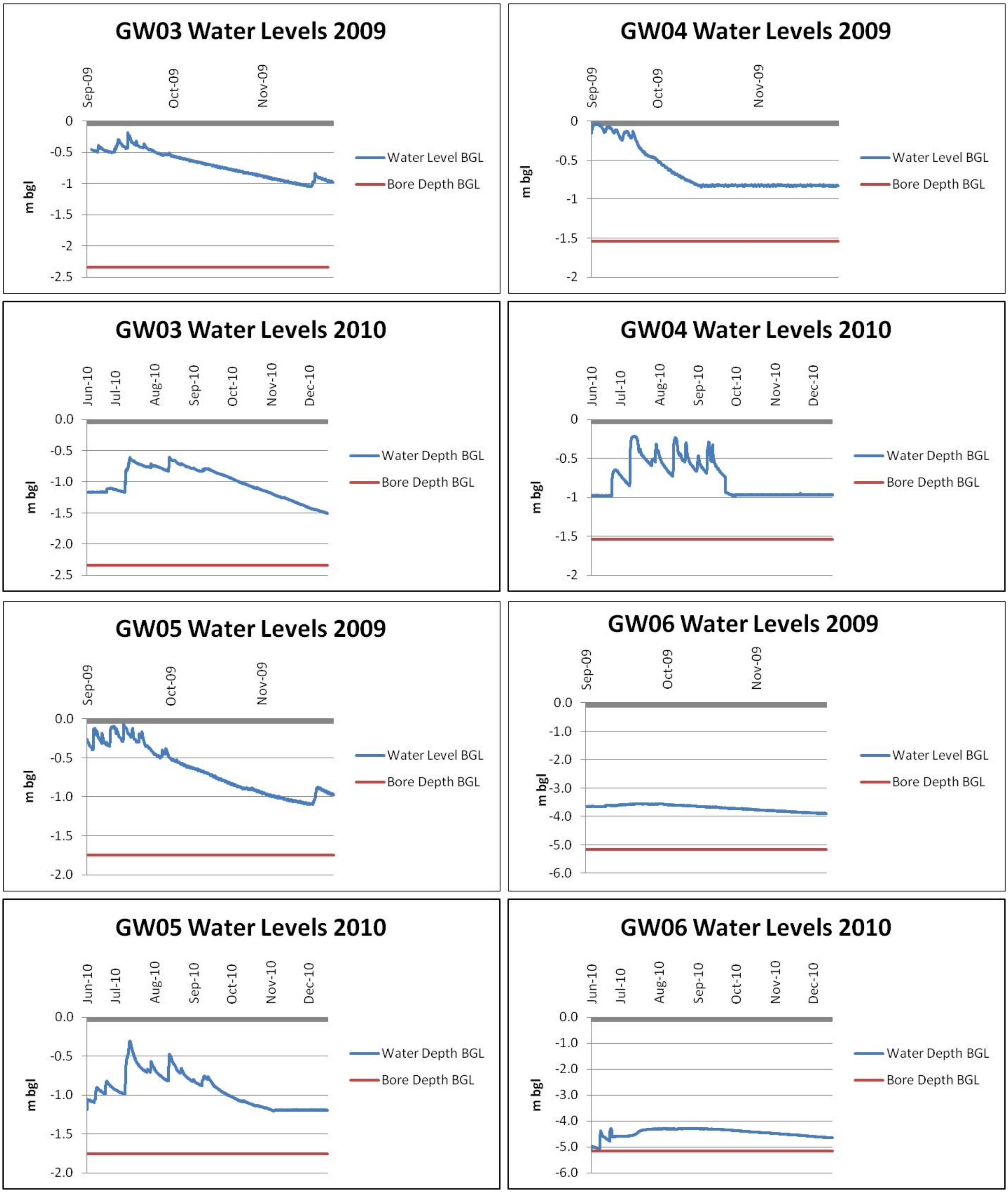


Figure 77: Uncorrected groundwater hydrographs for bores GW 3 - 6 (blue) with the base of the bore screen (red) and ground surface (grey) highlighted (2009 and 2010 datasets).

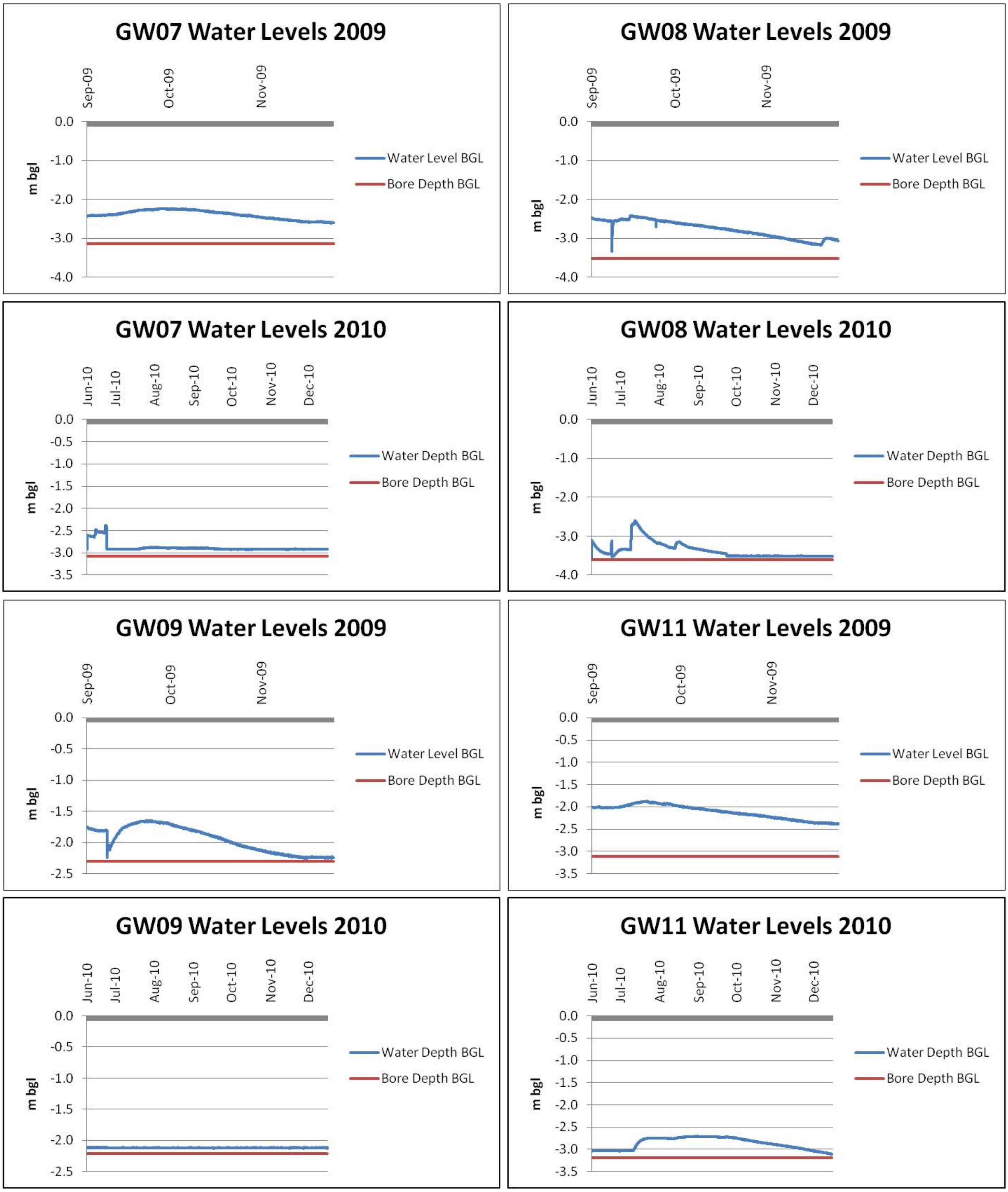


Figure 88: Uncorrected groundwater hydrographs for bores GW 7 - 11(blue) with the base of the bore screen (red) and ground surface (grey) highlighted (2009 and 2010 datasets).

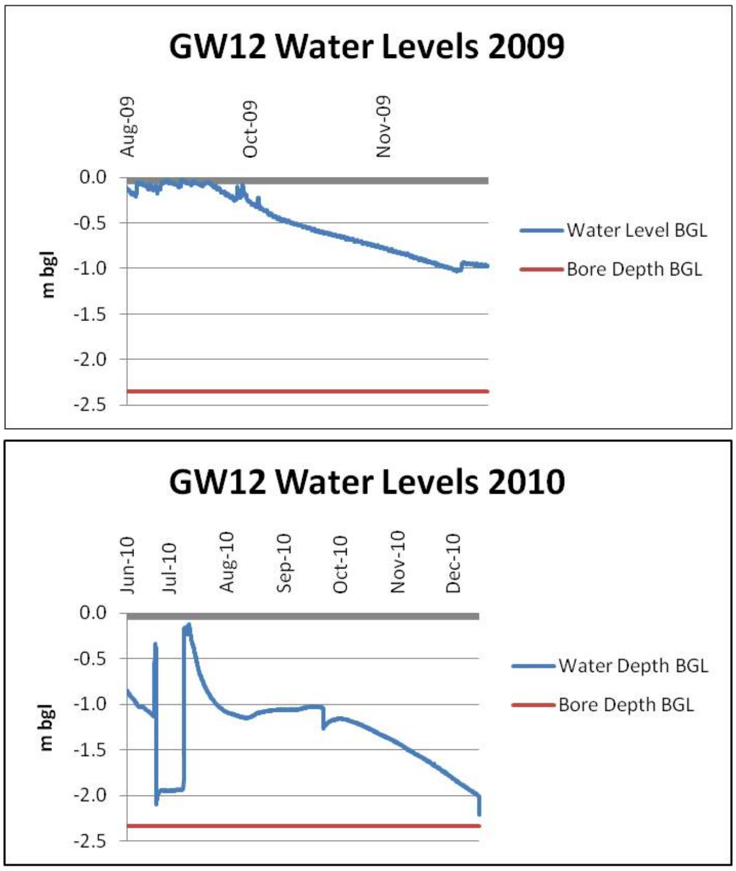


Figure 99: Uncorrected groundwater hydrographs for bore GW12 (blue) with the base of the bore screen (red) and ground surface (grey) highlighted (2009 and 2010 datasets).

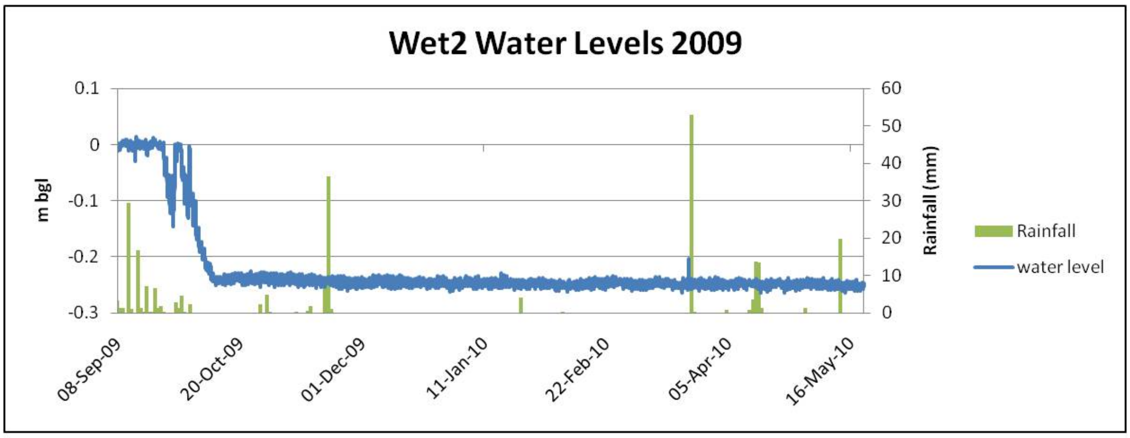
4.2 Wetland Water Levels

Endemic has been conducting wetland water level monitoring at the MKSEA site using automatic water level loggers (Insitu Troll 100s) set at hourly intervals. Wetland levels were recorded within the study area at a 1 hour frequency using continuous data loggers (Insitu Level Troll 100).

Hydrographs for these wetlands are presented as Figures 10 to 13 below. Wetland water level stations 7 and 8 had shorter hydrographs in 2009 due to the troll seal failure discussed in 4.1. All wetland loggers were replaced with newly designed Troll 500 loggers which have higher accuracy and do not suffer from seal failure in the field.

The following wetland water level trends were observed during the monitoring period:

- Wetlands water levels appear to be highly responsive to rainfall due to the shallow impervious calcrete horizon which sub-crops in much of the area within and adjacent to the Brixton Street Wetland reserve;
- Peak wetland levels for the MKSEA site typically occurred during September in 2009, and during July in 2010. This is reflective of the lower rainfall during 2010, with September 2010 the driest September on record for Perth;
- A peak water level of 0.2 m AGL was encountered at bore Wet 4 in 2009, and maximum 2010 water level found to be 0.13 m AGL at bore Wet 4; and
- Minimum wetland levels encountered varied from 0.40 m BGL in 2009 at bore Wet 4 at the base of the inlet holes to 1 m BGL in 2010 at bore Wet 3 and 1.65 at bore Wet 8.



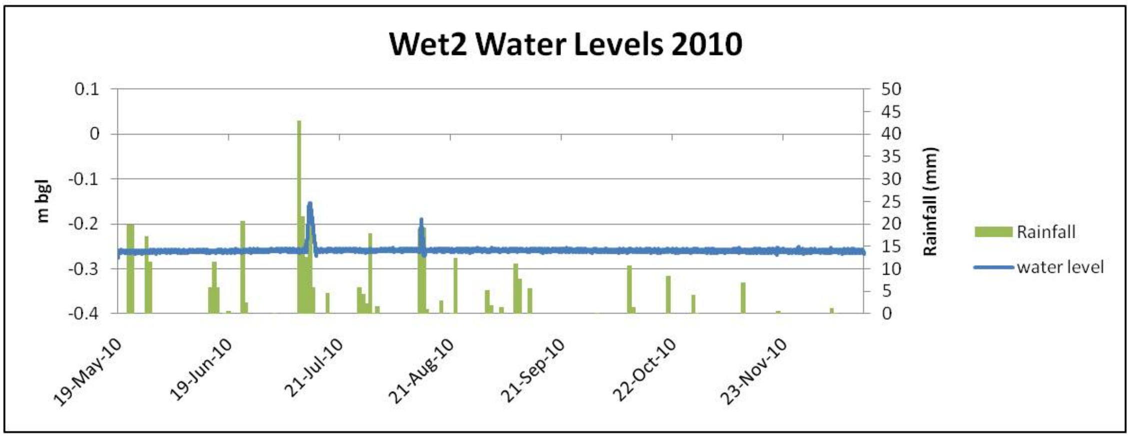


Figure 1010: Wetland hydrograph (blue) and rainfall (green) for WET2 site.

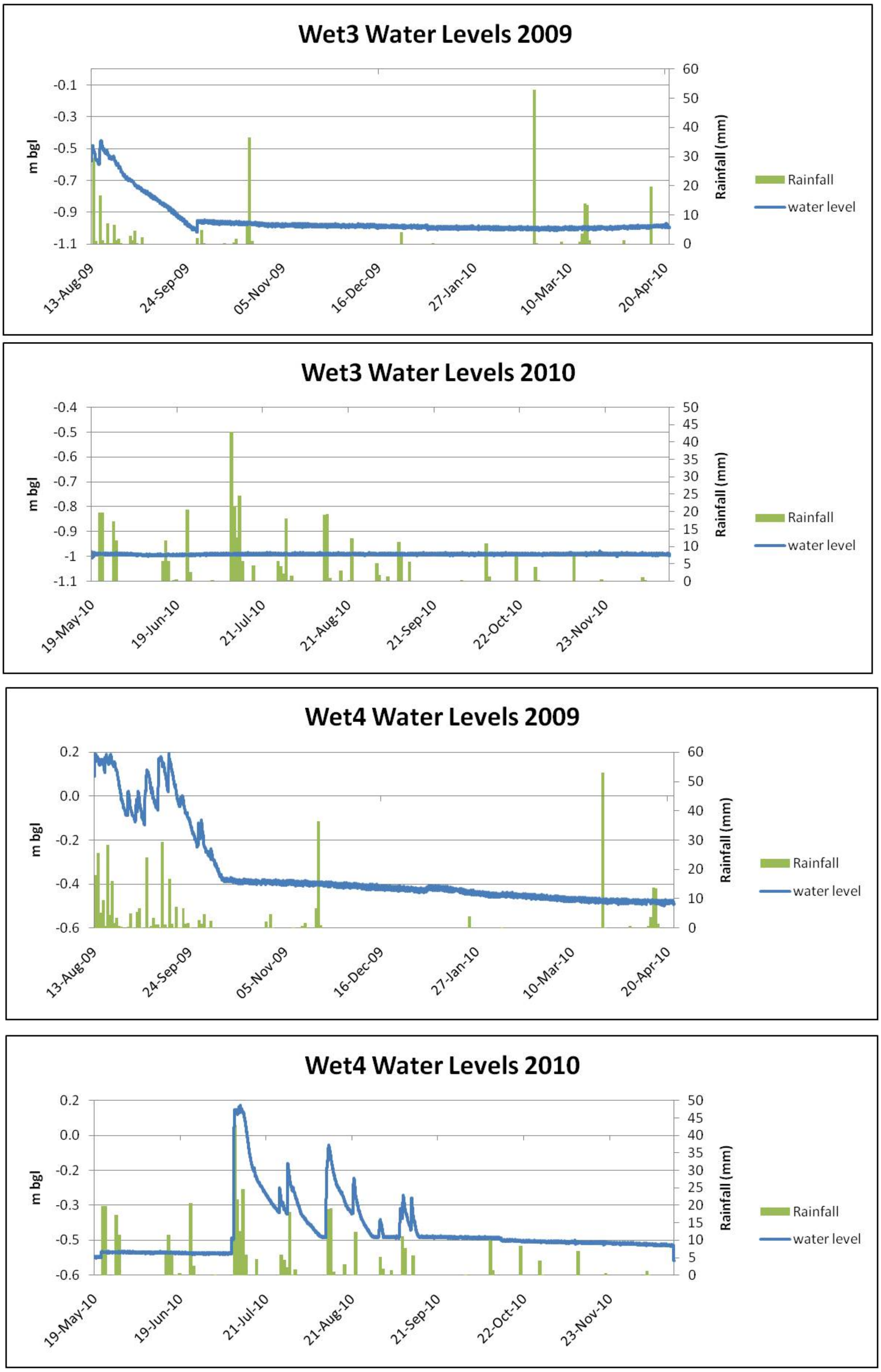
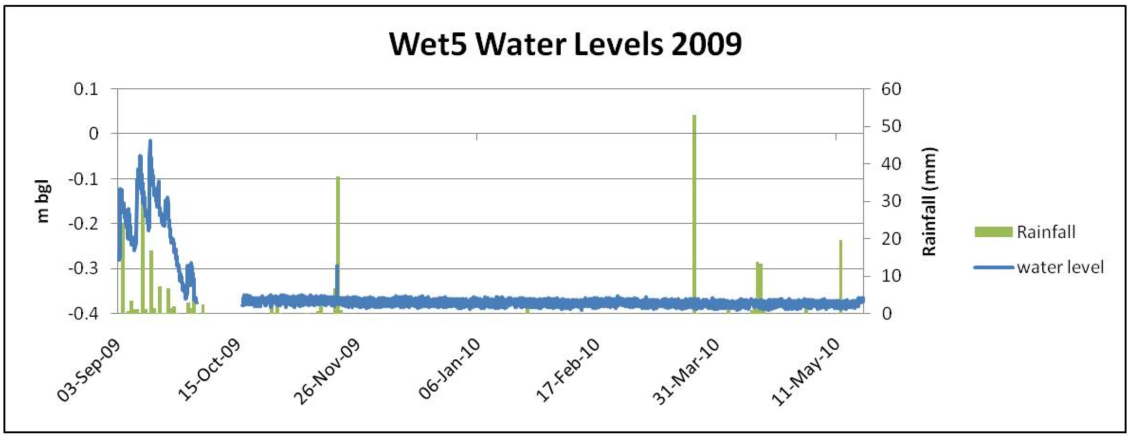
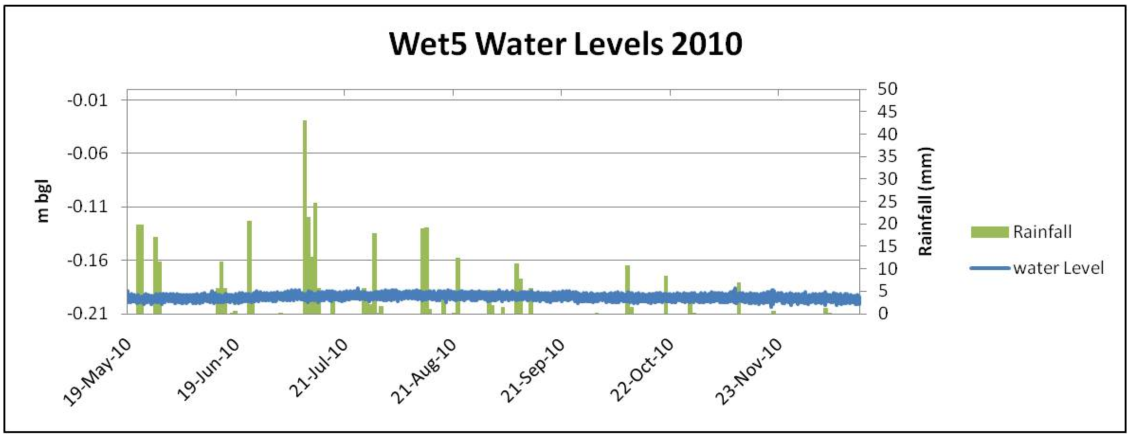
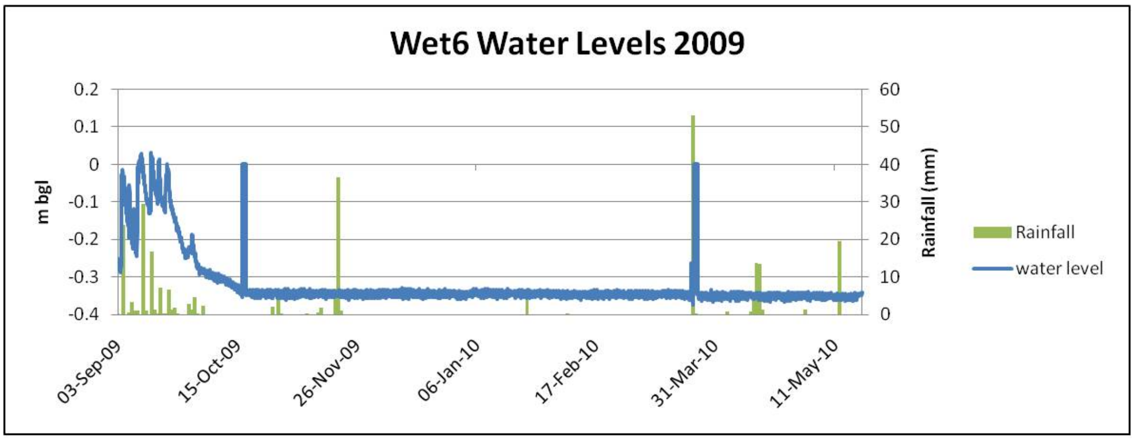


Figure 1111: Wetland hydrographs (blue) and rainfall (green) for WET3 and WET4 sites.







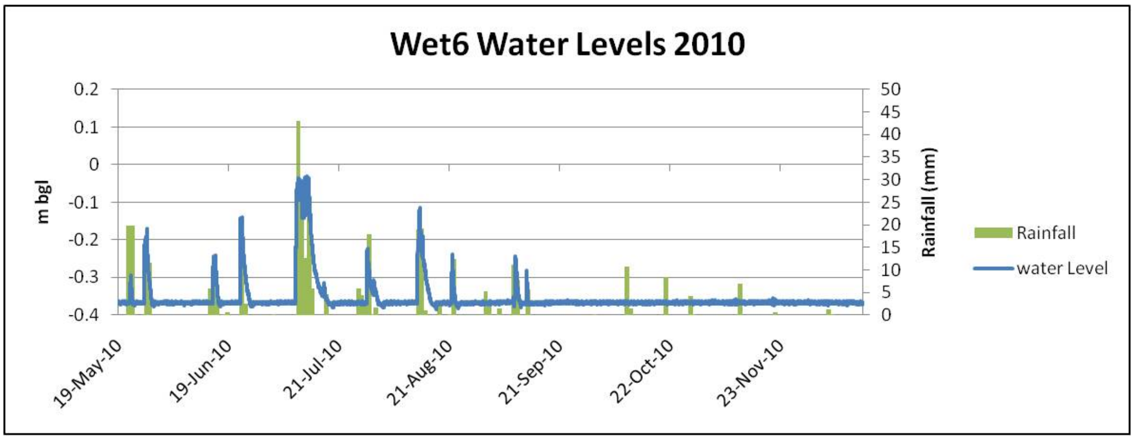
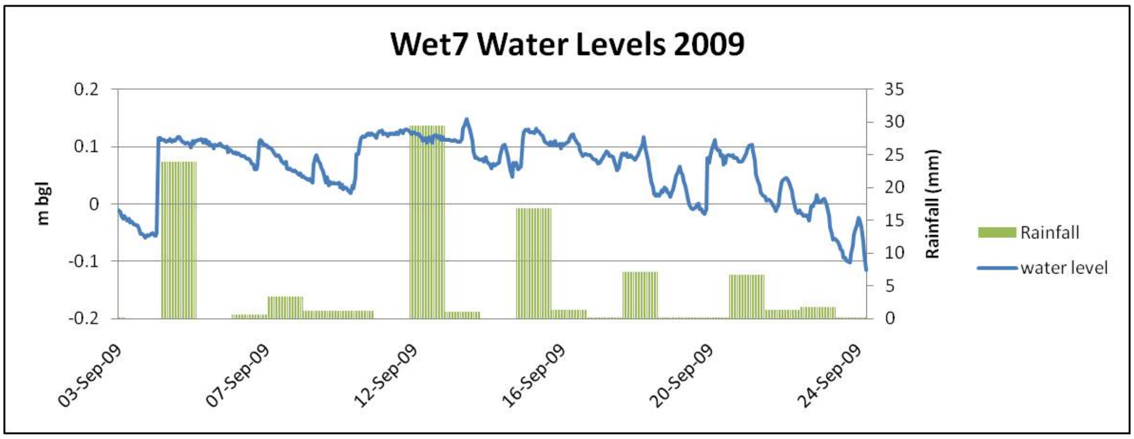
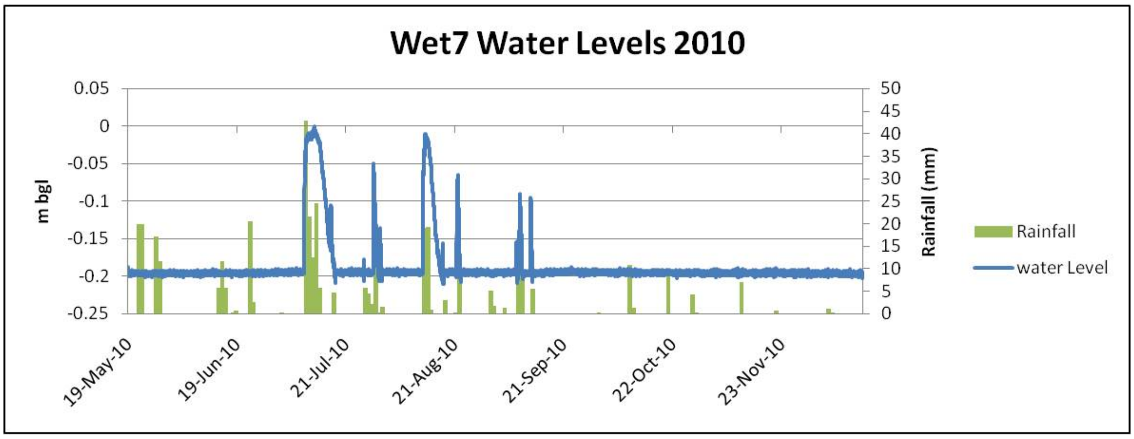
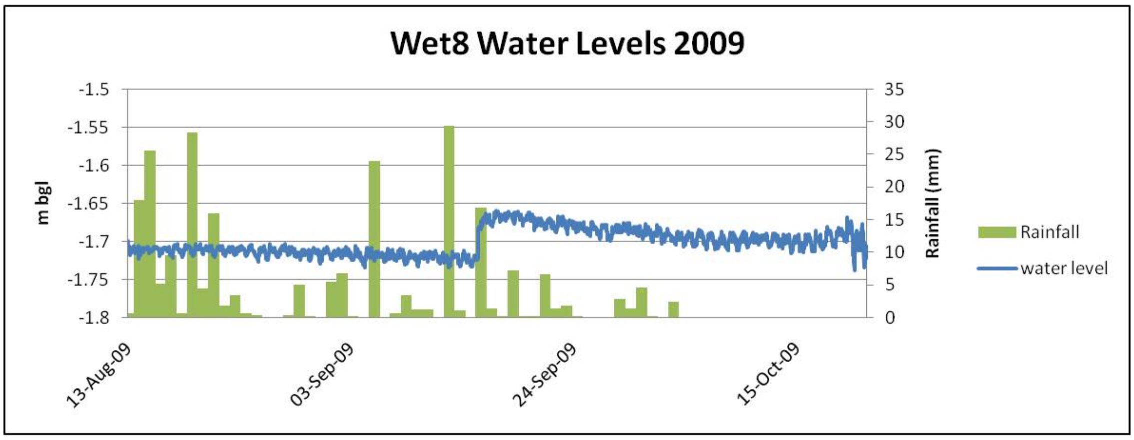


Figure 1212: Wetland hydrographs (blue) and rainfall (green) for WET5, and WET6 sites.







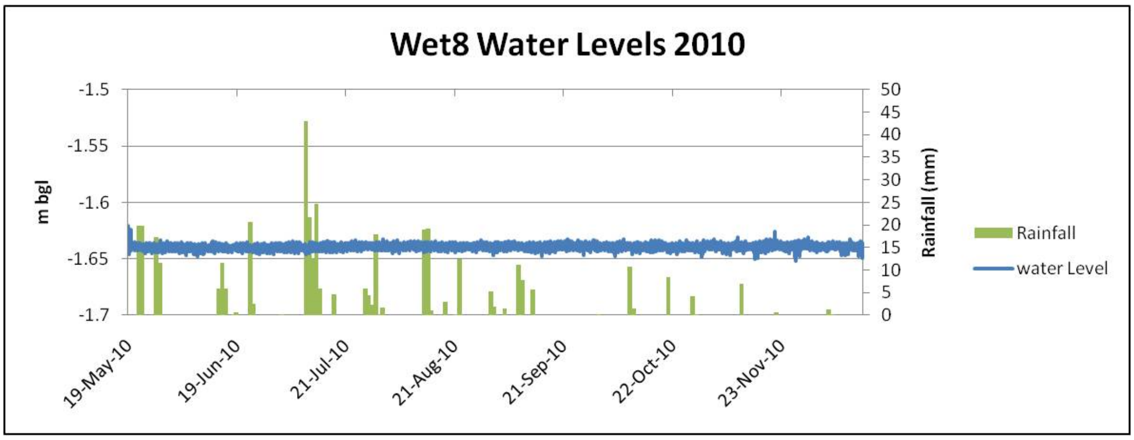


Figure 1313: Wetland hydrographs (blue) and rainfall (green) for WET7, and WET8 sites.

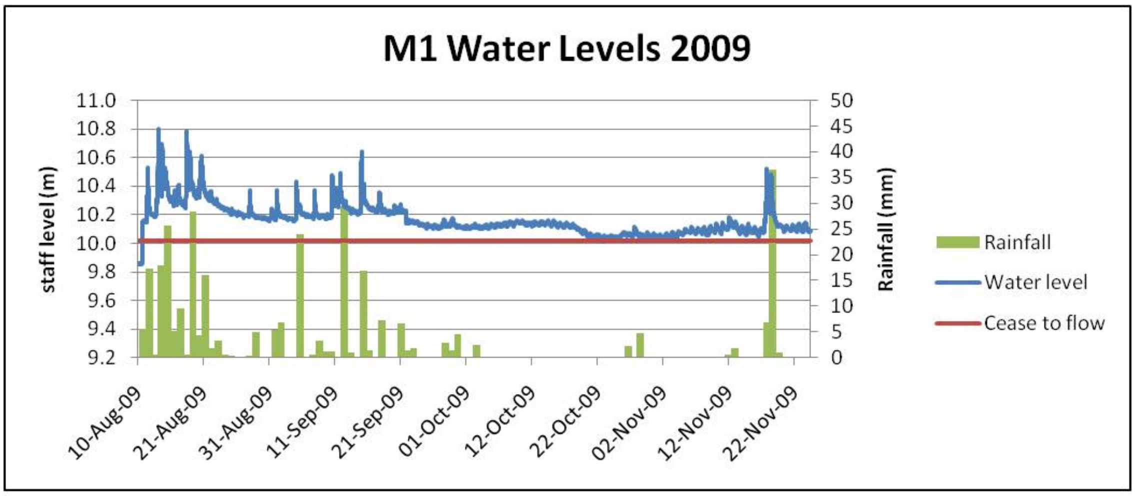
4.3 Surface Water Levels

Surface water levels were monitored continuously using data loggers (Insitu Level Troll 100) to record average surface water levels at a 1 hour interval. Hydrographs for these surface water sites are presented as Figures 14 to 18 below.

Surface water stations 1, 2, 3 and 5 have shorter continuous hydrographs for the 2009 dataset due to the troll seal failure discussed in 3.1. All wetland trolls were replaced with Troll 500s which have a higher accuracy and seal stability in the field.

The following surface water level trends were observed during the monitoring period

- Surface water levels appear to be highly responsive to rainfall, particularly in proximity to the GBSW due to the presence of a shallow aquitard (impervious calcrete horizon) (Figure 19).
- Surface water drainage is strongly controlled by roadside drainage. Roadside drains along Boundary Road, Brook Road, and Brentwood Road have been cut down to the aquitard (calcrete or clay B horizon) and serve to dewater the superficial groundwater and control waterlogging.



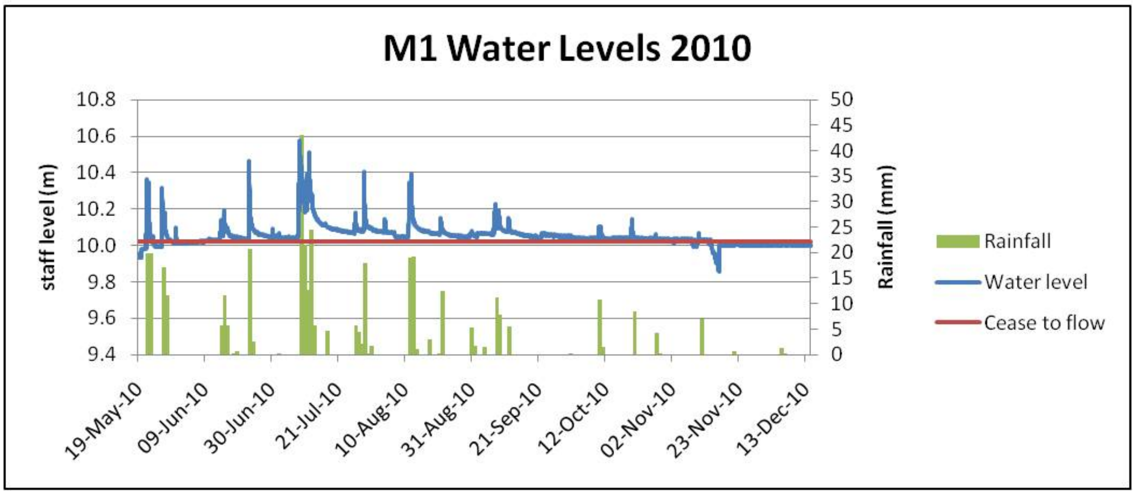
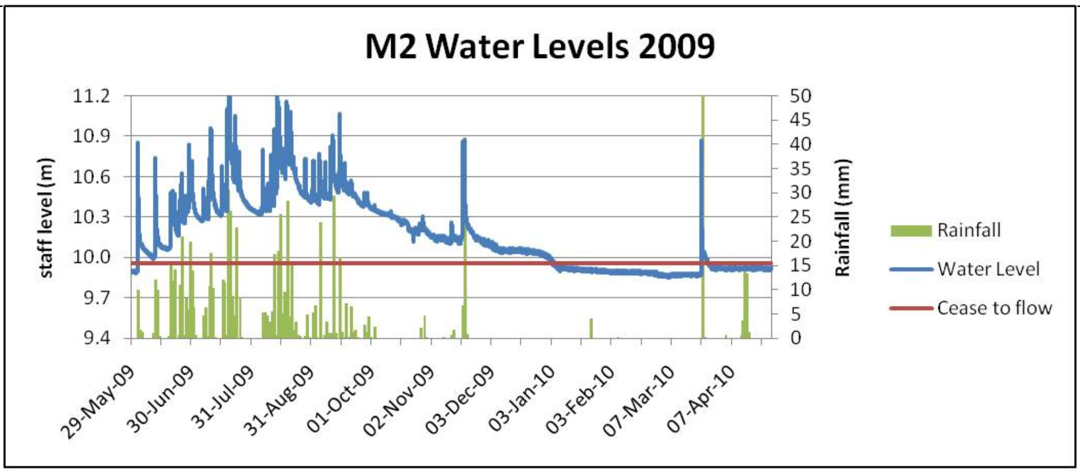
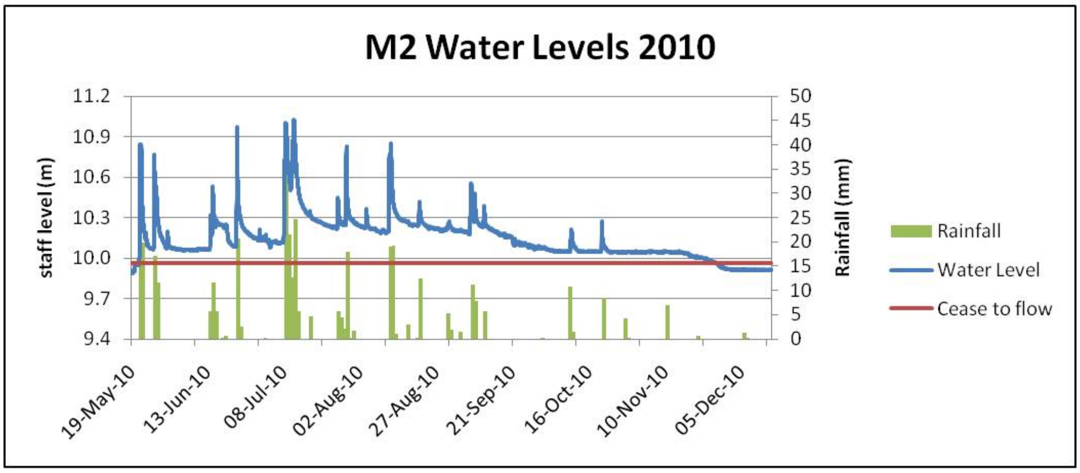
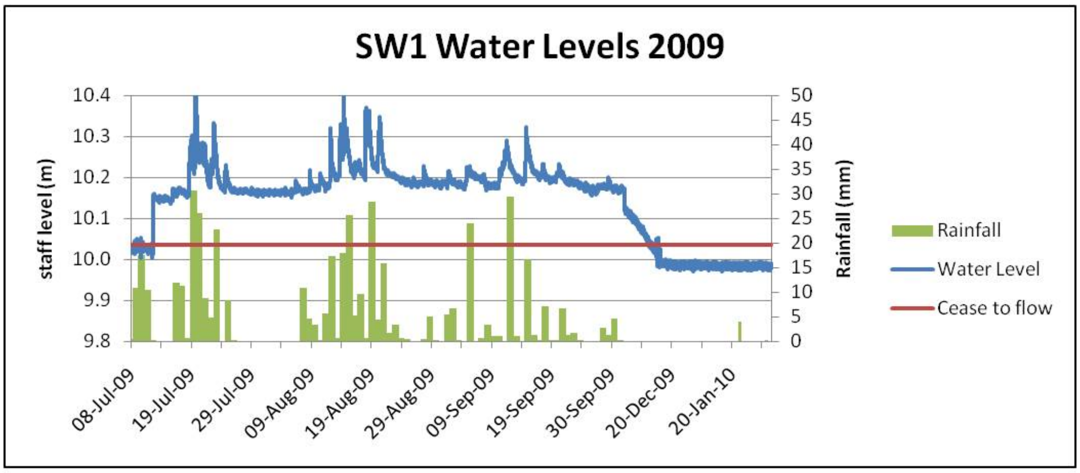


Figure 1414: Stream hydrograph (blue) and rainfall (green) compared to cease to flow (red) for M1.







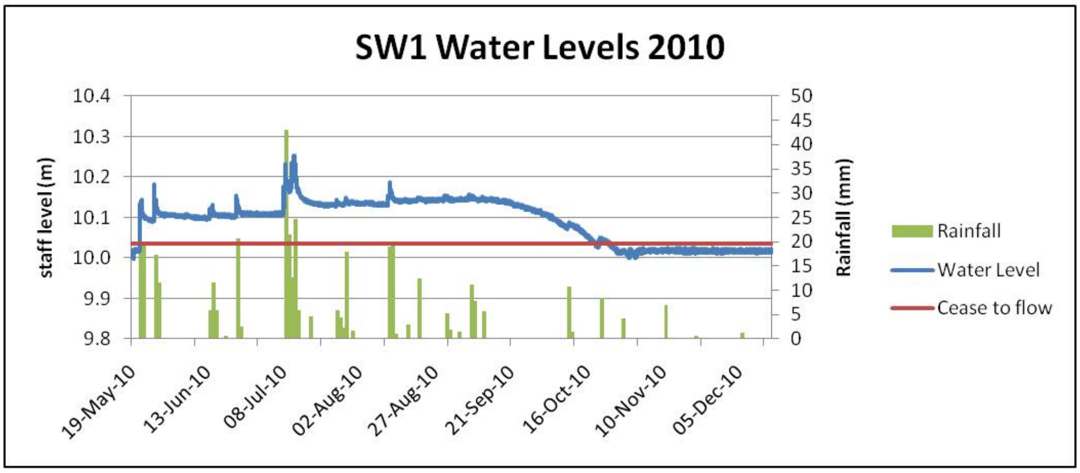


Figure 1515: Stream hydrographs (blue) and rainfall (green) for M2 and SW1.

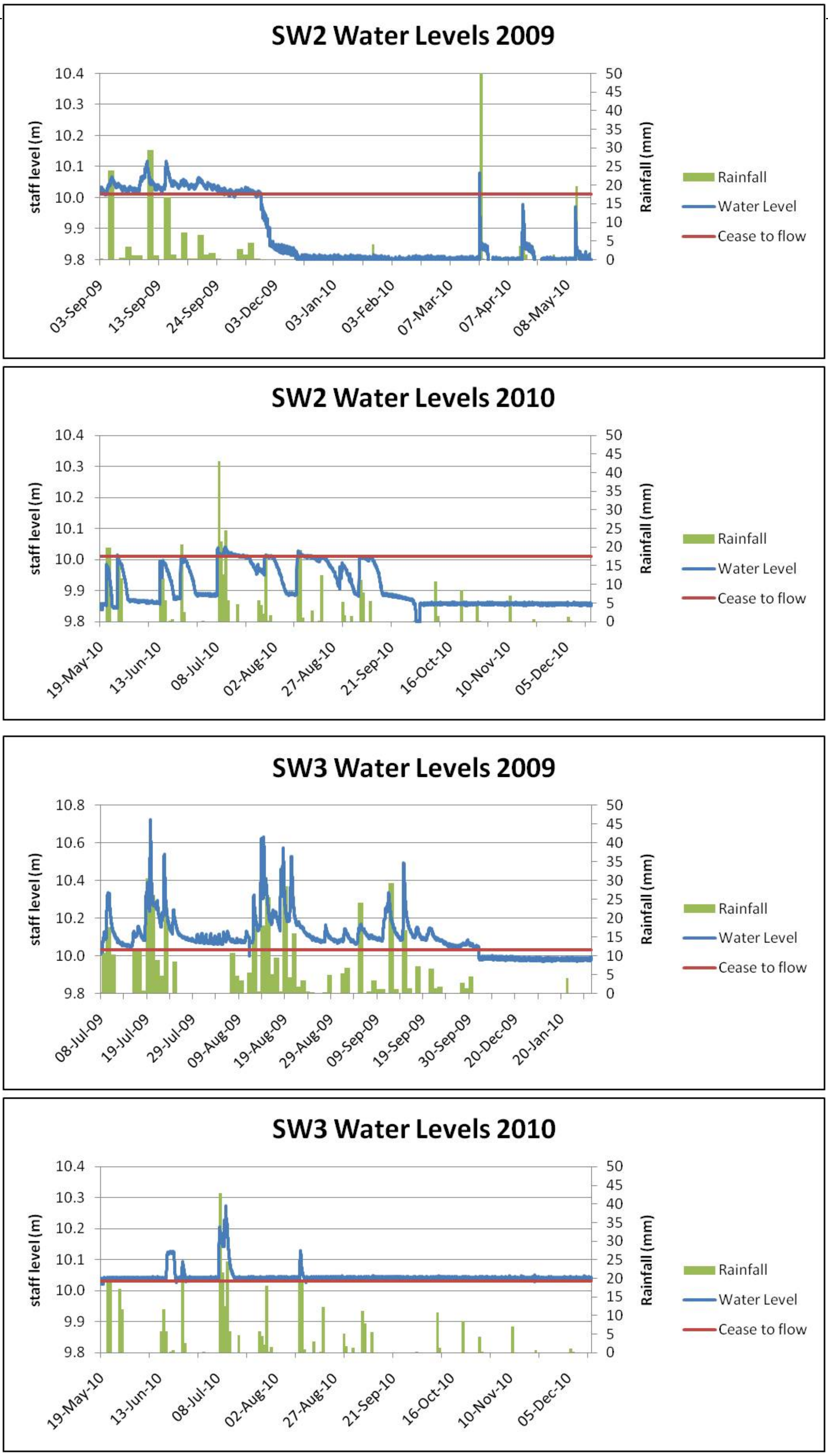


Figure 1616: Stream hydrographs (blue) and rainfall (green) for SW2 and SW3.

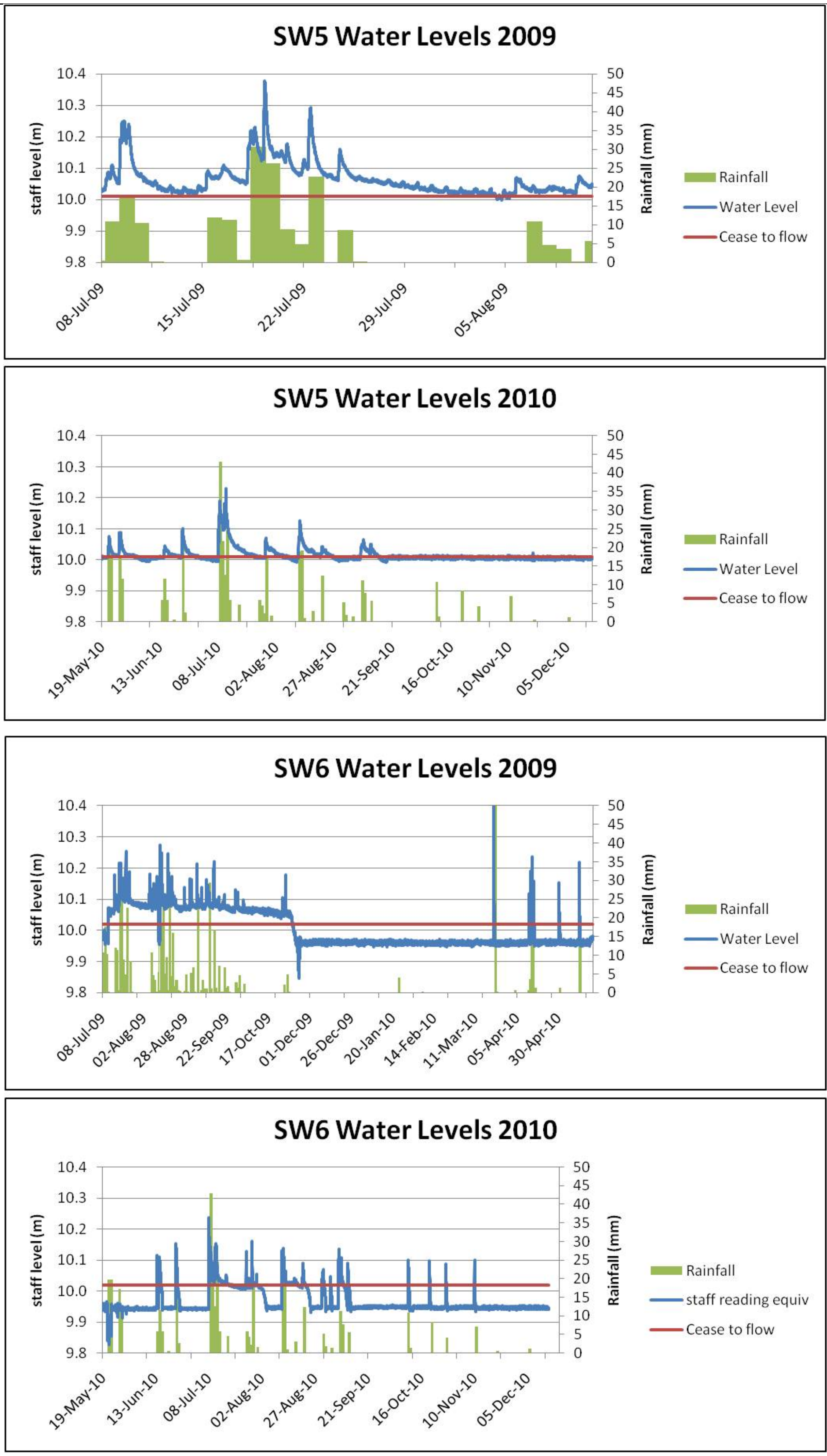
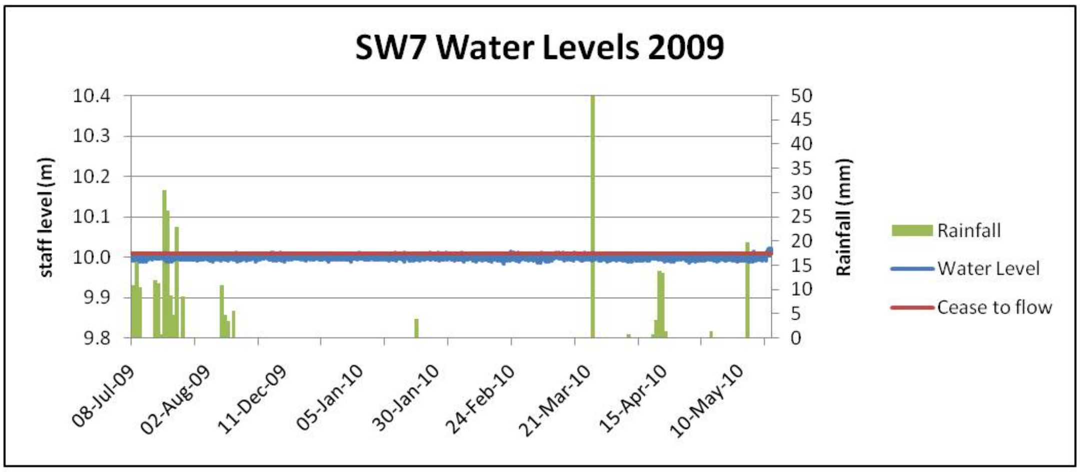


Figure 1717: Stream hydrographs (blue) and rainfall (green) for SW5 and SW6.



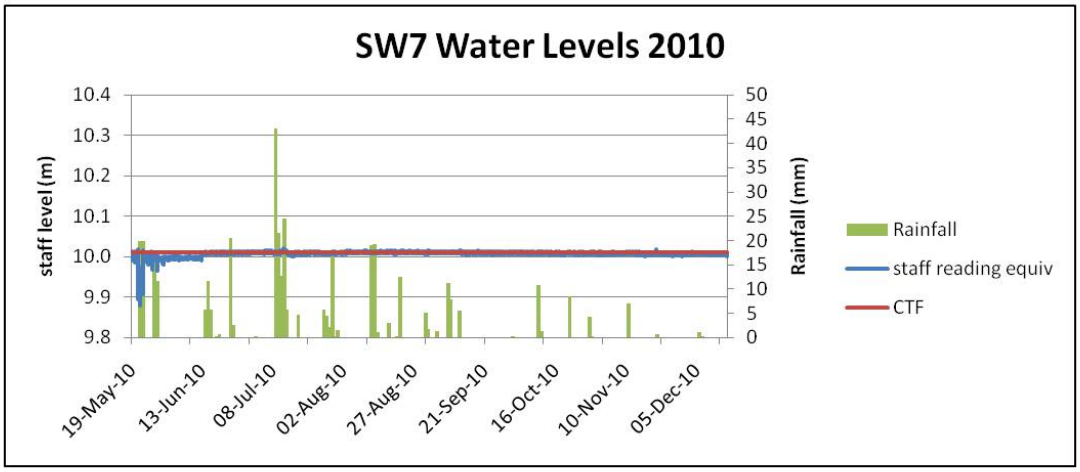


Figure 1818: Stream hydrograph (blue) and rainfall (green) for SW7.

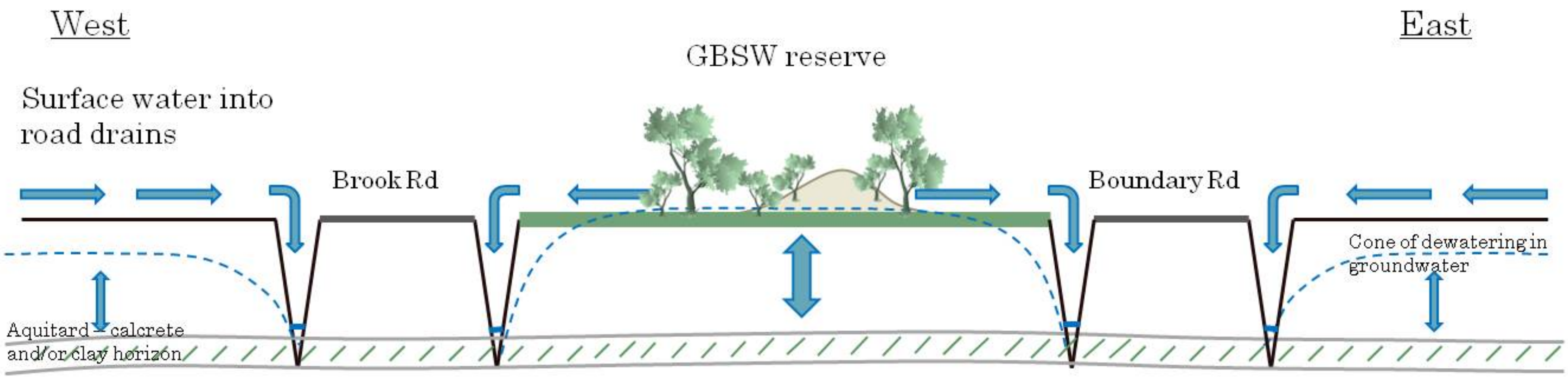


Figure 1919: Conceptual diagram depicting drainage impacts on groundwater and surface water at the site.

4.4 Surface Water Flow

Stream gauging for the purpose of developing stage height / flow relationships at the eight surface water sites was undertaken during the winters of 2009 and 2010. However, opportunities to obtain high flow discharge measurements was limited due to below average rainfall observed during this period (in particular 2010, which was the driest winter on record for Perth).

Endemic considers that additional high flow discharge measurements at a number of the surface water sites would be advantageous in order to produce more reliable rating curves.

Rating curves can be extrapolated via various software programs using slope/area/channel roughness coefficient methods; however, given the nature of the channels Endemic considers it would be more appropriate and accurate to collect additional discharge measurements.

Endemic recommends that high flow discharge measurements be undertaken opportunistically during winter 2011, enabling sufficient data to be collected for the development of rating curves with improved reliability. At M1 and M2, where safety concerns preclude wading during high flow conditions, this be achieved through the short-term deployment of continuous area velocity flow monitoring devices. Endemic installed mountings to cater for this potential deployment in March 2011.

4.5 Groundwater Quality

This Water Quality Monitoring Report has been prepared following the completion of the two winters of ground and surface water monitoring (as at December 2010). This report includes the May 2009 to December, 2010 datasets. The results have been summarised in Table 6, exceedances of the adopted trigger values in Table 7 and the entire groundwater quality datasets are included in Tables 8 to 12. Laboratory Certificates of Analysis have been provided electronically.

Table 66: MKSEA groundwater quality results summary.

Monitoring Bores GW01-GW12	Sampling Period Sep 2009 - Dec 2010 (n=38)				
	Units	Min	Max	Average	Median
Temp	C	15.5	29.8	19.9	19.5
pH	-	4.15	8.18	7.11	7.24
Electrical Conductivity	mS/cm	0.148	40.600	6.504	2.167
Dissolved Oxygen	mg/L	0.0	6.9	2.5	1.9
Redox	mV	-65.0	30.1	-18.2	-17.0
TSS	mg/L	30	24000	2947	1360
TDS	ppk	0.1	14.0	2.6	0.6
BOD	mg/L	5.0	120.0	49.3	51.5
COD	mg/L	30.0	13000.0	3517.2	580.0
TN	mg/L	0.760	19.00	4.31	3.25
NOx_N	mg/L	<0.005	7.700	1.111	0.070
NO2_N	mg/L	<0.005	0.100	0.021	0.006
Nitrate-NO3	mg/L	<0.01	7.68	0.91	0.06
TKN	mg/L	0.750	12.000	3.513	2.700
TP	mg/L	<0.01	1.50	0.40	0.24
FRP	mg/L	<0.005	0.680	0.067	0.010
Aluminium	mg/L	0.009	200.000	25.162	7.000
Arsenic	mg/L	<0.001	0.200	0.026	0.006
Cadmium	mg/L	<0.0001	0.0330	0.0022	0.0004
Cobalt	mg/L	<0.001	0.1480	0.0208	<0.005
Chromium	mg/L	<0.001	1.700	0.199	0.014
Copper	mg/L	0.002	0.480	0.084	0.015
Iron	mg/L	0.018	970.000	63.951	8.740
Hg	mg/L	<0.0001	0.0057	0.0006	0.0002
Manganese	mg/L	<0.001	6.900	0.500	0.048
Nickel	mg/L	<0.001	0.980	0.092	0.011
Lead	mg/L	<0.001	0.190	0.044	0.027
Selenium	mg/L	<0.001	0.016	0.004	<0.002
Zinc	mg/L	<0.001	1.900	0.301	0.110
TRH	ug/L	<260	401.000	<260	<260
C6-9	ug/L	<20	<20	<20	<20
C10-14	ug/L	<40	<40	<40	<40
C15-28	ug/L	<100	401.000	<100	<100
C29-36	ug/L	<100	<100	<100	<100
Benzene	ug/L	<0.5	<0.5	<0.5	<0.5
Toluene	ug/L	<1.0	<1.0	<1.0	<1.0
Ethylbenzene	ug/L	<1.0	<1.0	<1.0	<1.0
Xylene	ug/L	<3.0	<3.0	<3.0	<3.0

Table 77: Groundwater trigger value exceedances at the MKSEA site.

Analyte	Units	Number samples (n)	DOH Domestic non-potable 5	Irrigation trigger exceedances 4
Temp	C	38	-	-
pH	-	38	-	-
Electrical Conductivity	mS/cm	38	-	-
Dissolved Oxygen	mg/L	37	-	-
Redox	mV	26	-	-
TSS	mg/L	30	-	-
TDS	mg/L	36	-	-
BOD	mg/L	21	-	-
COD	mg/L	21	-	-
TN	mg/L	29	-	-
NOx_N	mg/L	26	-	-
NO2_N	mg/L	34	0	-
Nitrate-NO3	mg/L	34	0	-
TKN	mg/L	34	-	-
TP	mg/L	34	-	-
FRP	mg/L	34	-	-
Aluminium	mg/L	30	21	17
Arsenic	mg/L	30	1	1
Cadmium	mg/L	30	1	1
Cobalt	mg/L	30	-	0
Chromium	mg/L	30	4	10
Copper	mg/L	30	0	5
Iron	mg/L	30	19	25
Hg	mg/L	30	0	1
Manganese	mg/L	30	1	10
Nickel	mg/L	30	5	5
Lead	mg/L	30	4	0
Selenium	mg/L	30	0	0
Zinc	mg/L	30	0	0
TRH	ug/L	11	-	-
C6-9	ug/L	15	-	-
C10-14	ug/L	15	-	-
C15-28	ug/L	15	-	-
C29-36	ug/L	15	-	-
Benzene	ug/L	17	0	-
Toluene	ug/L	17	0	-
Ethylbenzene	ug/L	17	0	-
Xylene	ug/L	17	0	-

4. Long Term Irrigation Guidelines Values (ANZECC/ARMCANZ, 2000 / DEC, 2010)
5. Domestic Non-Potable Groundwater Use (DEC, 2010)

* Unspeciated Chromium trigger value (DEC, 2010)

Table 88: Groundwater Metals Concentrations from filtered analysis, sorted by bore

Sample ID	Date	Filtered Metals Concentrations												
		Aluminium	Arsenic	Cadmium	Cobalt	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Selenium	Zinc
Domestic non-potable		2	0.07	0.02	-	0.5	20	3	0.01	5	0.2	0.1	0.1	30
LT Irrigation		5	0.1	0.01	0.05	0.1	0.2	0.20	0.002	0.2	0.2	2	0.02	2
GW01	Sep-09	0.061	<0.001	<0.0001	0.007	0.005	0.012	<0.01	0.0007	0.032	0.012	<0.001	<0.001	0.25
GW01	Sep-10	0.05	<0.001	<0.0001	0.014	0.002	0.006	0.16	<0.0001	0.011	0.02	<0.001	<0.01	<0.005
GW01	Dec-10	Insufficient sample for analysis												
GW02	Sep-09	<0.005	<0.001	<0.0001	0.009	<0.001	0.003	1	<0.0001	3	0.03	<0.001	0.009	0.027
GW02	Sep-10	19.8	<0.001	0.0002	0.081	0.019	0.023	14.4	<0.0001	1.72	0.161	0.007	<0.01	0.924
GW02	Dec-10	17.8	0.001	0.0002	0.06	0.037	0.029	27.3	<0.0001	2.08	0.31	0.002	0.01	0.115
GW03	Sep-09	0.007	<0.001	<0.0001	<0.005	<0.001	0.005	0.03	<0.0001	0.019	0.004	<0.001	0.002	0.024
GW03	Sep-10	0.03	<0.001	<0.0001	<0.001	<0.001	0.002	0.08	<0.0001	0.02	0.002	<0.001	<0.01	0.018
GW03	Dec-10	Insufficient sample for analysis												
GW05	Sep-09	0.017	<0.001	<0.0001	<0.005	<0.001	0.006	0.36	<0.0001	0.021	0.018	<0.001	0.002	0.023
GW05	Sep-10	0.04	<0.001	<0.0001	<0.001	<0.001	0.004	0.13	<0.0001	0.004	0.004	<0.001	<0.01	0.008
GW05	Dec-10	Insufficient sample for analysis												
GW06	Sep-09	2.4	<0.001	<0.0001	<0.005	0.003	0.008	1.3	<0.0001	0.004	0.005	<0.001	0.003	0.031
GW06	Sep-10	0.02	<0.001	<0.0001	0.002	<0.001	0.002	0.06	<0.0001	0.016	0.002	<0.001	<0.01	0.202
GW06	Dec-10	0.02	<0.001	<0.0001	0.003	<0.001	0.002	0.95	<0.0001	0.009	0.001	<0.001	<0.01	0.037
GW07	Sep-09	0.024	<0.001	<0.0001	<0.005	<0.001	0.005	0.05	<0.0001	<0.001	0.004	<0.001	0.002	0.027
GW07	Sep-10	Insufficient sample for analysis												
GW07	Dec-10	Insufficient sample for analysis												
GW08	Sep-09	0.098	<0.001	<0.0001	<0.005	<0.001	0.004	0.21	<0.0001	0.084	0.007	<0.001	0.002	0.018
GW08	Sep-10	Insufficient sample for analysis												
GW08	Dec-10	Insufficient sample for analysis												
GW09	Sep-09	0.098	<0.001	<0.0001	<0.005	<0.001	0.005	0.04	<0.0001	<0.001	0.004	<0.001	<0.001	0.029
GW09	Sep-10	Insufficient sample for analysis												
GW09	Dec-10	Insufficient sample for analysis												
GW11	Sep-09	0.28	0.001	<0.0001	<0.005	0.004	0.009	8.5	0.0005	0.52	0.018	0.001	0.001	0.1
GW11	Sep-10	0.09	<0.001	<0.0001	<0.001	<0.001	0.004	0.06	<0.0001	0.004	0.003	<0.001	<0.01	0.008
GW11	Dec-10	Insufficient sample for analysis												
GW12	Sep-09	5.7	<0.05	<0.001	<0.005	0.013	0.015	6	0.0015	0.04	<0.005	<0.01	<0.1	<0.005
GW12	Sep-10	<0.01	0.002	<0.0001	0.005	0.006	0.027	0.25	<0.0001	0.101	0.193	<0.001	<0.01	0.024
GW12	Dec-10	<0.01	0.004	<0.0001	0.005	0.003	0.014	0.07	<0.0001	0.466	0.094	<0.001	<0.01	0.013

Table 99: Ground water Quality Results for the MKSEA: Field Parameters and Nutrients.

Sample ID	Date	Field Parameters									Nutrients						
		Temp	pH	Electrical Conductivity	Dissolved Oxygen	Redox	TSS	TDS	BOD	COD	TN	NOx_N	NO2_N	Nitrate-NO3	TKN	TP	FRP
	units	ºC		mS/cm	mg/L	mV	mg/L	ppk	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Domestic non-potable trigger values		-	-	-	-	-	-	-	-	-	-	-	30	500	-	-	-
LT Irrigation trigger values		-	6-9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW01	9-Sep-09	18.4	7.37	4.810	0.0	-22.0	130	2.02	53.0	500.0	3.30	<0.005	<0.005	<0.01	3.3	0.27	<0.005
GW02	9-Sep-09	17.2	6.96	23.960	6.2	-3.4	10000	10.88	82.0	10000.0	3.10	<0.005	<0.005	<0.01	3.1	0.12	<0.005
GW03	9-Sep-09	15.9	7.11	0.525	1.1	-9.2	200	0.2	82.0	61.0	0.76	0.015	0.011	<0.01	0.75	0.07	<0.005
GW04	9-Sep-09	Insufficient sample for analysis															
GW05	9-Sep-09	16.4	7.23	0.653	0.6	-14.9	3300	0.251	7.0	580.0	3.80	0.015	<0.005	<0.01	3.8	0.07	<0.005
GW06	9-Sep-09	19.4	6.99	0.586	1.3	2.9	1600	0.225	7.0	1600.0	19.00	7.7	0.006	7.6806	12	0.21	<0.005
GW07	9-Sep-09	18.3	7.31	0.278	6.9	-17.1	4900	0.103	78.0	720.0	4.70	1.2	<0.005	1.19727	3.5	0.28	<0.005
GW08	10-Sep-09	18.3	7.3	0.240	0.0	-16.8	1700	0.88	64.0	190.0	2.30	0.38	0.018	0.36144	2	0.22	<0.005
GW09	9-Sep-09	17.2	7.02	0.523	1.0	0.6	-	0.2	-	-	-	-	-	-	-	-	-
GW11	9-Sep-09	18.3	6.73	0.220	6.9	7.8	2500	0.0796	74.0	190.0	3.20	0.12	<0.005	0.119727	3	0.97	0.078
GW12	9-Sep-09	15.5	7.39	8.830	0.5	-22.6	710	8.76	92.0	290.0	3.90	<0.005	<0.005	<0.01	3.9	0.99	0.68
GW01	25-Nov-09	21.9	7.84	3.750	0.2	-65.0	2900	0.91	-	-	3.30	-	<0.1	<0.01	3.2	0.15	<0.005
GW02	25-Nov-09	23.6	6.12	19.690	4.8	28.9	-	-	60.0	6400.0	2.00	-	<0.1	0.02259	1.9	<0.01	<0.005
GW03	25-Nov-09	20.6	7.25	2.258	1.6	-34.5	24000	0.158	50.0	4800.0	1.20	-	<0.1	0.04518	1.2	0.17	0.081
GW04	25-Nov-09	-	-	-	-	-	7000	0.202	-	-	-	-	-	-	-	-	-
GW05	25-Nov-09	22	7.79	0.421	4.2	-48.0	1300	0.093	42.0	9600.0	3.10	-	<0.1	0.04518	3	0.05	<0.005
GW06	25-Nov-09	20.1	6.88	0.533	0.3	9.5	-	0.0534	24.0	13000.0	4.20	-	<0.1	1.06173	3	0.25	<0.005
GW07	25-Nov-09	21.7	7.05	0.251	2.8	-17.9	-	-	39.0	8000.0	3.30	-	<0.1	1.42317	1.8	0.15	0.11
GW08	25-Nov-09	21.6	7.55	0.148	1.9	-36.4	3700	0.097	-	-	2.80	-	<0.1	0.24849	2.4	0.09	0.16
GW09	25-Nov-09	-	-	-	-	-	8800	12	-	-	-	-	-	-	-	-	-
GW11	25-Nov-09	21.3	6.91	0.263	0.9	-9.6	-	-	21.0	6400.0	2.30	-	<0.1	0.51957	1.7	0.48	0.11
GW12	25-Nov-09	19.9	7.68	26.6	0.2	-51.5	-	-	71.0	11000	2.70	-	<0.1	<0.01	2.6	1.4	<0.005
GW01	23-Mar-10	Insufficient sample for analysis															
GW02	23-Mar-10	Insufficient sample for analysis															
GW03	23-Mar-10	Insufficient sample for analysis															
GW04	23-Mar-10	Insufficient sample for analysis															
GW05	23-Mar-10	Insufficient sample for analysis															
GW06	23-Mar-10	23.2	6.02	0.578	0.0	30.1	-	0.22	120.0	120.0	-	-	-	-	-	-	<0.005
GW07	23-Mar-10	Insufficient sample for analysis															
GW08	23-Mar-10	Insufficient sample for analysis															
GW09	23-Mar-10	Insufficient sample for analysis															
GW11	23-Mar-10	Insufficient sample for analysis															
GW12	23-Mar-10	Insufficient sample for analysis															
GW01	24-Jun-10	17.9	7.81	4.22	0.1	-43.5	918.000	1.75	5	91	-	0.05	<0.01	0.05	2.2	0.17	0.02
GW02	24-Jun-10	Insufficient sample for analysis															
GW03	24-Jun-10	16.3	7.73	0.824	0.3	-38.8	<5	0.318	6	30	-	7.55	<0.01	7.55	9	0.05	<0.01
GW04	24-Jun-10	16.1	8.02	0.422	1.4	-53.5	-	0.198	-	-	-	0.06	0.02	0.03	1.9	0.26	0.07
GW05	24-Jun-10	15.5	7.27	0.783	4.8	-11.7	320.000	0.304	<2	93	-	0.58	<0.01	0.58	2.8	0.1	<0.01
GW06	24-Jun-10	19.6	6.81	0.638	0.0	26.2	1420.000	0.246	8	197	-	0.08	<0.01	0.08	2.6	0.3	<0.01
GW07	24-Jun-10	Insufficient sample for analysis															
GW08	24-Jun-10	Insufficient sample for analysis															
GW09	24-Jun-10	Insufficient sample for analysis															
GW11	24-Jun-10	Insufficient sample for analysis															
GW12	24-Jun-10	16.9	8.18	7.23	4.4	-62.0	-	3.05	-	-	-	0.54	<0.01	0.54	2.6	0.52	0.07
GW01	23-Sep-10	19.1	7.85	4.61	2.7	-	390	1.93	-	-	8.5	0.07	<0.01	0.07	8.4	1.08	<0.01
GW02	23-Sep-10	19.6	4.15	3.3	3.6	-	306	1.1	-	-	<1.0	0.02	<0.01	0.02	<1.0	0.95	<0.01
GW03	23-Sep-10	18.2	7.38	5.53	1.8	-	422	2.05	-	-	1.2	0.06	<0.01	0.06	1.1	0.08	<0.01
GW04	23-Sep-10	-	-	-	-	-	220	-	-	-	7.8	4.02	0.07	3.95	3.8	0.64	<0.01
GW05	23-Sep-10	18.2	7.16	4.9	4.3	-	30	1.86	-	-	6.2	4.5	<0.01	4.5	1.7	0.12	<0.01
GW06	23-Sep-10	20.3	6.29	10.52	3.0	-	-	4.09	-	-	-	-	-	-	-	-	-
GW07	23-Sep-10	Insufficient sample for analysis															
GW08	23-Sep-10	Insufficient sample for analysis															
GW09	23-Sep-10	-	-	-	-	-	-	-	-	-	4.1	0.04	<0.01	0.04	4.1	1.11	0.08
GW11	23-Sep-10	21.2	7.22	8.41	4.2	-	60	0.324	-	-	2.1	0.61	<0.01	0.61	1.5	0.26	0.05
GW12	23-Sep-10	16.7	7.24	2.076	3.2	-	-	0.933	-	-	-	-	-	-	-	-	-
GW01	15-Dec-10	29.8	7.87	40.6	5	-	-	14	-	-	8.9	<0.01	-	-	8.9	0.39	-
GW02	15-Dec-10	25.9	4.86	15.8	4.2	-	1060	7.3	-	-	2.1	0.02	<0.01	0.02	2.1	0.24	0.01
GW03	15-Dec-10	26	8.17	20.1	-	-	-	6.46	-	-	-	-	-	-	-	-	-
GW04	15-Dec-10																
GW05	15-Dec-10																
GW06	16-Dec-10	23.3	6.7	1.075	6.2	-	686	0.417	-	-	-	-	-	-	-	-	-
GW07	15-Dec-10	Insufficient sample for analysis															
GW08	15-Dec-10	Insufficient sample for analysis															
GW09	15-Dec-10	Insufficient sample for analysis															
GW11	15-Dec-10	Insufficient sample for analysis															
GW12	15-Dec-10	25	6.98	20.98	3.0	-	1480	9.8	-	-	8.4	0.08	0.02	0.05	8.3	1.5	0.09

Table 1010: Groundwater Quality results for the MKSEA: Metals.

Sample ID	Date	Metals												
		Aluminium	Arsenic	Cadmium	Cobalt	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Selenium	Zinc
	units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Domestic non-potable trigger		2	0.07	0.02	-	0.5	20	3	0.01	5	0.2	0.1	0.1	30
LT Irrigation trigger		5	0.1	0.01	0.05	0.1	0.2	0.20	0.002	0.2	0.2	2	0.02	2
GW01	9-Sep-09	5.7	<0.05	<0.001	<0.005	0.013	0.015	6	0.0015	0.04	<0.005	<0.01	<0.1	<0.005
GW02	9-Sep-09	200	0.2	0.033	0.032	0.43	0.3	970	0.0057	6.9	0.21	0.1	<0.1	0.66
GW03	9-Sep-09	1.8	<0.05	<0.001	<0.005	0.002	0.002	3	0.0003	0.04	<0.005	0.017	<0.1	<0.005
GW04	9-Sep-09	Insufficient sample for analysis												
GW05	9-Sep-09	4.3	<0.05	<0.001	<0.005	0.043	0.017	21	0.0005	0.062	0.014	0.017	<0.1	<0.005
GW06	9-Sep-09	30	<0.05	<0.001	<0.005	0.049	0.029	12	0.0004	0.027	0.004	0.014	<0.1	0.11
GW07	9-Sep-09	7	<0.05	<0.001	<0.005	0.008	<0.005	3.4	0.0006	0.006	<0.005	0.15	<0.1	<0.005
GW08	10-Sep-09	44	<0.05	0.0034	<0.005	0.74	0.18	76	0.0006	0.26	0.089	0.068	<0.1	0.36
GW09	9-Sep-09	Insufficient sample for analysis												
GW11	9-Sep-09	19	<0.05	<0.001	<0.005	0.007	0.005	1.9	0.0008	0.004	<0.005	0.15	<0.1	0.13
GW12	9-Sep-09	1.9	<0.05	<0.001	<0.005	0.015	0.013	10	0.0004	0.45	0.002	<0.01	<0.1	0.14
GW01	25-Nov-09	Insufficient sample for analysis												
GW02	25-Nov-09	38	<0.001	<0.0001	0.041	0.028	0.041	51	<0.0001	2.4	0.1	0.011	0.016	0.15
GW03	25-Nov-09	7	<0.001	<0.0001	0.012	0.006	0.007	9	<0.0001	0.12	0.009	0.044	0.002	0.085
GW04	25-Nov-09	Insufficient sample for analysis												
GW05	25-Nov-09	90	0.013	0.0006	<0.005	1.2	0.41	310	<0.0001	0.69	0.42	0.19	0.01	1.1
GW06	25-Nov-09	52	0.006	<0.0001	0.017	0.32	0.21	39	<0.0001	0.1	0.066	0.064	0.002	0.35
GW07	25-Nov-09	2	0.001	<0.0001	0.021	0.005	0.007	1.2	<0.0001	0.008	0.011	0.047	0.002	0.057
GW08	25-Nov-09	38	0.005	<0.0001	0.006	1	0.38	82	<0.0001	0.24	0.98	0.036	0.002	0.61
GW09	25-Nov-09	Insufficient sample for analysis												
GW11	25-Nov-09	19	0.003	<0.0001	0.02	0.008	0.01	1.4	<0.0001	0.004	0.013	0.041	<0.001	0.12
GW12	25-Nov-09	65	0.019	0.0001	0.017	1.7	0.48	210	<0.0001	1.5	0.2	0.088	<0.01	1.9
GW01	24-Jun-10	1.36	0.001	<0.00005	0.002	0.003	0.011	1	<0.0001	0.003	0.007	0.001	0.001	0.001
GW02	24-Jun-10	Insufficient sample for analysis												
GW03	24-Jun-10	0.01	<0.0002	<0.00005	<0.0001	0.001	0.003	0.018	<0.0001	0.003	0.004	<0.0001	<0.0002	<0.001
GW04	24-Jun-10	0.045	0.003	<0.00005	0.002	0.045	0.019	0.193	<0.0001	0.048	0.011	0.001	0.001	0.007
GW05	24-Jun-10	0.074	0.001	<0.00005	0.001	0.002	0.005	0.139	<0.0001	0.001	0.017	<0.0001	0.001	<0.001
GW06	24-Jun-10	0.081	<0.0002	<0.00005	0.001	0.001	0.003	0.201	<0.0001	0.005	0.001	<0.0001	<0.0002	0.001
GW07	24-Jun-10	Insufficient sample for analysis												
GW08	24-Jun-10	Insufficient sample for analysis												
GW09	24-Jun-10	Insufficient sample for analysis												
GW11	24-Jun-10	Insufficient sample for analysis												
GW12	24-Jun-10	0.009	0.005	<0.05	0.003	0.002	0.018	0.194	<0.0001	0.17	0.026	0.001	0.003	0.01
GW01	23-Sep-10	36.7	0.006	0.0001	0.148	0.107	0.164	37.6	0.0003	0.219	0.096	0.048	<0.01	0.326
GW02	23-Sep-10	45.7	0.011	0.0002	0.093	0.091	0.049	48.2	<0.0001	1.75	0.192	0.015	<0.01	1.68
GW03	23-Sep-10	1.04	<0.001	<0.0001	0.001	0.005	0.005	1.38	0.0001	0.03	0.003	0.003	<0.01	0.034
GW04	23-Sep-10	3.95	0.001	<0.0001	0.002	0.012	0.008	8.74	0.0002	0.015	0.01	0.01	<0.01	0.03
GW05	23-Sep-10	3.79	0.002	<0.0001	0.004	0.014	0.007	31.2	<0.0001	0.02	0.005	0.008	<0.01	0.299
GW06	23-Sep-10	Insufficient sample for analysis												
GW07	23-Sep-10	Insufficient sample for analysis												
GW08	23-Sep-10	Insufficient sample for analysis												
GW09	23-Sep-10	16.2	0.004	<0.0001	0.002	0.012	0.01	1.11	0.0002	0.021	0.011	0.039	<0.01	0.089
GW11	23-Sep-10	0.95	0.006	0.0001	0.006	0.095	0.036	2.21	<0.0001	0.118	0.222	0.001	<0.01	0.038
GW12	23-Sep-10	Insufficient sample for analysis												
GW01	15-Dec-10	45.4	0.007	0.0004	0.147	0.19	0.14	43.4	<0.0001	0.257	0.115	0.05	<0.01	0.421
GW02	15-Dec-10	Insufficient sample for analysis												
GW03	15-Dec-10	Insufficient sample for analysis												
GW04	15-Dec-10	Insufficient sample for analysis												
GW05	15-Dec-10	Insufficient sample for analysis												
GW06	16-Dec-10	Insufficient sample for analysis												
GW07	15-Dec-10	Insufficient sample for analysis												
GW08	15-Dec-10	Insufficient sample for analysis												
GW09	15-Dec-10	Insufficient sample for analysis												
GW11	15-Dec-10	Insufficient sample for analysis												
GW12	15-Dec-10	Insufficient sample for analysis												

Table 1111: Groundwater Quality Results for the MKSEA: Total Petroleum Hydrocarbons and BTEX, Polynuclear Aromatic Hydrocarbons.

Sample ID	Date	TPH and BTEX									Polynuclear Aromatic Hydrocarbons															
		TPH	C6-9	C10-14	C15-28	C29-36	Benzene	Toluene	Ethylbenzene	Xylene	Napthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Chrysene	Benzo(b)flruoranthene	Benzo(k)fluoranthene	Benzo(a)pyrene	Indeno(1.2.3cd)pyrene	Dibenz(a.h)anthracerene	Benzo(g.h.i)perylene
	units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Domestic non-potable		-	-	-	-	-	10	25	3	20	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-	-	-
LT Irrigation		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW01	9-Sep-09	<260	<20	<40	<100	<100	<0.5	<1.0	<1.0	<3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW02	9-Sep-09	<260	<20	<40	<100	<100	<0.5	<1.0	<1.0	<3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW03	9-Sep-09	<260	<20	<40	<100	<100	<0.5	<1.0	<1.0	<3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW04	9-Sep-09	<260	<20	<40	<100	<100	<0.5	<1.0	<1.0	<3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW05	9-Sep-09	<260	<20	<40	<100	<100	<0.5	<1.0	<1.0	<3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW06	9-Sep-09	<260	<20	<40	<100	<100	<0.5	<1.0	<1.0	<3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW07	9-Sep-09	<260	<20	<40	<100	<100	<0.5	<1.0	<1.0	<3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW08	10-Sep-09	401	<20	<40	401	<100	<0.5	<1.0	<1.0	<3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW09	9-Sep-09	<260	<20	<40	<100	<100	<0.5	<1.0	<1.0	<3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW11	9-Sep-09	<260	<20	<40	<100	<100	<0.5	<1.0	<1.0	<3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW12	9-Sep-09	<260	<20	<40	<100	<100	<0.5	<1.0	<1.0	<3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW01	24-Sep-09	-	-	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
GW02	24-Sep-09	-	-	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
GW03	24-Sep-09	-	-	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
GW04	24-Sep-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW05	24-Sep-09	-	-	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
GW06	24-Sep-09	-	-	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
GW07	24-Sep-09	-	-	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
GW08	24-Sep-09	-	-	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
GW09	24-Sep-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW11	24-Sep-09	-	-	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
GW12	24-Sep-09	-	-	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
GW01	24-Jun-10	-	<20	<50	<100	<50	<0.5	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0
GW02	24-Jun-10	Insufficient sample for analysis																								
GW03	24-Jun-10	-	<20	<50	<100	<50	<0.5	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0
GW04	24-Jun-10	-	-	-	-	-	<0.5	<1.0	<1.0	<3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW05	24-Jun-10		<20	<50	<100	<50	<0.5	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0
GW06	24-Jun-10		<20	<50	<100	<50	<0.5	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0
GW07	24-Jun-10	Insufficient sample for analysis																								
GW08	24-Jun-10	Insufficient sample for analysis																								
GW09	24-Jun-10	Insufficient sample for analysis																								
GW11	24-Jun-10	Insufficient sample for analysis																								
GW12	24-Jun-10	-	-	-	-	-	<0.5	<1.0	<1.0	<3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 1212: Groundwater Quality Results for the MKSEA: Organochloride and Organophosphate Pesticides.

Sample ID	DATE	alpha-BHC	Hexachlorobenzene (HCB)	beta-BHC	gamma-BHC	delta-BHC	Heptachlor	Aldrin	Heptachlor epoxide	trans-Chlordane	alpha-Endosulfan	cis-Chlordane	Dieldrin	4,4`-DDE	Endrin aldehyde	Endosulfan sulfate	4,4`-DDT	Endrin ketone	Endrin	Dichlorvos	Demeton-S-methyl	Monocrotophos	Dimethoate	Diazinon	Chlorpyrifos-methyl	Parathion-methyl	Malathion	Fenthion	Chlorpyrifos	Parathion	Pirimphos-ethyl	Chlorfenvinphos (Z)	Bromophos-ethyl	Fenamiphos	Prothiofos	Ethion
	units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Domestic non-potable		-	-	-	-	-	-	3	3	10	-	10	3	-	-	-	200	-	-	-	-	-	-	1	-	0.3	-	-	10	10	-	-	-	-	-	-
LT Irrigation		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW01	24/9/09	<1.0	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	-	<1.0
GW02	24/9/09	<1.0	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	-	<1.0
GW03	24/9/09	<1.0	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	-	<1.0
GW04	24/9/09	<1.0	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	-	<1.0
GW05	24/9/09	<1.0	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	-	<1.0
GW06	24/9/09	<1.0	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	-	<1.0
GW07	24/9/09	<1.0	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	-	<1.0
GW08	24/9/09	<1.0	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	-	<1.0
GW09	24/9/09	<1.0	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	-	<1.0
GW11	24/9/09	<1.0	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	-	<1.0
GW12	24/9/09	<1.0	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-	-	<1.0
GW01	24/6/10	<0.010	<0.010	<0.010	<0.010	<0.010	<0.005	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.10	<0.10	<0.10	<0.10	<0.10	<0.09	<0.10	<0.10	<0.10	<0.100	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
GW02	24/6/10	Insufficient sample for analysis																																		
GW03	24/6/10	<0.010	<0.010	<0.010	<0.010	<0.010	<0.005	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.10	<0.10	<0.10	<0.10	<0.10	<0.09	<0.10	<0.10	<0.10	<0.100	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
GW04	24/6/10	Insufficient sample for analysis																																		
GW05	24/6/10	<0.010	<0.010	<0.010	<0.010	<0.010	<0.005	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.10	<0.10	<0.10	<0.10	<0.10	<0.09	<0.10	<0.10	<0.10	<0.100	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
GW06	24/6/10	<0.010	<0.010	<0.010	<0.010	<0.010	<0.005	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.100	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
GW07	24/6/10	Insufficient sample for analysis																																		
GW08	24/6/10	Insufficient sample for analysis																																		
GW09	24/6/10	Insufficient sample for analysis																																		
GW11	24/6/10	Insufficient sample for analysis																																		
GW12	24/6/10	Insufficient sample for analysis																																		

Groundwater quality Summary

Pre-development groundwater varies across the site and is summarised as follows:

- pH levels across the site were neutral to slightly acidic across the monitoring network, with pH ranging from pH 4.15 to 8.18 and averaging pH 7.11. A pH range of 6.0 to 8.5 is considered typical of the area, however the pH of 4.15 in bore GW02 is considered low. A downwards trend in pH was observed in bore GW02 from the beginning of monitoring until the September 2010 monitoring round when the pH of 4.15 was recorded. This is likely due to natural ASS oxidation associated with the falling groundwater table. This hypothesis is supported by the elevated metals concentrations found in GW02 during the September and December 2010 monitoring rounds.
- Electrical Conductivity (EC) values averaged 6.504 mS/cm across the monitoring network and ranged from 0.148 to 40.6 mS/cm (GW12). This range is considered typical of freshwater, with lower EC values typically corresponding to months with rainfall and the influence of fresh, rainfall driven recharge on the site.
- Nutrient concentrations (N and P) remain at levels considered typical of grazing and rural agriculture activities undertaken in the broader area. Whilst nutrient levels in groundwater (TP and TN) are consistently above the SCWQIP long term targets for Yule Brook (median concentration 0.075 mg/L and 0.75 mg/L, respectively), this is commonplace, and assessment criteria should be considered a coarse screening tool only, useful in the identification of management priorities. Furthermore groundwater nutrient concentrations are not necessarily reflective of surface water nutrient trigger values due to particulate / soluble fractionations and attenuation pathways.
- The highest concentration of TN (19.0 mg/L) occurred in bore GW06 in September 2010, coinciding with elevated levels of TKN, Total Suspended Solids, nitrate, total phosphorus and COD. This suggests that much of the nutrients identified in this sample were likely to be particulate and/or organic in origin. There is also the possibility that leachate from a nearby domestic septic tank system may be causing these concentration spikes.
- The average FRP to TP groundwater concentration percentage was 23.2% over the monitoring period. This is indicative of clay terrains and hence a relatively high concentration of suspended particulate matter which readily adsorbs reactive phosphorus.
- Pesticides, PAH, BTEX suite and most TPH concentrations at the MKSEA were all found to be below the Laboratory Level of Reporting (LRL).
- Metals concentrations remain typical of broad scale grazing and rural land use activities undertaken in the broader area. Groundwater commonly exceeds the long term irrigation trigger values (for Al, Cr, Cu, Fe, Mn and Ni) and the domestic non-potable trigger values (for Al, Cr, Fe, Ni and Pb). It should be noted that the groundwater samples were not filtered prior to analyses.

  A comparison of filtered/unfiltered groundwater samples were undertaken during the September, 2009 monitoring round. The datasets were screened and any instances where the filtered result was greater than the unfiltered result and concentrations at the LRL (i.e. <0.01) were excluded from analysis. A high percentage of metals were found to be associated with the sediment particles in the sample (that is, not considered to be immediately bioavailable):

    - >90% particulate-bound (Al, As, Cd and Pb);

- o >65% particulate-bound (Co, Cr, Cu, Fe, Hg, , Mn, Se and Zn); and
- o >45% particulate-bound (Ni).

These values are considered typical of turbid flows emanating from iron and aluminium-rich clay and gravel soils associated with the Darling escarpment and its foothills. It is common to see total aluminium, total zinc and total iron exceed relevant water quality standards in clay soil terrains within the Perth Metropolitan area.

Additional filtered/unfiltered comparisons were undertaken during the September 2010 sampling round, and the December 2010 sampling round. The results from the three rounds of filtered metals analyses are presented in Table 8.

Significant differences between total (unfiltered) and soluble (filtered) metal concentrations were observed supporting the belief that most elevated metal concentrations are likely to be particulate (sediment) bound and are thus not readily bioavailable.

The analysis shows that there were soluble metal exceedances of trigger values for Aluminium, Iron, Manganese and Nickel. These slightly elevated concentrations of Al, Fe, Mn and Ni are not considered to be a threat to the natural environment as no complete exposure pathway is known to exist between the source of exceedances (the groundwater) and sensitive receptors (such as the GBSW).

Elevated Al, Fe and Mn levels in bore GW02 (within the GBSW reserve), in the September 2010 and December 2010 monitoring rounds could be indicative of a naturally occurring ASS release event. These high concentrations (for example 19.8 mg/L of Al in September 2010 and 27.3 mg/L of Fe in December 2010) coincide with lower than average pH in bore GW02. Endemic suspects that these monitoring rounds have taken place following a natural ASS release event associated with a falling groundwater table in the lead up to summer. There is noticeable iron oxide surface (‘rust’) staining in the vicinity of this bore.

4.6 Surface Water Quality

Endemic has conducted 14 surface water sampling events up to the end of December, 2010 with water quality rounds completed in June, August, September, October and November, 2009, and June, July, August, September, October, 2010.

The results of the water quality analysis are summarised below. The results have been summarised in Table 13 below and exceedances of the adopted trigger values in Table 14, and the entire surface water quality datasets are included in Tables 15 to 19. Laboratory Certificates of Analysis have been provided electronically.

Table 1313: MKSEA surface water quality results summary June 09 – Dec 10.

SW sample sites M1 - SW7	Sampling Period June 2009 - Dec 2010 (n=76)				
	Units	Min	Max	Average	Median
Temp	C	11.2	28.0	15.7	15.8
pH	-	6.22	9.34	7.53	7.54
Electrical Conductivity	mS/cm	36.0	8590.0	988.2	489.5
Dissolved Oxygen	mg/L	0.7	11.6	6.6	6.6
Redox	mV	-67.8	216.0	5.8	-29.3
TSS	mg/L	1	234	24	14
TDS	mg/L	1.4	2360.0	335.3	254.0
BOD	mg/L	2.0	210.0	24.4	12.0
COD	mg/L	6.0	10000.0	437.9	83.0
TN	mg/L	0.40	7.70	1.92	1.65
NOx_N	mg/L	0.008	3.400	0.533	0.265
NO2_N	mg/L	<0.005	0.089	0.022	0.015
Nitrate-NO3	mg/L	0.01	3.39	0.55	0.29
TKN	mg/L	0.150	4.600	1.466	1.500
TP	mg/L	<0.005	0.94	0.16	0.10
FRP	mg/L	<0.005	0.510	0.089	0.039
Aluminium	mg/L	<0.02	2.420	0.450	0.300
Arsenic	mg/L	<0.001	0.004	0.002	0.002
Cadmium	mg/L	<0.0001	<0.002	<0.0001	<0.0001
Cobalt	mg/L	<0.005	0.0020	<0.005	0.00100
Chromium	mg/L	<0.001	0.002	0.001	0.001
Copper	mg/L	<0.005	0.047	0.005	0.004
Iron	mg/L	0.070	2.500	0.940	0.810
Mercury	mg/L	<0.0001	0.1600	<0.0001	0.0280
Manganese	mg/L	<0.0001	0.180	0.039	0.017
Nickel	mg/L	<0.001	0.014	0.003	0.005
Lead	mg/L	<0.001	0.006	0.002	0.002
Selenium	mg/L	<0.001	0.003	0.002	0.002
Zinc	mg/L	0.006	0.182	0.033	0.026
TRH	ug/L	<50	340.000	<50	200.000
C6-9	ug/L	<20	<20	<20	<20
C10-14	ug/L	<50	<50	<50	<50
C15-28	ug/L	<00	<00	<00	<00
C29-36	ug/L	<50	<50	<50	<50
Benzene	ug/L	<1	<1	<1	<1
Toluene	ug/L	<2	<2	<2	<2
Ethylbenzene	ug/L	<2	<2	<2	<2
Xylene	ug/L	<2	<2	<2	<2

Table 1414: Surface water trigger value exceedances at the MKSEA site.

Surface water quality analysis: AWQG trigger value exceedances				
Analyte	**Units**	**Number samples (n)**	**Irrigation trigger exceedances**	**Marine Ecosystem triggers**
Temp	C	69	-	-
pH	-	74	-	67
Electrical Conductivity	mS/cm	74	-	-
Dissolved Oxygen	mg/L	69	-	-
Redox	mV	31	-	-
TSS	mg/L	74	-	-
TDS	mg/L	69	-	-
BOD	mg/L	71	-	-
COD	mg/L	71	-	-
TN	mg/L	76	-	-
NOx_N	mg/L	68	-	-
NO2_N	mg/L	76	-	-
Nitrate-NO3	mg/L	76	-	-
TKN	mg/L	76	-	-
TP	mg/L	76	-	-
FRP	mg/L	76	-	-
Aluminium	mg/L	33	0	0
Arsenic	mg/L	33	0	0
Cadmium	mg/L	33	0	0
Cobalt	mg/L	33	0	0
Chromium	mg/L	33	0	0
Copper	mg/L	33	0	31
Iron	mg/L	33	30	13
Hg	mg/L	33	2	3
Manganese	mg/L	33	0	0
Nickel	mg/L	33	0	2
Lead	mg/L	33	0	2
Selenium	mg/L	33	0	0
Zinc	mg/L	33	0	22
TRH	ug/L	15	-	-
C6-9	ug/L	15	-	-
C10-14	ug/L	15	-	-
C15-28	ug/L	15	-	-
C29-36	ug/L	15	-	-
Benzene	ug/L	15	-	-
Toluene	ug/L	15	-	-
Ethylbenzene	ug/L	15	-	-
Xylene	ug/L	15	-	-

1. Long Term Irrigation Guidelines Values (ANZECC/ARMCANZ, 2000 / DEC, 2010)
2. Domestic Non-Potable Groundwater Use (DEC, 2010)

*	Unspeciated Chromium trigger value (DEC, 2010)

Table 1515: Surface Water Quality results for the MKSEA: Field Parameters and Nutrients – 2009 monitoring.

Sample ID	Date	Field Parameters									Nutrients						
		Temp	pH	Electrical Conductivity	Dissolved Oxygen	Redox	TSS	TDS	BOD	COD	TN	NOx_N	NO2_N	Nitrate-NO3	TKN	TP	FRP
	units	ºC		mS/cm	mg/L	mV	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Marine trigger		-	8.0-8.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LT Irrigation trigger		-	6.0-8.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M1	30-Jun-09	12.6	6.22	430	8.7	8.8	<1	280	7.0	<5	1.10	<0.760	<0.023	<0.74	0.32	0.02	<0.005
M2	30-Jun-09	12.8	6.41	450	8.5	-1.0	<1	290	<5	10.0	1.10	0.85	<0.028	<0.82	0.29	0.02	<0.005
SW1	30-Jun-09	16.2	6.68	1300	5.6	5.6	100	860	36.0	150.0	7.70	3.1	0.073	3	4.6	0.94	0.11
SW2	30-Jun-09	Insufficient or no flow															
SW3	30-Jun-09	12.8	6.45	1300	5.8	5.8	3	820	8.0	120.0	3.10	1.3	0.048	1.3	1.8	0.28	0.18
SW5	30-Jun-09	16.8	7.09	430	10.2	10.2	<1	280	8.0	570.0	2.60	1.2	0.032	1.1	1.4	0.04	<0.005
SW6	30-Jun-09	Insufficient or no flow															
SW7	30-Jun-09	Insufficient or no flow															
M1	11-Aug-09	14.8	6.58	410	8.6	-	2	158	53.0	6.0	0.88	0.52	0.008	<0.52	0.36	0.01	<0.005
M2	11-Aug-09	15	7.2	556	8.3	-	1	212	50.0	12.0	1.00	0.53	0.014	0.51957	0.48	<0.02	<0.005
SW1	11-Aug-09	16	7.18	1448	9.1	-	40	578	20.0	650.0	4.30	1.6	0.028	1.5813	2.7	0.35	0.19
SW2	11-Aug-09	Insufficient or no flow															
SW3	11-Aug-09	14.4	7.36	1900	6.7	-	22	770	20.0	450.0	3.60	0.22	0.019	0.2259	3.4	0.3	0.17
SW5	11-Aug-09	17.5	7.99	502	10.7	-	<1	192	57.0	350.0	1.60	0.04	0.007	0.04518	1.5	0.03	<0.005
SW6	11-Aug-09	16.4	7.3	1334	3.5	-	100	529	210.0	400.0	5.20	3.4	0.013	3.3885	1.9	0.17	0.025
SW7	11-Aug-09	Insufficient or no flow															
M1	18-Aug-09	-	7.2	240	-	-	66	150	<5	100.0	1.50	0.47	0.015225	0.4518	1	0.06	<0.005
M2	18-Aug-09	-	7	360	-	-	58	230	<5	300.0	1.80	0.58	0.01218	0.56475	1.2	0.08	0.005
SW1	18-Aug-09	-	7	420	-	-	19	270	<5	500.0	3.10	0.37	0.009135	0.36144	2.8	0.53	0.32
SW2	18-Aug-09	Insufficient or no flow															
SW3	18-Aug-09	-	7	560	-	-	60	360	<5	300.0	2.10	0.21	0.009135	0.20331	1.9	0.18	0.023
SW5	18-Aug-09	-	7	170	-	-	7	110	<5	400.0	1.90	0.037	0.00609	0.02259	1.8	0.05	0.005
SW6	18-Aug-09	-	7.3	440	-	-	27	280	7.0	300.0	3.30	0.9	0.015225	0.88101	2.4	0.63	0.51
SW7	18-Aug-09	-	7.3	290	-	-	19	180	<5	400.0	1.90	0.05	0.009135	0.04518	1.9	0.06	0.008
M1	11-Sep-09	15.8	7.98	399	8.0	-	8	150	<5	<5	0.71	0.56	<0.005	0.56475	0.15	0.01	<0.005
M2	11-Sep-09	16.6	7.83	601	7.8	-	14	230	<5	<5	1.10	0.46	0.005	0.4518	0.68	0.05	<0.005
SW1	11-Sep-09	16.1	7.7	1060	5.8	-	20	417	<5	100.0	3.20	0.25	0.006	0.24849	2.9	0.6	0.25
SW2	11-Sep-09	16	7.81	742	5.7		11	288	<5	48.0	2.40	0.62	0.033	0.58734	1.8	0.09	0.01
SW3	11-Sep-09	15	7.45	1050	7.2	-	30	417	<5	64.0	1.90	0.066	<0.005	0.06777	1.8	0.18	0.037
SW5	11-Sep-09	17.2	7.81	408	8.5	-	6	154	<5	60.0	1.60	0.008	<0.005	<0.1	1.6	0.04	<0.005
SW6	11-Sep-09	17	7.87	796	6.5	-	4	310	<5	36.0	2.30	0.77	<0.005	0.76806	1.6	0.27	0.15
SW7	11-Sep-09	17.2	7.67	662	5.7	-	7	254	<5	68.0	1.90	0.014	<0.005	<0.1	1.9	0.07	<0.005
M1	16-Sep-09	16.2	8	428	8.0		6	162	<5	52.0	1.10	-	<0.005	0.63252	1.1	0.01	<0.005
M2	16-Sep-09	16.4	7.86	555	8.0	-	9	213	<5	60.0	1.00	-	0.005	0.54216	1	0.02	<0.005
SW1	16-Sep-09	18.7	7.44	242	5.9	-	8	289	13.0	92.0	2.80	-	0.011	0.92619	2.8	0.3	0.14
SW2	16-Sep-09	17.5	7.51	674	6.2	-	6	258	<5	120.0	2.50	-	0.033	0.51957	2.5	0.1	0.015
SW3	16-Sep-09	20.1	7.9	1264	7.3	-	16	501	<5	340.0	2.20	-	0.006	0.11295	2.2	0.18	0.088
SW5	16-Sep-09	22.4	8.31	428	7.7	-	5	162	18.0	300.0	2.10	-	<0.005	0.006777	2.1	0.07	<0.005
SW6	16-Sep-09	16.8	7.81	1058	5.8	-	4	417	<5	240.0	4.00	-	0.007	2.430684	4	0.14	0.09
SW7	16-Sep-09	18.2	7.37	785	4.5	-	23	305	13.0	350.0	2.70	-	<0.005	0.033885	2.7	0.08	<0.005
M1	2-Nov-09	16.7	7.78	320	7.8	-8.0	<1	119	32.0	<5	0.63	0.36	<0.01	0.36144	0.27	0.5	<0.005
M2	2-Nov-09	19.2	7.75	572	9.0	-30.1	5	219	28.0	<5	0.64	0.27	<0.01	0.27108	0.37	0.5	<0.005
SW1	2-Nov-09	Insufficient or no flow															
SW2	2-Nov-09	Insufficient or no flow															
SW3	2-Nov-09	Insufficient or no flow															
SW5	2-Nov-09	Insufficient or no flow															
SW6	2-Nov-09	Insufficient or no flow															
SW7	2-Nov-09	Insufficient or no flow															
M1	19-Nov-09	17.7	7.45	246	7.4	-43.4	35		32.0	16.0	1.30	0.24	<0.005	0.24849	1.1	0.16	<0.005
M2	19-Nov-09	18	7.45	282	5.2	-44.6	35		49.0	100.0	1.20	1.2	0.008	1.17468	<0.05	0.05	<0.005
SW1	19-Nov-09	22.3	7.48	3640	4.9	-46.2	36		67.0	10000.0	3.20	0.54	0.089	0.4518	2.7	0.49	0.21
SW2	19-Nov-09	Insufficient or no flow															
SW3	19-Nov-09	26.2	7.83	3480	7.3	-64.2	35		64.0	10000.0	3.00	1.2	0.026	1.17468	1.9	0.1	0.016
SW4	19-Nov-09	-	-	-	-	-	14	-	59.0	300.0	2.30	0.51	0.007	0.49698	1.8	0.11	<0.005
SW5	19-Nov-09	28	7.88	422	5.9	-67.8	-	-	-	-	-	-	-	-	-	-	-
SW6	19-Nov-09	Insufficient or no flow															
SW7	19-Nov-09	Insufficient or no flow															

Table 1616: Surface Water Quality for the MKSEA: Field Parameters and Nutrients – 2010 Monitoring.

Sample ID	Date	Field Parameters									Nutrients						
		Temp	pH	Electrical Conductivity	Dissolved Oxygen	Redox	TSS	TDS	BOD	COD	TN	NOx_N	NO2_N	Nitrate-NO3	TKN	TP	FRP
	units	ºC		mS/cm	mg/L	mV	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Marine trigger		-	8.0-8.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LT Irrigation trigger		-	6.0-8.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M1	24-Jun-10	11.5	7.36	319	6.8	-15.4	<5	117	10	9	0.6	0.26	<0.01	0.26	0.3	0.01	<0.01
M2	24-Jun-10	11.2	7.69	388	6.6	-35.5	<5	146	6	11	0.6	0.23	<0.01	0.23	0.4	0.02	<0.01
SW1	24-Jun-10	Insufficient or no flow															
SW2	24-Jun-10	Insufficient or no flow															
SW3	24-Jun-10	11.8	7.79	1534	5.1	-42.3	<5	610	8	59	1.2	0.01	<0.01	0.01	1.2	0.19	0.12
SW5	24-Jun-10	16.7	8.11	279	6.9	-61.2	<5	103	8	73	1.7	0.04	<0.01	0.04	1.7	0.1	0.02
SW6	24-Jun-10	Insufficient or no flow															
SW7	24-Jun-10	Insufficient or no flow															
M1	9-Jul-10	12.2	7.06	185	10.1	99.5	25	120	12	13	0.6	0.24	<0.01	0.24	0.4	0.05	<0.01
M2	9-Jul-10	12	7.13	199	6.9	119.0	16	129	23	16	0.7	0.22	<0.01	0.22	0.5	0.04	<0.01
SW1	9-Jul-10	13.9	7.02	429	7.7	102.9	10	270	15	52	1.9	0.42	<0.01	0.42	1.5	0.25	0.24
SW2	9-Jul-10	13.6	6.97	313	6.5	108.3	36	204	8	25	1.1	0.14	<0.01	0.14	1	0.13	0.04
SW3	9-Jul-10	12	7.01	477	8.6	132.0	5	310	12	53	1.5	0.22	<0.01	0.22	1.3	0.12	0.09
SW5	9-Jul-10	12.4	7	139	9.4	216.0	13	90	17	57	1.6	0.2	0.02	0.18	1.4	0.04	0.02
SW6	9-Jul-10	13	6.81	36	9.8	141.0	5	23	12	<5	0.4	0.13	0.02	0.11	0.3	0.07	0.02
SW7	9-Jul-10	Insufficient or no flow															
M1	13-Jul-10	11.5	7.43	460	6.9	-20.4	<5	181	2	22	1.1	0.83	<0.01	0.83	0.3	0.01	<0.01
M2	13-Jul-10	12.3	8.13	386	6.4	-62.8	11	145	3	32	1.3	0.73	<0.01	0.73	0.6	0.03	<0.01
SW1	13-Jul-10	13	7.57	950	3.8	-29.3	234	371	5	233	5	2.31	0.02	2.29	2.7	0.37	0.11
SW2	13-Jul-10	12.5	7.82	690	5.4	-43.0	<5	265	5	49	2.2	0.74	0.03	0.71	1.5	0.1	0.02
SW3	13-Jul-10	12.6	7.89	750	5.2	-47.6	20	290	<2	86	1.9	0.16	<0.01	0.16	1.7	0.18	0.1
SW5	13-Jul-10	14.6	7.64	301	7.3	-32.7	<5	111	<2	83	1.5	0.03	<0.01	0.03	1.5	0.53	<0.01
SW6	13-Jul-10	15.8	7.64	1279	0.7	-33.0	<5	500	3	186	2.4	1.54	0.02	1.52	0.9	0.07	0.02
SW7	13-Jul-10	13	7.79	630	2.6	-42.3	<5	239	<2	88	1.6	0.01	<0.01	0.01	1.6	0.1	<0.01
M1	12-Aug-10	12.8	6.86	330	6.8	-	11	123	<2	31	0.9	0.3	<0.01	0.3	0.6	0.04	<0.01
M2	12-Aug-10	12.5	7.69	284	6.1	-	10	106	<2	20	0.7	0.3	<0.01	0.3	0.4	0.03	<0.01
SW1	12-Aug-10	13.7	7.63	2400	4.9	-	10	811	<2	57	3.6	1.69	0.04	1.66	1.9	0.25	0.13
SW2	12-Aug-10	Insufficient or no flow															
SW3	12-Aug-10	14.3	7.32	871	5.6	-	<5	337	<2	73	2	0.22	0.01	0.21	1.8	0.13	0.03
SW5	12-Aug-10	15.3	8.33	325	6.6	-	5	121	<2	36	2.1	0.38	<0.01	0.38	1.7	0.11	0.02
SW6	12-Aug-10	14.5	7.88	159	3.4	-	7	57	<2	16	0.8	0.28	<0.01	0.28	0.5	0.06	0.02
SW7	12-Aug-10	Insufficient or no flow															
M1	1-Sep-10	14	8.32	460	6.7	-	<5	174	2	45	0.6	0.25	<0.01	0.25	0.4	<0.02	<0.01
M2	1-Sep-10	14	8.14	572	7.8	-	<5	217	<2	48	0.5	0.22	<0.01	0.22	0.3	<0.01	<0.01
SW1	1-Sep-10	16.1	8.04	3390	5.0	-	26	1390	6	115	3.3	1.36	0.04	1.32	1.9	0.2	0.1
SW2	1-Sep-10	17.4	8.2	700	4.0	-	44	270	17	83	2.1	0.01	<0.01	0.01	2.1	0.23	0.01
SW3	1-Sep-10	18.7	7.37	2815	2.5	-	6	1135	7	122	1.4	0.01	<0.01	0.01	1.4	0.14	0.15
SW5	1-Sep-10	21.5	9.34	371	11.6	-	16	1.39	11	102	3	0.26	0.07	0.2	2.7	<0.05	0.04
SW6	1-Sep-10	16.2	7.9	316	2.9	-	<5	117	7	77	0.9	0.04	<0.01	0.04	0.9	0.05	0.02
SW7	1-Sep-10	Insufficient or no flow															
M1	23-Sep-10	13.4	7.85	6180	6.3	-	10	2360	-	-	0.8	0.19	<0.01	0.19	0.6	0.02	<0.01
M2	23-Sep-10	13.4	7.33	8590	5.5	-	<5	334	-	-	0.4	0.04	<0.01	0.04	0.4	0.03	<0.01
SW1	23-Sep-10	17.7	7.43	4110	4.3	-	14	170	-	-	2.2	0.03	<0.01	0.03	2.2	0.14	0.03
SW2	23-Sep-10	Insufficient or no flow															
SW3	23-Sep-10	Insufficient or no flow															
SW5	23-Sep-10	Insufficient or no flow															
SW6	23-Sep-10	Insufficient or no flow															
SW7	23-Sep-10	Insufficient or no flow															
M1	14-Oct-10	17.9	8.1	956				374	-	-	0.8	0.038	0.024	0.014	0.76	0.02	<0.005
M2	14-Oct-10	16.9	7.35	1850				745	-	-	0.83	0.034	<0.005	0.034	0.8	0.02	<0.005
SW1	14-Oct-10	Insufficient or no flow															
SW2	14-Oct-10	Insufficient or no flow															
SW3	14-Oct-10	Insufficient or no flow															
SW5	14-Oct-10	Insufficient or no flow															
SW6	14-Oct-10	Insufficient or no flow															
SW7	14-Oct-10	Insufficient or no flow															

Table 1717: Surface Water Quality Results for the MKSEA: Metals – 2009 and 2010 Monitoring.

Sample ID	Date	Metals												
		Aluminium	Arsenic	Cadmium	Cobalt	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Selenium	Zinc
	units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Marine trigger		-	-	0.0007	0.001	0.0044	0.0013	1	0.0001	-	0.007	0.0044	-	0.015
LT Irrigation trigger		5	0.1	0.01	0.05	0.1	0.2	0.20	0.002	0.2	0.2	2	0.02	2
M1	18-Aug-09	0.24	0.004	<0.0001	<0.005	<0.001	0.002	0.11	<0.0001	<0.001	<0.005	<0.001	<0.002	0.015
M2	18-Aug-09	0.044	0.001	<0.0001	<0.005	<0.001	0.002	0.07	<0.0001	0.034	<0.005	<0.001	0.003	0.01
SW1	18-Aug-09	0.49	0.002	<0.0001	<0.005	0.001	0.002	0.87	<0.0001	0.016	<0.005	<0.001	0.002	0.035
SW2	18-Aug-09	Insufficient or no flow												
SW3	18-Aug-09	0.12	0.004	<0.0001	<0.005	<0.001	0.002	0.26	<0.0001	0.16	<0.005	<0.001	0.002	0.012
SW5	18-Aug-09	0.11	0.004	<0.0001	<0.005	<0.001	0.002	0.39	<0.0001	0.004	<0.005	<0.001	0.002	0.022
SW6	18-Aug-09	0.15	0.003	<0.0001	<0.005	<0.001	0.002	0.31	<0.0001	0.01	<0.005	<0.001	0.002	0.03
SW7	18-Aug-09	0.24	0.003	<0.0001	<0.005	<0.001	0.002	0.32	<0.0001	0.006	<0.005	<0.001	0.001	0.016
M1	11-Sep-09	0.12	0.002	<0.0001	<0.028	<0.006	0.012	0.21	<0.0001	0.007	0.004	0.001	<0.001	0.048
M2	11-Sep-09	0.3	<0.001	<0.0001	<0.028	<0.006	0.011	0.48	<0.0001	0.045	0.005	0.003	<0.001	0.041
SW1	11-Sep-09	0.28	0.003	<0.0001	<0.028	<0.006	0.014	2.5	<0.0001	0.079	0.005	0.001	0.002	0.047
SW2	11-Sep-09	0.15	0.002	<0.0001	<0.028	<0.006	0.014	1.1	<0.0001	0.018	0.005	0.001	0.002	0.042
SW3	11-Sep-09	1.5	0.002	<0.0001	<0.028	<0.006	0.013	1.3	<0.0001	0.18	0.014	<0.001	0.001	0.044
SW5	11-Sep-09	0.57	<0.001	<0.0001	<0.028	<0.006	0.013	0.81	<0.0001	0.011	0.007	0.002	0.003	0.039
SW6	11-Sep-09	0.11	0.003	<0.0001	<0.028	<0.006	0.016	0.56	<0.0001	<0.006	0.005	0.001	0.003	0.054
SW7	11-Sep-09	0.36	0.002	<0.0001	<0.028	<0.006	0.047	1	<0.0001	0.08	0.006	0.002	0.003	0.04
M1	9-Jul-10	1.37	<0.001	<0.0001	<0.001	0.001	0.004	1.52	<0.0001	0.016	<0.001	0.004	<0.01	0.015
M2	9-Jul-10	1.55	<0.001	<0.0001	<0.001	0.001	0.003	1.39	<0.0001	0.011	<0.001	0.002	<0.01	0.009
SW1	9-Jul-10	0.74	0.002	<0.0001	<0.001	<0.001	0.005	0.89	<0.0001	0.01	0.001	0.002	<0.01	0.029
SW2	9-Jul-10	2.42	<0.001	<0.0001	0.001	0.002	0.007	2.14	<0.0001	0.046	0.002	0.006	<0.01	0.03
SW3	9-Jul-10	0.79	<0.001	<0.0001	<0.001	<0.001	0.003	0.98	<0.0001	0.01	<0.001	<0.001	<0.01	0.012
SW5	9-Jul-10	1.25	<0.001	<0.0001	<0.001	0.001	0.002	1.66	<0.0001	0.009	<0.001	0.001	<0.01	0.011
SW6	9-Jul-10	1.21	<0.001	<0.0001	<0.001	0.002	0.008	0.76	<0.0001	0.005	<0.001	0.005	<0.01	0.031
SW7	9-Jul-10	Insufficient or no flow												
M1	12-Aug-10	0.32	<0.001	<0.0001	<0.001	0.002	0.006	1.09	<0.0001	0.018	<0.001	0.003	<0.01	0.011
M2	12-Aug-10	0.44	<0.001	<0.0001	<0.001	<0.001	0.003	1.19	<0.0001	0.017	<0.001	0.001	<0.01	0.007
SW1	12-Aug-10	0.25	0.002	<0.0001	0.001	<0.001	0.004	1.89	0.0001	0.074	<0.001	0.002	<0.01	0.025
SW2	12-Aug-10	Insufficient or no flow												
SW3	12-Aug-10	0.24	<0.001	<0.0001	<0.001	<0.001	0.005	0.23	<0.0001	0.017	0.001	<0.001	<0.01	0.006
SW5	12-Aug-10	0.46	0.001	<0.0001	<0.001	<0.001	0.003	0.69	<0.0001	0.007	<0.001	<0.001	<0.01	<0.005
SW6	12-Aug-10	0.31	<0.001	<0.0001	<0.001	<0.001	0.007	0.29	<0.0001	0.004	<0.001	0.002	<0.01	0.026
SW7	12-Aug-10	Insufficient or no flow												
M1	23-Sep-10	0.27	<0.001	<0.0001	<0.001	<0.001	0.003	0.77	<0.0001	0.017	<0.001	0.002	<0.01	0.182
M2	23-Sep-10	0.22	<0.001	<0.0001	0.001	<0.001	0.002	1.19	<0.0001	0.097	<0.001	<0.001	<0.01	0.045
SW1	23-Sep-10	0.12	0.002	<0.0001	0.002	<0.001	0.003	1.5	<0.0001	0.105	0.002	<0.001	<0.01	0.013
SW2	23-Sep-10	Insufficient or no flow												
SW3	23-Sep-10	Insufficient or no flow												
SW5	23-Sep-10	Insufficient or no flow												
SW6	23-Sep-10	Insufficient or no flow												
SW7	23-Sep-10	Insufficient or no flow												
M1	14-Oct-10	<0.02	<0.001	<0.002	<0.005	<0.005	<0.005	0.24	0.028	<0.0001	<0.005	0.001	0.003	0.01
M2	14-Oct-10	<0.02	<0.001	<0.002	<0.005	<0.005	<0.005	0.07	0.16	<0.0001	<0.005	<0.001	0.003	0.02
SW1	14-Oct-10	Insufficient or no flow												
SW2	14-Oct-10	Insufficient or no flow												
SW3	14-Oct-10	Insufficient or no flow												
SW5	14-Oct-10	Insufficient or no flow												
SW6	14-Oct-10	Insufficient or no flow												
SW7	14-Oct-10	Insufficient or no flow												

Table 1818: Surface Water Quality Results for the MKSEA: Total Petroleum Hydrocarbons, BTEX, Polynuclear Aromatic Hydrocarbons – 2009 and 2010 monitoring.

Sample ID	Date	TPH and BTEX									Polynuclear Aromatic Hydrocarbons															
		TPH	C6-9	C10-14	C15-28	C29-36	Benzene	Toluene	Ethylbenzene	Xylene	Napthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Chrysene	Benzo(b)flruoranthene	Benzo(k)fluoranthene	Benzo(a)pyrene	Indeno(1.2.3cd)pyrene	Dibenz(a.h)anthracerene	Benzo(g.h.i)perylene
	units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Marine trigger		-	-	-	-	-	500	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LT Irrigation trigger		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M1	18-Sep-09	290	<20	<50	200	110	<1	<2	<2	<2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0
M2	18-Sep-09	60	<20	<50	<100	60	<1	<2	<2	<2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0
SW1	18-Sep-09	<50	<20	<50	<100	<50	<1	<2	<2	<2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0
SW2	18-Sep-09	Insufficient or no flow																								
SW3	18-Sep-09	<50	<20	<50	<100	<50	<1	<2	<2	<2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0
SW5	18-Sep-09	<50	<20	<50	<100	<50	<1	<2	<2	<2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0
SW6	18-Sep-09	180	<20	<50	100	50	<1	<2	<2	<2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0
SW7	18-Sep-09	340	<20	<50	200	100	<1	<2	<2	<2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.6	<1.0	<1.0	<1.0
M1	13-Jul-10	<50	<20	<50	<100	<50	<1	<2	<2	<2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0
M2	13-Jul-10	<50	<20	<50	<100	<50	<1	<2	<2	<2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0
SW1	13-Jul-10	<50	<20	<50	<100	<50	<1	<2	<2	<2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0
SW2	13-Jul-10	200	<20	<50	150	50	<1	<2	<2	<2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0
SW3	13-Jul-10	<50	<20	<50	<100	<50	<1	<2	<2	<2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0
SW5	13-Jul-10	<50	<20	<50	<100	<50	<1	<2	<2	<2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0
SW6	13-Jul-10	<50	<20	<50	<100	<50	<1	<2	<2	<2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0
SW7	13-Jul-10	<50	<20	<50	<100	<50	<1	<2	<2	<2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0

Table 1919: Surface Water Quality Results for the MKSEA: Organochloride and Organophosphate Pesticides – 2009 and 2010 monitoring

Sample ID	Date	OC/OPs																																		
		alpha-BHC	Hexachlorobenzene	beta-BHC	Gamma_BHC	Delta-BHC	Heptachlor	Aldrin	Heptaclor epoxide	Trans-Chlordane	Alpha–Endosulfan	Cis-Chlordane	Dieldrin	4.4 - DDE	Endrin aldehyde	Endosulfan Sulfate	4.4 DDT	Endrin Ketone	Methoxychlor	Dichlorvos	Demeton-S-methyl	Monocrotophos	Dimethoate	Diazinon	Chlorpyrifos-methyl	Parathion-methyl	Malathion	Fenthion	Chlorpyrifos	Parathion	Pirimphos-ethyl	Chlorfenvinphos (Z)	Bromophos-ethyl	Fenamiphos	Prothiofos	Ethion
	units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Marine trigger		-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-	-	-	-	-	-	-	0.009	-	-	-	-	-	-	-
LT Irrigation trigger		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M1	18-Sep-09	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<0.5	<2	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
M2	18-Sep-09	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<0.5	<2	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
SW1	18-Sep-09	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<0.5	<2	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
SW2	18-Sep-09	Insufficient or no flow																																		
SW3	18-Sep-09	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<0.5	<2	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
SW5	18-Sep-09	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<0.5	<2	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
SW6	18-Sep-09	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<0.5	<2	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
SW7	18-Sep-09	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<0.5	<2	<0.6	<0.6	<2	<0.6	<0.6	<0.6	<2	<0.6	<0.6	<0.6	<2	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
M1	13-Jul-10	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<0.5	<2	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
M2	13-Jul-10	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<0.5	<2	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
SW1	13-Jul-10	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<0.5	<2	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
SW2	13-Jul-10	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<0.5	<2	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
SW3	13-Jul-10	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<0.5	<2	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
SW5	13-Jul-10	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<0.5	<2	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
SW6	13-Jul-10	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<0.5	<2	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
SW7	13-Jul-10	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<0.5	<2	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

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Surface Water Quality Summary

Predevelopment surface water varies across the site, reflecting current and historical land use practices and is summarised as follows:

- pH levels across the site were neutral to slightly acidic across the surface water monitoring network, with pH ranging from pH 6.22 to 9.34 and averaging pH 7.52.
- Electrical Conductivity (EC) values were considered representative of freshwater with a maximum value of 8590 µS/cm (TDS of 334 mg/L). This is considered freshwater with lower EC values typically corresponding to months with rainfall and the influence of fresh, rainfall driven surface runoff on the site.
- Nutrient concentrations (N and P) remain at levels considered typical of grazing and rural agriculture activities undertaken in the broader area.
    - Total N (TN) surface water concentrations averaged 1.92 mg/L and exhibited a median of 1.65 mg/L, both of which are above the Swan Canning SCWQIP long term target for Yule Brook of median TN of 0.75 mg/L (SRT, 2009);
    - Total P (TP) groundwater concentrations averaged 0.16 mg/L and exhibited a median of 0.10 mg/L, both of which are above the Swan Canning SCWQIP long target for Yule Brook of median TP of 0.075 mg/L (SRT, 2009);
    - On average, the groundwater FRP concentration was 39.0% of that for TP over the monitoring period;
- Although existing nutrient concentrations in Yule Brook may at times exceed the Swan Canning Estuary long term water quality targets, this tributary has largely met the short term targets since 1994 (SRT, 2007). Future development provides an opportunity for the application of Water Sensitive Urban Design principles which, if applied appropriately, could serve to reduce nutrient loads to the sensitive downstream receptor (ie. the Canning River).
- Surface water concentrations commonly exceeded the 95^{th} percentile marine trigger values for Cu, Fe and Zn and the long term irrigation trigger value for Fe. Total Suspended Solids values were consistently high across all monitoring rounds with a maximum of 234 mg/L and an average of 24 mg/L.
- A comparison of filtered/unfiltered metal samples conducted in September 2010 indicate that filtered Cu, Fe and Zn, still return concentrations exceeding the Marine Ecosystem and Long Term Irrigation trigger values. However this is a common occurrence and considered typical of runoff from broad scale rural activities undertaken in the broader catchment.
- Pesticides, PAH and BTEX suite concentrations at the site were all found to be below, or very close to the Laboratory's Level of Reporting (LRL) and no trigger value exceedances were observed.

4.7 QA/QC

Quality control samples collected during the program included collecting field blind replicates (duplicate samples) which were collected at a rate of 1 per 20 samples. Table 20 indicates conformance to specific QA/QC procedures.

Table 2020: QA/QC Data Validation

QA/QC requirement	Completed	Comments
Groundwater		
Bores were developed and purged according to AS/NZS 5667.11	Yes	At least five purge volumes were removed from each bore prior to sampling
Samples delivered to laboratory within sample holding times and with correct preservative	Yes	Refer to sample receipt advice
All analyses completed using a NATA accredited method	Yes	Nil
Required number of sample duplicates and blanks taken	Yes	3 groundwater duplicate samples taken
Sample duplicates reported RPDs within limits set by AS4482.1	Yes	Some exceptions, see below
Surface Water		
Samples delivered to laboratory within sample holding times and with correct preservative	Yes	Refer to sample receipt advice
All analyses completed using a NATA accredited method	Yes	Nil
Required number of sample duplicates and blanks taken	Yes	6 surface water duplicate samples taken
Sample duplicates reported RPDs within limits set by AS4482.1	Yes	One exception, see below

Groundwater

The RPDs between the primary and duplicate samples were generally within the 50% acceptance threshold. Exceedances of greater than 50% were encountered for:

September 2009

- Co in GW2 and Dup 2 (128.2 %)- **LRL**;
- Hg in GW2 and Dup 2 (140.3 %)- **LRL**; and
- COD in GW2 and Dup 2 (147.8 %)- **X**.

November 2009

- TP in GW12 and Dup 4 (170.9 %)- **X**;
- FRP in GW12 and Dup 4 (128.6 %)- **LRL**;

- Cu in GW12 and Dup 4 (56.7 %)- **X**; and
- Ni in GW12 and Dup 4 (54.6 %)- **X**.

Of the above samples, those labelled with LRL indicates that the sample result concentration was considered to be close to the LRL and higher RPDs may be expected by virtue of the small numbers involved. Those samples labelled with X indicate that either sample heterogeneity, or laboratory operator error may have impacted the results of the analysis.

Surface Water

The RPDs between the primary and duplicate samples were generally within the 50% acceptance threshold for metals and with few exceptions. Exceedances of greater than 50% were accounted for:

July 2010

- COD in SW6 and Dup 1 (88.89%) – **X**

September 2010

- TKN in M1 and Dup 1 (66.67%) – **X**

December 2010

- Al in M2 and Dup 1 (56.60%) – **X**

Of the above samples, those labelled with X indicate that either sample heterogeneity, or laboratory operator error may have impacted the results of the analysis.

RPD conclusion

Examination of the results shows that with respect to the RPDs, the greater concentration was not consistently found in either the primary or duplicate sample. This suggests that these exceedances were not likely due to sample heterogeneity (where a consistent trend would be apparent) and is likely to have been caused by storage or laboratory operator error.

Endemic has referred several rounds of groundwater and surface water samples collected since May 2010 to a second laboratory (ALS Laboratories) for chemical analysis in an effort to resolve a number of outlier RPD results. The laboratory change has not completely resolved outlier RPD issues, suggesting that the small number of RPD exceedances could be a consequence of low reporting limits, and high levels of suspended solids in groundwater and surface water at the site resulting in high potential for suspended solids variations between primary and duplicate samples.

Although, some RPD values indicated variability between the primary and duplicate samples, the results do not alter significantly the overall water quality assessment or risks to the environment. In our opinion, the QA/QC procedures and laboratory results are acceptable for the purposes of this monitoring investigation.

4.8 Geological and Ecological Points of Interest

Endemic installed nine soil bores in June 2009 for the purpose of a preliminary Acid Sulfate Soil Investigation which were turned into groundwater bores for the purpose of this Water Quality Investigation. The depth of these bores varied based on the depth at which groundwater occurred, and the depth at which refusal was reached due to the presence of heavy clay, gravel or calcrete.

Bores installed within the GBSW reserve, namely bores GW02, GW04, GW05 and GW12 all reached refusal at depths of 2 m bgl or shallower. Endemic suspects that refusal, in each of these bores, was reached due to the presence of sub-cropping calcrete at shallow depths. This hypothesis is supported by the observation of calcrete within roadside drains and the incidence of associated vegetation both within and surrounding the GBSW reserve. It is suggested that sub-cropping calcrete may be more extensive in the area than previously believed.

Endemic sought access to the Department of Water's WIN bore database to analyse bore log information on a number of WIN bores located within the MKSEA. The database included detailed bore log information on a small proportion of the total number of registered WIN bores within the site, none within close proximity of the suspected calcrete horizon. This may in fact be significant, given the reported hardness of this horizon making bore installation problematic. Notwithstanding, limestone was noted at greater depths in a cluster of bores to the north west of the GBSW reserve, and calcrete can be seen within the road side drains cut along the borders of the GBSW reserve.

Limestone and calcrete is associated with several geological formations of the Perth Basin, such as the Cretaceous Leederville formation. Along the foothills of the Darling Scarp, the more ancient geological formations such as the Leederville formation are known to be closer to the surface and to outcrop is some areas. Sub-cropping calcrete could constitute a confining layer (aquitard) with the ability to support groundwater perching and hence wetland formation. A calcrete horizon is inferred to underlie much of the GBSW reserve.

The map below (Figure 20) shows

- the locations of the DoW bores within which the incidence of limestone and/or calcrete has been recorded previously;
- Endemic bores which showed drilling refusal at shallow depths; and
- other observed and inferred occurrences of shallow limestone and/or calcrete beyond the GBSW reserve boundary.

This provides some insight as to the potential extent of a shallow aquitard which is thought to underlie (at least) the GBSW reserve, but likely the broader area.

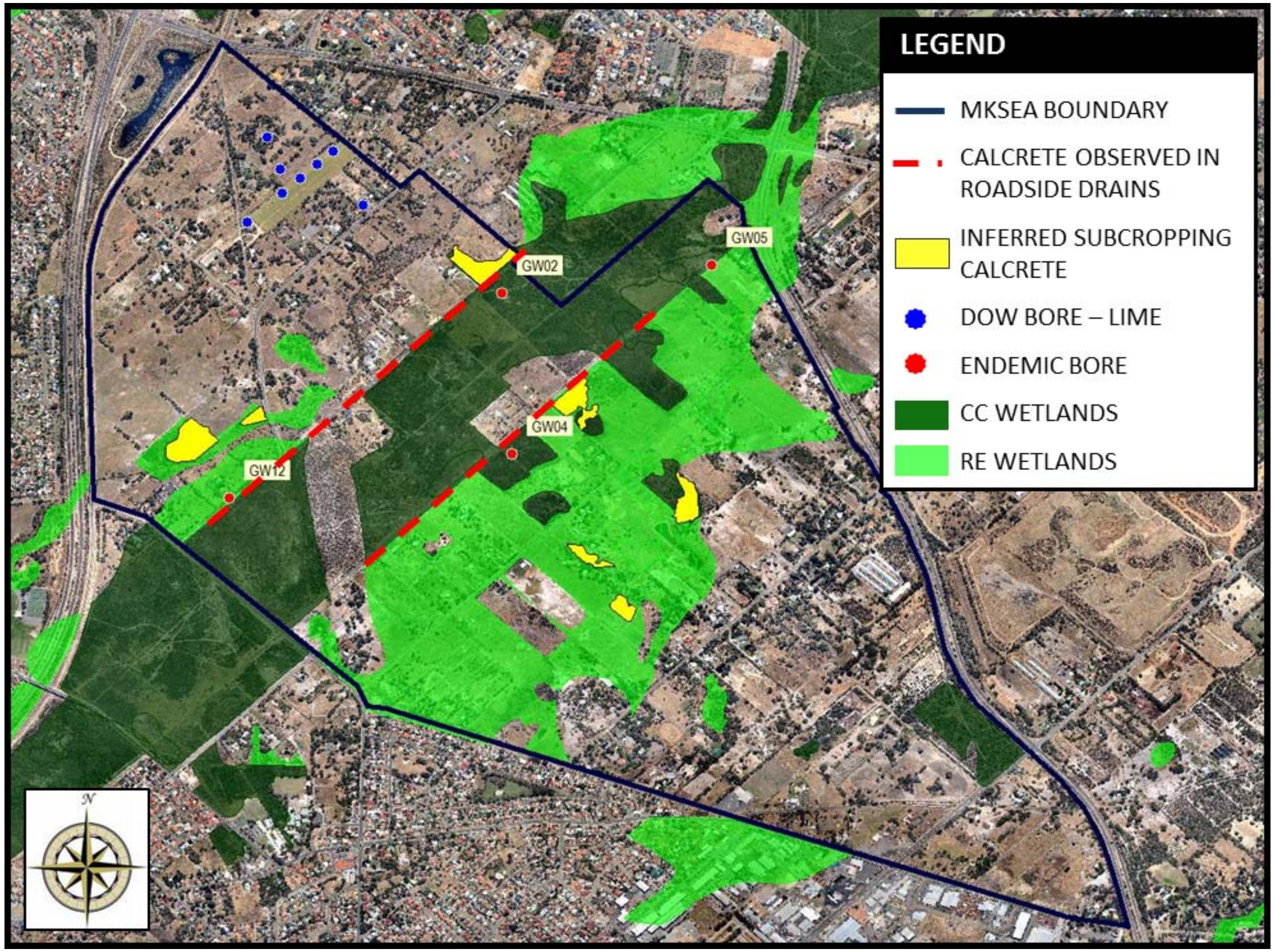

Figure 2020: Map showing distribution of observed and inferred indications of calcrete subcropping

5. Conclusions

In accordance with the Aquaterra *MKSEA Surface Water and Ground Water Investigation and Monitoring Program*, this Water Quality Monitoring Report has been prepared in order to fulfil the aims of determining:

- baseline environmental conditions;
- the interaction between groundwater and surface water;
- groundwater / surface water hydrological interactions with areas of environmental significance (including the Greater Brixton Street Wetlands);
- groundwater / surface water hydrological divide in regard to Precinct 1 and Precinct 2; and
- the interaction between local and district water regimes.

This Section outlines the conclusions that have been drawn relating to these aims, based on the two winter water monitoring program undertaken between June 2009 and December 2010.

5.1 Baseline Environmental Conditions

Water Quality

Groundwater

All groundwater and surface water samples returned below LRL levels of pesticides, PAHs and BTEX. Generally groundwater samples did not return concentrations of nutrients, TPH or metals at levels exceeding the relevant DEC and DoH trigger values, except in the cases of Al, Cr, Cu, Fe, Mn, Ni, and Pb. There were also one-off exceedances of As, Cd, and Hg trigger value guideline that all occurred within the one sample, namely bore GW02 during the September 23rd, 2010 monitoring round. Endemic suspects this may be an artefact of this bore being located down gradient from a rural residence (likely to be on septic tank and leach drains).

Elevated concentrations of Al, Fe and Mn in groundwater can be attributed to the presence of iron and mineral rich soils within the study area, which were recorded within the bore logs. The elevated concentrations may also be a result of evapo-concentration of analytes within the surficial (perched) water table. There is also direct evidence of iron precipitation (‘staining’) within the Greater Brixton Street Wetland reserve in the vicinity of GW02. Notably, bore GW02 recorded low pH and elevated Al, Fe, Mn and Ni concentrations as well as As, Cd, and Hg, noted in the September 2010 monitoring round. These elevated concentrations are not considered to be anthropogenic in origin because of the lack of disturbance within the GBSW reserve in this area.

The filtered/unfiltered groundwater comparison shows that unfiltered groundwater samples contain significant amounts of particulates and a large portion of the contaminant levels are likely to be associated with this phase. As a result, the chemistry shows elevated concentrations (especially for some metals) that are not considered to be readily bio-available to downstream receptors.

Surface Water

Elevated concentrations of Cu, Fe, Zn (and on occasion hydrocarbons) have been observed within streamflow but are considered typical of rural and road runoff (both within and upstream of the MKSEA catchment). No adverse impacts associated with these elevated concentrations were observable within sensitive receptors located within the study area. It is important to note that water quality trigger values for aquatic ecosystem protection should not be applied to stormwater and urban drains *per se* (ANZECC/ARMCANZ, 2000). In this regard attainment of the water quality trigger values for the receiving waterbody (Swan River Estuary) is paramount.

Median TP and TN concentrations in surface waters are consistently above the Swan Canning Water Quality Improvement Plan (WQIP) long term targets for Yule Brook (median concentrations of TP=0.075 mg/L, TN=0.75 mg/L; SRT, 2009). Average surface water TP concentrations increase from 0.046 to 0.203 mg/L, and average FRP from 0.005 to 0.085 between sites SW5 and SW3, respectively. The FRP to TP ratio also increases from 1.4% to 36.5% between these sites, indicating that phosphorus (likely of anthropogenic origin) may be entering the drainage network between these two surface water monitoring sites. The existing aquaculture operation (70 Brook Road, Kenwick) may be one potential source of the observed elevated filterable phosphorus concentrations.

It should be noted, however, that the Yule Brook consistently met the short term (and in many cases long term) WQIP targets between 1994 and 2006 at the Swan River Trust/Department of Water's monitoring station on Yule Brook to the south west of the site, near its discharge point into the Canning River (SRT, 2009).

Data Quality

A number of samples contained RPDs in excess of 50%. Generally, greater variations can normally be expected at low contaminant concentrations (% errors are magnified) and/or samples with significant turbidity or particulate load which may generate issues of homogeneity and representative sampling (a source of further error).

The small absolute errors (eg. 0.01mg/L) of the RPD exceedances are not a cause for concern for data integrity and Endemic considers that the quality of data is adequate for the purposes of this investigation.

Conclusions

In summary, based upon the results of site visits, and sampling and analysis conducted, Endemic believes there are no significant or potentially harmful concentrations of OC/OP pesticides, TPH, BTEX, PAHs or COD/BOD present in the surface or ground waters at the MKSEA. Elevated concentrations of nutrients and metals have been detected in surface and ground waters; however a significant proportion appears to be particulate bound and thus not considered to be readily bioavailable. Exceedances of Al, Fe and Zn trigger values in turbid surface and groundwater samples is a common occurrence on the eastern Swan Coastal Plain and reflective of the high clay content and mineralogy of the soils in the vicinity of the Darling Escarpment.

Appropriately designed and located future development may be seen as an opportunity to attenuate currently elevated concentrations of surface water nutrients and metals through the incorporation of Water Sensitive Urban Design (WSUD) Principles. Typically, the incorporation of WSUD is assumed to reduce nutrient and metal contaminant concentrations by 60% over conventional piped urban drainage systems (DoW, 2007). The predominance of particulate bound metals and nutrients suggests that future treatment trains would be geared towards erosion control and sedimentation.

The analysis of BTEX, TPH, PAHs, OC/OP pesticides and COD and BOD analytes over two winters meets the DoW's pre-development monitoring requirements. Based upon the results of this study, Endemic recommends that monitoring of these water quality parameters be discontinued as the existing data is sufficient to establish pre-development baseline conditions.

Continuation of streamflow monitoring and nutrient sampling at sites M1 and M2 is, however, recommended in order to assess the flow dynamics of the catchment and to appraise the inter-annual variability of streamflow and nutrient transport arising from above average rainfall/flow conditions.

In addition, the introduction of water quality sampling at wetland sites in the future may aid in satisfying recent changes to the DoW's pre-development monitoring requirements (DoW, 2011).

Groundwater and Wetland Levels

Groundwater and surface water level monitoring results show that groundwater levels (and streamflows) are highly responsive to rainfall in proximity to the Greater Brixton Street Wetland reserve. This is largely as a result of the presence of:

- well-formed calcrete at shallow depth (<1m bgl) underlying much of the Great Brixton Street Wetland complex;
- soils with a high clay content at shallow depth (<1m bgl), which inherently exhibit a high runoff coefficient;

The calcrete, where encountered, is shallow and well formed (rock-like) and largely impervious and is largely responsible for the high responsiveness of groundwater to rainfall infiltration and for the surficial (perched) groundwater that sustains the ecohydrology of the Greater Brixton Street Wetland complex.

The perched groundwater underlying the GBSW complex commonly reaches (or approaches) the ground surface during the winter months giving rise to extensive areas of wetland habitat. By mid to late summer the perched groundwater has receded to such an extent that there is no surficial groundwater evident during the summer months within the area of the GBSW complex.

In many instances it is difficult to draw a distinction between 'groundwater' and 'wetland' monitoring sites *per se* due to the proximity of the seasonal groundwater perching to the ground surface.

To the east of Victoria Road and to the west of Yule Brook, a greater depth of overlying sand gives rise to reduced inundation and a more substantial (and conventional) surficial groundwater system, which is discussed in detail in Section 5.2.

Streamflow

Stream discharge measurements (gaugings) were conducted during 2009 and 2010 to establish stage height/discharge rating curves for each streamflow monitoring site. Due to sporadic and low rainfall experienced during this period (including Perth's driest year on record) it was not possible to obtain discharge measurements that approximated the actual hydrographic peak over this same period. Endemic subsequently undertook further streamflow monitoring during 2011 to overcome this deficiency and to complete computation and analysis of streamflows for the three year period (see Addendum to this report). This now completes a three year recording of streamflow for watercourses identified under the scope of works for this project.

5.2 Groundwater and Surface Water Interactions

Topographic controls on groundwater elevation within the study area are apparent, as evidenced by groundwater mounding beneath the Bassendean Sand dunes. However because of the relatively low density of investigative bores and the complexity of the stratigraphy in the area, additional bores and lithological logging would be required to provide detailed understanding of the spatial variability and groundwater/surface water interactions to a level sufficient to formulate a hydrological/groundwater model for the area.

Notwithstanding, the bore network that has been developed and monitored during the course of this project provides an important insight into the important role that the aquitard (clays/calcrete) performs in terms of promoting groundwater perching and wetland formation in the area.

Based upon the available bore logs and soil profiles exposed in roadside drains, the central (wetland) portion of the study area is underlain by a contiguous sheet of calcrete and/or clay which is of sufficiently low permeability (aquitard) to retard downward leakage. The calcrete horizon is impermeable and rock-like where present, such that the base of the roadside drains bordering the Brixton Street Wetland reserve (proper) now rest on this profile.

Figure 21 shows shallow groundwater gradients calculated from maximum winter water levels observed at the groundwater and wetland monitoring sites during 2009.

Figure 22 shows surface water (topographic) catchments derived from LiDAR elevation data. Included are drainage lines as reported by GHD (2005) and indicative flowlines derived from field observation and LiDAR data (where access was not possible). This image highlights the importance of roadside drains (generally) in terms of regulating flows within the MKSEA.

The low groundwater gradients generally means groundwater throughflow in the area is minor. Drains, where benched onto the underlying calcrete or clay aquitard, function as cut-off drains to intercept shallow groundwater throughflow that might otherwise enter the Greater Brixton Street wetland (from up-gradient source areas) and divert this to surface drains.

The generally low groundwater gradient in the surficial groundwater is evidenced by the extensive waterlogging (including wetland formation) that occurs during the winter months. Once surficial groundwater reaches ground surface, the resultant surface flow is controlled by topography and constructed drainage network.

Sub-cropping calcrete plays a crucial role in determining groundwater-surface water interactions; however the extent of the continuity of this aquitard in the area is largely unknown. A scope of work has been previously provided to the City of Gosnells in order to gain a fuller understanding of the extent of this aquitard.

Notwithstanding, the initial indications are that the spatial extent of the calcrete underlying the GBSW reserve may be more extensive than first thought. Future drainage strategies (DWMS) and hence fill costs will be highly contingent upon a detailed understanding of the depth and spatial extent of the underlying aquitard. The importance of this aquitard to the maintenance of wetland water level regimes is considered to be critical.

Endemic concludes that the formation of wetlands within the GBSW complex are almost entirely as a result of groundwater perching (surficial groundwater), with negligible interaction with the deeper aquifer (regional groundwater). The calcrete aquitard is responsible for the formation of most of the wetlands within the GBSW complex, with the remainder in this area being sustained by a shallow clay soil horizon. Further investigation of the interaction between ground and surface waters for specific wetlands is warranted in order to determine the EWRs for these wetlands and their distinct hydrological boundaries which will impact the potential extents of future development.

In particular, the likely application of subsoil drainage systems in any future drainage strategy underpinning development within the broader area will require that these systems be adequately setback from important wetland habitats and that these drains be established at an invert that does result in drawdown or dewatering of wetlands. This will necessitate that the depth and extent of the calcrete/clay aquitard be more fully understood when designing these drainage systems.

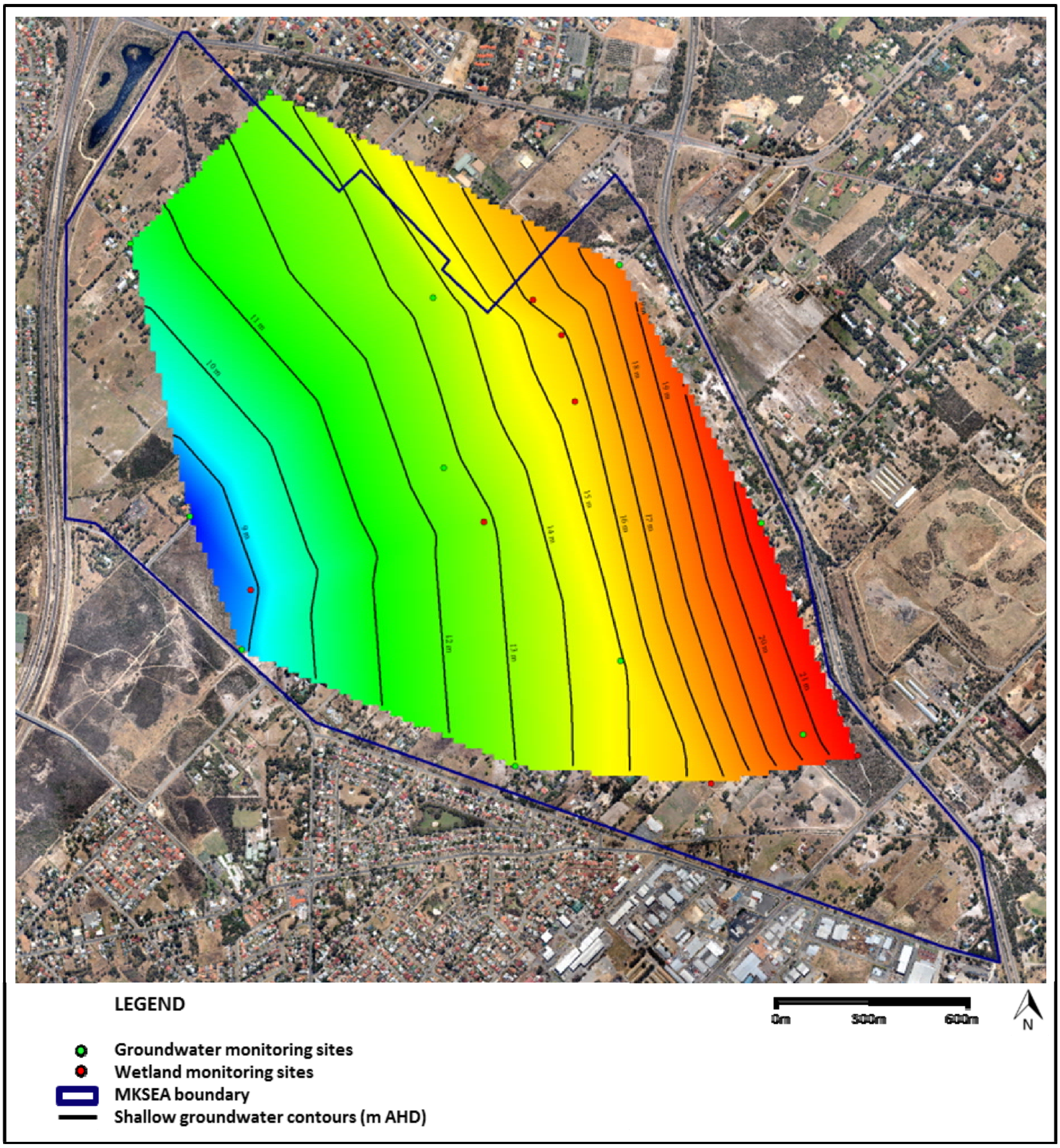

Figure 2121: Shallow groundwater contours calculated from maximum winter water levels in 2009 from groundwater and wetland monitoring sites

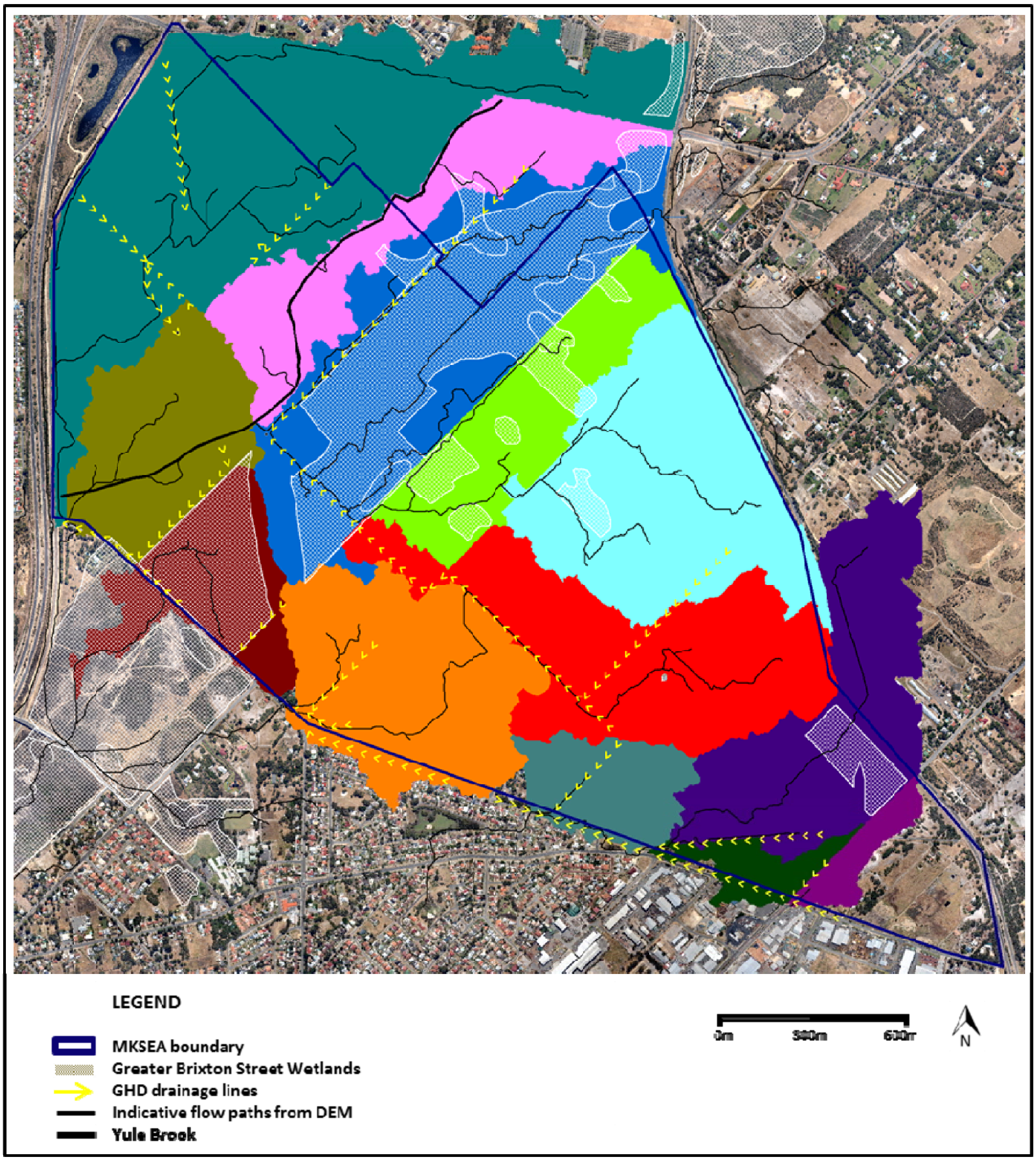

Figure 2222 Indicative topographical sub-catchments and flow lines derived using field observation and LiDAR data.

Data collected during this investigation suggest that the GBSW complex is hydrologically distinct from most of the site with respect to groundwater and, to a certain extent, surface water. Some surface water runoff, originating from land within Precinct 2, currently traverses the GBSW, draining through the Reserve in a westerly direction to the Yule Brook. Groundwater separation is likely a result of the cutting of deep roadside (cut-off) drains up-gradient and down-gradient of the GBSW reserve which have been benched onto the underlying impermeable calcrete horizon.

Endemic recommends that further investigation of the spatial extent of sub-cropping calcrete at the site, and its impact on site hydrology and wetlands outside of the GBSW, is warranted. Additional water level monitoring may also be warranted with respect to identifying pre-development environmental conditions in proximity to, and within, the GBSW and for determining EWRs for various specific wetlands.

Recent changes have been made by DoW to its pre-development monitoring requirements which now include provisions for wetland monitoring (DoW, 2011). Such monitoring can also provide an understanding of the interaction between surficial groundwater controls and wetland habitats which can be used to inform future drainage design (DWMS, LWMS, UWMP) as well as defining wetland water level maintenance objectives (EWRs) for post development management. In addition, Endemic believes that the presence of TECs, Priority Flora, and Wetlands of National Importance within the MKSEA may trigger environmental impact assessment of future development proposals in the area by the Commonwealth under the EPBC Act. This will likely increase the need for a greater understanding of the interaction between ground and surface water and wetland hydrology in the area.

Based upon the above discussion, Endemic therefore recommends that investigations be undertaken to define the spatial extent of sub-cropping calcrete and/or clay in the area. The proposed approach involves:

- Undertaking a survey using Ground Penetrating Radar (GPR) to define the extent of the calcrete and/or clay aquitard in the vicinity of the Greater Brixton Street Wetland complex;
- Installing further groundwater monitoring bores in ‘gap’ areas (largely located on private property) to improve spatial coverage and to inform the (future) District Water Management Strategy and hydrological modelling thereto;
- Aquifer (drawdown) pump testing be undertaken to verify the assumed hydraulic disconnection between the deeper (regional) aquifer and surficial wetlands (supported by a calcrete aquitard); and
- Pump testing and level monitoring of the surficial groundwater be undertaken to verify the lateral (horizontal) extent of potential shallow groundwater drawdown impacts to inform buffer (setback) requirements for future drainage design.

5.3 Interaction between Precincts 1 and 2

The hydrological controls within Precinct 1 of the MKSEA (the south eastern corner of the area) are somewhat distinct from the remainder of the site. An analysis of a DEM (digital elevation model) constructed for the MKSEA suggests that Precinct 1 straddles the Yoganup Formation (formerly Ridge Hill Shelf Formation).

The Yoganup Formation is interpreted as being a sand/clay/gravel complex associated with outwash from the escarpment. Within Precinct 1, this soil is thought to underly the eastern portion of the precinct and is overlain by more recent Bassendean Sands of aeolian origin. This has served to create a ‘duplex’ or sand over clay soil profile in this area.

The ‘heavier’ phases of the Yoganup Formation typically contain gravels and unlike the Guildford Formation clays, commonly exhibit a topographic slope arising from their outwash and deltaic origins. Bore logs (WET8) show Yoganup soils (ORANGE

SANDY CLAY) underlying BushForever Site 53 at ~2.0m bgl (inferred to be sloping to the west). The sloping nature of the Yoganup B soil horizon (sandy clay) at this location is thought to be the reason why WET8 rarely contains groundwater, yet further downslope (westward) GW9 exhibits more pronounced groundwater development.

Waterlogging within Precinct 1 is rarely observed due to the presence of greater depths of permeable Bassendean Sands. Hydrological processes within this sub-catchment are more strongly controlled by infiltration/recharge as reflected by the lagged and less-responsive form of the hydrograph for GW9 and lack of observed surface flow at SW7. For this reason, groundwater storage in Precinct 1 is likely to be more pronounced than other areas of the MKSEA.

Groundwater samples were retrieved from GW09 and exhibited elevated concentrations of Al and Fe, which can be attributed to the presence of mineral rich sandy clays underlying the area. Hydrocarbon and BTEX concentrations remained below the LRL level of detection.

By contrast, the hydrological controls within Precinct 2 are more heavily influenced by the presence of a shallow aquitard thought to underlie much of this area. This promotes winter waterlogging and the predominance of surface runoff within this precinct. The aquitard is believed to grade from calcrete adjacent to the GBSW (as evidenced in roadside drains) to a shallow sandy clay B horizon nearer Victoria Road. The nature and location of the transition is as yet unknown, however, is considered to be of critical importance for development of a future drainage strategy and to the maintenance of groundwater-dependent ecosystems in the area. The hydrological processes within Precinct 2 (and wetland perching) are considered to be dependent upon the presence of this shallow aquitard and disturbance of this horizon by future drainage or sewer installation in support of development needs to be more fully considered.

5.4 Final Recommendations

The baseline (pre-development) data collected over the duration of the 18 month monitoring period suggests that groundwater and surface water chemistry is typical of urban and rural activities undertaken in the broader catchment.

Although several trigger value exceedances have been recorded for some metals and nutrients, these exceedances are typical of soils, topography and landuses commonly associated with the eastern Swan Coastal Plain.

Groundwater and surface water level monitoring shows that both ground and surface waters in the vicinity of the GBSW reserve are highly responsive to rainfall, due largely to the presence of a shallow aquitard (calcrete and/or clay) beneath this area. This horizon is largely responsible for the groundwater ‘perching’ that sustains the hydrological regime of the Greater Brixton Street Wetland.

Endemic considers that while the groundwater monitoring network is suitable for defining maximum groundwater levels and groundwater quality within the study area, consideration should be given to extending the network for the purposes of defining environmental water requirements (EWRs) for specific wetlands.

Endemic recommends further investigations be undertaken to improve the understanding of the interaction between surficial ‘perched’ groundwater, the extent of the shallow aquitard and connectivity with the deeper (regional) aquifer, including:

1. A continuation of the groundwater level, streamflow and wetland water level monitoring for an additional winter period to overcome the exceptionally dry winter of 2010. This will also assist definition of AAMGL. (See the Addendum to this report).
2. Short term deployment of area/velocity (Doppler) loggers at M1 and M2 during winter 2011 to capture high flow rating points to improve the definition and reliability of the rating curves for these sites (and to overcome the lack of peak flows during 2010). (See the Addendum to this report).
3. The inclusion of a baseline wetland water quality monitoring program, to meet the recently proposed changes to the DoW’s pre-development monitoring requirements (DoW, 2011).
4. Expansion of wetland water level monitoring for the purposes of adequately defining environmental water requirements (EWRs) for specific wetlands.
5. Undertaking a field investigation to determine the spatial extent of the shallow calcrete/clay aquitard using ground penetrating radar and field validation. Data obtained from this investigation will also provide valuable information for geotechnical interpretation of the area and drainage design considerations in the future.
6. Drawdown testing be undertaken to verify the hydraulic connectivity (or lack thereof) between ’perched’ wetland habitats and deeper groundwater. The assumption that these two systems are hydraulically disconnected will require a degree of field validation and provide valuable information for environmental impact assessment, drainage design and determination of drainage exclusion zones in order to maintain groundwater-dependent ecosystems in the future.

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7. Statement of Limitations

Scope of Services

This environmental report ("the report") has been prepared in accordance with the scope of services ("scope of services") set out in the contract, or as otherwise agreed, between the Client and Endemic Pty Ltd (Endemic). In some circumstances the scope of services may have been limited by a range of factors such as time, budget, access and/or site disturbance constraints.

Reliance on Data

In preparing the report, Endemic has relied upon data, surveys, analyses, designs, plans and other information provided by the Client and other individuals and organisations, most of which are referred to in the report ("the data"). Except as otherwise stated in the report, Endemic has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in the report ("conclusions") are based in whole or part on the data, those conclusions are contingent upon the accuracy and completeness of the data. Endemic will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to Endemic.

Environmental Conclusions

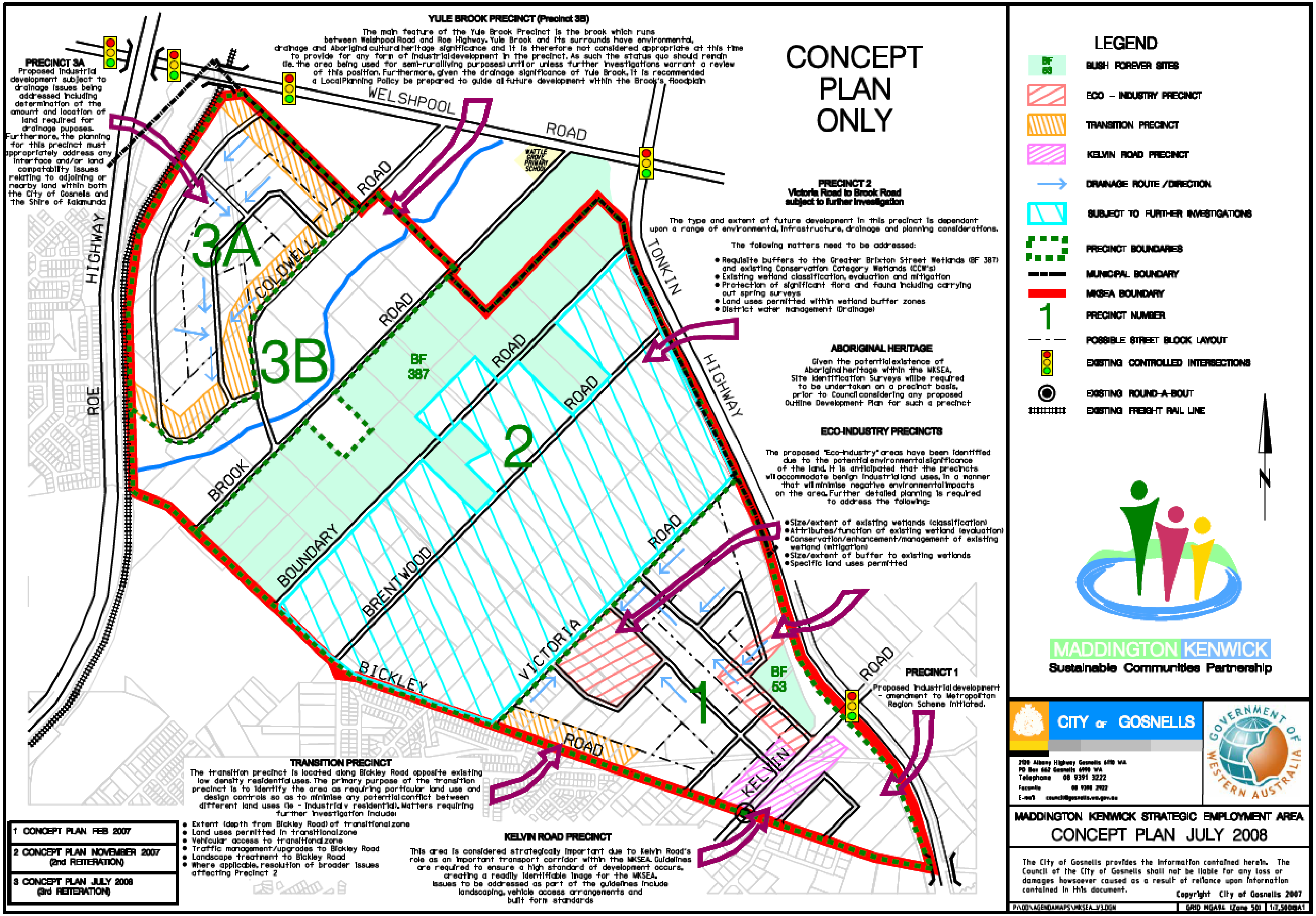
In accordance with the scope of services, Endemic has relied upon the data and has conducted environmental field monitoring and/or testing in the preparation of the report. The nature and extent of monitoring and/or testing conducted is described in the report. On all sites, varying degrees of non-uniformity of the vertical and horizontal soil or groundwater conditions are encountered. Hence no monitoring, common testing or sampling technique can eliminate the possibility that monitoring or testing results/samples are not totally representative of soil and/or groundwater conditions encountered. The conclusions are based upon the data and the environmental field monitoring and/or testing and are therefore merely indicative of the environmental condition of the site at the time of preparing the report, including the presence or otherwise of contaminants. Also, it should be recognised that site conditions, including the extent and concentration of contaminants, can change with time. Within the limitations imposed by the scope of services, the monitoring, testing, sampling and preparation of this report have been undertaken and performed in a professional manner, in accordance with generally accepted practices and using a degree of skill and care ordinarily exercised by reputable environmental consultants under similar circumstances. No other warranty, expressed or implied, is made.

Report for Benefit of Client

The report has been prepared for the benefit of the Client and no other party. Endemic assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including without limitation matters arising from any negligent act or omission of Endemic or for any loss or damage suffered by any other party relying upon this report. Other parties should not rely upon the report or the accuracy or completeness of any conclusions and should make their own enquiries and obtain independent advice in relation to such matters.

Appendix A

Current Concept Plan- MKSEA
City of Gosnells, July 2008


YULE BROOK PRECINCT (Precinct 3B)
The main feature of the Yule Brook Precinct is the brook which runs between Welshpool Road and Roe Highway. Yule Brook and its surrounds have environmental, drainage and Aboriginal cultural heritage significance and it is therefore not considered appropriate at this time to provide for any form of industrial development in the precinct. As such the status quo should remain (ie. the area being used for semi-rural living purposes) until or unless further investigations warrant a review of this position. Furthermore, given the drainage significance of Yule Brook, it is recommended a Local Planning Policy be prepared to guide all future development within the Brook's floodplain
CONCEPT PLAN ONLY
PRECINCT 3A
Proposed industrial development subject to drainage issues being addressed including determination of the amount and location of land required for drainage puposes. Furthermore, the planning for this precinct must appropriately address any interface and/or land compatability issues relating to adjoining or nearby land within both the City of Gosnells and the Shire of Kalamunda
WELSHPOOL
ROAD
ROAD
COLDWELL
ROAD
ROAD
ROAD
HIGHWAY
ROE
3A
3B
BF 387
2
BROOK
BOUNDARY
BRENTWOOD
ROAD
VICTORIA
BICKLEY
ROAD
KELVIN
1
BF 53
ROAD
TONKIN
HIGHWAY
WATTLE GROVE PRIMARY SCHOOL
PRECINCT 2
Victoria Road to Brook Road subject to further investigation
The type and extent of future development in this precinct is dependant upon a range of environmental, infrastructure, drainage and planning considerations.
The following matters need to be addressed:
• Requisite buffers to the Greater Brixton Street Wetlands (BF 387) and existing Conservation Category Wetlands (CCW's)
• Existing wetland classification, evaluation and mitigation
• Protection of significant flora and fauna including carrying out spring surveys
• Land uses permitted within wetland buffer zones
• District water management (Drainage)
ABORIGINAL HERITAGE
Given the potential existence of Aboriginal heritage within the MKSEA, Site Identification Surveys will be required to be undertaken on a precinct basis, prior to Council considering any proposed Outline Development Plan for such a precinct
ECO-INDUSTRY PRECINCTS
The proposed "Eco-Industry" areas have been identified due to the potential environmental significance of the land. It is anticipated that the precincts will accommodate benign industrial land uses, in a manner that will minimise negative environmental impacts on the area. Further detailed planning is required to address the following:
• Size/extent of existing wetlands (classification)
• Attributes/function of existing wetland (evaluation)
• Conservation/enhancement/management of existing wetland (mitigation)
• Size/extent of buffer to existing wetlands
• Specific land uses permitted
PRECINCT 1
Proposed industrial development - amendment to Metropolitan Region Scheme initiated.
TRANSITION PRECINCT
The transition precinct is located along Bickley Road opposite existing low density residential uses. The primary purpose of the transition precinct is to identify the area as requiring particular land use and design controls so as to minimise any potential conflict between different land uses (ie - industrial v residential). Matters requiring further investigation include:
• Extent (depth from Bickley Road) of transitional zone
• Land uses permitted in transitional zone
• Vehicular access to transitional zone
• Traffic management/upgrades to Bickley Road
• Landscape treatment to Bickley Road
• Where applicable, resolution of broader issues affecting Precinct 2
KELVIN ROAD PRECINCT
This area is considered strategically important due to Kelvin Road's role as an important transport corridor within the MKSEA. Guidelines are required to ensure a high standard of development occurs, creating a readily identifiable image for the MKSEA. Issues to be addressed as part of the guidelines include landscaping, vehicle access arrangements and built form standards
1 CONCEPT PLAN FEB 2007
2 CONCEPT PLAN NOVEMBER 2007 (2nd REITERATION)
3 CONCEPT PLAN JULY 2008 (3rd REITERATION)
LEGEND
BF 53 BUSH FOREVER SITES
ECO - INDUSTRY PRECINCT
TRANSITION PRECINCT
KELVIN ROAD PRECINCT
DRAINAGE ROUTE / DIRECTION
SUBJECT TO FURTHER INVESTIGATIONS
PRECINCT BOUNDARIES
MUNICIPAL BOUNDARY
MKSEA BOUNDARY
1 PRECINCT NUMBER
POSSIBLE STREET BLOCK LAYOUT
EXISTING CONTROLLED INTERSECTIONS
EXISTING ROUND-A-BOUT
EXISTING FREIGHT RAIL LINE
N
MADDINGTON KENWICK
Sustainable Communities Partnership
CITY OF GOSNELLS
2120 Albany Highway Gosnells 6110 WA
PO Box 662 Gosnells 6990 WA
Telephone 08 9391 3222
Facsimile 08 9398 2922
E-mail council@gosnells.wa.gov.au
GOVERNMENT OF WESTERN AUSTRALIA
MADDINGTON KENWICK STRATEGIC EMPLOYMENT AREA
CONCEPT PLAN JULY 2008
The City of Gosnells provides the information contained herein. The Council of the City of Gosnells shall not be liable for any loss or damages howsoever caused as a result of reliance upon information contained in this document.
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MKSEA SURFACE WATER AND GOUNDWATER MONITORING AND INVESTIGATION REPORT

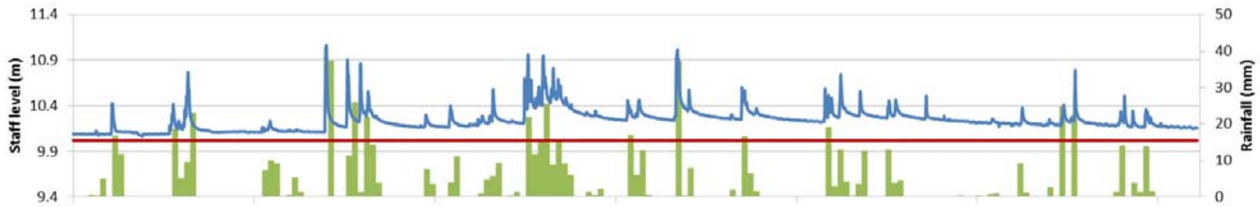
ADDENDUM

2011 MONITORING DATA

Prepared for
City of Gosnells
by
Endemic Pty Ltd

July 2012

Endemic



Contents

INTRODUCTION

This addendum presents additional data collected and compiled subsequent to May 2011. In addition, data from 2009 and 2010 contained in the main report has been reproduced and may differ somewhat owing to the collection of additional data relating to the sites. Where they differ, data in this addendum should be considered correct.

RAINFALL DATA

The following table presents monthly and annual rainfall totals for 2009 to 2011 recorded at Gosnells City (BoM site 009106), approximately 2.5km south of the MKSEA, compared with median values calculated since records began in 1961.

Table 1: Monthly and annual rainfall totals recorded at Gosnells 2009-2011

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2009	2	13	4	5	40	161	184	162	118	10	47	0	746
2010	4	0	53	34	93	61	141	50	25	21	8	11	500
2011	30	0	19	28	59	179	137	126	115	48	45	55	841
Median	2	8	11	33	97	168	170	128	76	42	22	7	825

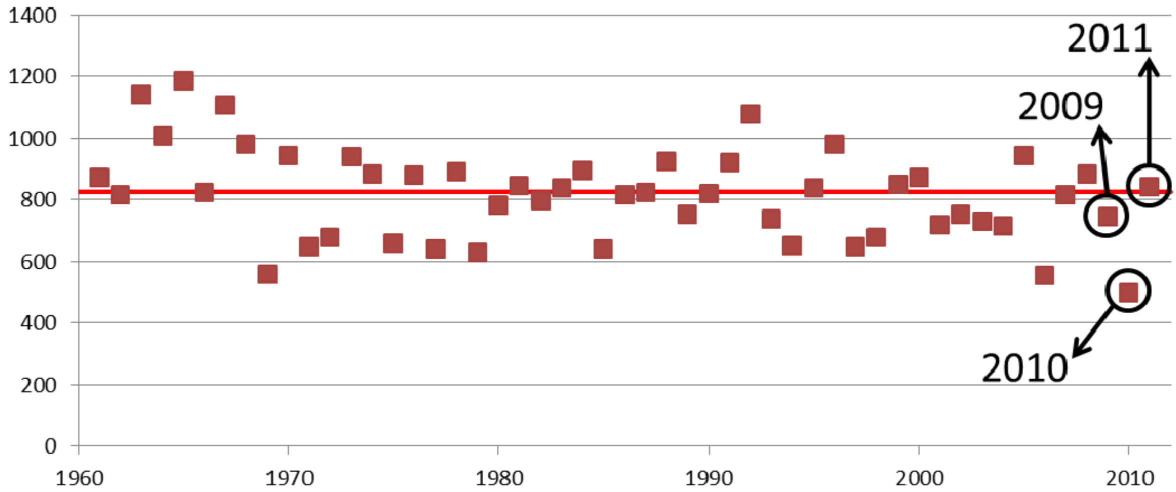


Figure 1: Annual rainfall totals 1961-2011 at Gosnells City, supplemented with data from Perth Airport (BoM site 009021) where there are gaps in the dataset. Median annual rainfall is represented by the red line.

Figure 1 shows that 2010 was the driest at Gosnells City since records began in 1961. 2009 and 2011 represent 32 and 58 percentile rainfall years respectively.

SITE SURVEY MEASUREMENTS

The following tables present survey data for all groundwater, wetland and surface water sites installed by Endemic as part of the MKSEA monitoring program. **Top of Case** measurements correspond to the top of the PVC bore case, whilst **Bottom of Hole** indicates the depth to which the bore was installed, depending on where refusal was reached due to the presence of limestone or heavy clay.

Table 2: Survey measurements for groundwater sites

	Easting	Northing	Top of Case m AHD	Ground Level m AHD	Bottom of Hole m AHD
GW1	403742	6458396	13.519	12.840	10.619
GW2	404354	6457624	14.094	13.414	11.444
GW3	403634	6456299	9.647	8.974	7.327
GW4	404395	6456985	13.279	12.534	11.729
GW5	405055	6457747	19.410	18.836	17.660
GW6	404664	6455861	16.703	16.028	10.883
GW7	405060	6456259	17.539	16.966	13.889
GW8	405590	6456777	24.614	23.999	20.484
GW9	405746	6455981	22.445	21.680	19.545
GW11	403216	6457827	12.574	12.116	9.074
GW12	403440	6456803	9.392	8.902	6.572

Table 3: Survey measurements for wetland sites

	Easting	Northing	Top of Case m AHD	Ground Level m AHD	Bottom of hole m AHD
Wet2	403668	6456525	10.550	9.111	8.900
Wet3	405400	6455795	17.309	16.644	15.809
Wet4	404836	6457484	16.704	15.482	14.944
Wet5	404731	6457616	17.306	15.948	15.672
Wet6	404545	6456780	14.122	12.493	12.219
Wet7	404888	6457234	16.665	15.062	14.955
Wet8	405952	6455901	24.096	23.567	21.806

Table 4: Survey measurements for surface water sites

	Easting	Northing	Top of Case m AHD	Cease to Flow m AHD	CTF on staff m	Survey point m AHD	Top of culvert m AHD
M1	404670	6458369	16.006	14.793	10.020		
M2	403002	6456871	6.827	5.312	9.960		
SW1	403926	6456059	10.383	9.009	10.035	9.826	
SW2	404915	6456120	13.468	11.928	10.025	12.786	
SW3	403768	6457101	10.092	8.574	10.020	9.306	
SW5	404337	6457016	13.691	11.912	10.024	12.912	12.608
SW6	405240	6457943	15.775	14.780	10.040	15.225	15.857
SW7	405037	6455598	13.685	12.049	10.007	12.998	

DATA

The following pages present water level data collected from each of the groundwater, wetland and surface water sites for 2009, 2010 and 2011, the only exceptions being 2011 level data for Wet5 (logger stolen), Wet6 (logger failure) and Wet8 (redeployed, as showing no water table).

Data is presented as follows:

Section 1- *Groundwater hydrographs*

Section 2- *Wetland hydrographs*

Section 3- *Surface water hydrographs*

Over the period of surface water monitoring, opportunistic stream gaugings were undertaken to collect information on the relationship between stage height and discharge in order to develop a rating curve for each site. The number of measurements for each site varied according to the occurrence of flow.

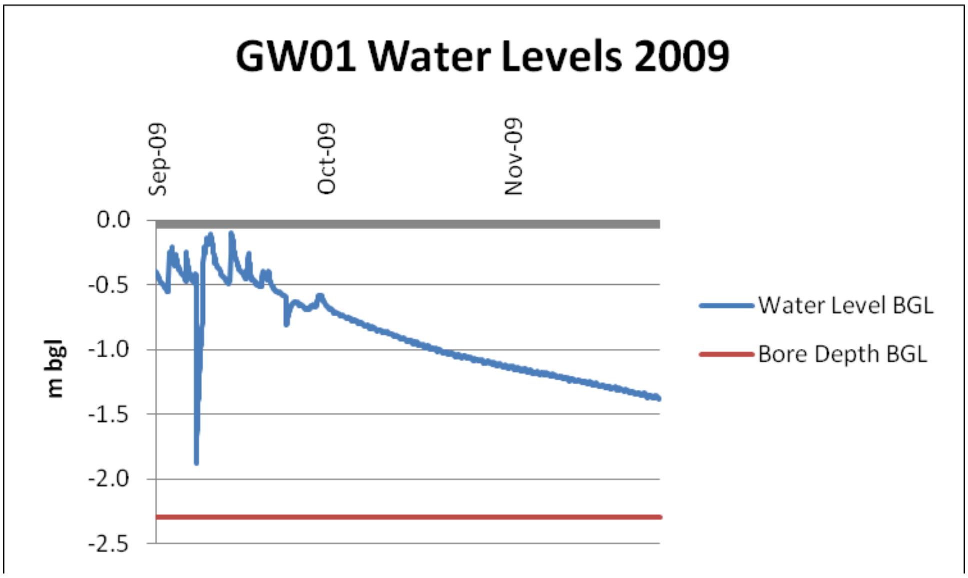
At sites M1 and M2, where it was not possible to manually measure discharge under high flow events due to safety concerns, ISCO 4150 area-velocity (AV) devices were deployed short-term over high flow periods in order to collect instantaneous stage and velocity measurements. Velocity measurements were converted to discharge using cross-section survey data.

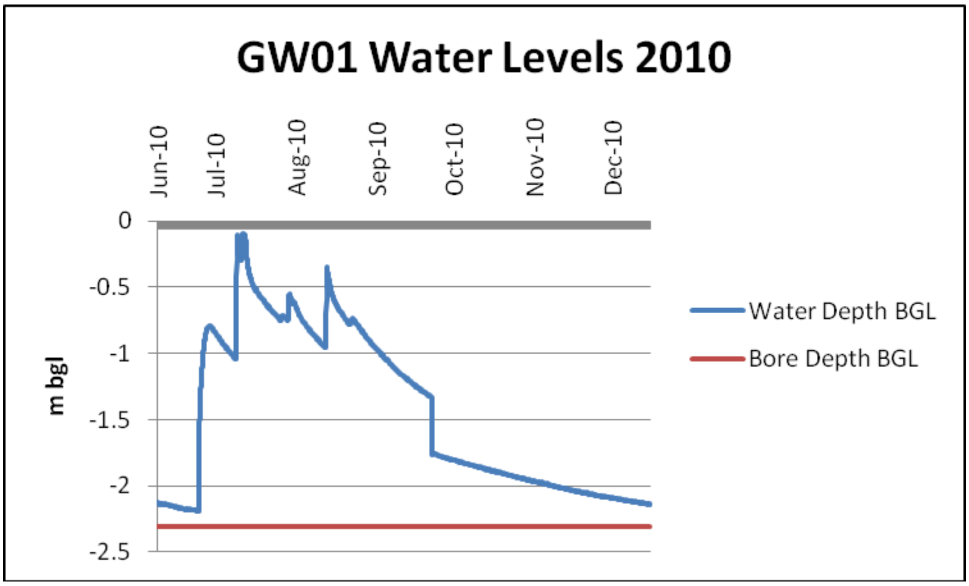
The use of these gaugings in order to develop rating curves is discussed further in **Section 4** of this Addendum- *Rating Curve Derivation*. Ratings have been used to calculate total monthly flows, presented in **Section 5**.

Section 6 presents photographs of surface water monitoring sites and control structures.

Section 1
Groundwater hydrographs

GW01
GW02
GW03
GW04
GW05
GW06
GW07
GW08
GW09
GW11
GW12





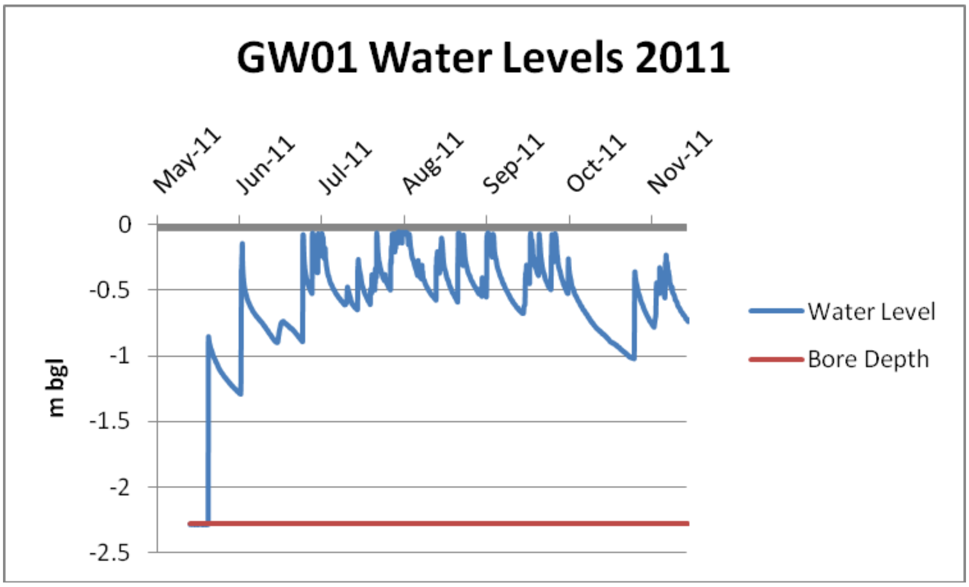
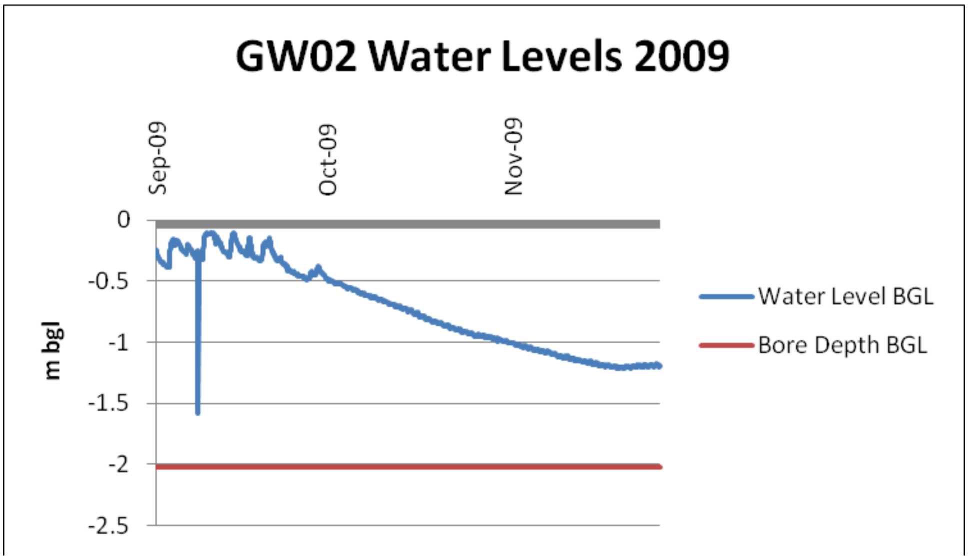
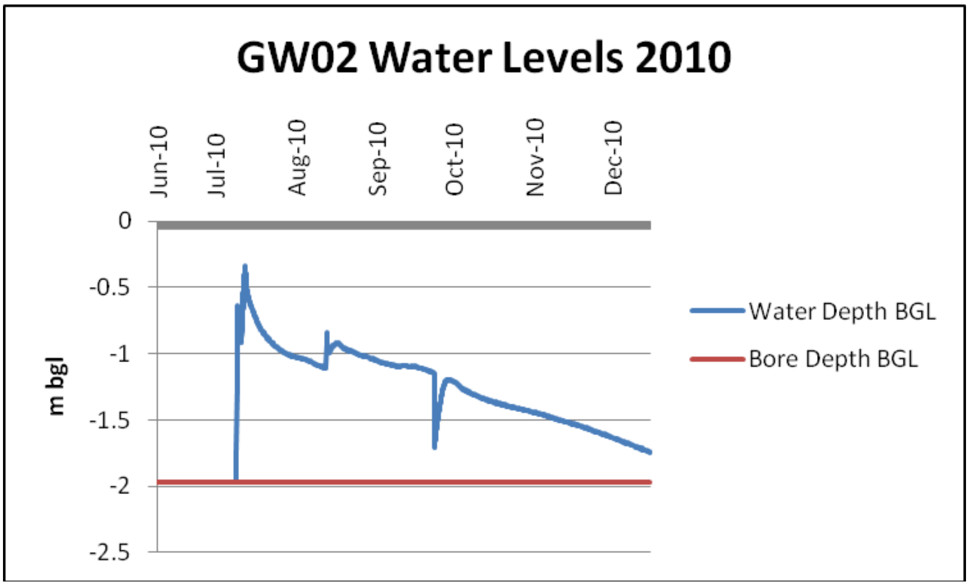


Figure 2: Groundwater hydrographs for GW01





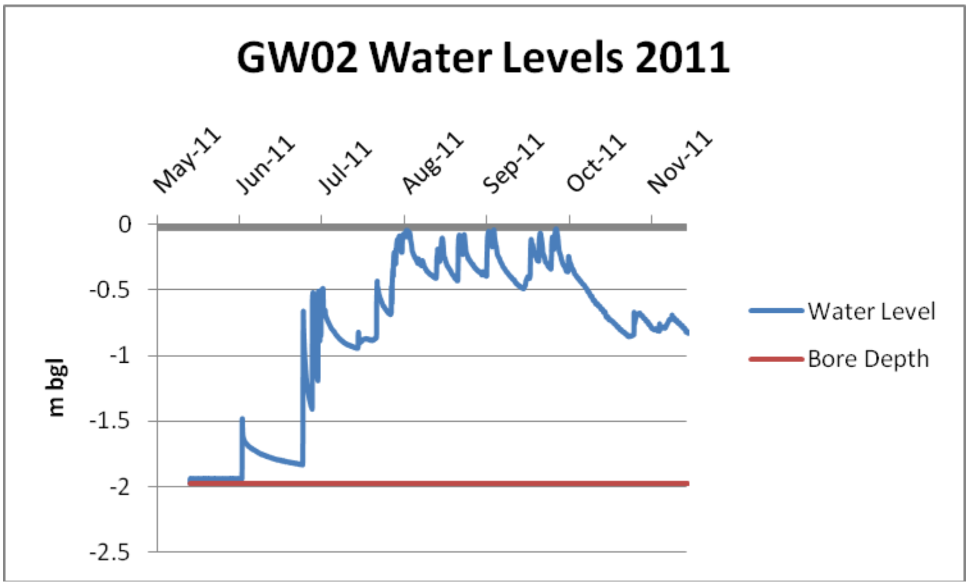
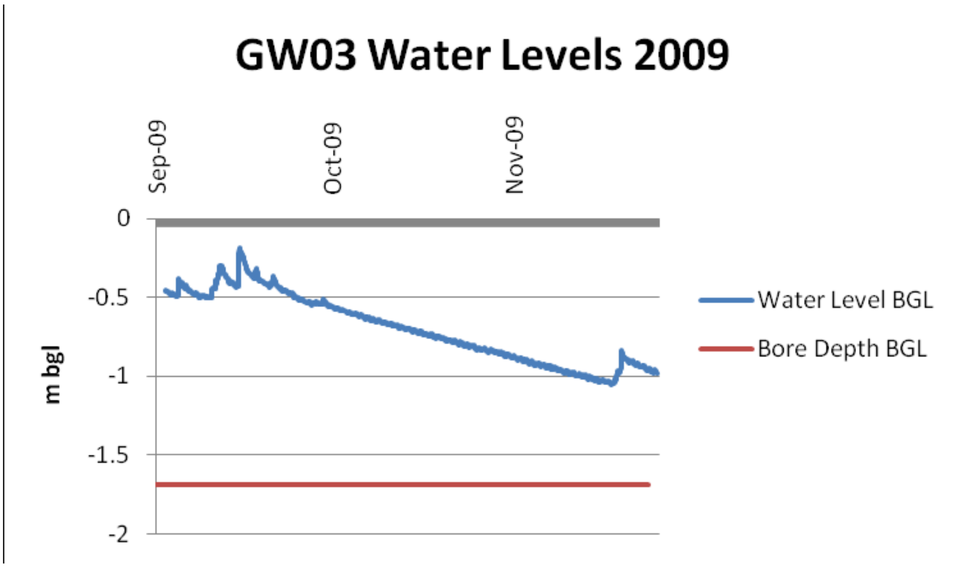
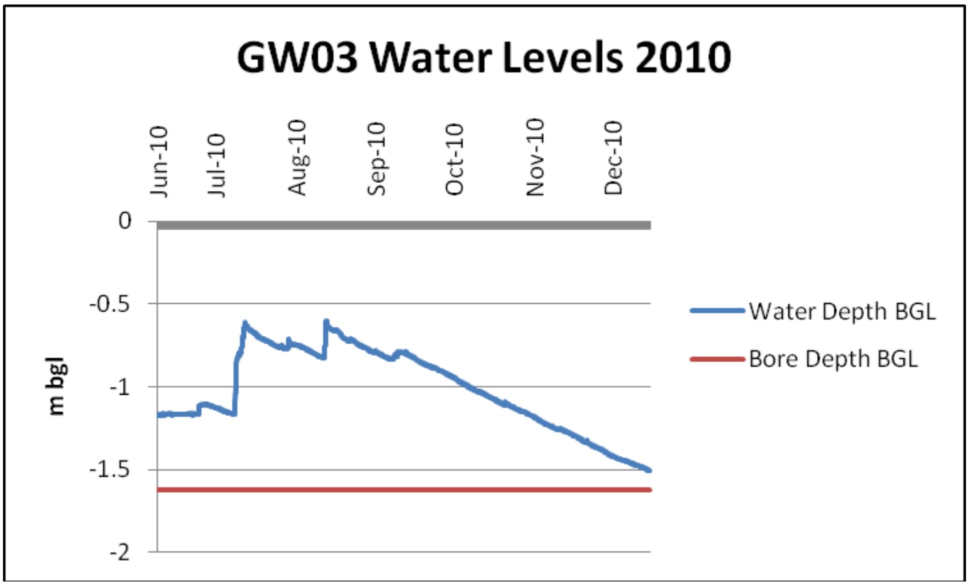


Figure 3: Groundwater hydrographs for GW02





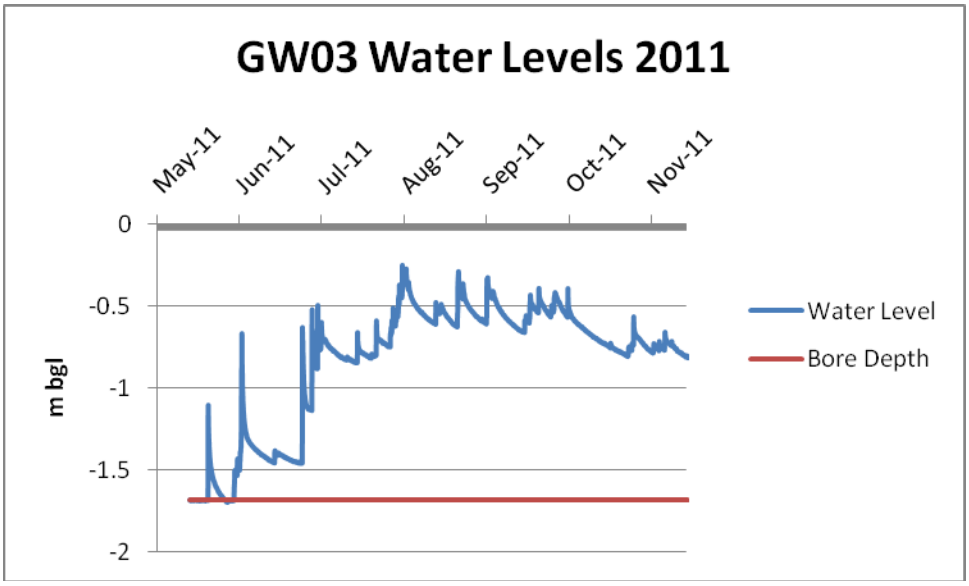
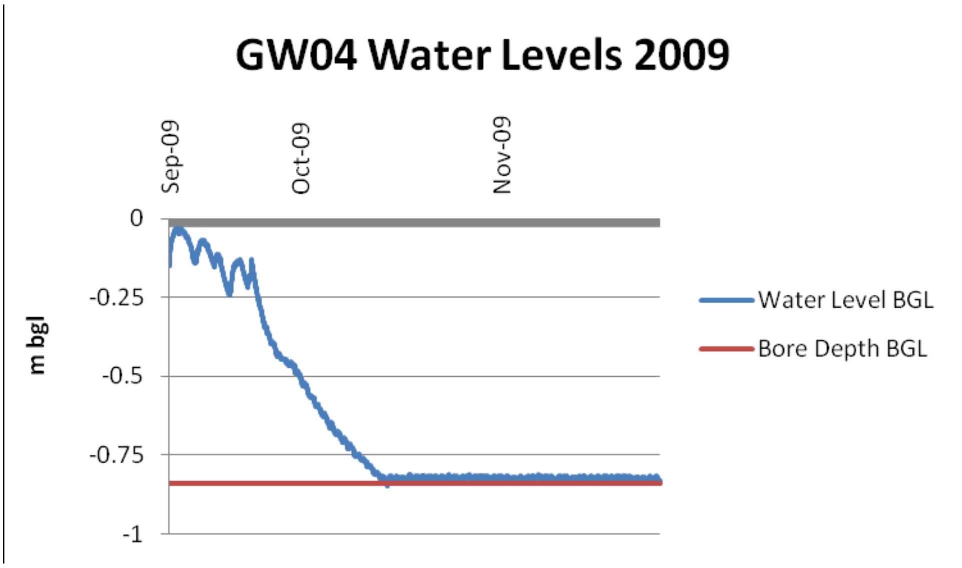
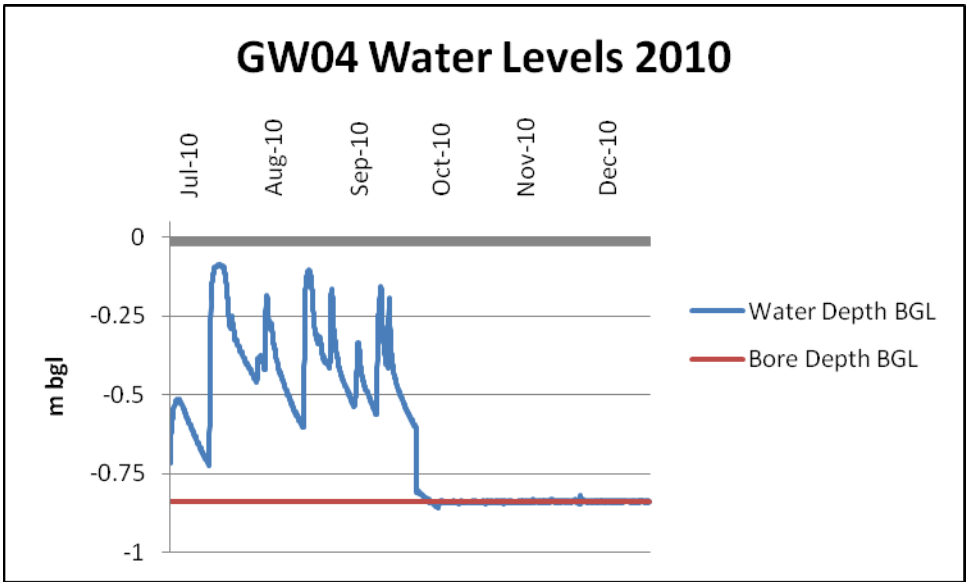


Figure 4: Groundwater hydrographs for GW03





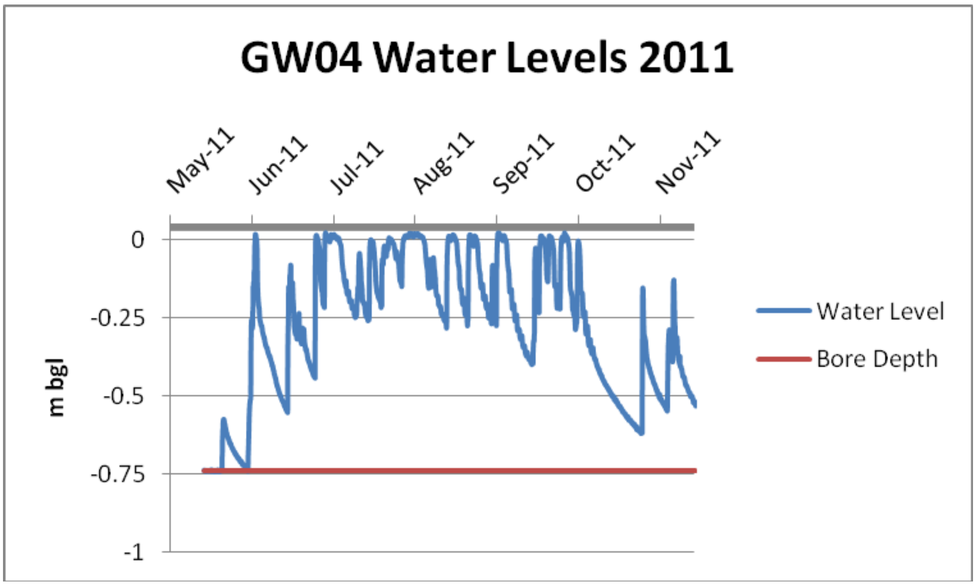
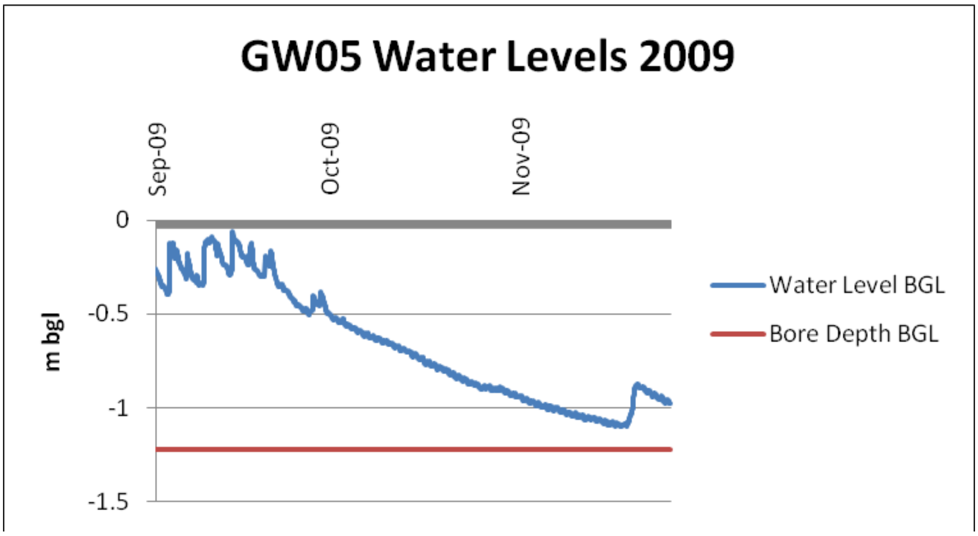
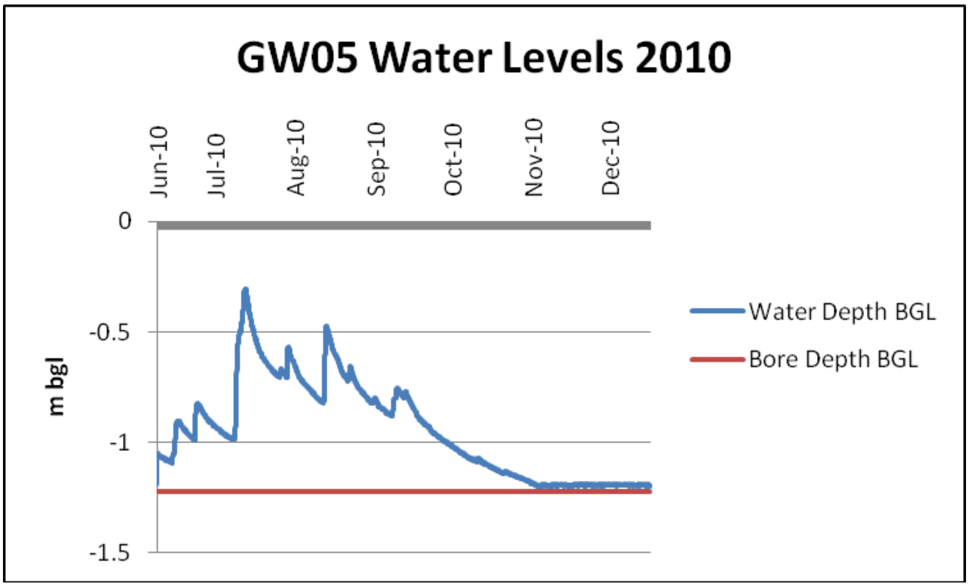


Figure 5: Groundwater hydrographs for GW04





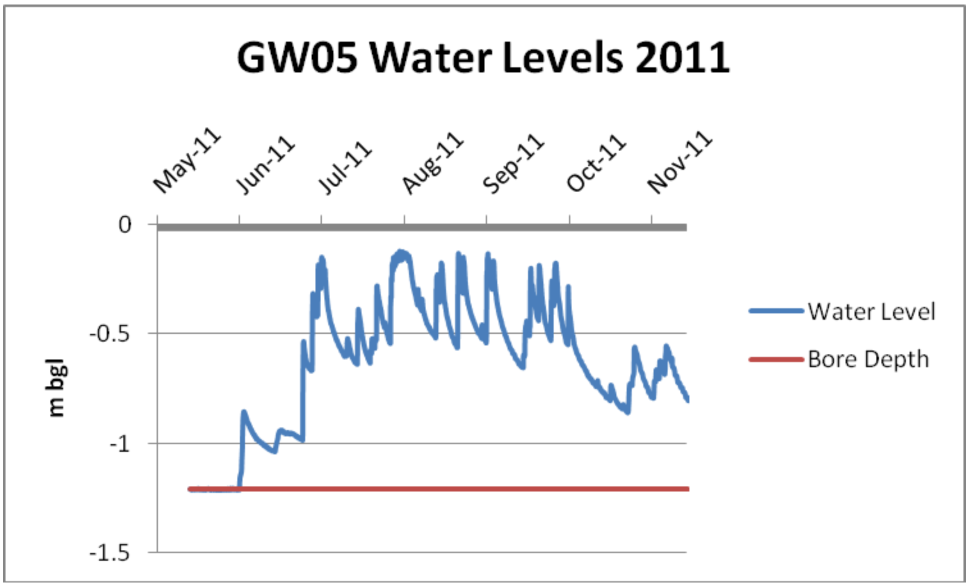
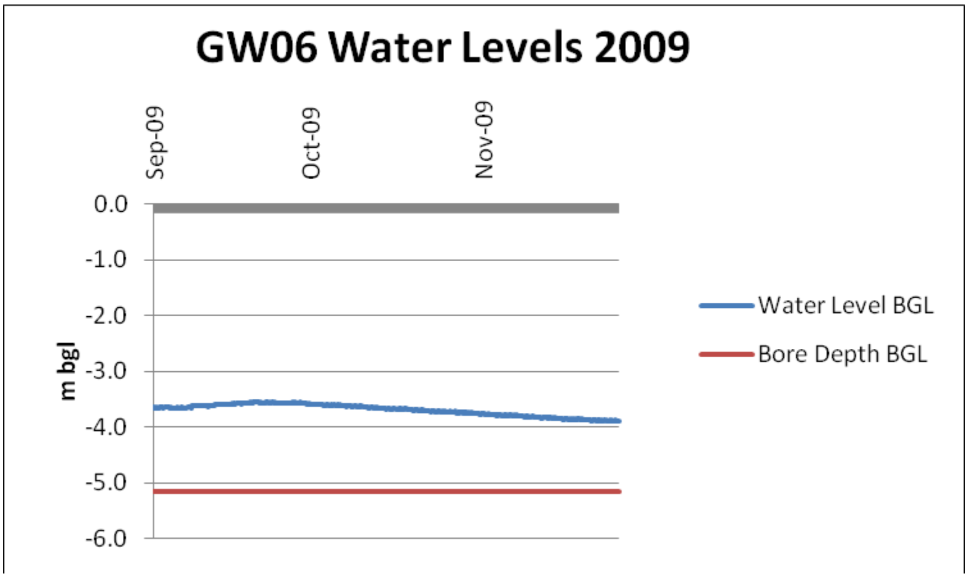
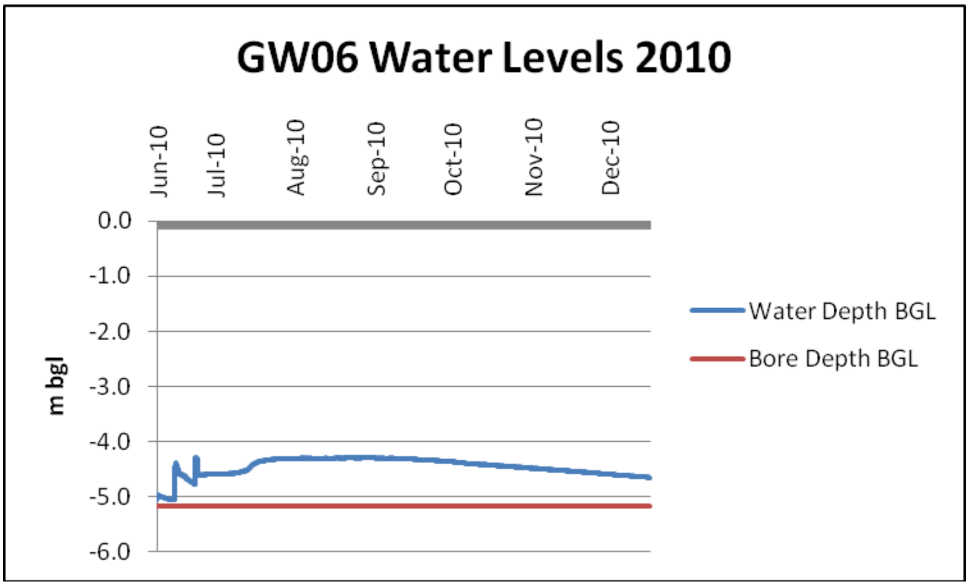


Figure 6: Groundwater hydrographs for GW05





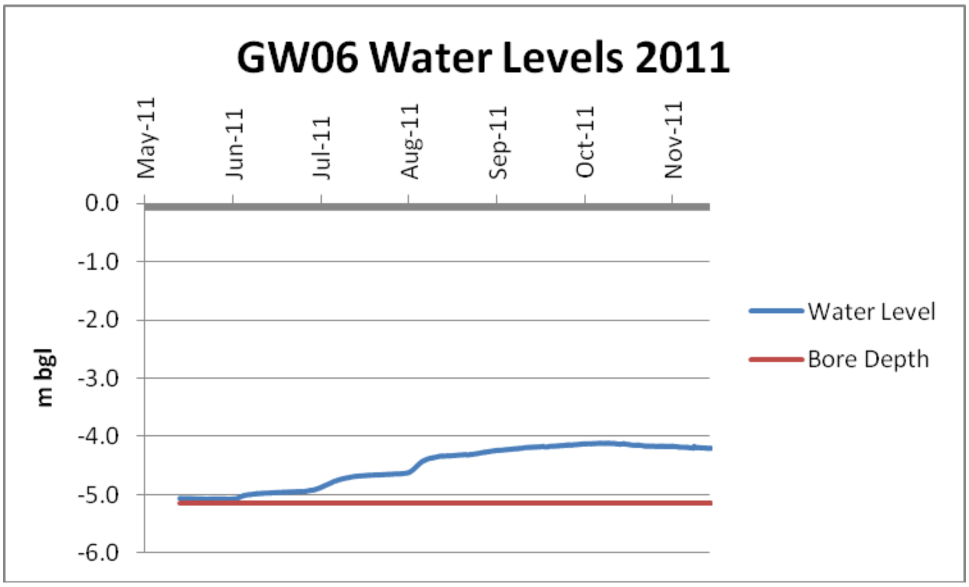
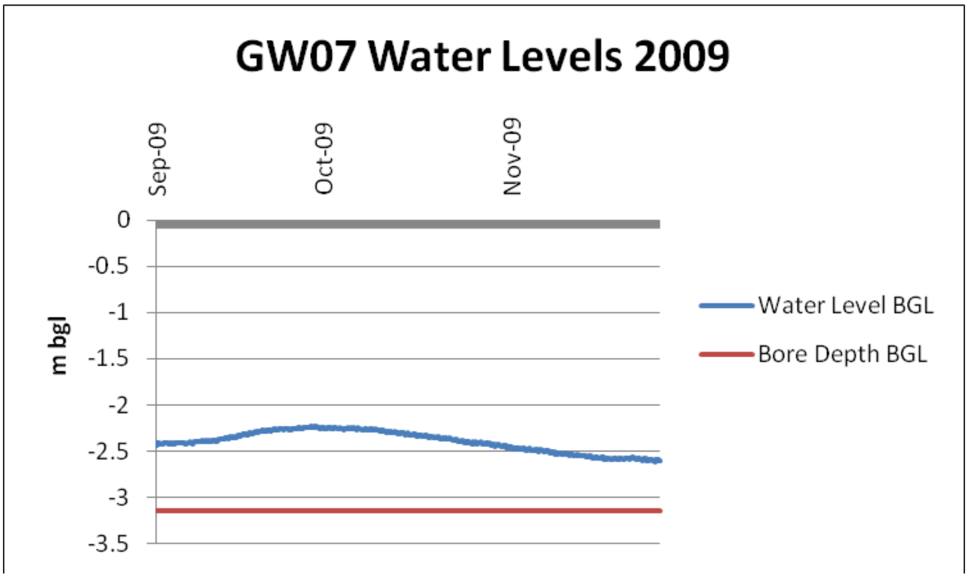
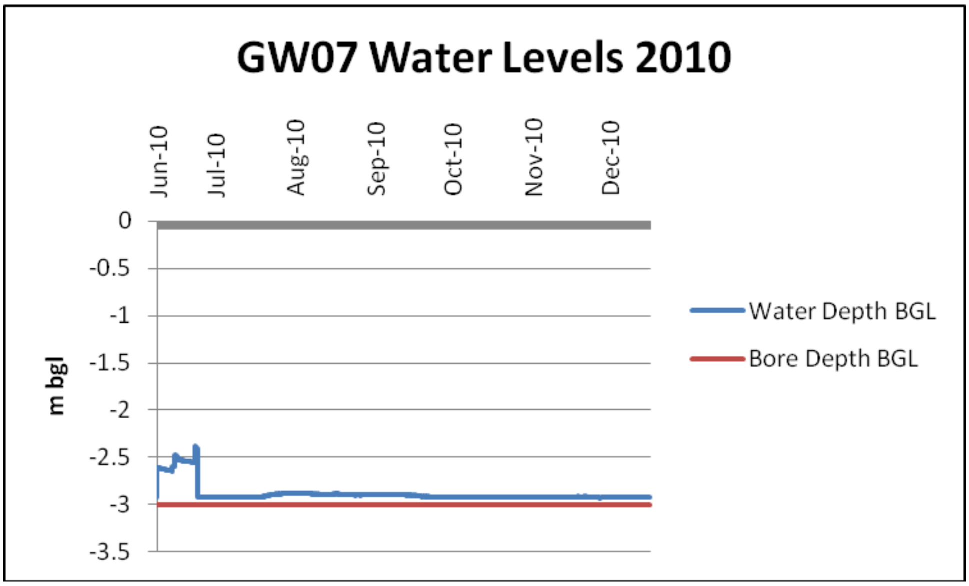


Figure 7: Groundwater hydrographs for GW06





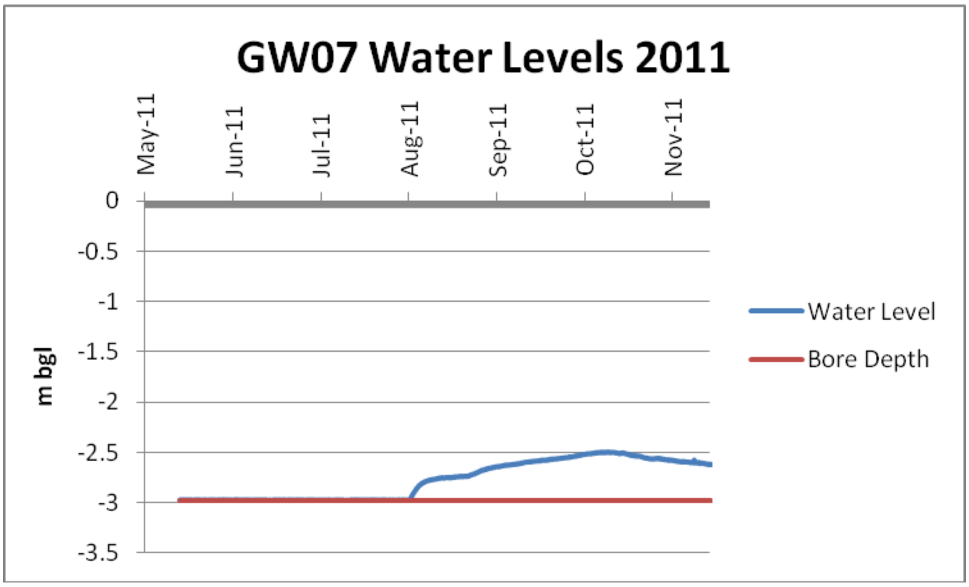
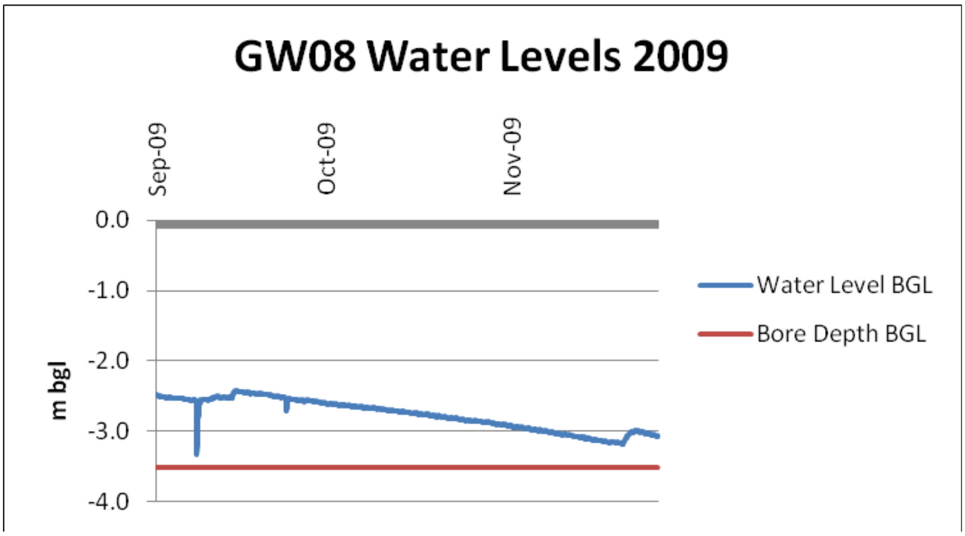
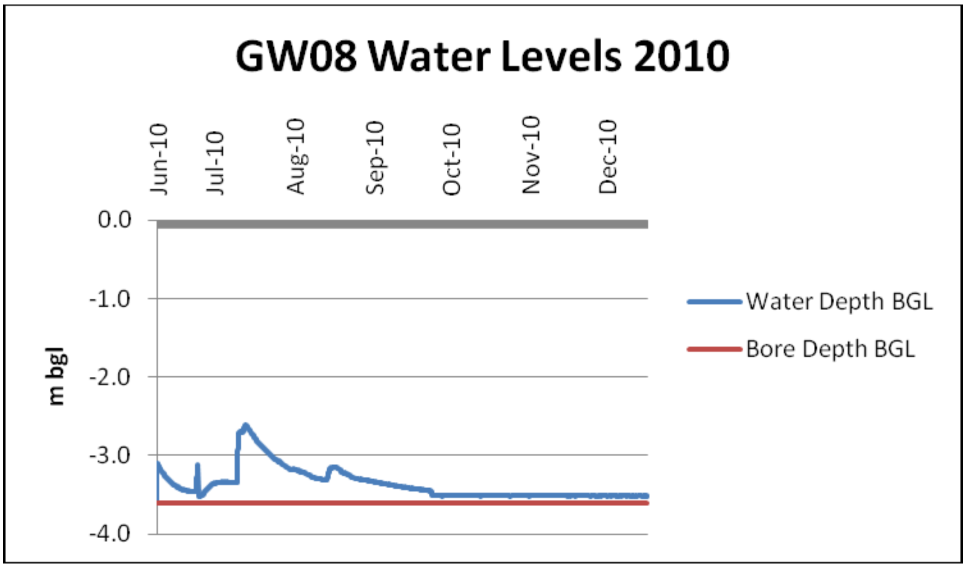


Figure 8: Groundwater hydrographs for GW07





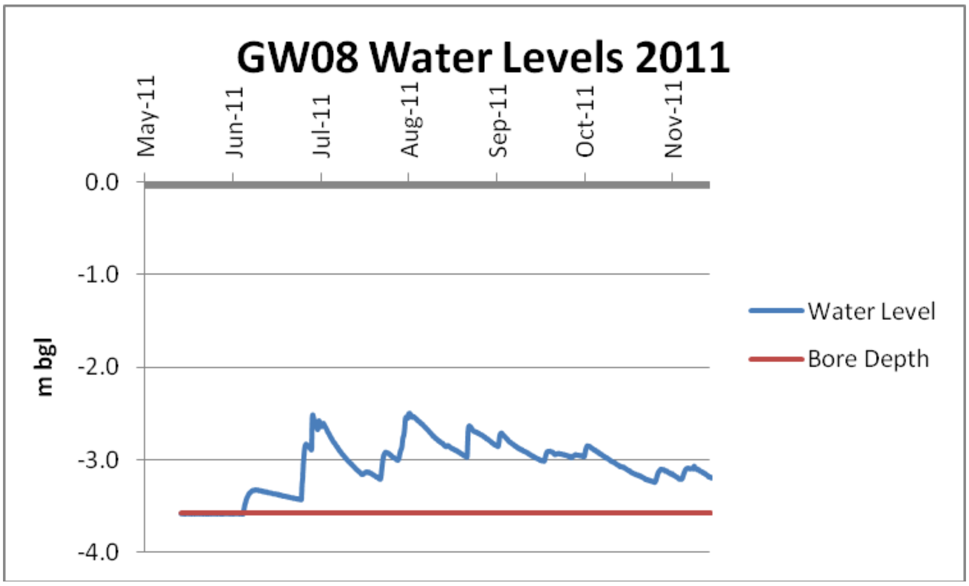
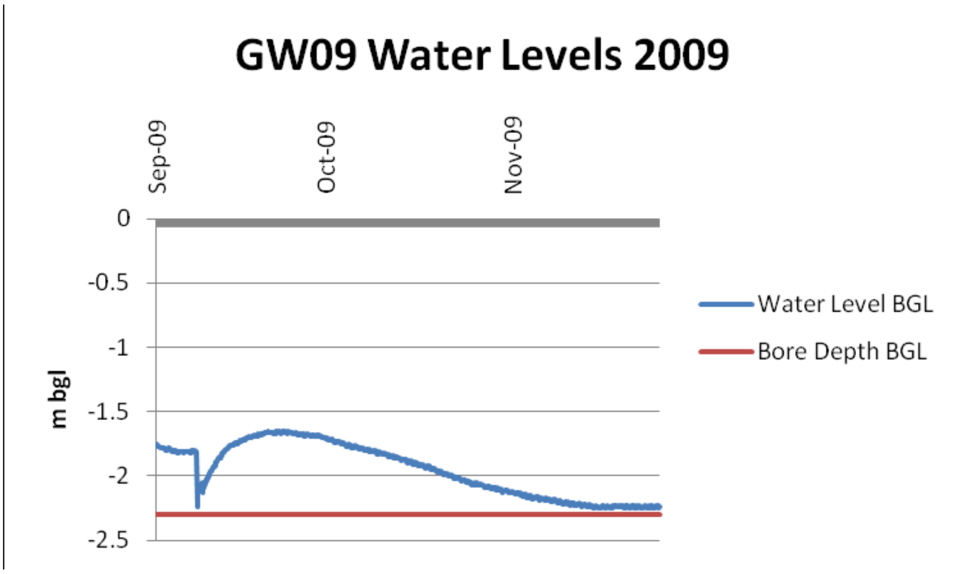
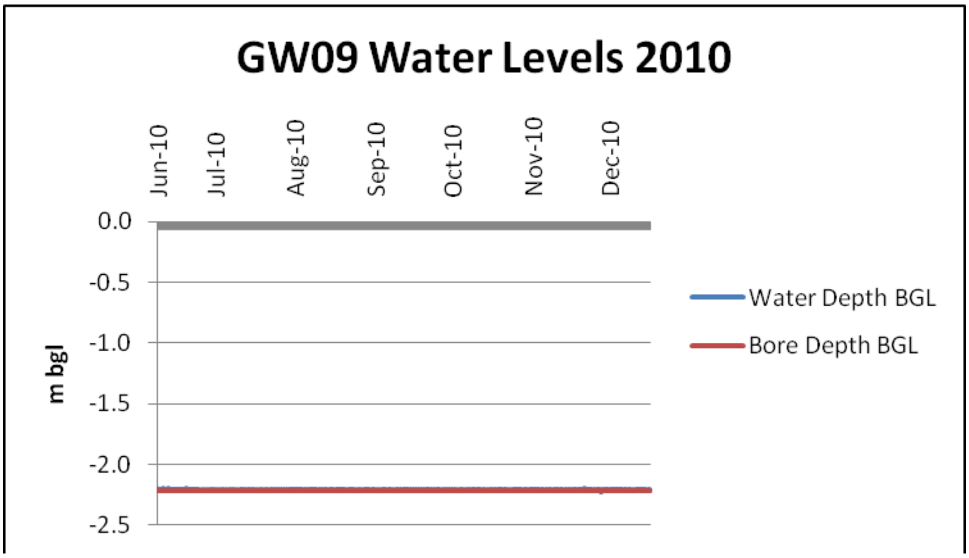


Figure 9: Groundwater hydrographs for GW08





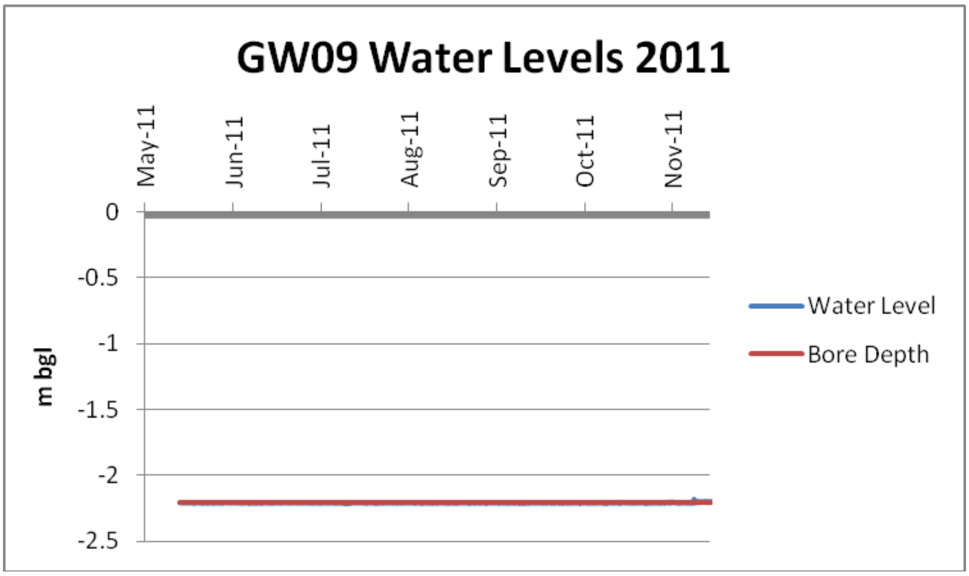
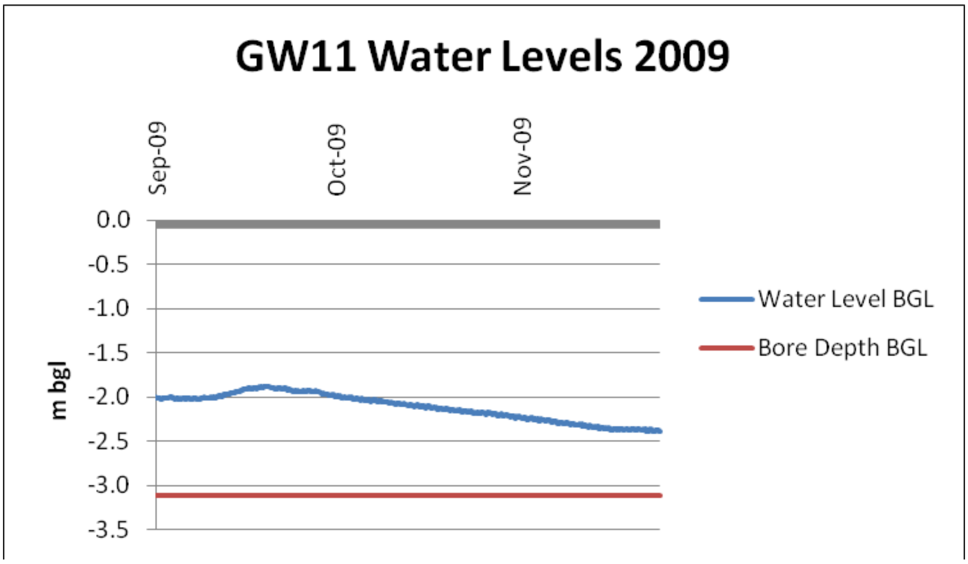
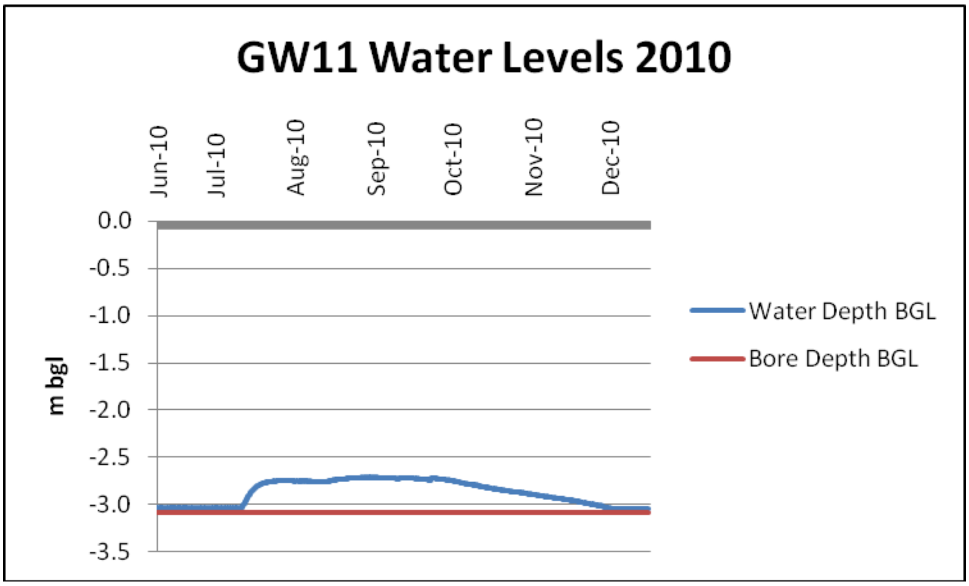


Figure 10: Groundwater hydrographs for GW09





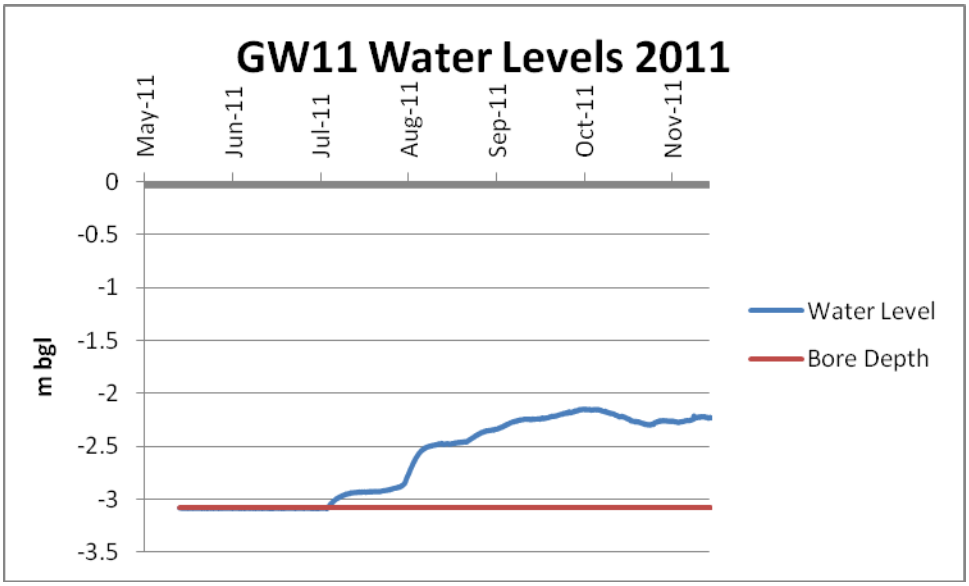
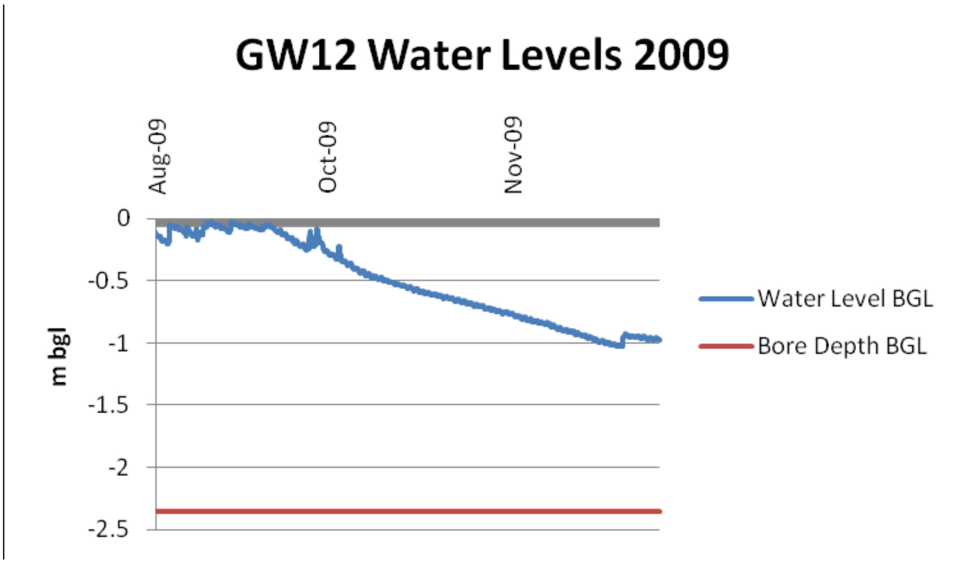
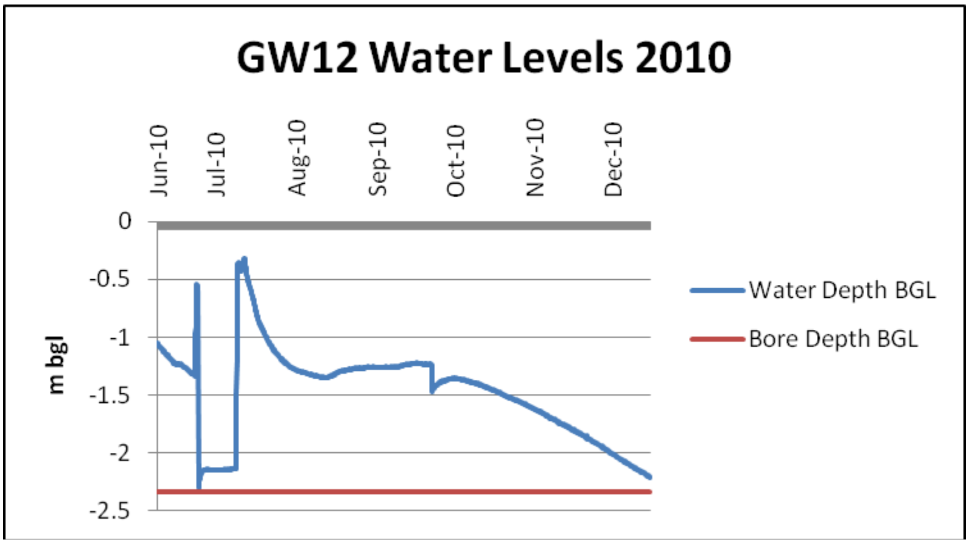


Figure 11: Groundwater hydrographs for GW11





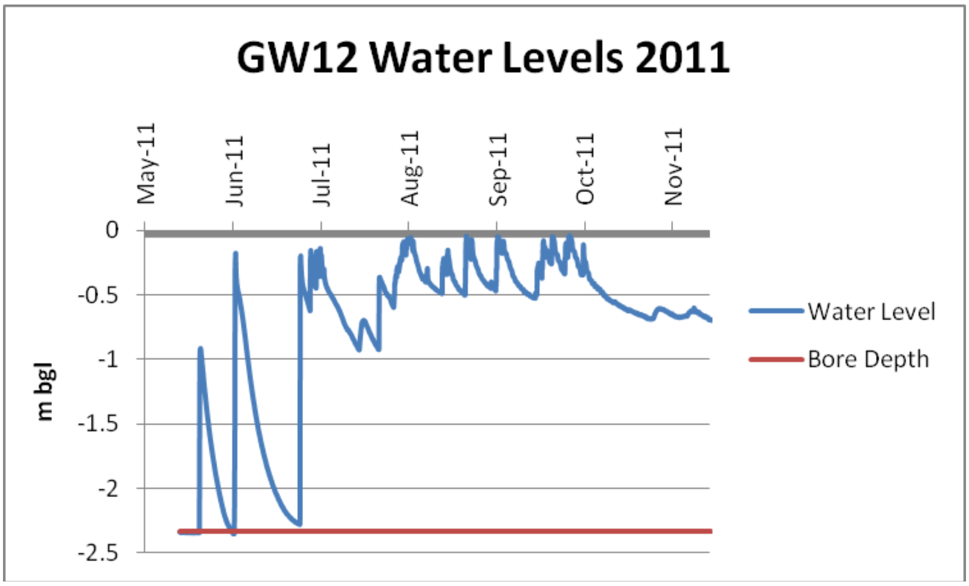
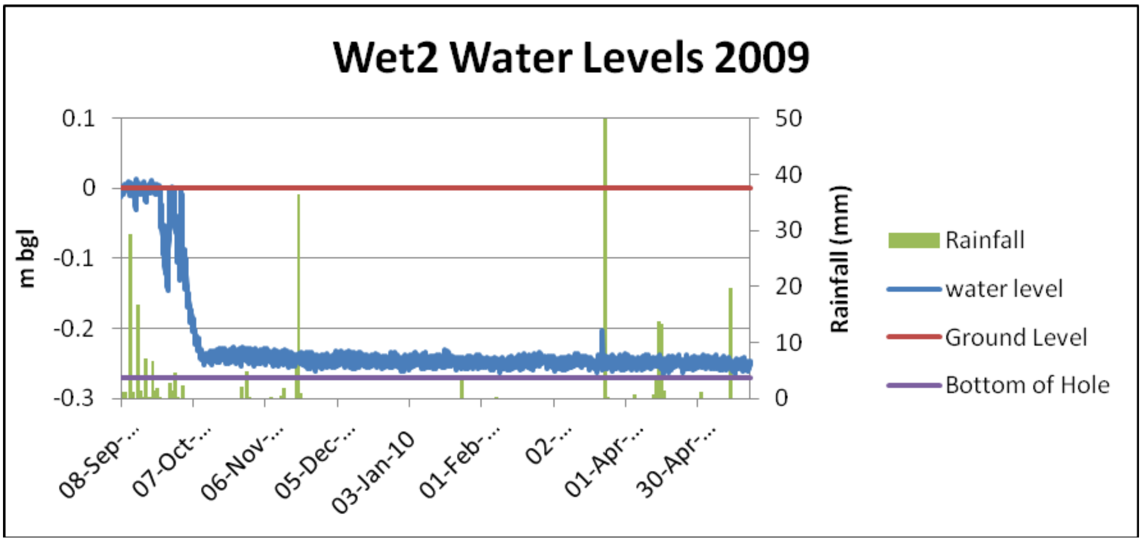
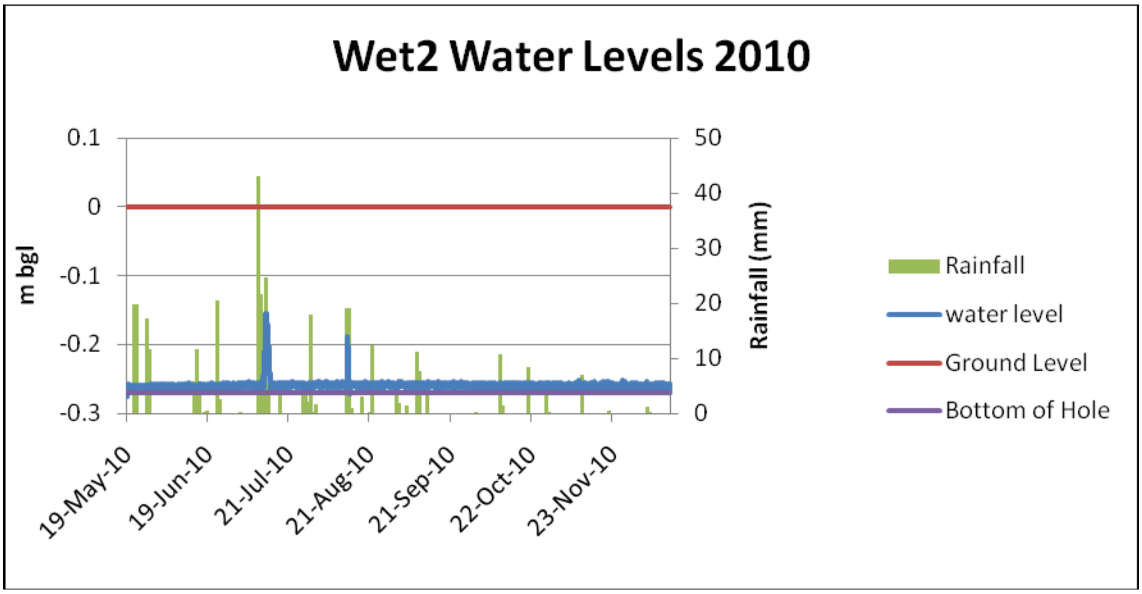


Figure 12: Groundwater hydrographs for GW12

Section 2
Wetland hydrographs

Wet2
Wet3
Wet4
Wet5
Wet6
Wet7
Wet8





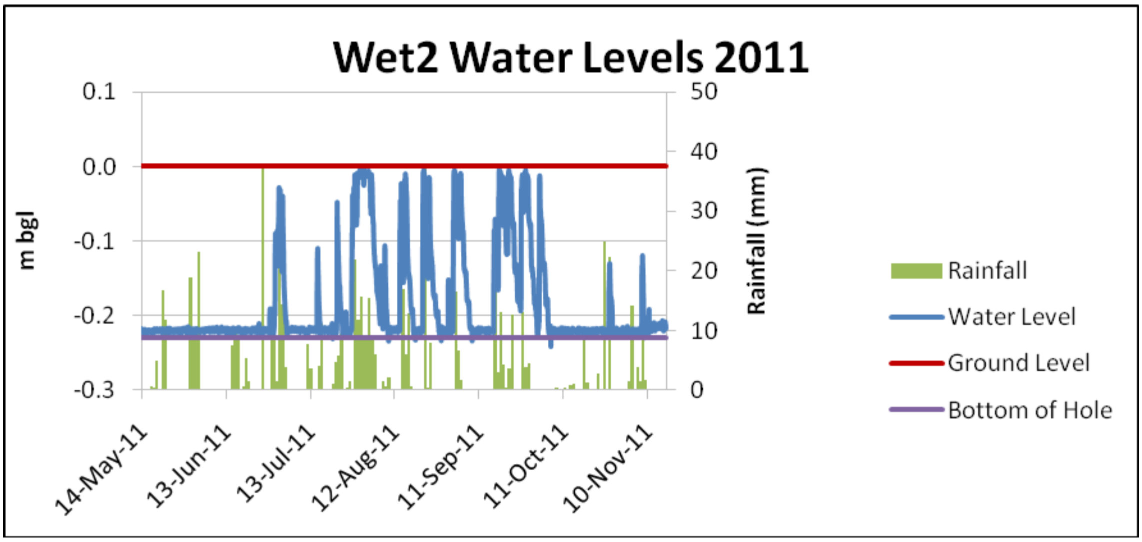
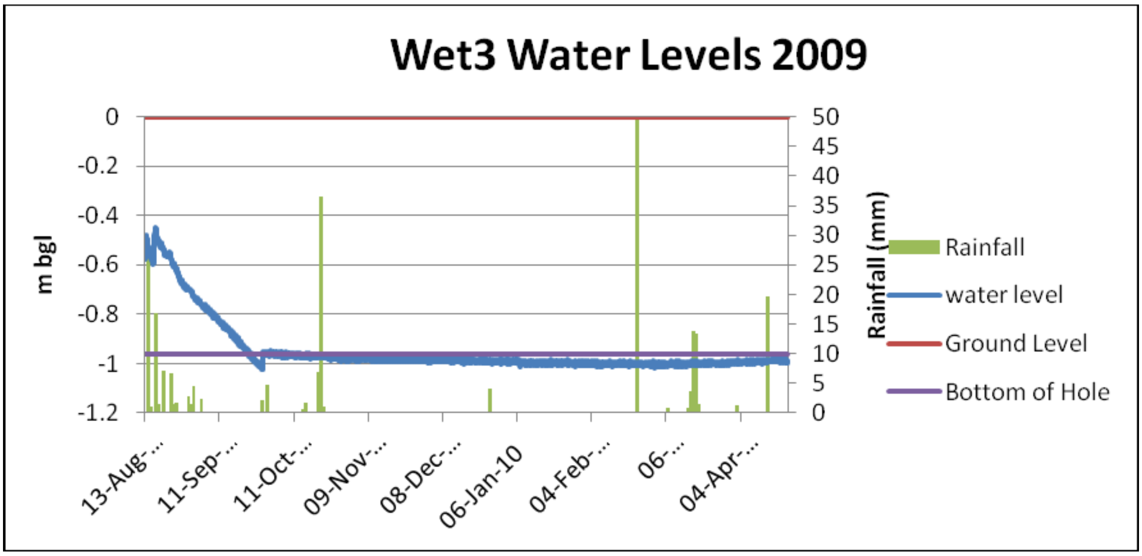
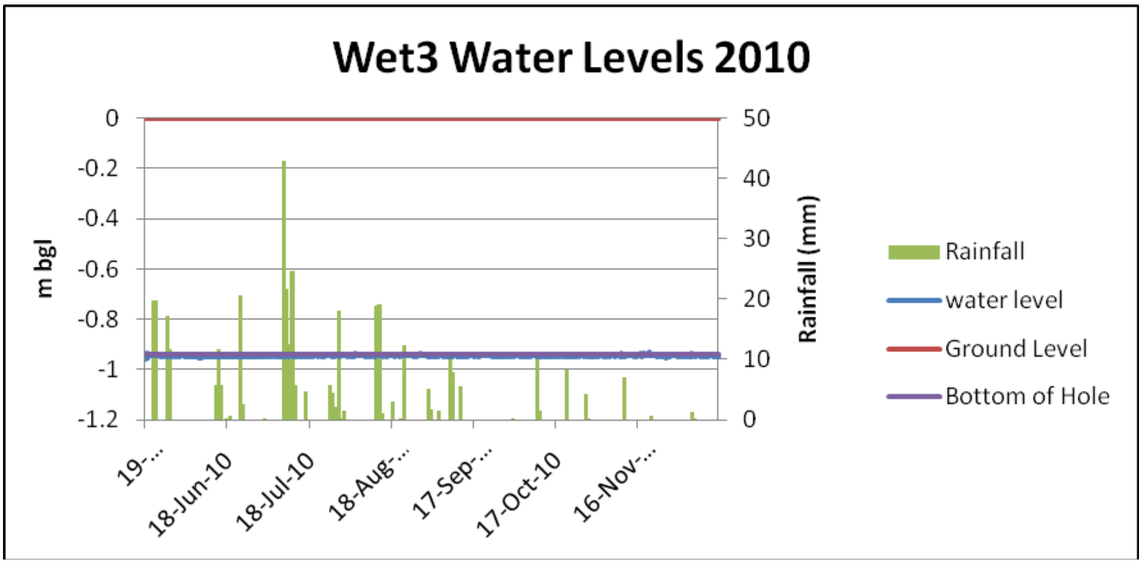


Figure 13: Wetland hydrographs for Wet2





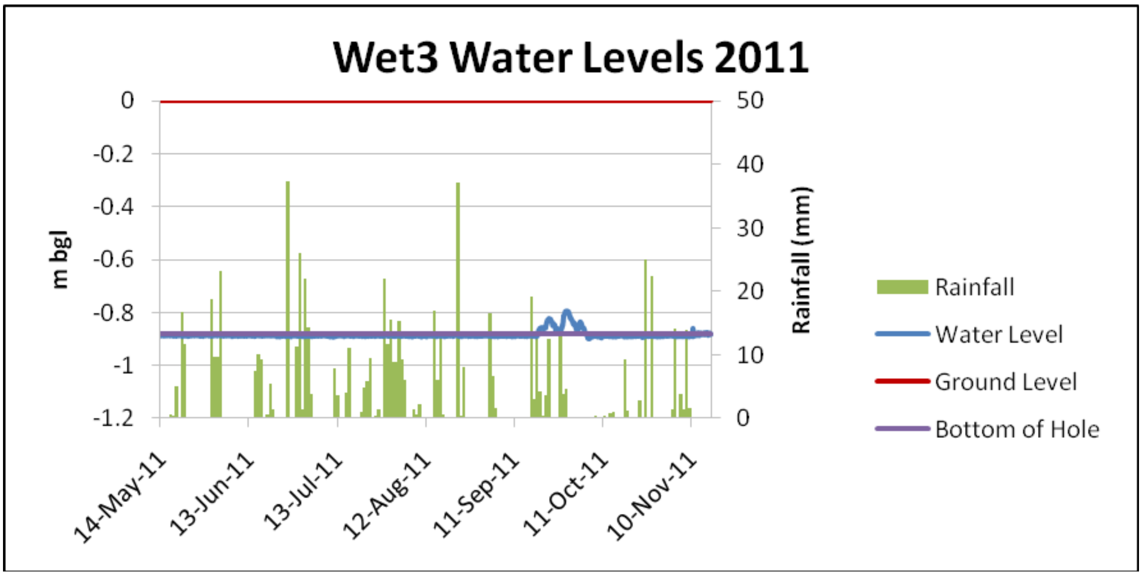


Figure 14: Wetland hydrographs for Wet3

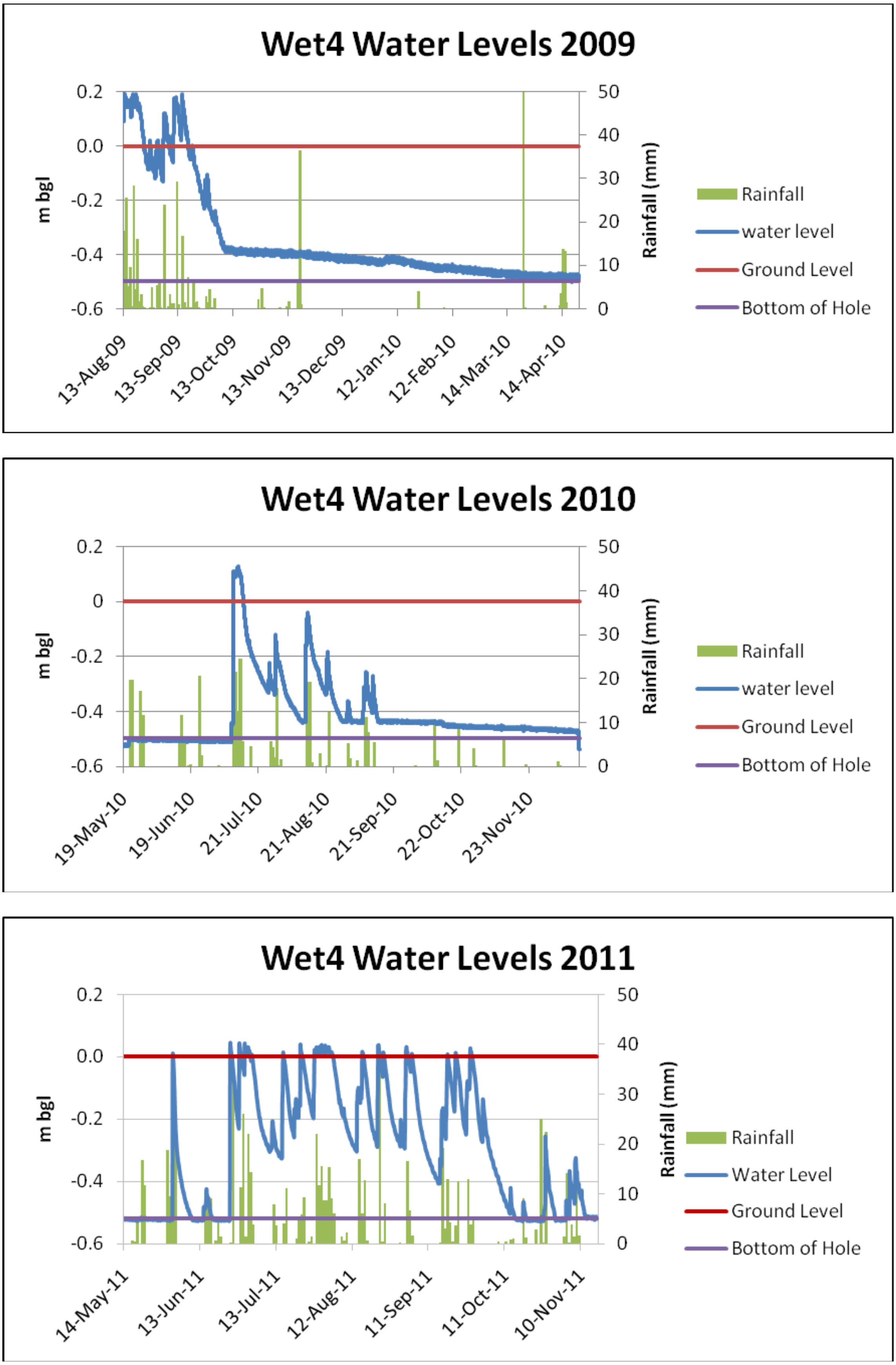


Figure 15: Wetland hydrographs for Wet4

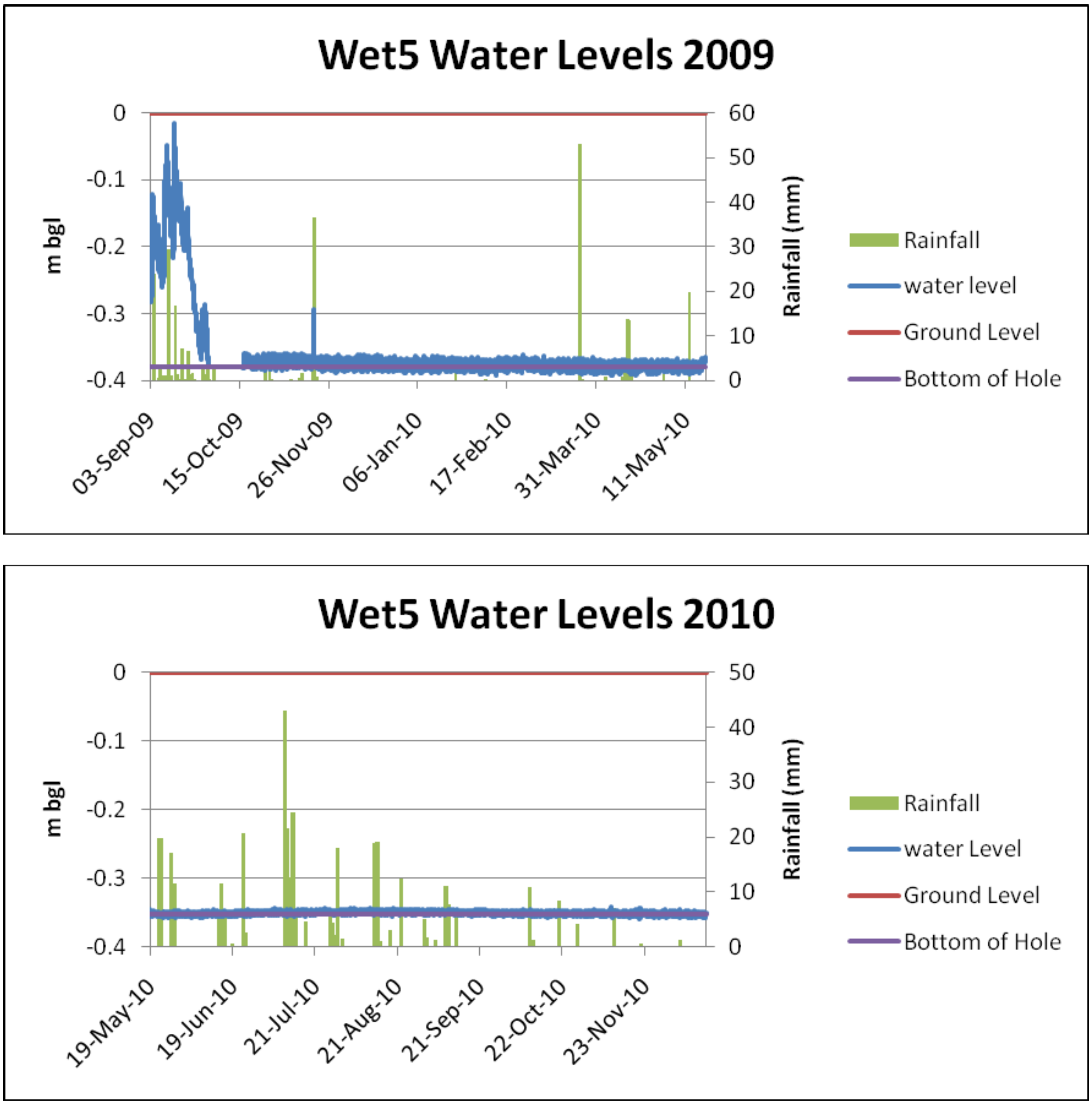
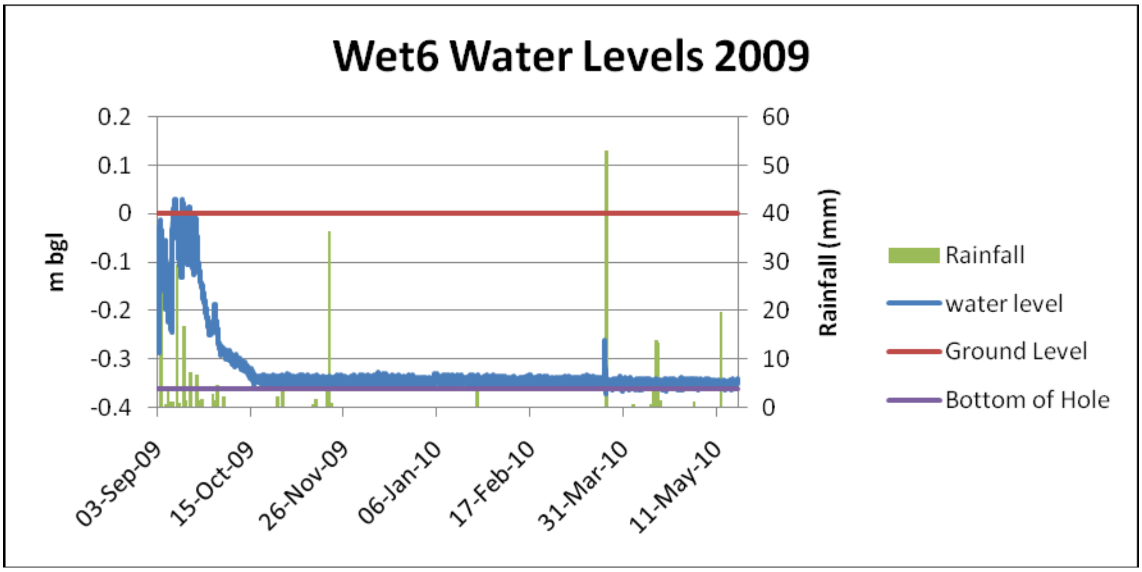


Figure 16: Wetland hydrographs for Wet5



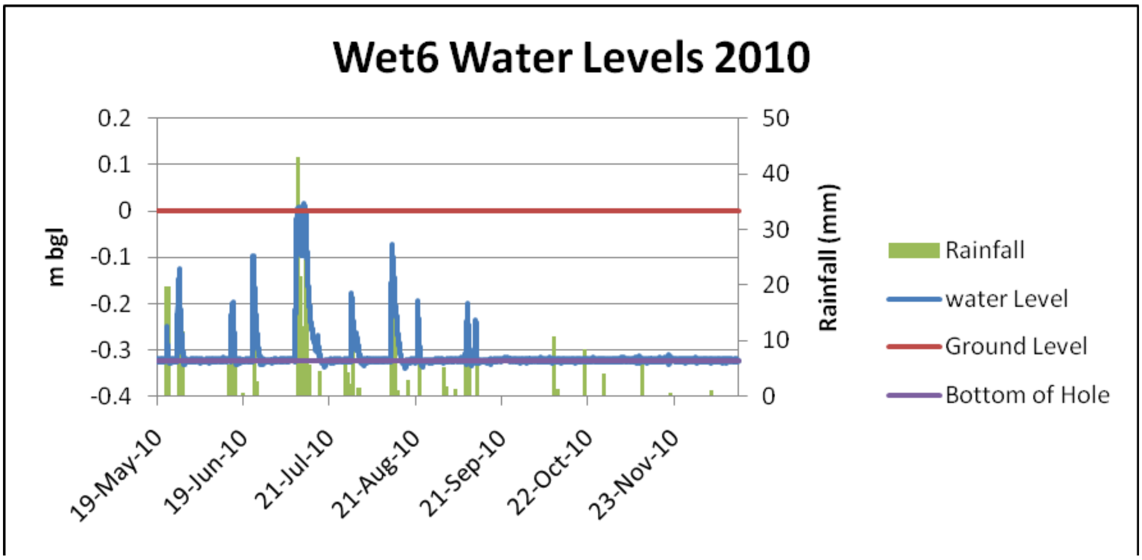


Figure 17: Wetland hydrographs for Wet6

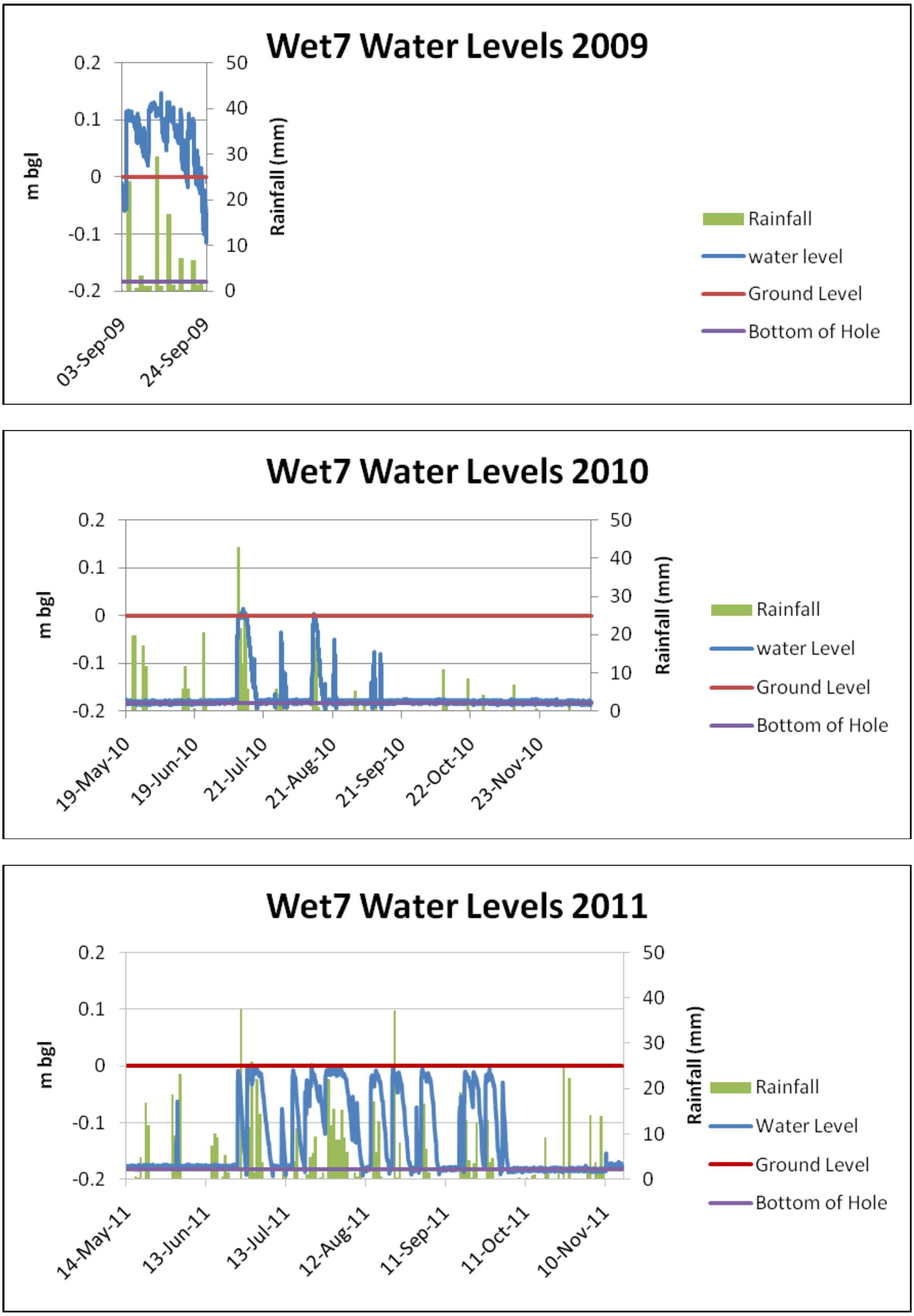
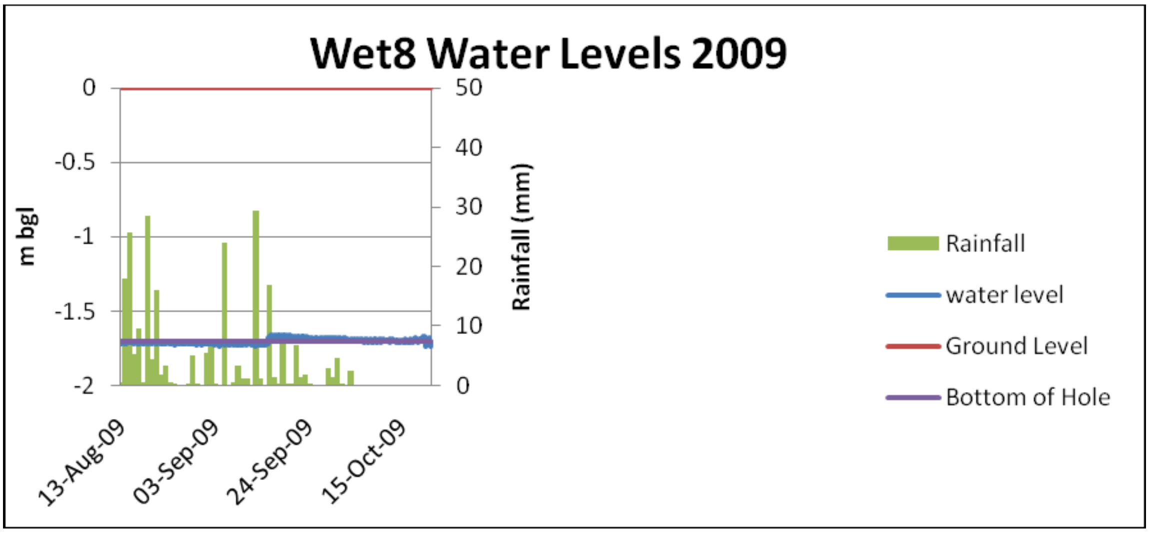


Figure 18: Wetland hydrographs for Wet7



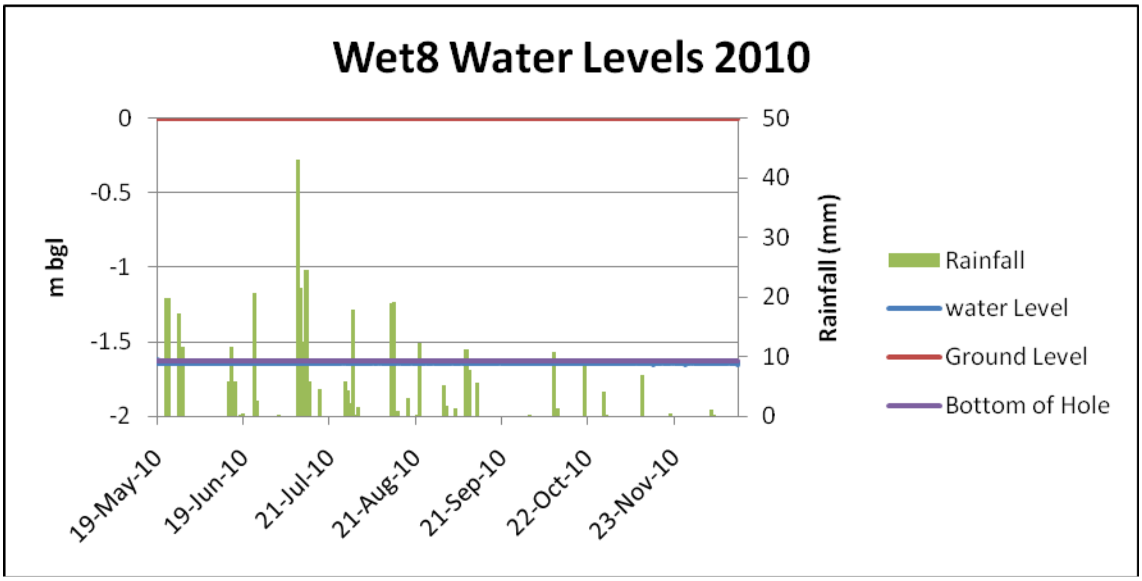
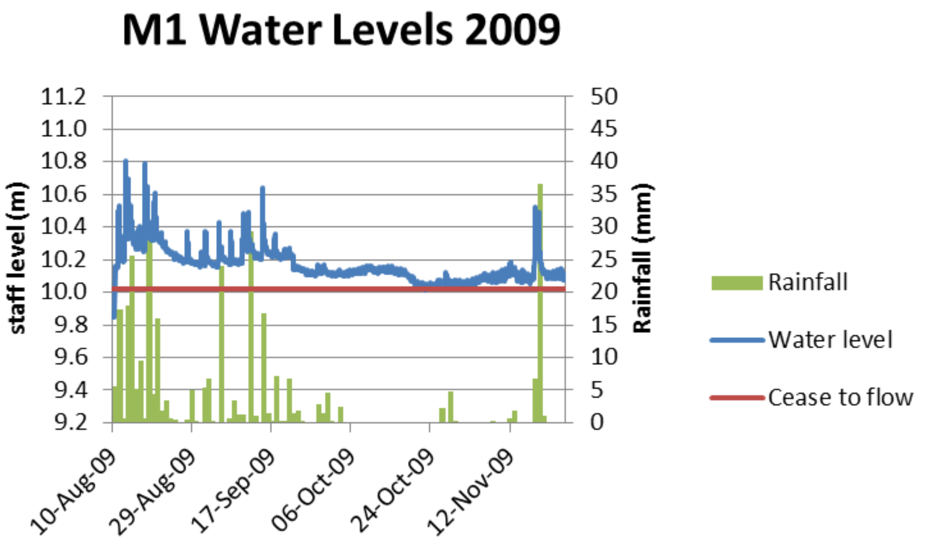


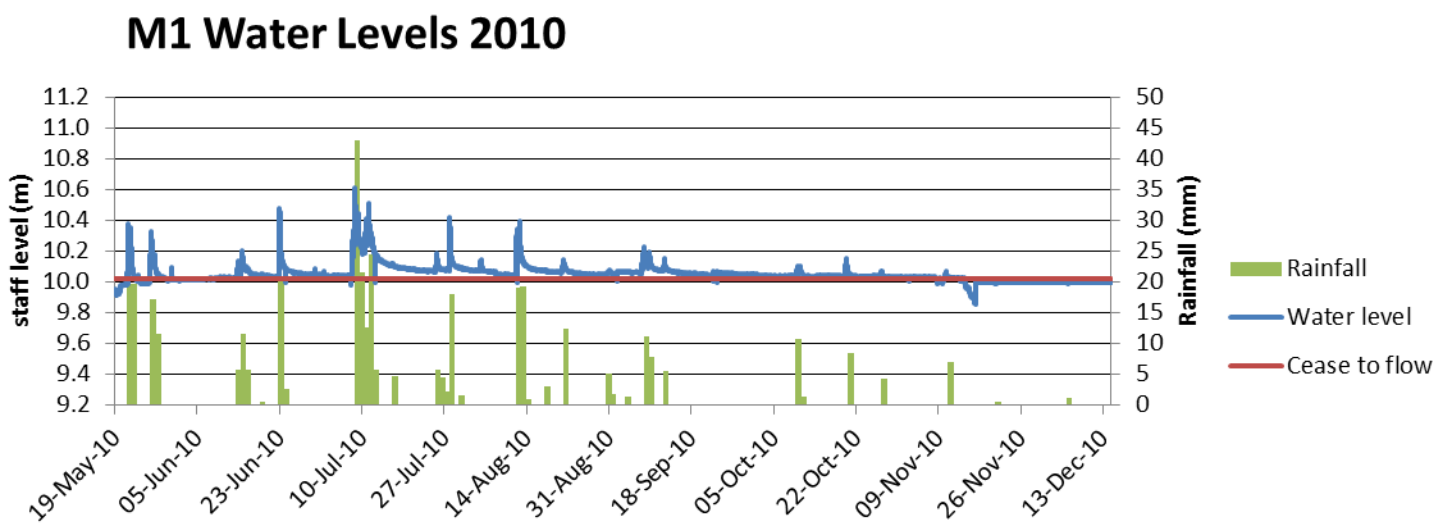
Figure 19: Wetland hydrographs for Wet8

Section 3
Surface water hydrographs

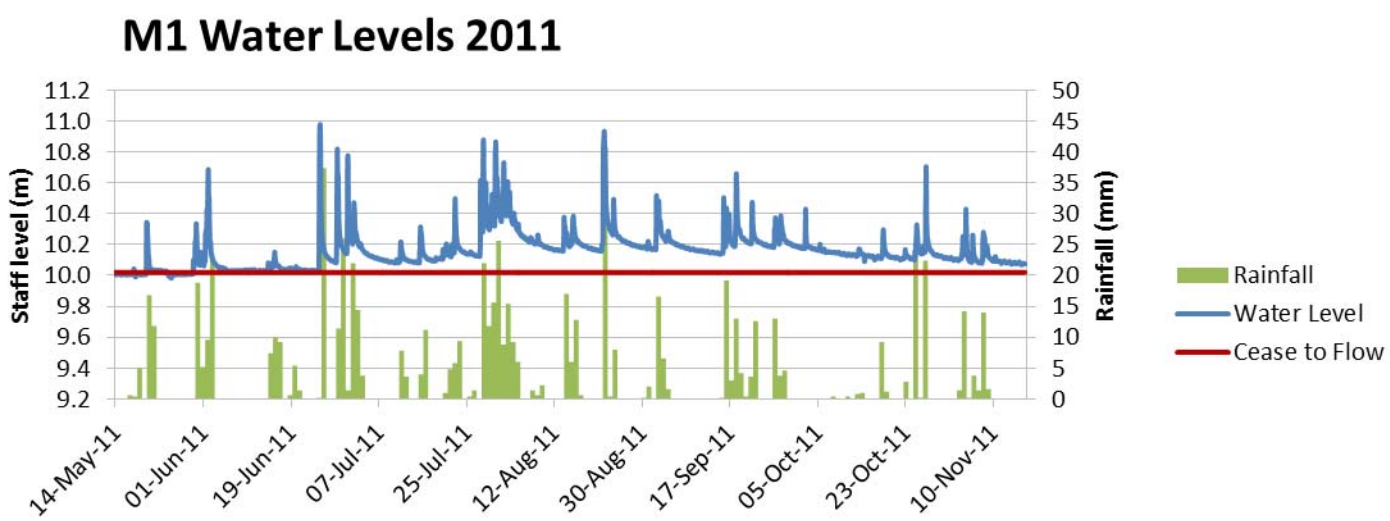
M1
M2
SW1
SW2
SW3
SW5
SW6
SW7



M1 Water Levels 2009
staff level (m)
Rainfall (mm)
11.2
11.0
10.8
10.6
10.4
10.2
10.0
9.8
9.6
9.4
9.2
50
45
40
35
30
25
20
15
10
5
0
10-Aug-09
29-Aug-09
17-Sep-09
06-Oct-09
24-Oct-09
12-Nov-09
Rainfall
Water level
Cease to flow

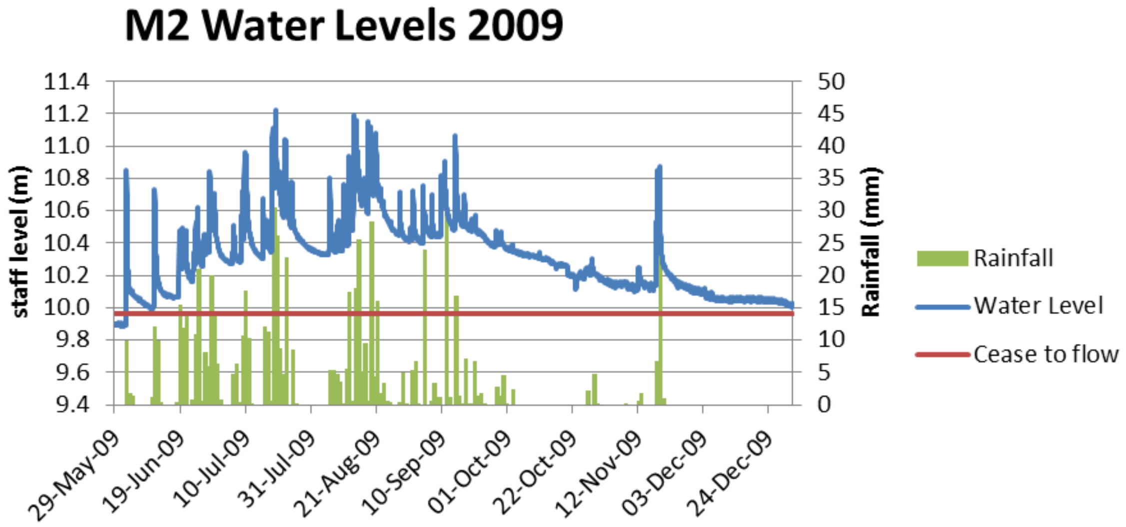


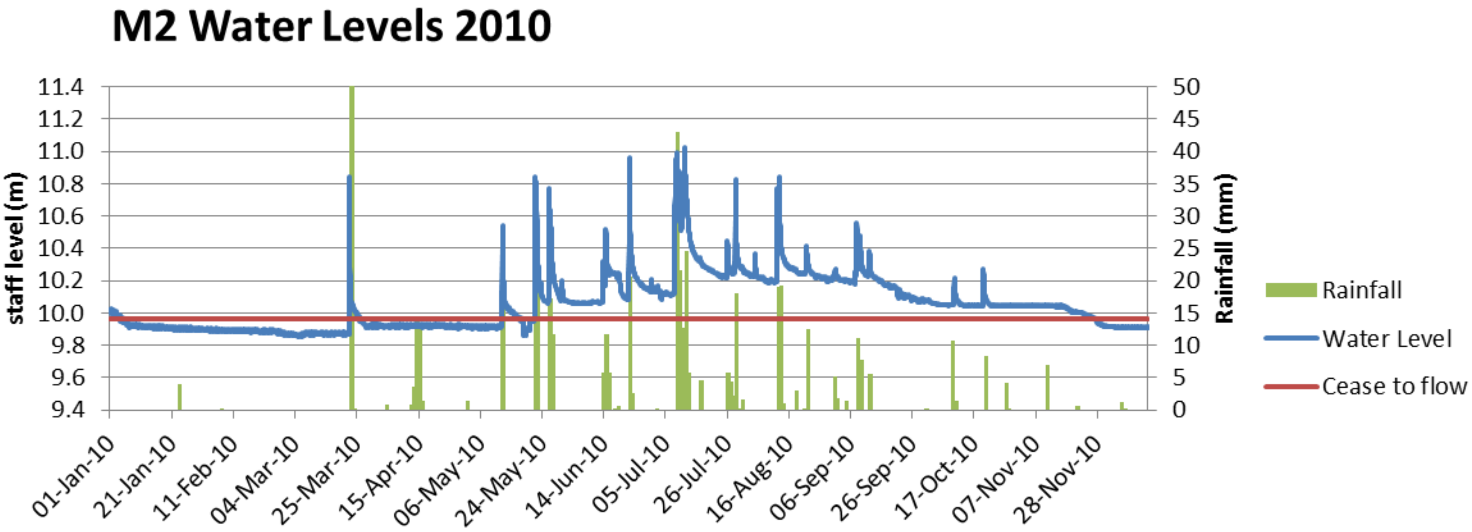
M1 Water Levels 2010
staff level (m)
Rainfall (mm)
11.2
11.0
10.8
10.6
10.4
10.2
10.0
9.8
9.6
9.4
9.2
50
45
40
35
30
25
20
15
10
5
0
19-May-10
05-Jun-10
23-Jun-10
10-Jul-10
27-Jul-10
14-Aug-10
31-Aug-10
18-Sep-10
05-Oct-10
22-Oct-10
09-Nov-10
26-Nov-10
13-Dec-10
Rainfall
Water level
Cease to flow



M1 Water Levels 2011
Staff level (m)
Rainfall (mm)
11.2
11.0
10.8
10.6
10.4
10.2
10.0
9.8
9.6
9.4
9.2
50
45
40
35
30
25
20
15
10
5
0
14-May-11
01-Jun-11
19-Jun-11
07-Jul-11
25-Jul-11
12-Aug-11
30-Aug-11
17-Sep-11
05-Oct-11
23-Oct-11
10-Nov-11
Rainfall
Water Level
Cease to Flow

Figure 20: Surface water hydrographs for M1





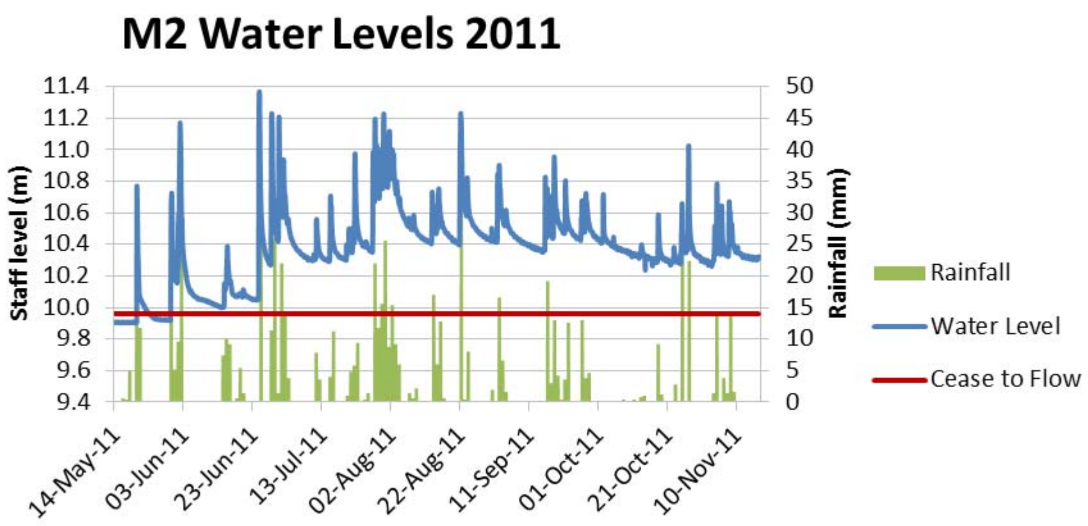
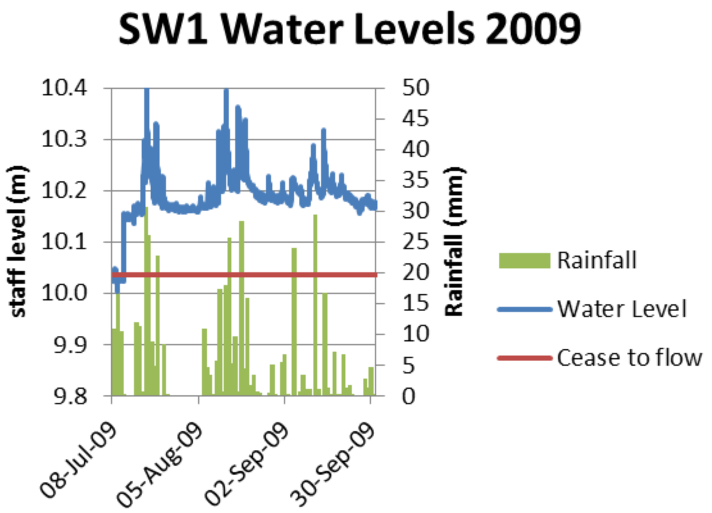
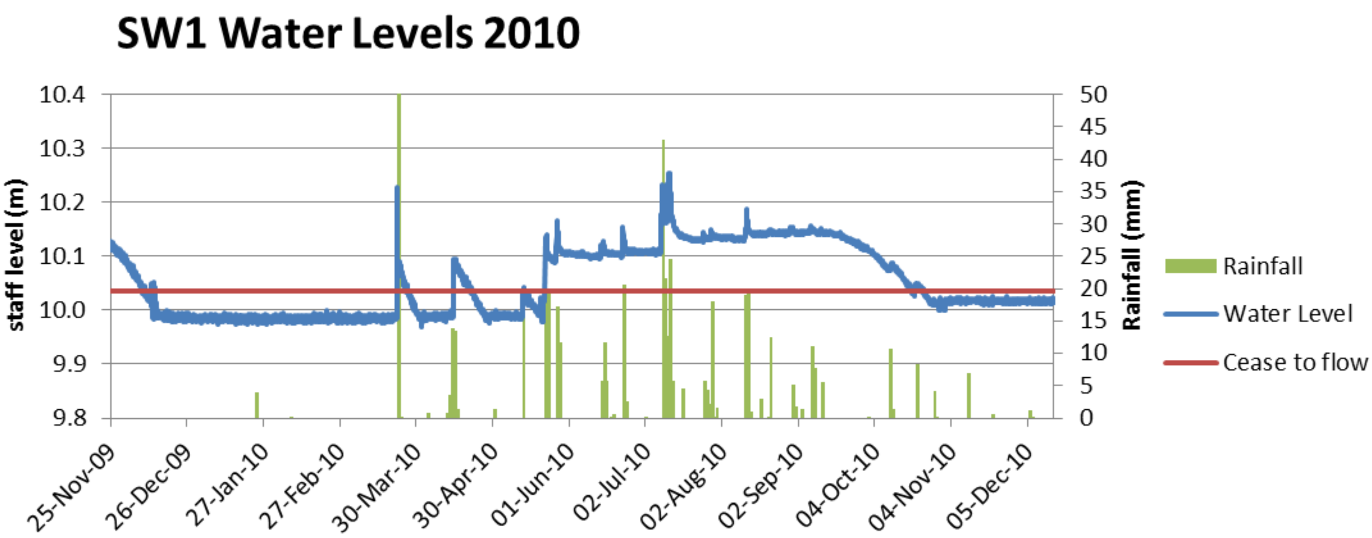


Figure 21: Surface water hydrographs for M2





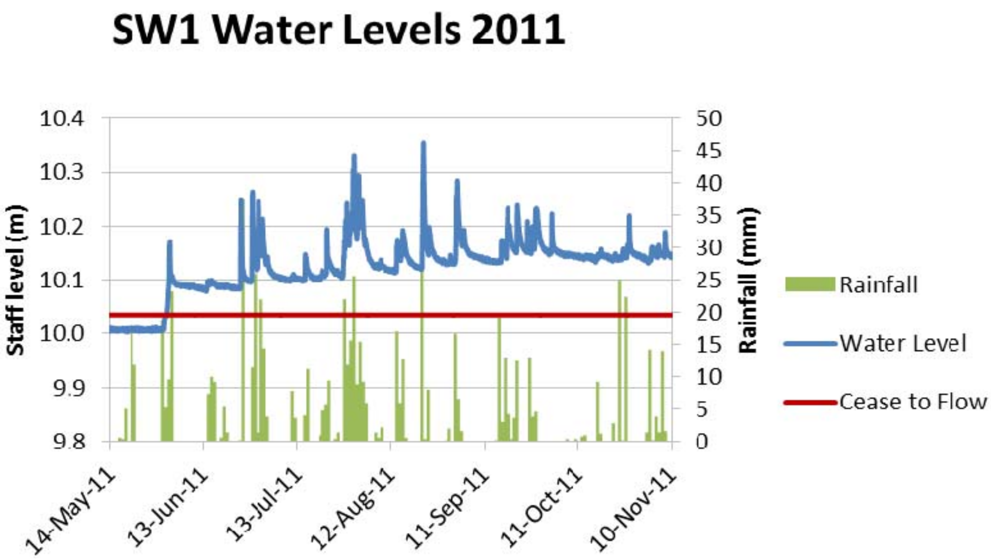
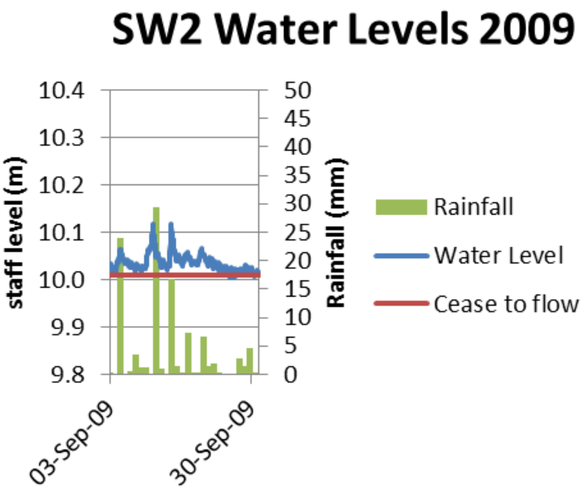
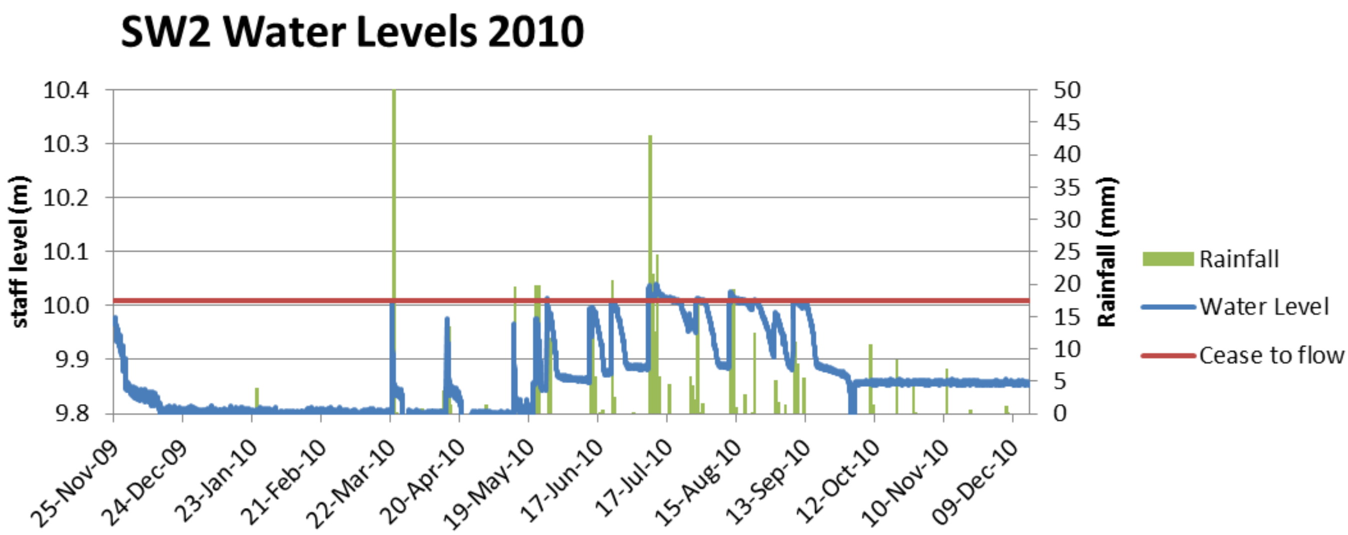


Figure 22: Surface water hydrographs for SW1





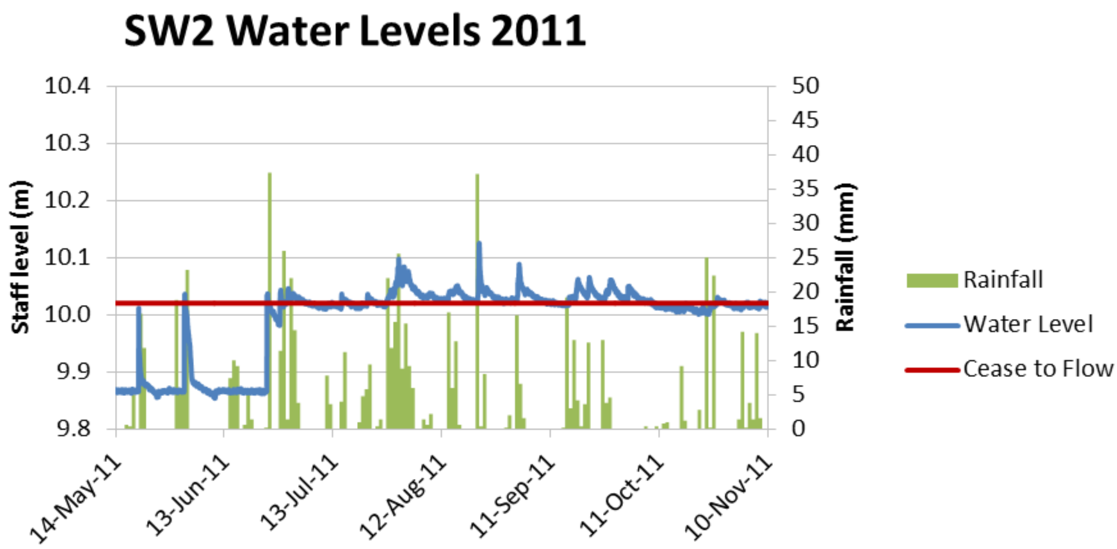
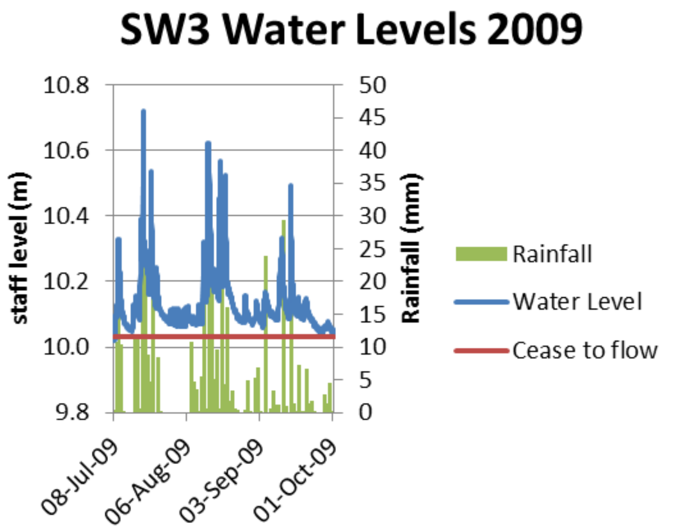
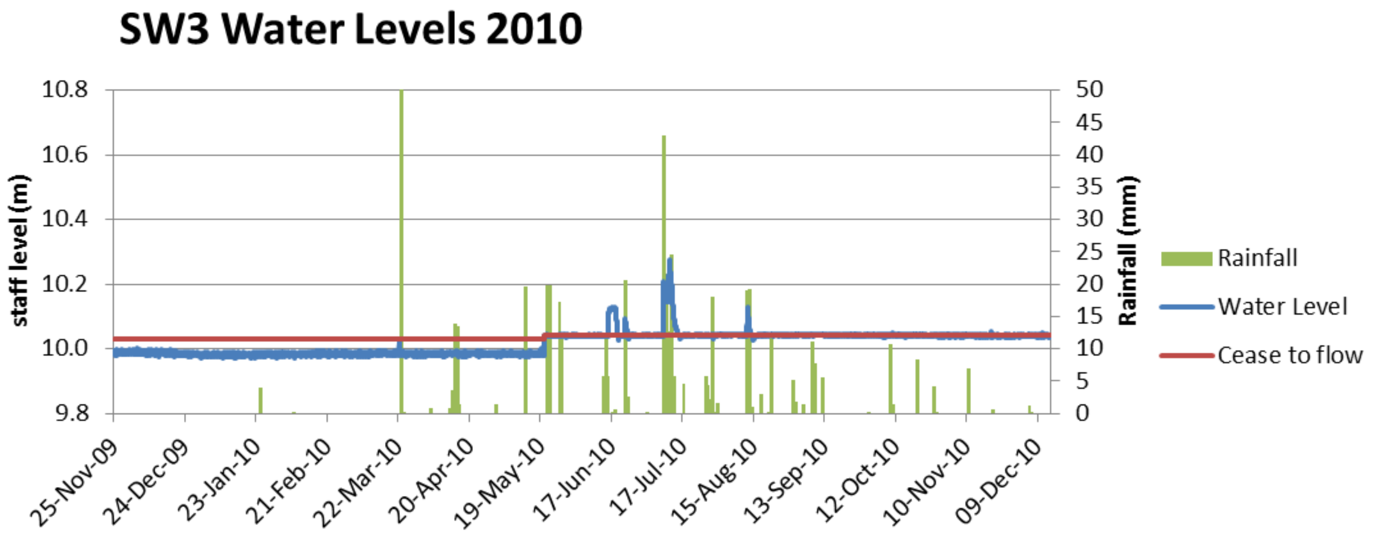


Figure 23: Surface water hydrographs for SW2





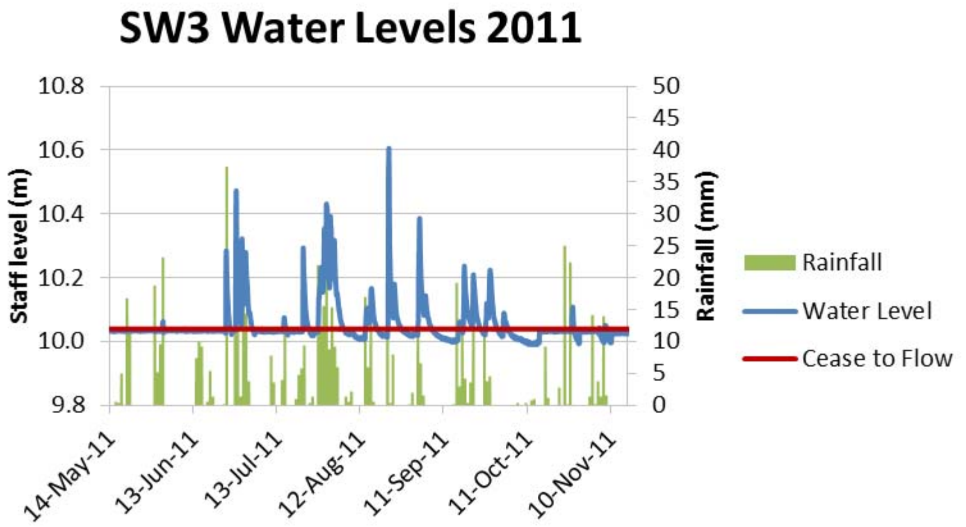
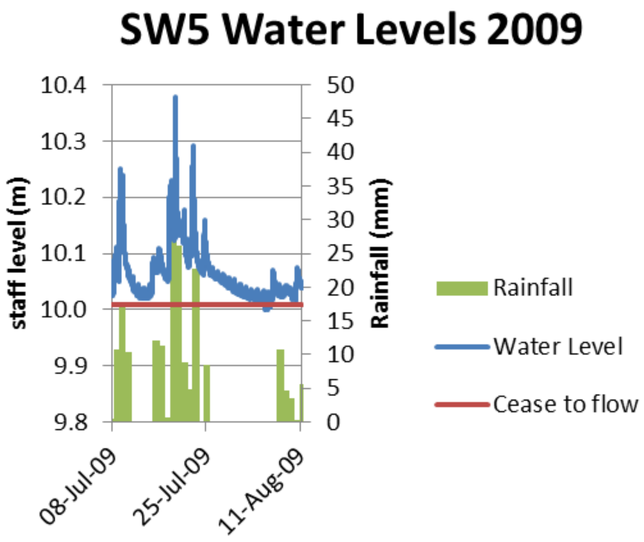
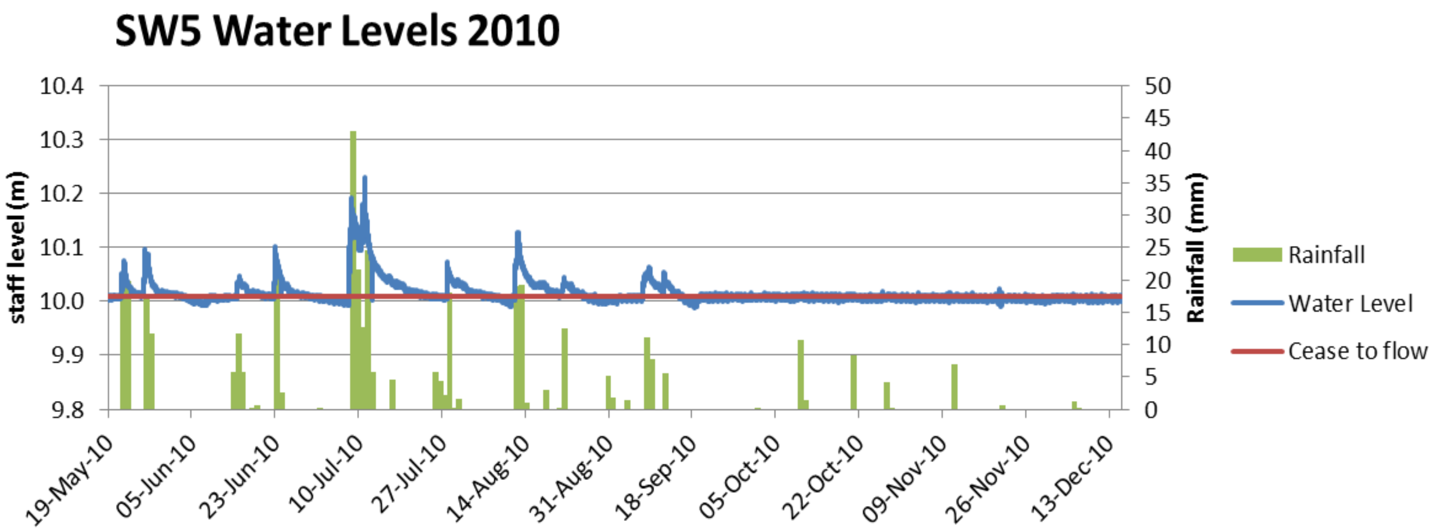


Figure 24: Surface water hydrographs for SW3





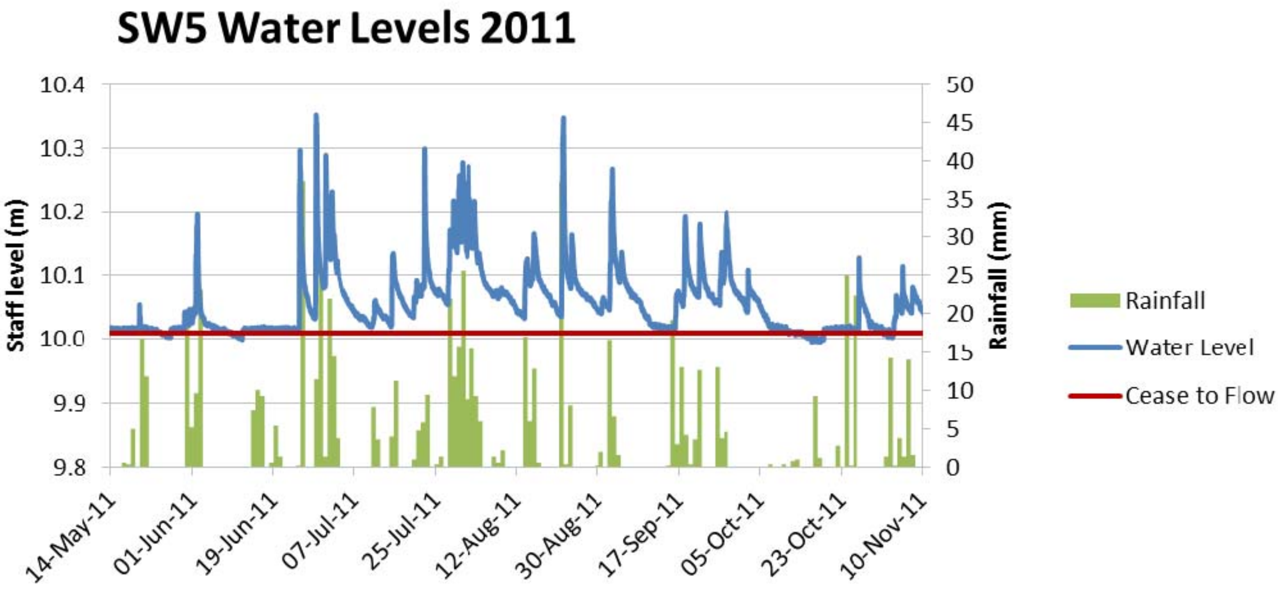
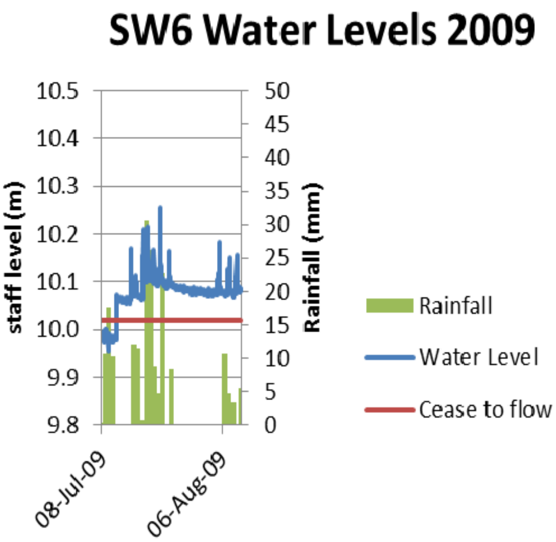
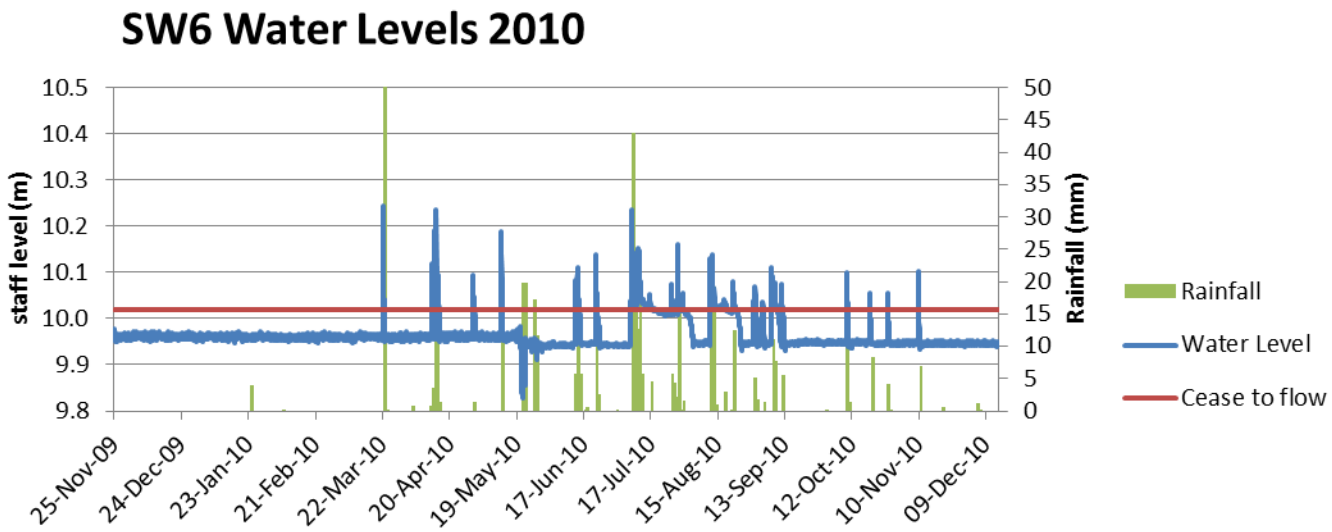


Figure 25: Surface water hydrographs for SW5





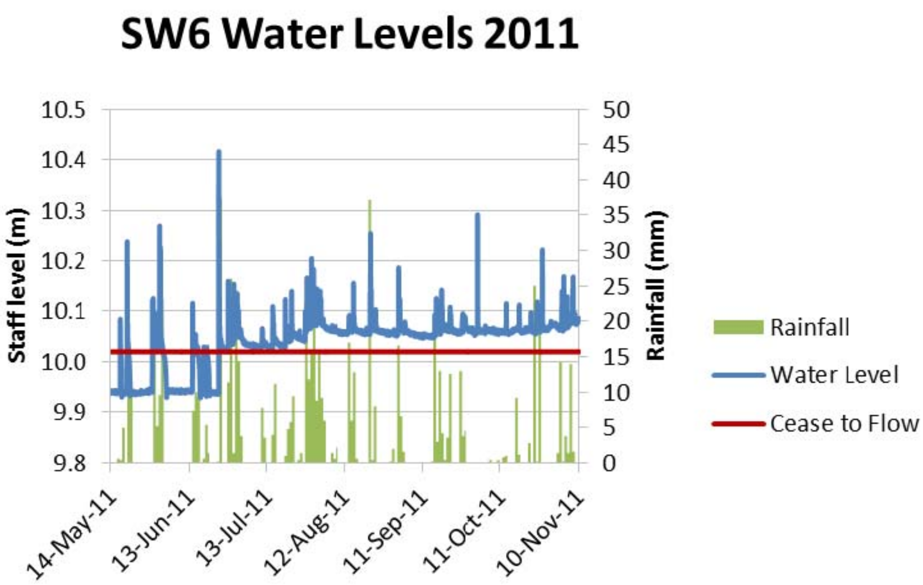
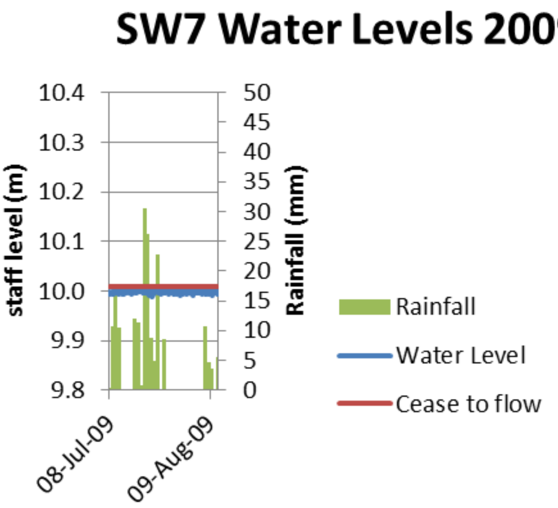
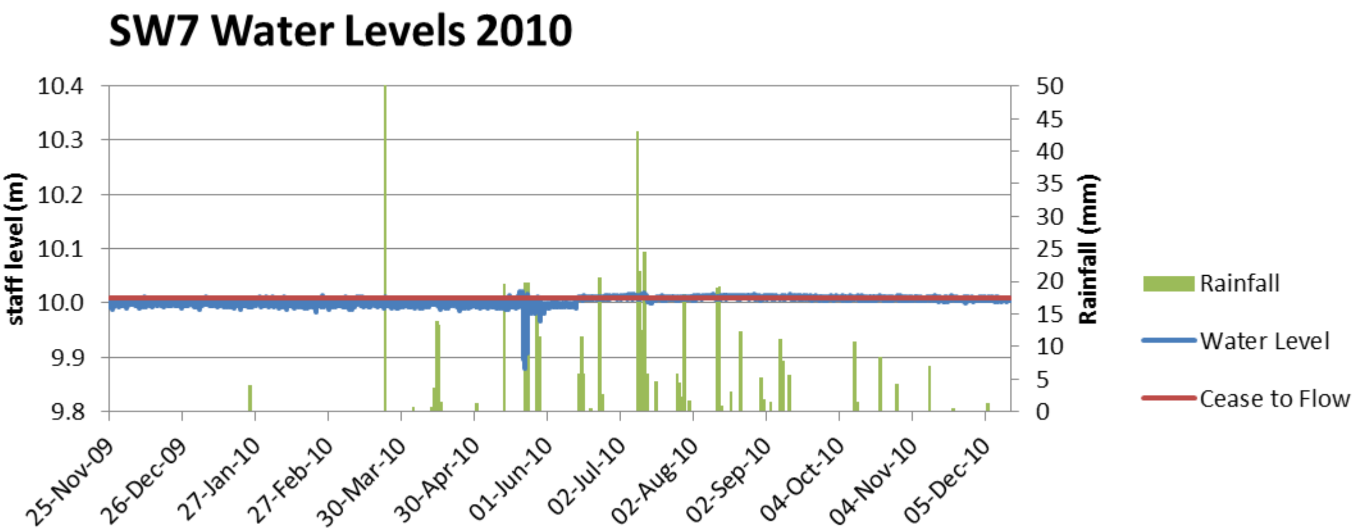


Figure 26: Surface water hydrographs for SW6





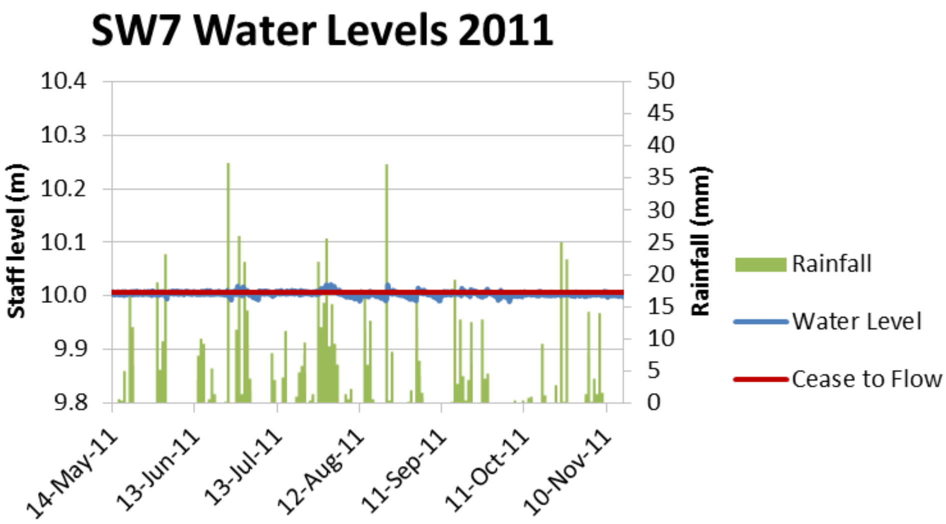


Figure 27: Surface water hydrographs for SW7

Section 4
Rating curve derivation

Surface water sites

Methodology

Various methods are available in order to derive rating curves from stage- discharge measurements. The following describes how stream gauging data collected at the MKSEA surface water sites was used to derive rating curves in order to enable calculation of stream flows. Graphs are provided for each site showing the actual gaugings, any extrapolated gauging points and the derived rating curves.

Apart from sites M1 and M2, where ISCO 4150 Area-Velocity (AV) instruments were deployed, it was not possible to collect flow measurements under high flow conditions. This is due to the particularly flashy nature of these catchments and practicalities of being present during these events and safety concerns associated with wading under high flow conditions.

At sites SW1, SW2 and SW5, located in open channels, a rating point at the highest recorded stage was extrapolated from measured gaugings using the Mannings equation, with Mannings n/ slope coefficient calculated from the highest measured gauging. Flow area and hydraulic radius were calculated using stream survey data.

Two methods have been used for fitting curves to the gauging points dependant on which provided a better fit to the measured stage-discharge points.

1) A power curve was fitted to the data (M1, M2). This is a simplification of the Mannings equation which assumes the conveyance function ($AR^{2/3}$) can be described by a simple power function of the water depth. Discharge equations are listed against the sites on the following pages.

2) Log-log linear curve. A linear equation was fitted to log-log stage discharge points (SW1), or linear interpolation was used between log-log stage discharge points (SW2, SW3, SW5, SW6 and SW7) depending on the number and scatter of points. Where linear interpolation has been used, these points are listed below.

Rating curves were split into a number of segments where this was found to be appropriate as suggested by the gauging points, and/or stage cross section, suggesting a change in control. More detail is listed below against the individual sites.

The application of these rating curves is limited by the number of gaugings, particularly those collected under high flow conditions. Confidence in the rating is generally good to the maximum stage of actual gaugings and/or ISCO AV measurements. Where rating curves have been extrapolated beyond this point, however, confidence in the rating is low.

M1

Part 1 Stage application: 10.020-10.300

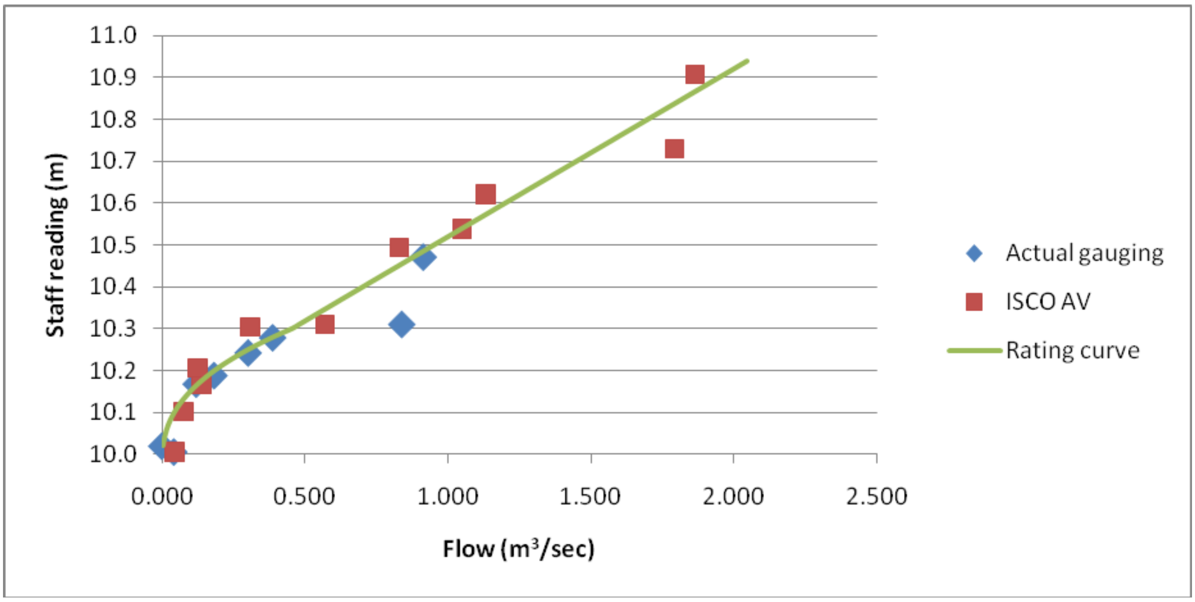
Method: Power curve based on 6 actual gaugings, cease to flow measurement and 6 ISCO AV measurements.

Discharge= 7.2068132*(Depth above CTF^2.4240187)

Part 2 Stage application: 10.300-10.939

Method: Power curve based on 1 actual gauging and 5 ISCO AV measurements.

Discharge= 2.4952929*(Depth above 10.3^1.0026265)+0.455216

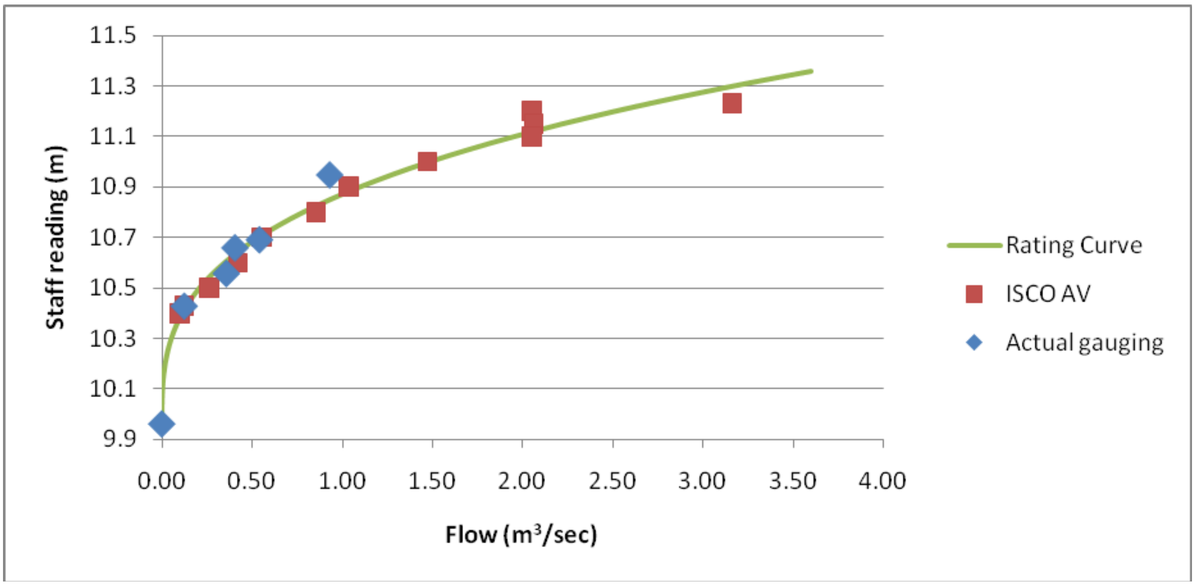


M2

Stage application: 9.960-11.360

Method: Power curve based on 5 actual gaugings, cease to flow measurement and 12 ISCO AV measurements.

Discharge=1.316652*(Depth above CFT^2.9862506)

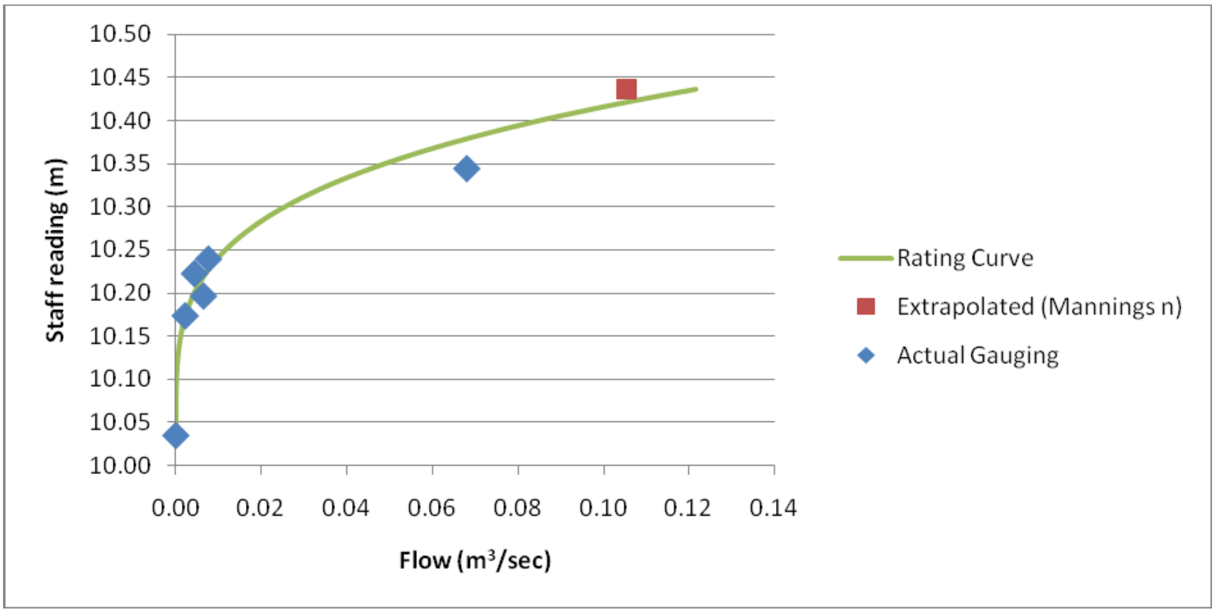


SW1

Stage application: 10.035- 10.436

Method: Log-Log linear curve fitted to 6 actual gauging points from 10.035-10.345 and one extrapolated point (see introduction).

Log(Discharge)= 3.7692*(log(Depth above CTF)) + 0.5808

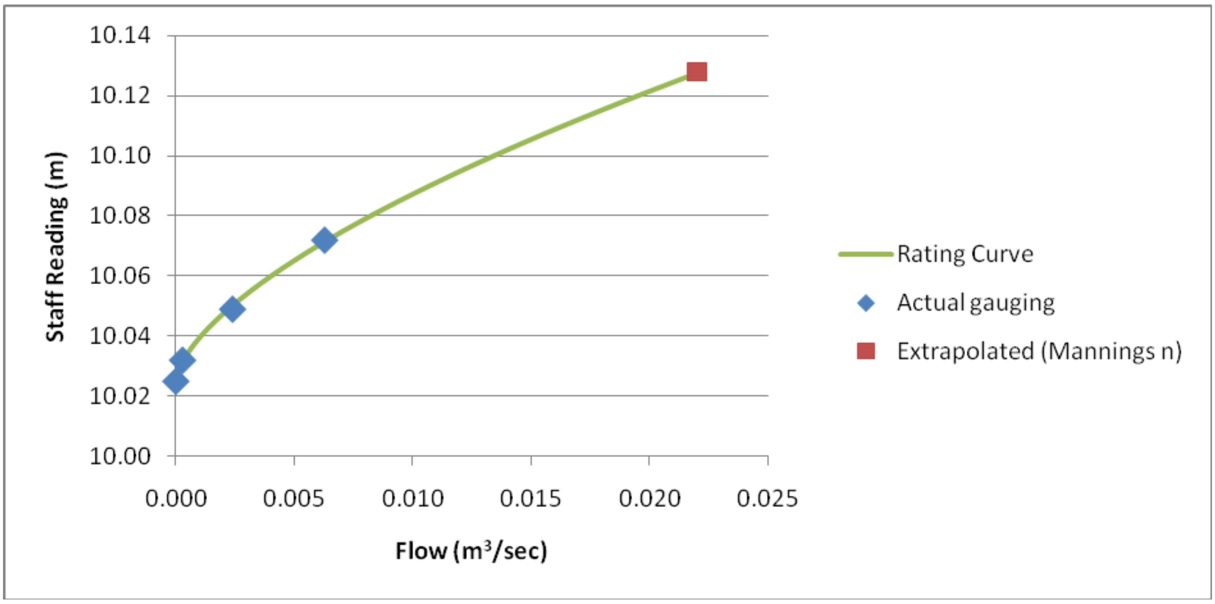


SW2

Stage application: 10.025- 10.128

Method: Log-log linear interpolation between 4 actual gauging points and extrapolated to highest stage.

log(Q)	log(depth above CTF)
-1.65758	-0.98716
-2.20038	-1.3279
-2.61979	-1.61979
-3.54212	-2.1549

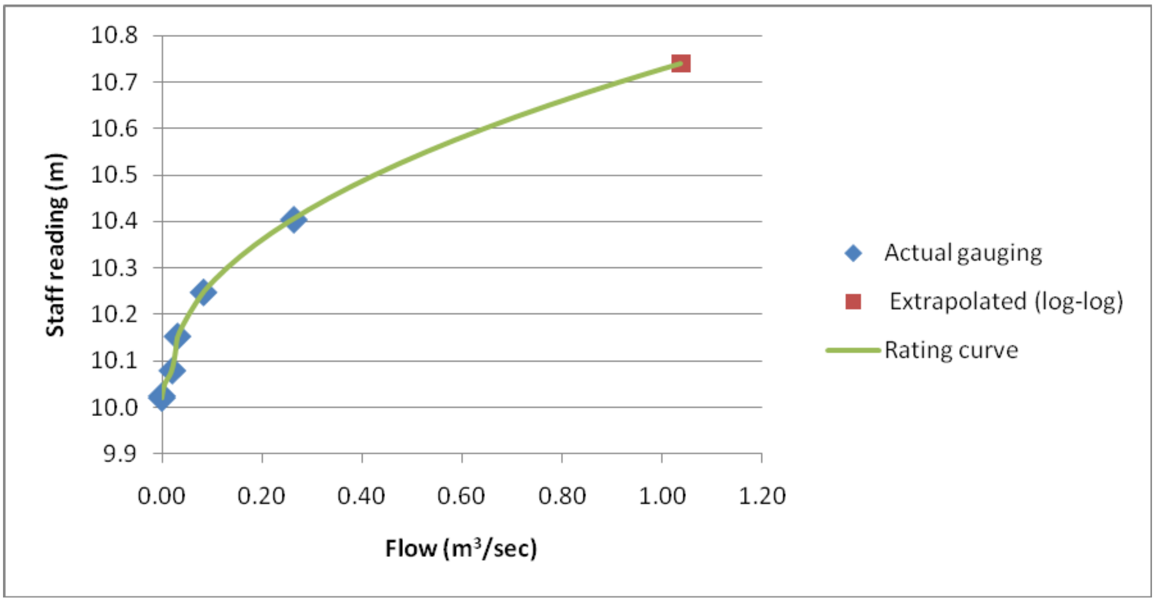


SW3

Stage application: 10.020- 10.740

Method: Log-log linear interpolation between 5 actual gauging points and extrapolated to highest stage.

log(Q)	log(depth above CTF)
-4	-2.39794
-1.68469	-1.22915
-1.50945	-0.87615
-1.08216	-0.64207
-0.58178	-0.41454
0.016116	-0.14267

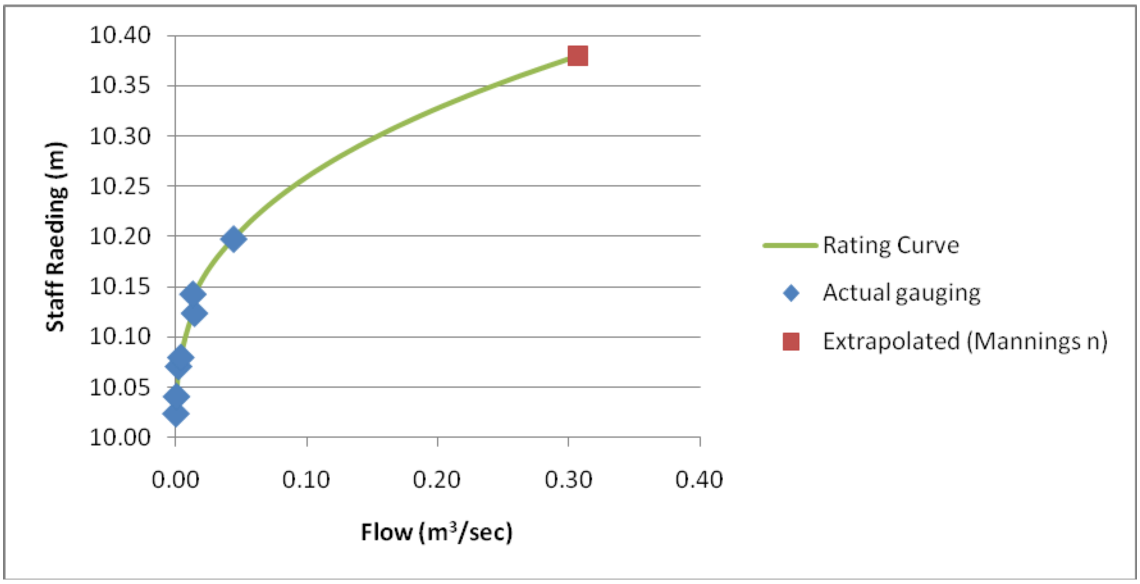


SW5

Stage application: 10.024- 10.380

Method: Log-log linear interpolation between 7 actual gauging points and one extrapolated point (see introduction).

log(Q)	log(depth above CTF)
-3.378478	-1.76955
-2.707301	-1.3279
-2.42899	-1.25181
-1.887462	-0.92445
-1.848937	-1
-1.357931	-0.75945
-0.513235	-0.44855

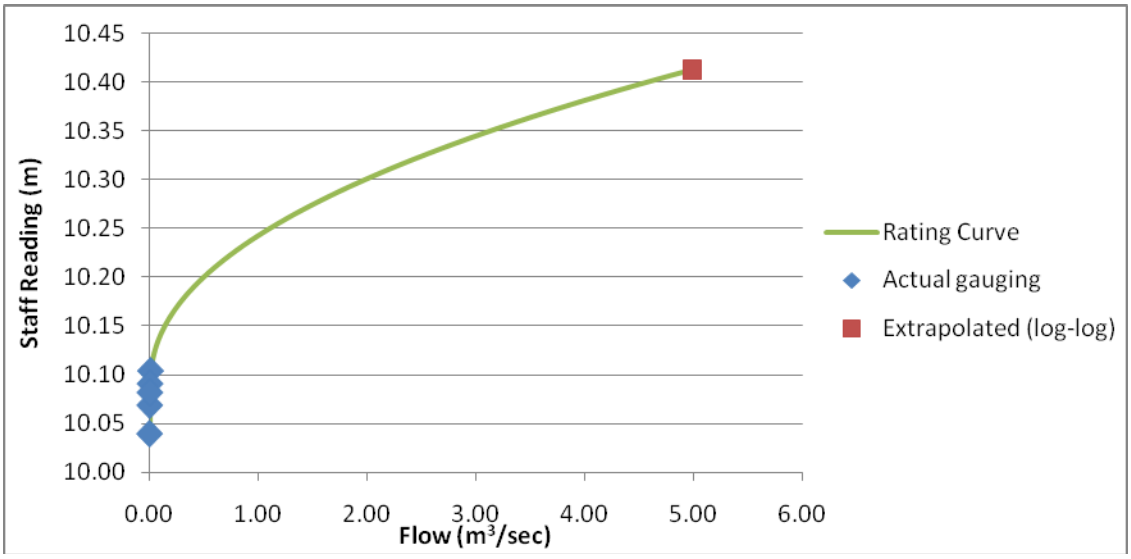


SW6

Stage application: 10.040- 10.413

Method: Log-log linear interpolation between 5 actual gauging points and extrapolated to highest stage.

log(Q)	log(depth above CTF)
-2.86232946	-1.537602
-2.54867419	-1.37675071
-2.39577395	-1.29242982
-2.04277594	-1.19382003
0.689851206	-0.42829117

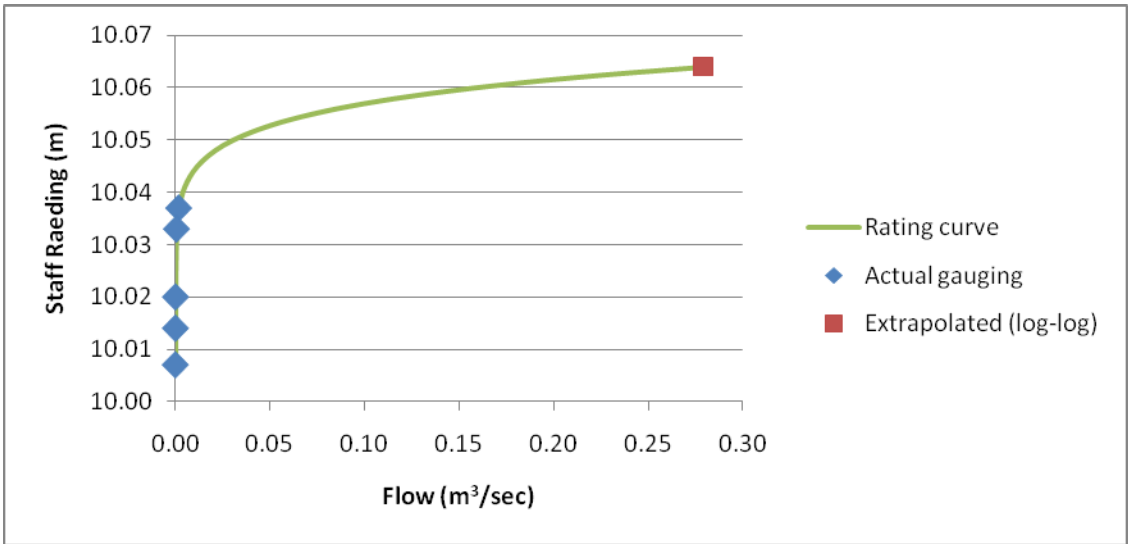


SW7

Stage application: 10.007- 10.064

Method: Log-log linear interpolation between 5 actual gauging points and extrapolated to highest stage.

log(Q)	log(depth above CTF)
-0.55441	-1.24413
-2.75129	-1.52288
-3.24109	-1.58503
-4.27572	-1.88606
-4.5376	-2.1549



Section 5
Monthly flows

Surface Water Sites

Total monthly flows at each of the 8 surface water monitoring sites (m^3)

		M1	M2	SW1	SW2	SW3	SW5	SW6	SW7
2009	**JUN**		156253						
2009	**JUL**		695387	9484*		111792*	19742*	106501*	0*
2009	**AUG**	735036*	984807	17649		161243	220*	95*	3251
2009	**SEP**	548303	593082	11746		77208			874
2009	**OCT**	130204	123162	234	3524*	561			0
2009	**NOV**	121352*	74652	113	0	4			0
2009	**DEC**		3476	20	0	0			0
2010	**JAN**		27	0	0	0			0
2010	**FEB**		0	0	0	0			0
2010	**MAR**		6714	45	14	31			0
2010	**APR**		0	12	0	0			0
2010	**MAY**	28756*	62875	188	0	2401	306*	0*	0
2010	**JUN**	47322	61282	483	0	14809	303	384	9
2010	**JUL**	261682	354125	2963	475	24872	5907	1698	22
2010	**AUG**	89310	130640	2171	73	9197	795	235	32
2010	**SEP**	55336	53893	1935	0	7161	149	106	22
2010	**OCT**	23199	4365	105	0	6965	0	49	11
2010	**NOV**	6540	1269	0	0	5967	0	9	6
2010	**DEC**	854*	0*	0*	0*	2891*	0*	0*	2*
2011	**JAN**								
2011	**FEB**								
2011	**MAR**								
2011	**APR**								
2011	**MAY**	31472*	27942*	0*	0*	2125*	52*	2084*	0*
2011	**JUN**	260070	395744	1119	84	23278	14070	14066	3
2011	**JUL**	531691	733001	3423	1078	48616	23473	5455	9
2011	**AUG**	835962	912995	5026	3143	57444	22354	8306	10
2011	**SEP**	621286	589628	5251	2408	38195	14675	4916	2
2011	**OCT**	280875	256584	2731	284	4048	1048	6992	0
2011	**NOV**	83082*	127262*	811*	0*	733*	703*	3093*	0*

* Indicates that the dataset for this month is incomplete.

Section 6
Photographs

Surface water sites
Survey marks at SW1-7
Debris collected on the weir at M1

Photograph 1 and 2: Survey mark at site SW1

Photograph 3: Survey mark at site SW2

Photograph 4 and 5: Survey mark at site SW3

Photograph 6,7 and 8: Survey marks on fence posts at site SW5

Photograph 9: Survey mark at site SW6

Photograph 10: Survey mark at site SW7

Photograph 11 and 12: Debris collected on the weir and potentially affecting stage discharge relationships at Site M1 in June 2009