Holcim (Australia) Pty Ltd

Rooty Hill Regional Distribution Centre

Environmental Monitoring - Annual Report: 2011 - 2012

3 October 2012

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1. Introduction

1.1 Background

HOLCIM (formerly CEMEX and Readymix) has begun preliminary construction work on a Regional Distribution Centre (RDC) in Rooty Hill, Western Sydney, NSW. The RDC will facilitate the logistics of receiving, blending and distributing bulk building products such as sand and aggregate to the Sydney market. Raw materials would be transported to the site by rail, processed, and then transported to the Sydney market in smaller loads via the road network (Readymix, 2005).

The majority of quarried building material used in the Sydney region has been sourced from the Penrith Lakes Development Scheme (PLDC). Quarry activities at PLDC will cease in the near future. Future supply of construction material for the Sydney market will be required from sources external to the Sydney basin, and a greater reliance on bulk import and redistribution in anticipated, hence the requirement for the RDC.

The Rooty Hill RDC development includes:

- storage silos for a range of building materials including sand and aggregate
- a concrete batching plant
- a concrete testing laboratory
- a conveyor system linking a rail unloading station with the storage facilities
- bridges at two locations across Angus Creek
- stormwater collection and sedimentation ponds
- workshops, office buildings, weighbridges and truck parking

The proposed development was designated as a 'Major Project' under Part 3A of the *NSW Environmental Assessment and Planning Act*, 1979. The development application for the RDC was approved in 2006, with conditions set out to minimise the Centre's impact on the local community and the environment (NSW Department of Planning, DOP, 2006).

Preliminary construction work was completed in late 2011, and early 2012; and major construction work is set to commence by 2013. The construction of the facility is expected to take approximately 2 years to complete.

The Water Science Group of GHD Pty Ltd (formerly Ecowise Australia Pty Ltd; trading as ALS Water Sciences Group) was commissioned to conduct monitoring of water quality, air quality, aquatic ecology and riparian vegetation in the lead-up to construction of the Rooty Hill RDC.

The environmental monitoring program included key elements, required to be monitored under the Statement of Commitments made as part of the approval process (Holcim, 2006) and modifications approved in March 2011 (Holcim, 2011).

This Report presents the monitoring data collected to date (2009-12) with appropriate analyses, determining compliance with conditions of approval. It also provides comments on significant results and recommendations for future monitoring.

1.2 Monitoring Objective

The objective of this monitoring program has been to quantify environmental values of the RDC site, prior to the commencement of major construction activities, and to ascertain compliance with the approvals given for the Project (DoP, 2006) and the Statement of Commitments that were made (Holcim, 2006; 2011).

Information gathered prior to construction provides a benchmark condition of key environmental characteristics of the site, and its vicinity that might be expected to be impacted by the construction and operations of the facility.

Such information can be used to quantify and assess environmental changes that may occur, over time, as the construction and operation of the facility progresses.

As part of the monitoring requirements, under the approval conditions (DoP, 2006), the environmental factors considered by this study included:

- Aquatic Ecosystems and Water Quality
- Ambient Air Quality
- Terrestrial and Riparian Vegetation Communities

The design of the monitoring program essentially followed a BACI approach (Before-After, Control-Impact).

This Report focuses on data that has been collected ‘Before’ the construction phase (2009-12) and establishes a baseline condition of environmental conditions for comparison with data collected ‘After’ construction.

‘Control’ sites have been established at locations, both upstream and adjacent to the RDC, for the monitoring of aquatic ecology and air quality. These sites are compared to the potential ‘Impact’ sites, located downstream of, and on the RDC site, to enable monitoring of the influence of construction on aquatic ecosystems and air quality.

Vegetation assessments were conducted prior to construction and a map of existing terrestrial and riparian vegetation communities is presented. This may be used to assess the influence of the RDC construction on vegetation communities at and surrounding the site.

This Report collates the results of the environmental monitoring that have been conducted during 2009-12, establishing the ‘pre-construction’, environmental baseline conditions.

Over time, these results can be statistically compared to the ‘construction’ and ‘post-construction’ datasets to detect and/or examine any changes, which may occur as a result of the construction and operation of the Rooty Hill RDC.

2. Methodology

2.1 Study Area

The Holcim RDC is located in Rooty Hill, Western Sydney NSW (Figure 1). The site is at the end of Kellogg Road, Rooty Hill. The One Steel Mini Mill forms the site boundary to the west, Humes Pipe factory to the north, the railway and North Parade to the south, and Nurragingy Reserve, to the east.

2.2 Study Sites

The study sites for the various monitoring elements were located in accordance with the plans approved by the NSW Department of Planning (DoP, 2006). Figure 1 displays these environmental monitoring sites. Table 1 presents the exact locations of the monitoring sites and the frequency and approximate scheduling of sampling events for each AE site.

GPS coordinates of the site locations and the sampling frequency for the monitoring elements and events are presented in Table 2. The proposed number of sampling events per annum is presented, excluding samples missed due to equipment failure.

Six aquatic ecology (AE) sites were monitored along local waterways, including four located on Angus Creek and two on Eastern Creek. Two sites (AE6 and AE5) were located upstream of the RDC and considered as ‘control’ sites.

Water quality monitoring sites were established at the same locations as AE sites and both *in situ* and *ex situ* (grab) samples were collected to asses a variety of physico-chemical water quality parameters.

Three locations were selected for air quality monitoring, two within the proposed RDC site boundary and one within the Blacktown Olympic Park grounds, located to the south of the RDC. High Volume Air Samplers (HVAS) were installed at two of the sites; and depositional dust (DD) gauges installed at all three air quality monitoring sites.

A broad vegetation assessment was conducted within the RDC site boundary in 2010. Riparian vegetation assessments were conducted at each of the AE sites in 2009; and in May 2012 during the 2011-12 sampling period.

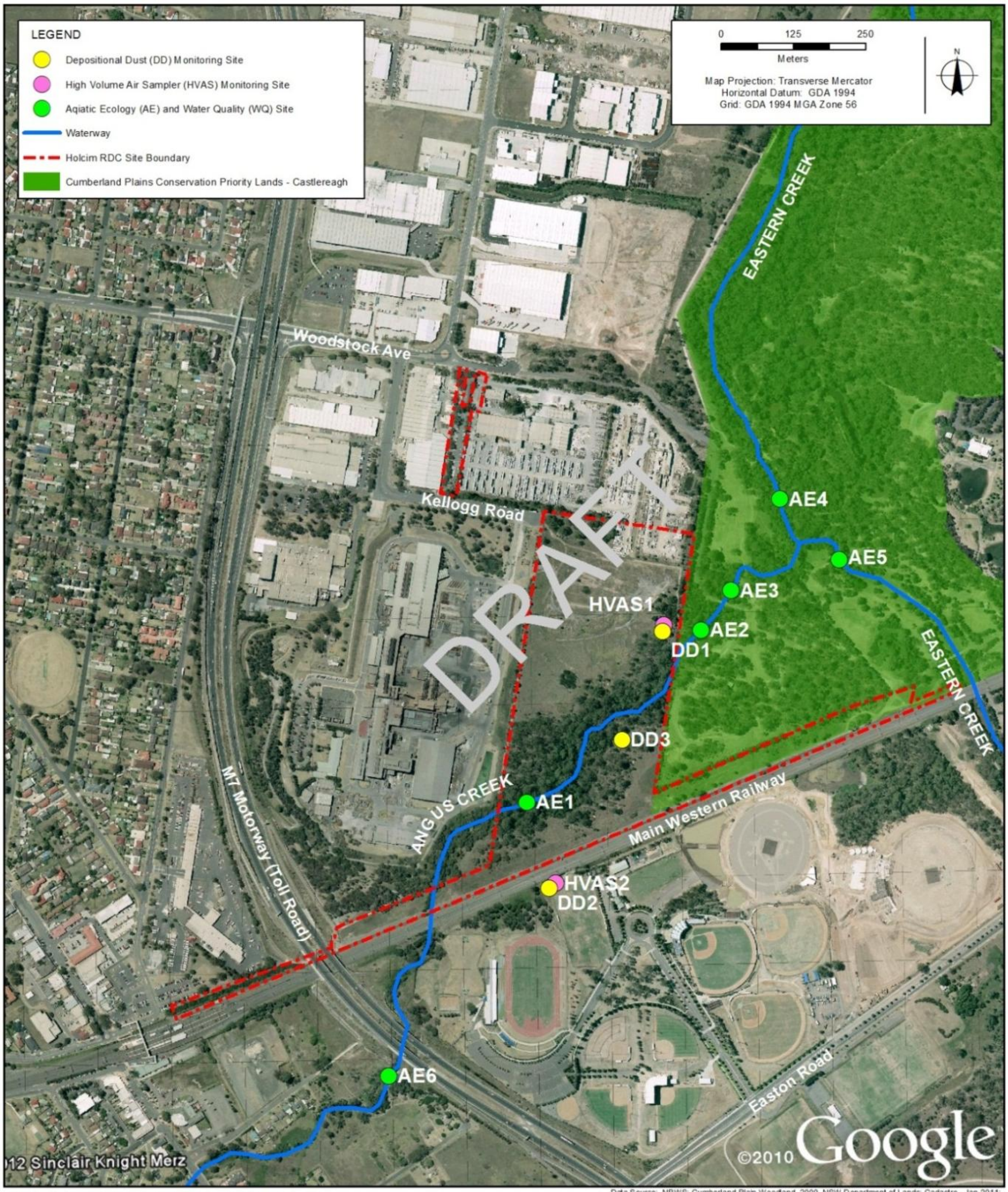
2.3 Ambient Air Quality Monitoring

2.3.1 TSP sampling using HVAS

Total Suspended Particulate matter (TSP) was monitored at two High Volume Air Sampler (HVAS) sites. All sampling and analysis for the measurement of TSP was conducted in accordance with the relevant Australian Standards; AS/NZS 3580.9.3 (2003).

HVAS calibration was performed, as required, every two months, to ensure the units were operating effectively and conforming to the required flow rate.

HVAS and TSP analyses were performed at the NATA accredited ALS Laboratory at Mudgee.



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Data Source: NPWS: Cumberland Plain Woodland, 2000. NSW Department of Lands: Cadastre - Jan 2011; Geoscience Australia: 250k Data - Jan 2011; Google Earth Pro image Jan 2011. Created by: adickson

Figure 1 Holcim Rooty Hill RDC Environmental Monitoring site locations [1]

[1] © 2012. Whilst every care has been taken to prepare this map, GHD (and NSW Department of Lands, Geoscience Australia, and Google) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Table 1 Site locations and scheduling of the monitoring program

Site Code	Location	Latitude	Longitude	Sample Type	Frequency / Timing
AE1	Angus Creek at upstream boundary of RDC	-33.76806	150.85173	Surface Water	4 events per annum 2009 to 2011 2 events completed in 2012
				Aquatic Ecology	Autumn 2009, 2010, 2011, 2012 Spring 2009, 2010, 2011
				Vegetation	Riparian 2009 and 2011-12 RDC site mapping 2010
AE2	Angus Creek at the downstream boundary of RDC	-33.76519	150.85497	Surface Water	4 events per annum 2009 to 2011 2 events completed in 2012
				Aquatic Ecology	Autumn 2009, 2010, 2011, 2012 Spring 2009, 2010, 2011
				Vegetation	Riparian 2009 and 2011-12 RDC site mapping 2010
AE3	Angus Creek 150 m downstream of RDC boundary	-33.76490	150.85567	Surface Water	4 events per annum 2009 to 2011 2 events completed in 2012
				Aquatic Ecology	Autumn 2009, 2010, 2011, 2012 Spring 2009, 2010, 2011
				Vegetation	Riparian 2009 and 2011-12 RDC site mapping 2010
AE4	Eastern Creek downstream of Angus Creek confluence	-33.76360	150.85655	Surface Water	4 events per annum 2009 to 2011 2 events completed in 2012
				Aquatic Ecology	Autumn 2009, 2010, 2011, 2012 Spring 2009, 2010, 2011
				Vegetation	Riparian 2009 and 2011-12 RDC site mapping 2010
AE5	Eastern Creek upstream of Angus Creek confluence	-33.76434	150.85748	Surface Water	4 events per annum 2009 to 2011 2 events completed in 2012
				Aquatic Ecology	Autumn 2009, 2010, 2011, 2012 Spring 2009, 2010, 2011
				Vegetation	Riparian 2009 and 2011-12 RDC site mapping 2010
AE6	Angus Creek 500 m upstream RDC	-33.77207	150.84926	Surface Water	4 events per annum 2009 to 2011 2 events completed in 2012
				Aquatic Ecology	Autumn 2009, 2010, 2011, 2012 Spring 2009, 2010, 2011
				Vegetation	Riparian 2009 and 2011-12 RDC site mapping 2010

Table 2 Description and sample regime of air quality monitoring sites

Site Code	Sample Type	Latitude	Longitude	Frequency	Ideal # events / yr
HVAS1	HVAS – TSP	-33.76539	150.85437	Every 6 days	61
DD1	Depositional Dust			Monthly	12
HVAS2	HVAS – TSP	-33.76934	150.76934	Every 6 days	61
DD2	Depositional Dust			Monthly	12
DD3	Depositional Dust	-33.76793	150.85411	Monthly	12

2.3.2 Depositional Dust Monitoring

Depositional dust, in the form of Total Insoluble Matter, was measured at all three Depositional Dust Gauge (DDG) monitoring sites. All sampling and analysis for the measurement of depositional dust, was conducted according to the relevant Australian Standards; AS/NZS 3580.10.1 (2003).

Samples were collected as close as possible to the first day of each month. Any potential contamination of the sample was noted on a field sheet. Common contaminants include insects, bird droppings and vegetation.

Depositional dust sample analyses were also undertaken at the ALS Laboratory in Mudgee.

2.3.3 Air Quality Assessment Guidelines

HVAS and DDG results were evaluated against the air quality goals outlined by the NSW Office of Environment and Heritage (OEH) and against the statement of commitments in the Director Generals Environmental Assessment Report (NSW Department of Planning, 2006). The specific air quality goals are presented in Table 3.

Table 3 NSW Department of Planning Air Quality Guidelines

Pollutant	Averaging period	Concentration guideline
TSP - HVAS	Annual	90 $\mu g/m^3$
Total insoluble matter - DDG	Annual	4 $grams/m^2/month$
	Maximum monthly increase	2 $grams/m^2/month$

2.4 Water Quality Monitoring

Water quality data were collected *in situ* using a calibrated water quality multi-probe; and samples were collected for laboratory analysis of select parameters, discussed below. Water sampling was undertaken four times each year; and only occurred under base flow conditions, and not during rain events.

2.4.1 *In situ* Physico-chemical Measurements

A Hydrolab MS5 Multi-parameter Sonde was used to measure water quality parameters *in situ* at each site. Calibration of the meter was completed prior to deployment. Measurements were taken approximately 10 cm below the water surface, in areas where water was flowing, or at the midpoint of the stream. The following parameters were recorded at each site:

- pH
- Dissolved oxygen (% saturation and mg/L)
- Temperature (°C)
- Electrical conductivity (µS/cm)
- Turbidity (NTU)

Turbidity was predominantly measured *in situ.* However, on some occasions, samples were collected for turbidity measurements in the laboratory.

2.4.2 Water Quality sampling and Laboratory Analysis

All water sample collection was conducted in accordance with the Australian/New Zealand standards for water quality sampling (AS/NZS S667:1:1998).

The following water quality analytes were measured in the laboratory;

- Total Nitrogen (mg/L)
- Total Phosphorus (mg/L)
- Total Alkalinity (mg/L)
- Turbidity (NTU)

Samples were analysed at the NATA accredited Ecowise/ALS laboratories in Canberra (during 2009-2010) and at the ALS Smithfield Laboratory in Sydney for the 2011-2012 samples.

2.4.3 Water Quality Assessment Guidelines

Water quality data were evaluated against the ANZECC (2000) Guidelines for the protection of 95% of species in 'slightly-to-moderately-disturbed' aquatic ecosystems of south-east Australian lowland rivers (Table 4).

One-way analyses of variance (ANOVA) were conducted to test the differences between Angus Creek and Eastern Creek samples for each of the main water quality variables measured.

Table 4 ANZECC (2000) Aquatic Ecosystem Guidelines

Parameter	Abbreviation	Units	ANZECC (2000) guidelines
Electrical conductivity	EC	µS/cm	125 - 2200
Dissolved oxygen	DO	% sat	85 - 110
pH	pH	pH units	6.5 - 8.0
Total nitrogen	TN	mg/L	0.5
Total phosphorous	TP	mg/L	0.05
Turbidity	Turbidity	NTU	50

2.5 Aquatic Macroinvertebrate Monitoring

2.5.1 Macroinvertebrate Sampling

Aquatic macroinvertebrate sampling followed the Rapid Bio-assessment (RBA) protocols, in accordance with the NSW AUSRIVAS Sampling and Processing Manual (Turak *et. al*., 2004). The AUSRIVAS program is a nationally recognised, standardised sampling protocol used to assess the health of Australian Rivers and developed for the *Australia's National River Health Program* (NRHP).

At each site, the littoral or edge habitat was sampled by sweeping the collecting net along the edge of the stream in areas of little or no current. The net was swept around overhanging terrestrial vegetation, against snags if present, in backwaters, and through beds of macrophytes. This process was continued, working upstream against the flow, over approximately 10 m of edge.

Sampling was conducted using a standard ISO 7828 (1983) design sweep-net with 250 µm mesh. Nets were washed thoroughly between sampling sites to remove any invertebrates retained on them.

For each RBA sample, the collected material was placed into a sorting tray and macroinvertebrates 'live picked' for a minimum of 40 minutes by professionally qualified and experienced aquatic biologists using forceps and pipettes. If new taxa were found between 30 and 40 minutes, sorting continued for a further 10 minutes up to a maximum of 1 hour.

This sorting protocol was amenable to obtaining a sample containing as diverse a fauna as possible (and hence, providing a useful measure of taxa richness). Bias towards abundant taxa was avoided in the sorting; thereby ensuring the collection of all taxa present in the sample, including rare or cryptic animals.

Samples were preserved in 70% methylated spirits and labelled with information including site, habitat, sampling method, date and sampler.

2.5.2 Laboratory Processing and Macroinvertebrate Identification

Aquatic macroinvertebrates were examined using stereo-dissection microscope with a zoom capability between 6 and 50. Freshwater macroinvertebrates were identified using published taxonomic keys, unpublished working keys, and an extensive specimen reference collection.

Most macroinvertebrates were identified to Family level, with some exceptions, following standard conventions of the NSW AUSRIVAS sampling and processing manual (Turak *et. al*., 2004). Chironomidae (Diptera) were identified to sub-family (e.g. Orthocladiinae, Chironominae, and Tanypodinae).

Groups, such as Nematoda, Oligochaeta and Acarina were identified to class or order level in accordance with accepted convention. Microcrustacea, Ostracoda, Copepoda and Cladocera were also identified to the Order level.

Upon completion of identification all samples were returned to 70% methylated spirits for long-term archiving. This allows samples to be re-examined at a later date if required. This may be important, particularly if the taxonomy changes significantly in the future under a long term monitoring program.

2.5.3 Macroinvertebrate Data Analyses

In order to elucidate spatial trends in the data and (where possible) to determine the underlying environmental factors responsible for any observed trends, a range of univariate and multivariate routines were adopted. Both techniques provide differing levels of information, with univariate indices concentrating mainly on assessing the condition or "health" of sites, whilst multivariate analysis allows comparisons between sites based upon community structure and can determine if relationships exist between relevant environmental variables and macroinvertebrate communities.

The statistical approach for data analyses in this project, discussed below, was designed to achieve the key objectives of developing an understanding of the health of the macroinvertebrate communities, and identifying environmental factors influencing the health of macroinvertebrate communities.

Univariate Analysis

The univariate techniques employed on macroinvertebrate data include:

- Taxa Richness Index (including EPT Taxa Index);
- SIGNAL 2 Biotic Index (Chessman, 2003);
- Current NSW AUSRIVAS models appropriate for the study region; and
- Relative Abundance of the major taxonomic Orders.

Taxa Richness and EPT Taxa Index

Richness refers to the number of different taxa contained in a sample. The EPT taxa index refers to the proportional representation of key macroinvertebrate taxa belonging to the Ephemeroptera, Plecoptera and Trichoptera groups. These groups are generally considered to be more sensitive to changes in aquatic habitat and water quality condition than many other macroinvertebrate taxa.

SIGNAL 2

SIGNAL2 (Stream Invertebrate Grade Number Average Level - Version 2) (Chessman, 2003) is a simple scoring system for macroinvertebrates of Australian rivers. SIGNAL is a biotic index based on pollution sensitivity values (grade numbers) assigned to aquatic macroinvertebrate families that have been derived from published and unpublished information on their tolerance to pollutants, such as sewage and nitrification (Chessman, 1995). Each taxon is assigned a grade from 1 (tolerant) to 10 (sensitive) based on eco-toxicity assessment data.

The average of the grades for each site is used as the SIGNAL 2 score. Those families in a sample for which no grade can be assigned are excluded from the analysis. The calculation of the SIGNAL 2 score has not been weighted in regards to the abundance of organisms.

For easier interpretation, SIGNAL 2 scores and the number of macroinvertebrate taxa have been graphed using a bi-plot (Chessman, 2003). The resulting bi-plot is placed into context using a quadrant diagram that divides the results into four general realms (Figure 2).

The quadrant boundaries have been set at a SIGNAL2 score of 4 and 15.5 for the number of macroinvertebrate families, after consideration of suggested NSW interim SIGNAL 2 boundaries (Chessman, 2001).

NSW AUSRIVAS Model

All macroinvertebrate data, water quality parameters and habitat variables required by the relevant AUSRIVAS models were collected according to the latest NSW AUSRIVAS manual (Turak *et. al*, 2004) and ANZECC (2000) guidelines for aquatic ecosystems in south-eastern Australia.

The appropriate NSW AUSRIVAS model and accompanying scores and bandings have been used to detect any changes in observed and expected macroinvertebrate communities within the CVO mine lease. AUSRIVAS generates site-specific predictions of the macroinvertebrate fauna expected to be present in the absence of environmental stress.

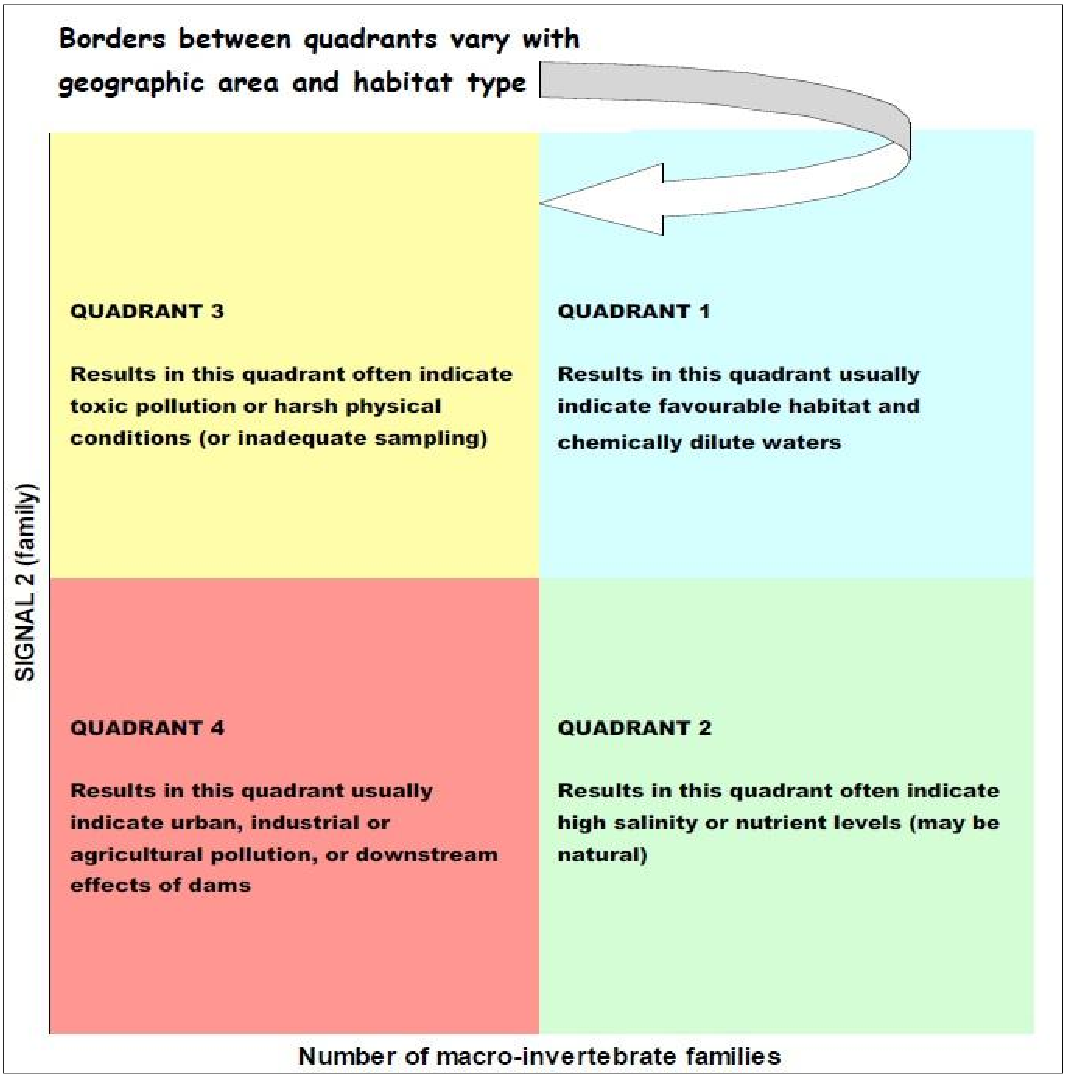

Figure 2 Bi-plot for assessment of SIGNAL 2 outputs

The expected fauna from sites with a similar set of physical and chemical characteristics are then compared to the observed fauna, and the ratio derived is used to indicate the extent of the impact. This ratio can range from zero (0), when none of the expected taxa are found at a site, to approximately one (1), when all of the expected taxa are present.

The value can also be greater than one (1) when more families are found at the site than predicted by the model. The ratio scores are placed in bands which indicate whether the site is richer than reference, reference quality, below reference quality, well below reference quality or impoverished (Table 5).

The NSW AUSRIVAS model also provides a list of missing taxa from individual sampling sites by comparing observed taxa against expected taxa. This data will be analysed and reported to provide a more detailed understanding of the health ratings assigned to individual sampling sites and observed trends in river health.

Table 5 Key to AUSRIVAS O/E bands, scores apply to NSW combined season eastern edge

Band Label	Bandwidth	Band Name	Comments
Band X	1.18 - Infinity	More biologically diverse than reference sites	More taxa found than expected. Potential biodiversity hot-spot. Possible mild organic enrichment.
Band A	0.83 - 1.17	Reference condition	Most/all of the expected families found. Water quality and/or habitat condition roughly equivalent to reference sites. Impact on water quality and habitat condition does not result in a loss of macroinvertebrate diversity.
Band B	0.49 - 0.82	Significantly impaired	Fewer families than expected. Potential impact either on water quality or habitat quality or both, resulting in loss of taxa.
Band C	0.15 - 0.48	Severely impaired	Many fewer families than expected. Loss of macroinvertebrate biodiversity due to substantial impacts on water and/or habitat quality.
Band D	0 - 0.14	Extremely impaired	Few of the expected families remain. Extremely poor water and/or habitat quality. Highly degraded.

Relative Abundance

The relative abundance (%) of the major taxonomic Orders is derived from the presence/absence data for each of the samples. This measure provides an estimate of the % contribution of the major macroinvertebrate Orders and, when presented in graphical form, allows for a visual representation of the macroinvertebrate community within each sample, each site and a pooled total representing the macroinvertebrate community across the study area.

Multivariate Analysis

A number of multivariate analyses were conducted to identify spatial and temporal trends between sites and over time. The multivariate methods included the following:

- Classification / Hierarchical agglomerative CLUSTERING
- Non-metric Multi-Dimensional Scaling (NMDS) Ordination
- ANalysis Of SIMilarity (ANOSIM)
- SIMilarity PERcentages (SIMPER)

The following factors were assigned to the sample data to investigate trends in macroinvertebrate community composition:

- Site Code (AE1 - AE6)
- Season (Autumn or Spring)
- Year (2009 to 2012)
- Creek (Angus Creek / Eastern Creek)
- Site Location (Relative to the RDC site; Upstream / Downstream)

Classification / Hierarchical agglomerative CLUSTERING

Cluster analysis is a means of classifying samples or sites into groups, based upon the similarity of variables (i.e. macroinvertebrate community composition). This analysis aims to find 'natural groupings' of samples such that samples within a group are more 'similar' to each other than samples in different groups. In the Cluster analysis, a hierarchical agglomerative approach is taken, which utilises the similarity matrix as its starting point and successively fuses the samples into groups and these groups into larger clusters, starting with the highest mutual similarities, then gradually lowering the similarity level at which groups are formed.

Hierarchical clustering was performed on the similarity matrix of macroinvertebrate data, derived using the Bray-Curtis similarity coefficient. The resultant dendrogram graphically represents the hierarchical groupings within the data set.

NMDS Ordination

Ordination also provides a representation of the relative similarity of entities (i.e. sites/samples), based on their attributes (i.e. macroinvertebrate community composition) within a reduced dimensional space. The more similar sites are to each other, the closer they are located in the ordination space. This procedure displays the samples' interrelationships on a continuous scale and allows a check to see how "real" the groups identified in the classification are.

A Non-metric Multi-Dimensional Scaling (NMDS) ordination was performed on the similarity matrix for all pairs of samples based on the Bray-Curtis similarity coefficient. The number of axes used in the ordination is based on resultant stress levels. The stress level is a measure of the distortion produced by compressing multi-dimensional data into a reduced set of dimensions and will increase as the number of axes (i.e. dimensions) is reduced.

ANOSIM

ANOSIM is a procedure that can be used to investigate the significance of any spatial and/or temporal variation (annual and seasonal) in similarity between and within sites and site groupings. ANOSIM, fully described by Clarke and Gorley (2006), compares the similarity of samples within groups to the similarity of samples between groups.

The test uses a randomisation procedure to test the hypothesis that there is 'no difference in community structure between sites/sample groups'. Each randomisation compares the R test statistic generated from randomly sorted data set with the R-value calculated from the original data set. One thousand randomisations of the data are undertaken for each comparison. The R-value can vary between -1 and 1; the greater the value the greater separation between groups.

SIMPER

The SIMPER procedure was used to investigate the taxa responsible for any observed temporal and spatial changes in macroinvertebrate community structure between and within sites. SIMPER computes the average dissimilarity (Bray-Curtis) between all pairs of inter-group samples (every sample in group 1 with every sample in group 2 etc.) and then breaks this average down into the separate contributions from each taxon. In addition to the average dissimilarity between groups, SIMPER also calculates the average similarity within a group.

2.6 Aquatic Habitat

Field data were recorded on a number of specialised recording sheets, modified from the *National Assessment of River Health* (NARH) data sheets. These modifications enhanced the efficiency of the habitat assessment without any loss of data accuracy or detail.

Descriptions were based on visual estimates of characteristics, such as stream-bed composition (% of total composition for each substrate category), aquatic and riparian vegetation cover, amount of in-stream organic material, area of aquatic habitats and canopy cover. The mean width (wetted width in metres), mean depth and general geomorphologic characteristics were also recorded at each site.

The assessment also included sketches of the longitudinal and cross-sectional profiles of the stream reach assessed displaying key habitat and morphological features of the biological sampling site, location of in-situ water quality sampling, riparian zone width, type and height and location where photos were taken. The cross-section included the approximate bank height, stream width and depth, and the approximate height of riparian vegetation.

A further assessment of the habitat condition was conducted following the reference condition selection criteria, which rates the level of impact for ten possible impact categories on a scale from extreme impact (1) to no impact (5).

Field sheet information includes:

- Site Information, Water Quality and Habitat Assessment Sheet
- Macroinvertebrate Sampling Sheet
- Reference Condition Selection Criteria Sheet

A broad range of physical habitat measurements were collected at each site, in accordance with the requirements of the NSW AUSRIVAS Manual (Turak *et. al*., 2004).

Observations of aquatic and riparian habitat were made during each aquatic ecology sampling event and were used in the analysis and interpretation of data. Field sheets containing field data were retained, and can be provided on request.

2.7 Vegetation Assessments

Records of riparian vegetation were collected during 2009 (September to December) and 2011-12 (January to March) along Transects perpendicular to the waterway, both upstream and downstream of all water quality (AE) sites.

These assessments were conducted using the line intercept method, extending 20 m from either bank or to the limit of acceptable riparian vegetation. Transect lines were placed in areas most representative of the vegetation in the local vicinity. Point, line and area features were collected on a hand-held GIS data collector (Trimble) and these allowed the vegetation observed to be accurately described.

Line and area features were used to represent obvious community boundaries and point observations were used to depict significant observations and individual trees outside the mapped community boundaries.

Particular attention was paid to identifying:

- The presence of listed Endangered Ecological Communities (EECs);
- Species or populations listed in the NSW *Threatened Species conservation Act* (1995);
- Plants declared as 'Noxious Weeds' by the NSW Noxious Weeds Act (1996); and
- Species widely considered as 'environmental weeds'.

The majority of vegetation community and individual species identifications were made on-site, using field guides. These were complemented by other identifications made from collected specimens. Complete lists of flora species present within the Transects and the vicinity were made for each AE monitoring site.

In late 2010, a broader scope of vegetation assessment was conducted to map the vegetation community groups present on-site and assign some contextual value to those groups.

All GIS information was differentially corrected and edited to produce a map of the significant vegetation within the RDC site.

Vegetation community values were assigned, taking into consideration the known ecological values and the legislative significance of the community, or species. This map was presented in the 2010-11 annual report, and was updated.

In 2011-12, the transect-based vegetation assessments were repeated, and the quantitative results obtained for cover/abundance compared with the 2009-10 surveys. The species lists were also updated.

3. Results and Discussion

This section presents results of all data collected from February 2009 up to July 2012.

3.1 Air quality

Results from High Volume Air Samplers (HVAS) and Depositional Dust (DD) gauges are presented in Table 6 and Table 7 below. Tables contain the mean and standard error (indicated in brackets), along with the number of samples.

3.1.1 Total Suspended Particulates

Mean values for all TSP data collected to date are provided in Table 6.

Table 6 Mean Total Suspended Particulates at HVAS1 and HVAS2

Site	Dataset	Mean TSP µg/m^3/day(SE)	No. samples
HVAS1	All data	32.5 (±3.6)	6
HVAS2	All data	37.8 (±1.3)	185
HVAS2	2009	39.9 (±2.5)	51
HVAS2	2010	35.1 (±2.0)	60
HVAS2	2011	41.9 (±2.8)	59
HVAS2	2012*	25.1 (±1.7)	15

* Data for January to March 2012 only

- HVAS1 was not operational since 2009. Only six (6) samples were collected with an average TSP of 32.5 µg/m^3, which is well below the DECC air quality guideline level of 90 µg/m^3/day (annual average).
- HVAS2 collected 185 samples since site inception in February 2009, with an average TSP of 37.8 µg/m^3, which is also well below the DECC Guideline of 90 µg/m^3/day.

TSP data from HVAS2 are presented in Figure 3, comparing the annual rolling average and rolling average TSP values with the air quality guideline.

The results (Figure 3) indicated that on two occasions (Feb 2011 and August 2011) TSP levels exceeded the DECC Guideline. However, the rolling averages were well below the guideline, which confirmed compliance with the air quality goal of 90 µg/m^3/day (annual average).

3.1.2 Depositional Dust

Mean values for all insoluble solids (depositional dust) results collected are provided in Table 7.

- DD1 collected 36 months of depositional dust data, with a mean of 1.5 g/m^2/month.
- DD2 collected 38 months of depositional dust data, with a mean of 2.2 g/m^2/month.
- DD3 collected 38 months of depositional dust data, with a mean of 2.0 g/m^2/month.
- The annual means of the depositional dust measured by the dust gauges were therefore well below the maximum allowable guideline (4.0 g/m^2/month); and the maximum increase in annual mean permitted (2.0 g/m^2/month).

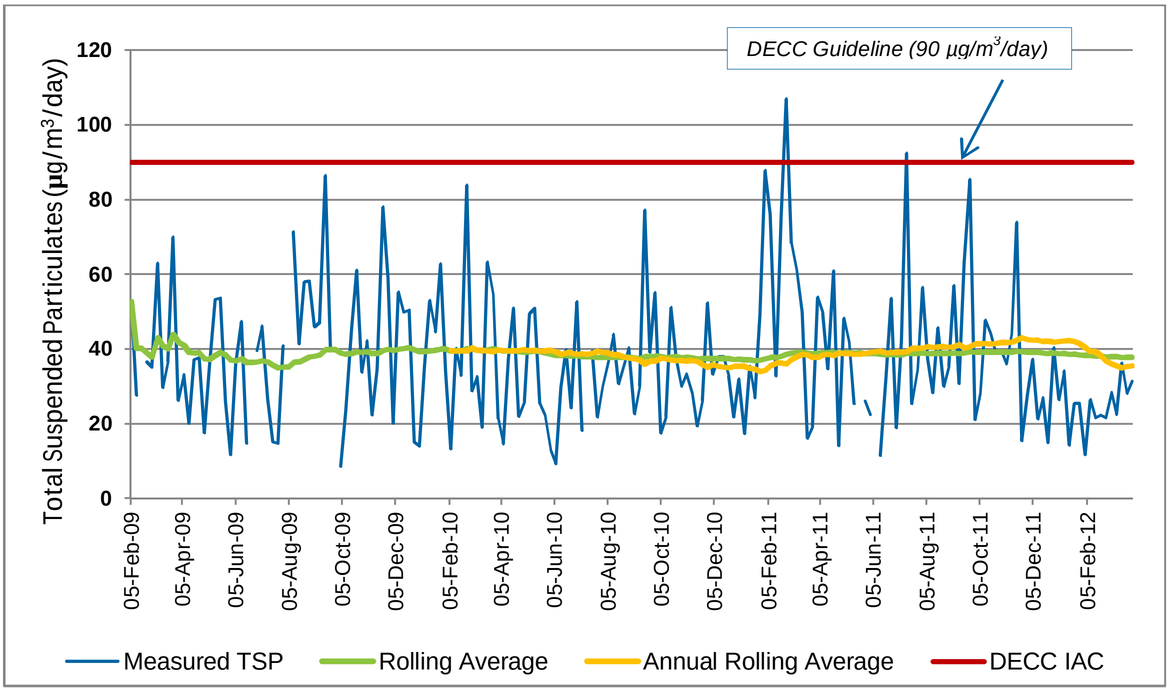

Figure 3 Total Suspended Particulates at HVAS2 and rolling averages

Table 7 Mean deposited insoluble matter and ash content at DDG monitoring sites

Site	Dataset	Total insoluble matter (g/m^2/month)	Mean ash content (% as decimal)	Samples collected (n)
DD1	All data	1.5 (0.2)	0.69 (0.02)	36
	2009	1.6 (0.4)	0.72 (0.01)	11
	2010	1.8 (0.2)	0.69 (0.05)	11
	2011	1.3 (0.2)	0.70 (0.04)	12
	2012*	0.7 (0.3)	0.50 (0.00)	2
DD2	All data	2.2 (0.2)	0.63 (0.02)	38
	2009	2.1 (0.4)	0.70 (0.01)	11
	2010	2.5 (0.6)	0.66 (0.05)	12
	2011	2.2 (0.3)	0.59 (0.05)	12
	2012*	1.3 (0.4)	0.48 (0.11)	3
DD3	All data	2.0 (0.2)	0.67 (0.02)	36
	2009	2.2 (0.5)	0.71 (0.02)	10
	2010	2.4 (0.4)	0.68 (0.04)	11
	2011	1.7 (0.2)	0.66 (0.03)	12
	2012*	1.2 (0.4)	0.53 (0.07)	3
Guideline = 4 g/m^2/month (annual average), 2 g/m^2/month maximum. increase				

* Data for January to March 2012 only

- All air quality measures recorded below average results for the four months between December 2011 and March 2012. This period corresponded with exceptionally high rainfall in the region and is almost certainly the reason for the consistent low results.

Results for DD1 are presented in Figure 4; DD2 in Figure 5; and DD3 in Figure 6. These also compare the rolling annual averages of depositional dust to DECC Guideline values (4.0 g/m^2/month of depositional dust) and highlight results, which exceed the acceptable maximum monthly increase values (2.0 g/m^2/month of depositional dust).

- The results indicated that in 2009, during a brief period (August and September), samples from all three sites exceeded the DECC Guideline, as well as the maximum accepted monthly increase of 2.0 g/m^2/month of insoluble matter. However, the rolling averages for 2009 were well below the air quality guideline.
- During 2010, at DD2 and DD3, there were additional periods (i.e. April to May 2010) during which there were significant exeedances of the acceptable maximum monthly increase values. Similar increases were noted at DD2 during December 2009 to January 2010 as well. However, these increases were transient, and despite the exeedances, the annual averages in 2010 for all three sites complied with the DECC air quality guidelines.
- During 2011, at all three sites, depositional dust levels were below the DECC Guidelines, and there were no instances of monthly increases exceeding 2.0 g/m^2 of insoluble matter.
- From the data available for 2012, depositional dust levels were low, and there were no instances of monthly increases, exceeding 2.0 g/m^2 of depositional dust.

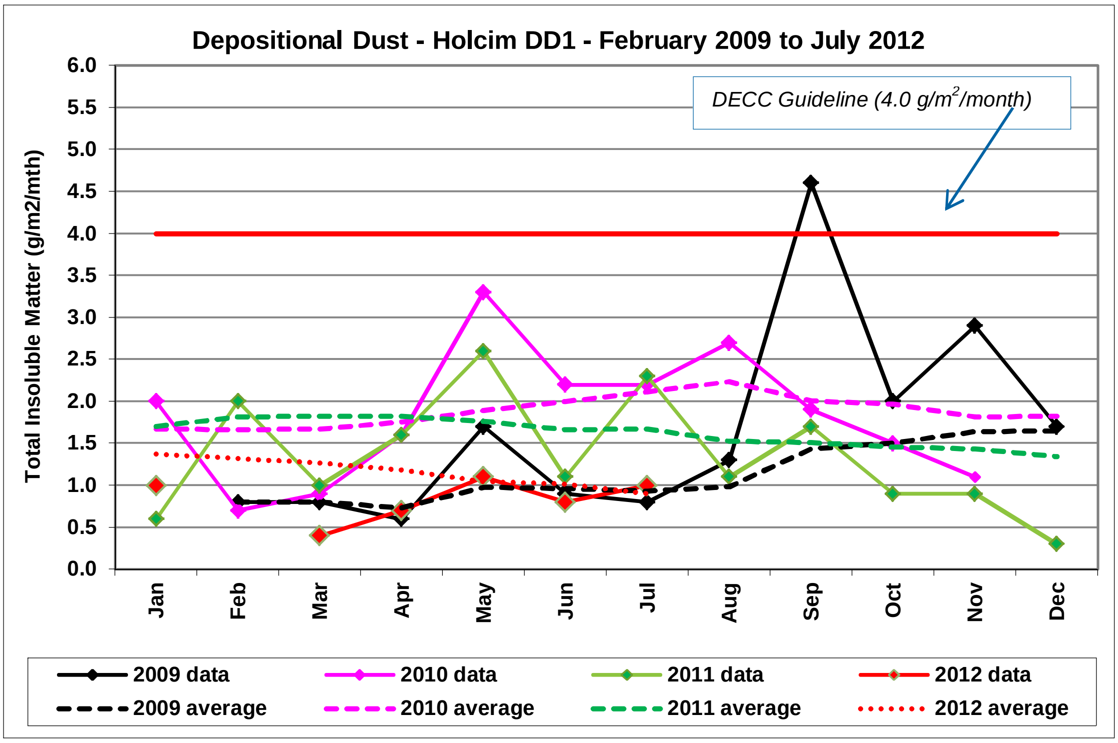

Figure 4 Results of depositional dust analysis at DD1

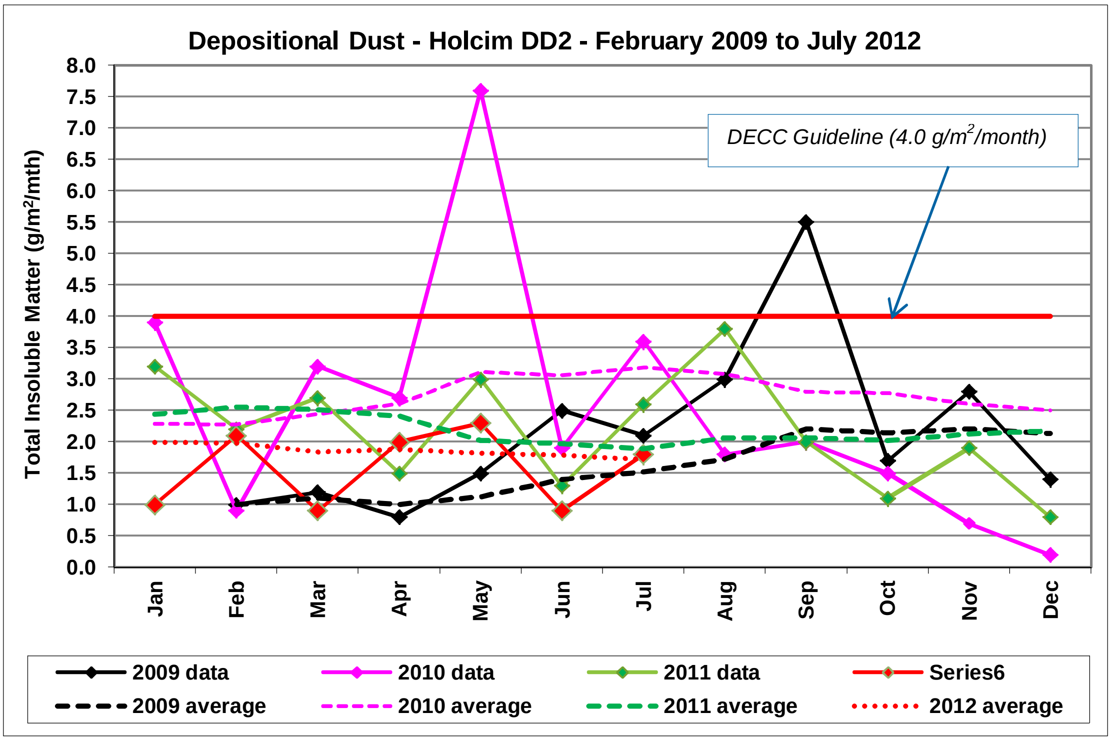

Figure 5 Results of depositional dust analysis at DD2

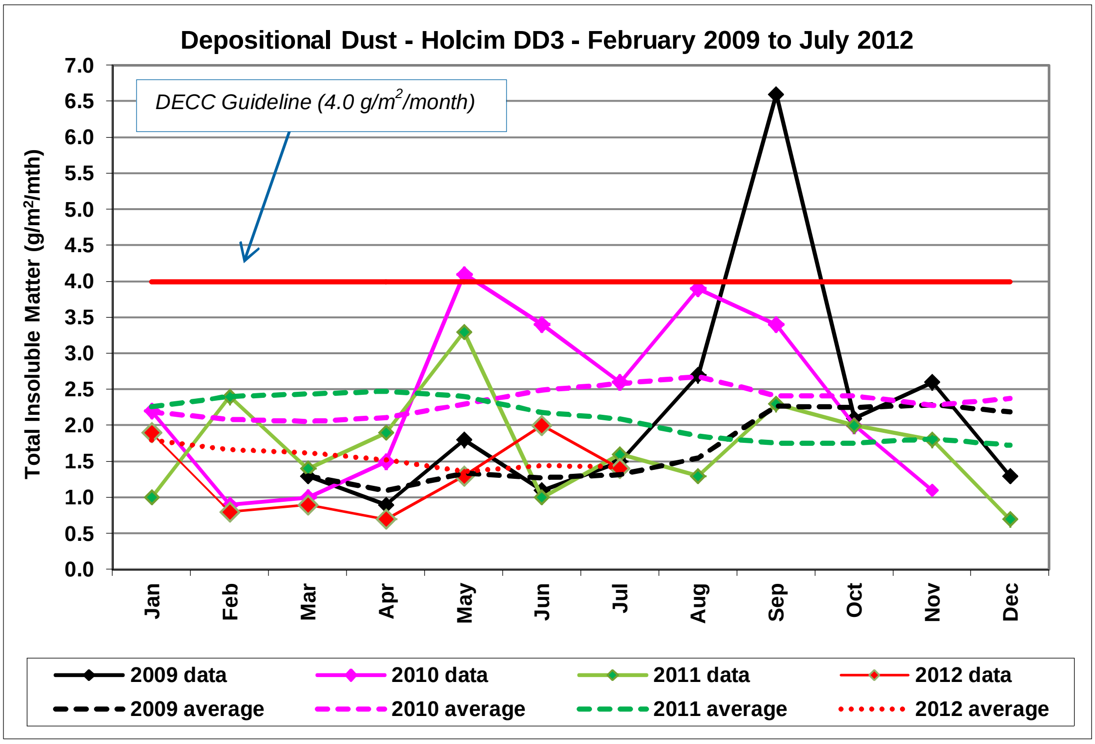

Figure 6 Results of depositional dust analysis at DD3

3.2 Rainfall

Rainfall data for the nearby Horsley Park meteorological station (067119) for the period of January 2009 to May 2012 is displayed in Figure 7. Data are presented is 5-day rolling average of daily rainfall. The water quality and aquatic macroinvertebrate survey sampling events are also indicated.

Table 8 provides some summary statistics of mean monthly rainfall and annual totals for the monitoring period, compared with the long-term average rainfall for the area, obtained from Horsley Park Monitoring Station, which is the nearest location to the RDC. The results indicate that the monthly rainfall has varied erratically during this period; and the total annual rainfall in each of the years: 2009, 2010 and 2011, has been much lower than the long-term value.

3.3 Water Quality

The summary results of water quality parameters measured are presented in Table 9. The mean values for each of the water quality sites, and each creek are provided and compared with ANZECC (2000) water quality guidelines for 95% of species protection in 'slightly-to-moderately disturbed' lowland waterways of south-east Australia.

The following observations can be highlighted from the results given in Table 9:

- The average EC for Angus Creek: 2163 µS/cm, was significantly higher than the value for the Eastern Creek Sites, which recorded an average of 978 µS/cm. ANOVA confirmed the differences between the two creeks with regard to EC as significant ($p = 7.03E^{-07}$).
- The pH values of both creeks were within the ANZECC (2000) Guideline values (pH 6.5 to 8.0) for the majority of sites and samples during much of the monitoring from February 2009 to July 2012.
- Mean total alkalinity was higher at Angus Creek (244 mg/L) than in Eastern Creek (120 mg/L) and ANOVA determined this difference to be significant ($p = 1.03E^{-09}$).
- Dissolved Oxygen (DO; % saturation) levels were low for all samples, at all sites, and below the ANZECC lower guideline value of 85 % saturation for both creeks. The mean value for Angus Creek was much lower than in Eastern Creek; and the ANOVA found there to be a significant difference in the DO values between the two creeks (p=0.003).
- Mean TN concentrations were elevated, and well above the ANZECC Guideline (0.5 mg/L) for all sites and both creeks. ANOVA found no significant differences between the two creeks (p=0.58).
- Mean TP concentrations were also above the ANZECC Guideline value (0.05 mg/L) for all sites and both creeks. Site AE2 recorded the highest mean TP value of all sites (0.24 mg/L) and AE3 the lowest (0.12 mg/L). There was no significant difference between the TP values for the two creeks (p=0.65)
- The mean turbidity levels of all Angus Creek sites were within the ANZECC Guideline (50 NTU). In contrast, mean turbidity of the Eastern Creek sites were above the guideline. Interestingly, Site AE4, the most downstream Eastern Creek site, recorded a lower mean turbidity value than Site AE5, which is upstream of the confluence with Angus Creek.

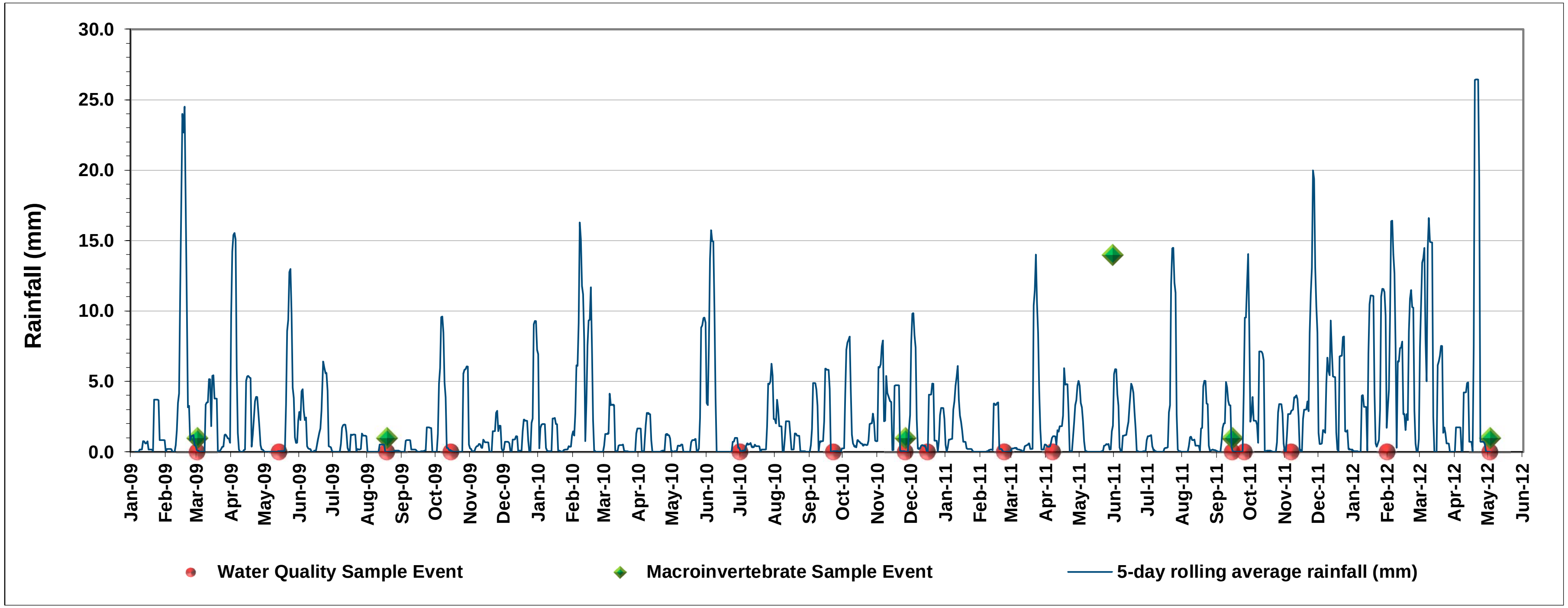

Figure 7 Rainfall at Horsley Park meteorological station (2009-12) and aquatic sampling events

Table 8 Summary statistics of rainfall at Horsley Park during the monitoring period

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean rainfall (mm) for years 1962 to 2001 (39 years)	97.6	94.9	101.0	85.3	68.8	71.3	40.2	55.9	45.6	61.6	78.3	67.4	867.7
Mean rainfall (mm) 2009	27.4	150.6	53.8	122.8	77.0	52.2	22.6	3.0	13.8	79.8	21.2	65.8	690.0
Mean rainfall (mm) 2010	25.2	139.6	32.4	16.2	63.4	83.6	37.4	26.6	58.8	62.0	95.6	79.2	720.0
Mean rainfall (mm) 2011	39.8	18.4	49.6	67.6	14.0	49.8	76.2	32.4	82.8	64.0	156.2	105.2	756.0
Mean rainfall (mm) 2012	135.0	189.4	187.6	169.8	13.2	102.2	22.6	8.6	-	-	-	-	-

Table 9 Mean values of water quality parameters at the water quality monitoring sites*

Site/ Creek	Temp (°C)	EC (µS/cm)	pH	DO (mg/L)	DO (%sat.)	TN (mg/L)	TP (mg/L)	Alkalinity (mg/L)	Turbidity (NTU)
AE1	15.7	2221	7.47	3.03	29.3	1.02	0.17	246.8	6.6
AE2	15.7	1927	7.44	2.17	20.5	0.95	0.24	217.8	26.2
AE3	16.2	1691	7.22	2.73	26.7	1.62	0.12	207.3	9.4
AE6	16.6	3489	7.35	4.11	40.6	1.01	0.17	304.0	9.7
Angus Creek	16.0	2332	7.37	3.01	29.3	1.15	0.17	244.0	13.0
AE4	16.4	1076	7.06	3.68	35.5	1.27	0.15	124.8	79.9
AE5	16.3	946	7.21	5.44	53.2	1.32	0.15	116.3	92.6
Eastern Creek	16.4	1011	7.14	4.56	44.4	1.29	0.15	120.5	86.2
All Sites	16.2	1891	7.29	3.52	34.3	1.20	0.16	202.8	37.4
ANZECC (2000)	N/A	125 - 2200	6.5 - 8.0	n/a	80-110	0.5	0.05	n/a	50

* Values highlighted in yellow are outside the respective ANZECC (2000) Guideline

The following sections provide graphical representations and relevant discussions on individual water quality parameters.

3.3.1 Electrical Conductivity (EC)

Electrical conductivity measures the amount of total dissolved salts (TDS), or the total amount of dissolved ions in water. The salts are usually composed of the sulphate, bicarbonate, and chlorides of calcium, magnesium, and sodium.

EC is primarily controlled by the geology **(**rock types and composition) of a catchment area, which determines the chemistry of a catchment's soil and ultimately the amounts of ions present in waterways draining the catchment. For example, limestone leads to higher EC, because of the dissolution of carbonate minerals.

EC values, above 1500 µS/cm, are known to be harmful to freshwater organisms, and the recommended ANZECC (2000) Guideline for freshwater rivers in NSW is 125-2200 µS/cm.

- The average EC for Angus Creek: 2163 µS/cm, was significantly higher than the value for the Eastern Creek Sites, which recorded an average of 978 µS/cm. ANOVA confirmed the differences between the two creeks with regard to EC as significant ($p=7.03E^{-07}$).
- Mean values for EC from two sites in Angus Creek (AE1 and AE6) were well above the ANZECC Guideline indicating high ionic concentrations. In particular, from March 2009 to February 2011, Site AE6, at the most upstream location of Angus Creek, recorded a high EC value, for the majority of sampling events (Figure 8).
- Similarly, EC values at Angus Creek Sites AE1, AE2 and AE3 were also well above the upper guideline value in May 2009, but fluctuated below the upper guideline for the majority of subsequent sampling events, with some exceptions.
- EC values of the Eastern Creek sites (AE4 and AE5) were also generally elevated; indicating high ionic content, but levels fluctuated within the guideline.

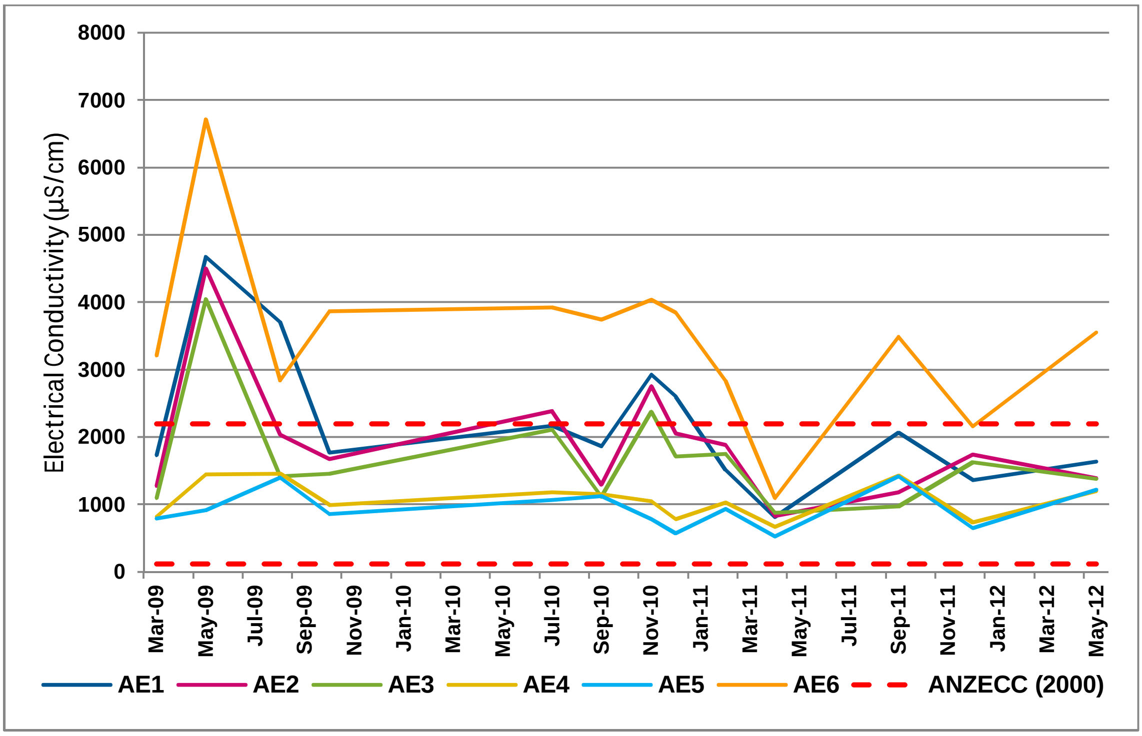

Figure 8 Electrical Conductivity recorded at the water quality monitoring sites

3.3.2 pH

The pH values of both creeks were within the ANZECC (2000) Guideline (pH 6.5 to 8.0) for the majority of sites and samples during much of the monitoring from February 2009 to July 2012.

The average value for Angus Creek (pH = 7.39) was significantly higher than the average value for the Eastern Creek (pH = 7.14) sites (p=0.03).

The few exceptions of non-compliant results (Figure 9) were the following:

- Alkaline pH, above pH 8.0, at AE6 in August 2009 and AE2 in December 2010; and
- Acidic pH, below pH 6.5, at AE3, AE4 and AE6 in December 2010

These instances are considered somewhat unusual, and transient, and could be related to a rain event, stormwater run-off, or an unknown discharge from the upstream catchments. Despite these instances, the capability of the waterways to resist pH changes (i.e. ‘buffering capacity’) is evident in the results (see Alkalinity below).

3.3.3 Total Alkalinity

Alkalinity is a total measure of the substances in water that have "acid-neutralizing" ability. The measurement indicates a solution’s power to react with acid and "buffer" its pH. The most important compounds in water that determine alkalinity include the carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions. Carbonate ions react with and neutralize hydrogen ions (H^+) and the bicarbonate ions are able to neutralize H^+ or hydroxide ions (OH^-) present in water.

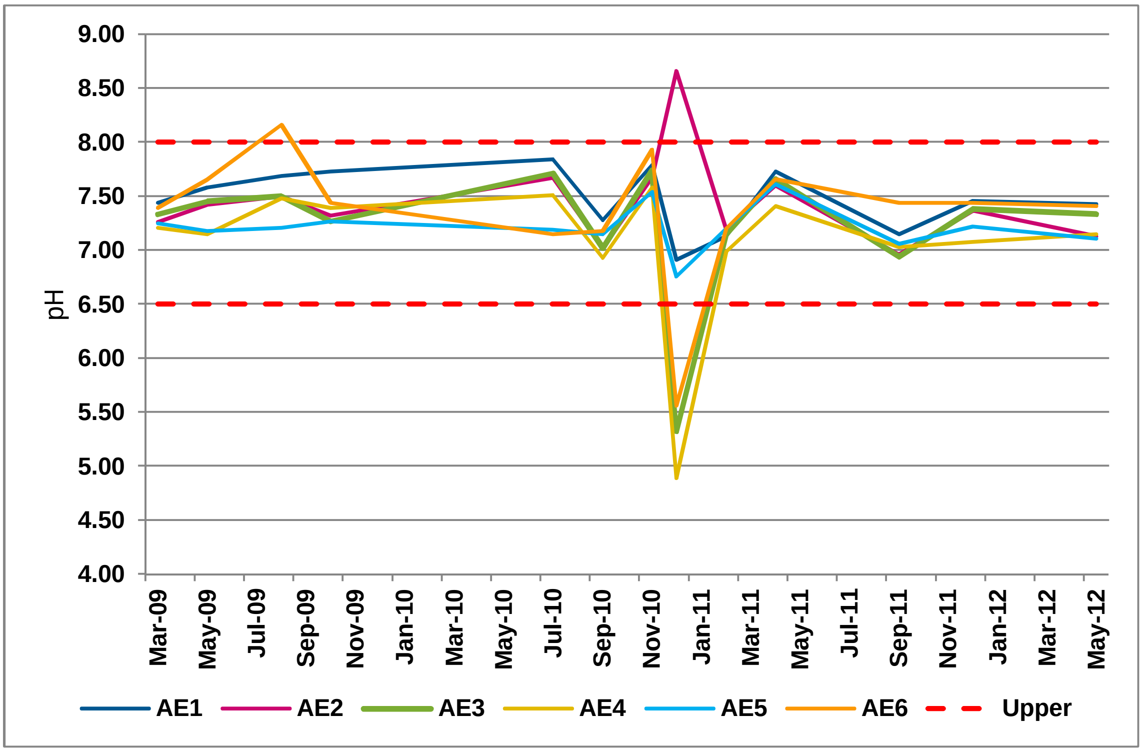

Figure 9 pH values recorded at the water quality monitoring sites

Alkalinity is important for fish and aquatic life because it protects or buffers against pH changes (keeps the pH fairly constant) and makes water less vulnerable to acid rain. The main sources of natural alkalinity are rocks, which contain carbonate, bicarbonate, and hydroxide compounds. Borates, silicates, and phosphates may also contribute to alkalinity.

Limestone is rich in carbonates; so water flowing through limestone will have high alkalinity and good buffering capacity. Conversely, granite does not have minerals that contribute to alkalinity; hence, water flowing through areas rich in granite has low alkalinity and poor buffering capacity.

Aquatic organisms benefit from a stable pH value in their optimal range. To maintain a fairly constant pH in a water body, a higher alkalinity is preferable. High alkalinity means that the water body has the ability to neutralize acidic pollution from rainfall or basic inputs from stormwater or wastewater.

A well buffered waterway also means that daily fluctuations of CO_2 concentrations result in only minor changes in pH throughout the course of a day. The buffering of acidity prevents harmful metal ions (such as Cadmium, Cd; Copper, Cu; Chromium, Cr; Lead, Pb; Nickel, Ni; and Zinc, Zn) in the sediments from dissolution, and thereby, has a protective function.

The range of water "hardness", measured by mg/L of $CaCO_3$, provides the context for evaluating the effect of alkalinity (a surrogate for buffer capacity). Extremely 'hard water', rich in Ca^{2+}, Mg^{2+} and other cations, would be in the range of 250-400 mg/L of alkalinity.

The monitoring data showed that the mean total alkalinity was higher at Angus Creek (244 mg/L) than in Eastern Creek (120 mg/L); and ANOVA indicated that this difference was significant ($p=1.03E^{-09}$).

Figure 10 shows the variation of alkalinity at the individual sites: AE1, AE2, AE3 and AE6 in Angus Creek, which would be regarded as 'very' or 'extremely' hard water. In contrast, alkalinity at the sites AE4 and AE5 in the Eastern Creek, varied much less, and were significantly lower than in Angus Creek.

The broad implication of these results is that both creeks are, not surprisingly, well buffered. Alkalinity levels of 100 to 200 mg/L are known to stabilize pH of a stream. Because aquatic organisms are adapted to living in restricted pH ranges (which are reflected in ANZECC Guidelines), they are likely to thrive better in more stable, buffered environments.

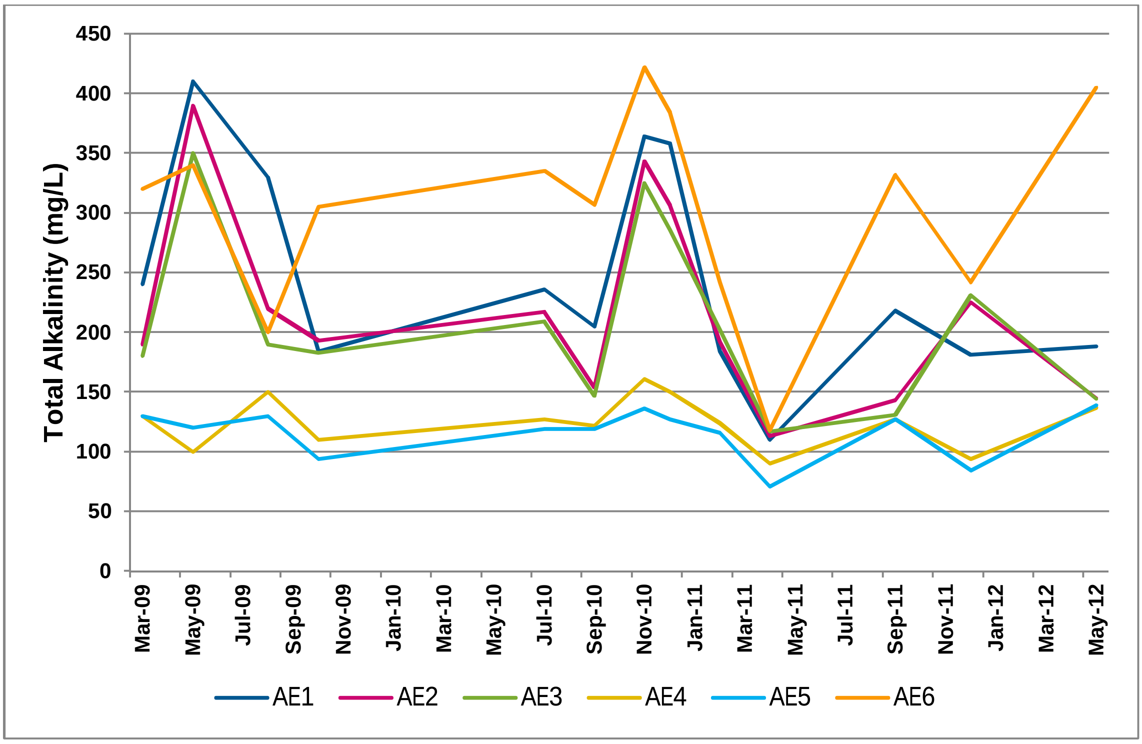

Figure 10 Total alkalinity values recorded for water quality monitoring sites

3.3.4 Total Nitrogen (TN)

Total Nitrogen was above the ANZECC (2000) Guideline of 0.5 mg/L for >90% of samples from all sites, with the exception of a few instances. These were: at Site AE1 in December 2010 and at Sites AE2 and AE3 in September 2010 (Figure 11). ANOVA revealed that there was no significant difference (p=0.89) between the two creeks for TN concentrations.

The average TN values for the two creeks were 3-times above the ANZECC Guideline (i.e. 1.42 mg/L and 1.38 mg/L for Angus Creek and Eastern Creek, respectively), indicating serious nitrogen enrichment.

The highest value for TN recorded was at Angus Creek Site AE3 in December 2011 (9.5 mg/L), 9-times above the guideline. Whilst this may be regarded as an inexplicable event, high TN values, recorded intermittently, confirm the propensity for regular inputs of nutrients from the upstream catchment, possibly associated with rain events and stormwater runoff.

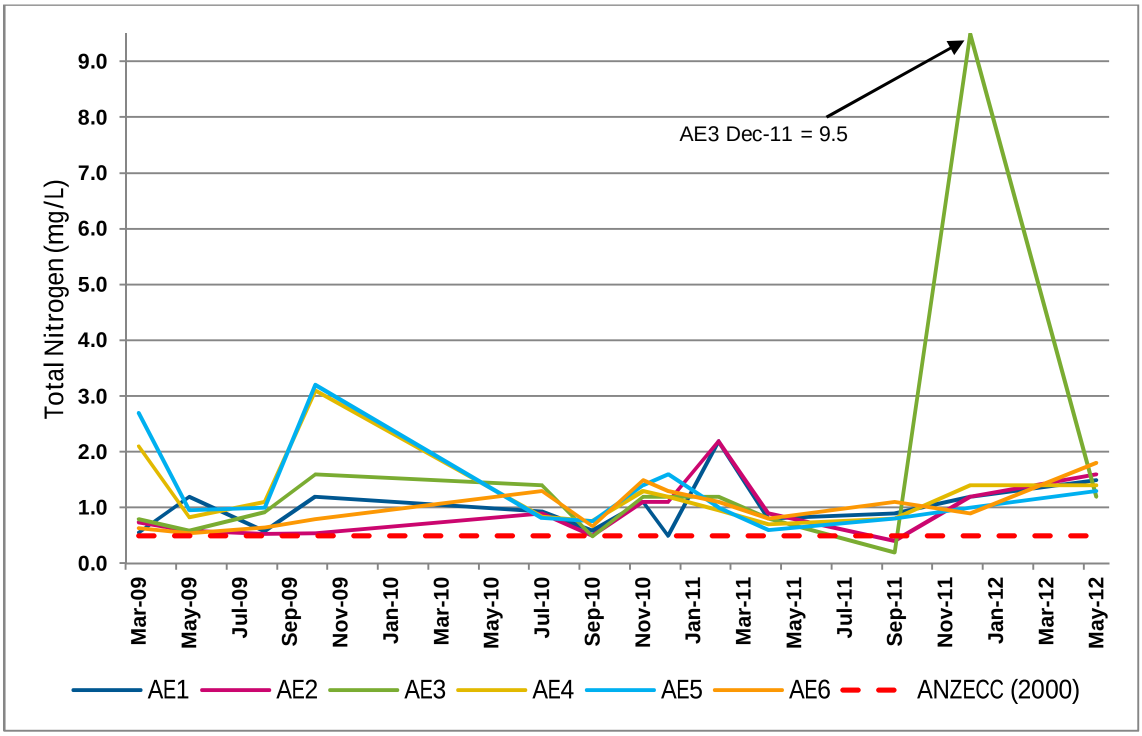

Figure 11 TN concentrations recorded at the water quality monitoring sites

3.3.5 Total Phosphorous (TP)

Total Phosphorous concentrations were about 4-8 times above the ANZECC (2000) Guideline value of 0.05 mg/L for the majority of sites and samples. Despite this, all sites recorded TP levels below the guideline during the sampling events in April and September 2011 (Figure 12).

During the sampling event in February 2011, two Angus Creek Sites recorded the highest TP levels (i.e. AE2: 1.3 mg/L; and AE1: 1.1 mg/L). These are probably related to moderate rainfall events, which occurred in late-February, early-March in 2011 (see Figure 7), just prior to the water quality sampling event.

The average TP concentration in Angus Creek (0.20 mg/L) was higher than the average for Eastern Creek (0.16 mg/L), although ANOVA did not show this difference to be significant ($p=0.52$). The high levels of TP in both creeks confirm the current poor state of water quality in the creeks, largely due to nutrient enrichment.

High TP, combined with high TN, are known to make the waterways highly productive, conducing to algal growth, and particularly susceptible to cyanobacterial blooms. Such conditions also support the excessive growth of floating aquatic plants, such as *Azolla*.

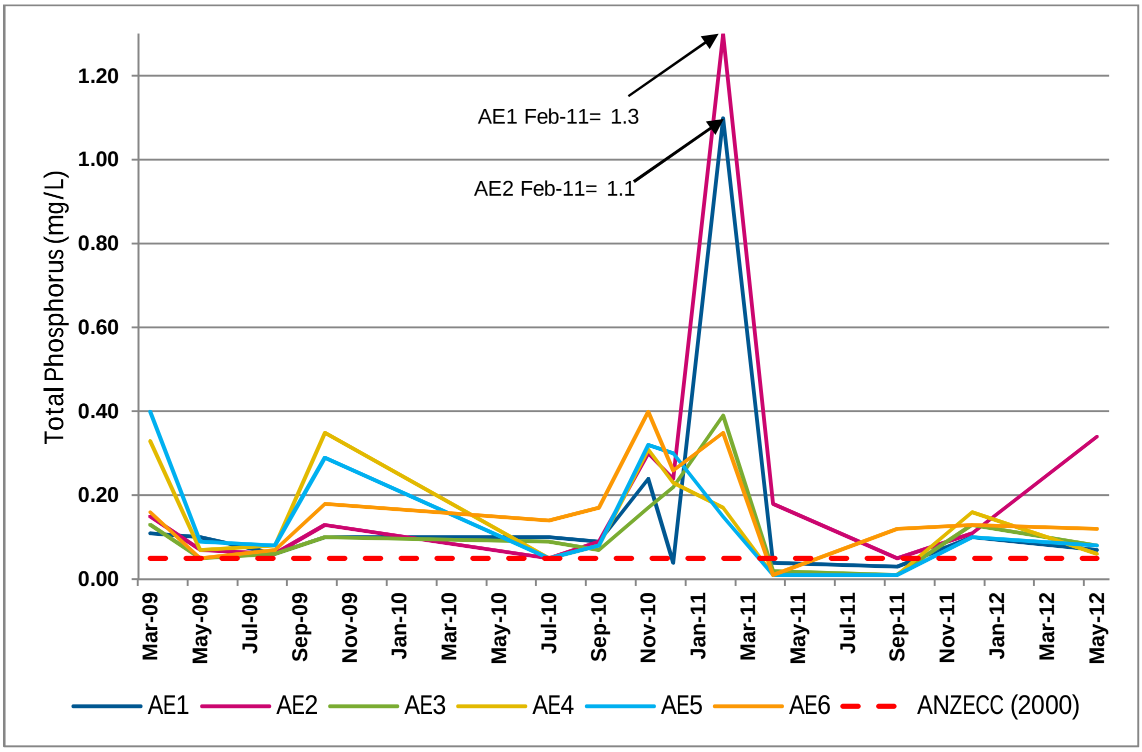

Figure 12 TP concentrations recorded at the water quality monitoring sites

3.3.1 Dissolved Oxygen

Overall, the measurements of DO (% saturation) indicated very poor water quality in both creeks with regard to this important water quality parameter. All but a few DO measurements were within the ANZECC (2000) Guideline range, for all sites and samples collected from March 2009 to May 2012 (Figure 13).

One sample at AE6 in August 2009 was above the upper guideline value of 110 % while all other samples at all sites were below the lower guideline value of 85 %. The lowest DO value (3.8 %) was recorded at AE1 in February 2011, and most sites recorded their lowest value during this sampling event.

ANOVA showed the average DO value for Angus Creek (34.23 %) to be significantly lower (p=0.03) than the average value for Eastern Creek (46.22 %). Although DO levels in freshwater streams can be variable, the tendency for low DO in Angus Creek is evident in the measurements, and indicates poorer water quality and aquatic health in the Angus Creek, compared to the Eastern Creek.

3.3.2 Turbidity

Turbidity is a direct measure of suspended solids, and is one of the biggest sources of stream water pollution. When suspended particles settle to the bottom of a water body, they become sediments, referred to as "silt". Water with high sediment loads is "muddy" or turbid in appearance, because the force of moving water keeps the sediment particles suspended.

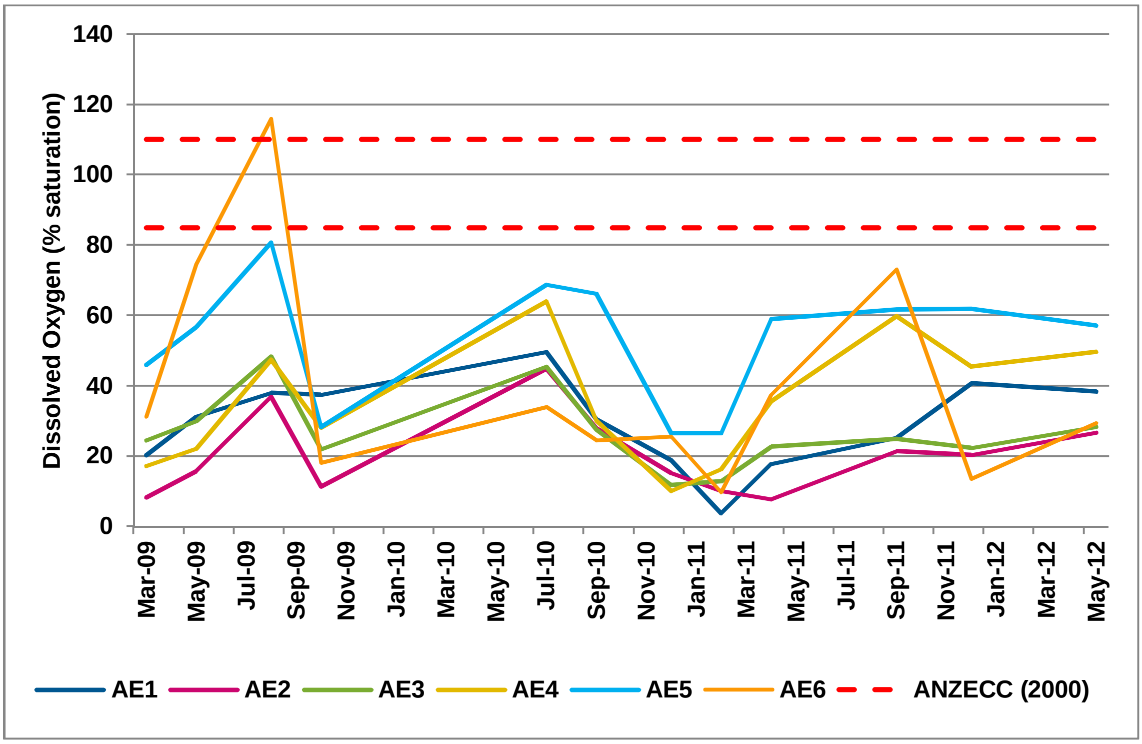

Figure 13 Dissolved Oxygen concentrations recorded at the water quality monitoring sites

Suspended solids consist of an inorganic fraction (small mineral particles, silts, clays, etc.) and an organic fraction (algae, zooplankton, bacteria, and detritus), which are carried along by water as it runs off the land. Both contribute to turbidity, or cloudiness of the water.

Higher TSS (>1000 mg/L) may greatly affect water use by limiting light penetration and can limit aquatic life through sedimentation of suspended matter. TSS-levels and fluctuations influence aquatic life, from phytoplankton to fish.

Figure 14 shows the variation of turbidity at the monitored sites.

- Turbidity levels were mostly within the ANZECC Guideline (50 NTU) for the Angus Creek sites (AE1; AE2; AE3 and AE6).
- In contrast, Eastern Creek had a much higher suspended solids load than Angus Creek, with higher turbidity measurements (commonly >50 NTU) recorded on all sampling occasions (Plate 1).
- In the Eastern Creek, Site AE5, which is upstream of the confluence with Angus Creek, recorded higher turbidity levels and wide fluctuations, compared with Site AE4 located downstream of the confluence.
- The high turbidity values in the Eastern Creek points to significant erosion, as a result of fast flows, and adverse influences of drainages from various sites in the upstream catchments, compared with Angus Creek.

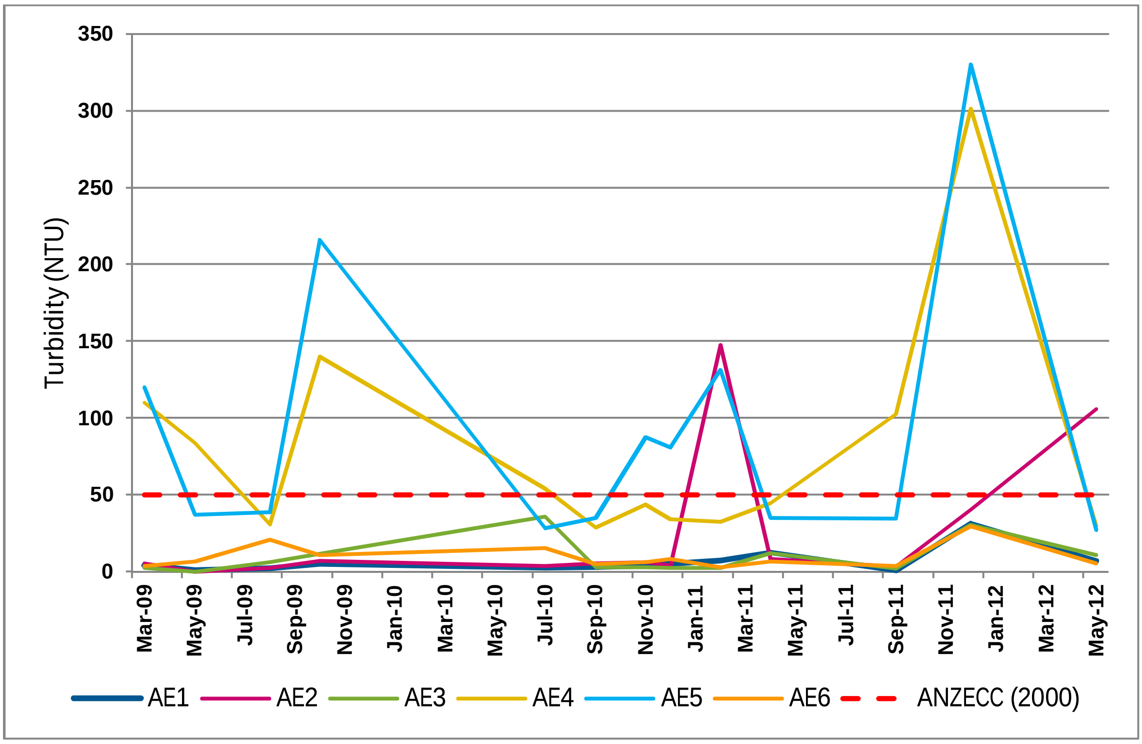

Figure 14 Turbidity values recorded for water quality monitoring sites

Plate 1 High Turbidity commonly encountered in Eastern Creek

3.4 Macroinvertebrate Ecology

3.4.1 Univariate Indices

A total of 61 macroinvertebrate taxa were recorded across the study area, 50 of which were from Angus Creek and 46 from the Eastern Creek. A summary table of macroinvertebrate indices for combined season data is provided in Table 10.

- Site AE5 recorded the highest total taxa richness and EPT taxa richness of all sites (39 and 5 respectively) and the highest richness values of the Eastern Creek sites. AE5 also consistently recorded the highest taxa richness over the sampling period (Figure 15). Site AE3 recorded the highest taxa richness of the Angus Creek sites (34). Both AE3 and AE1 from Angus Creek sites recorded taxa from the sensitive EPT taxa groups.
- SIGNAL2 scores were consistently low for all sites with AE5 scoring the highest SIGNAL 2 score (3.22). Such low scores across the region are indicative of macroinvertebrate communities dominated by taxa tolerant of physical and chemical stressors.
- Analysis of the SIGNAL2 bi-plot (Figure 16) showed the majority of samples to fall in Quadrant 2 (from Figure 2), which represents lower SIGNAL2 scores and a moderate to high diversity of macroinvertebrate taxa (Number of Families). Results in this Quadrant often indicate high salinity or nutrient enrichment.
- As shown in Figure 16, Sites AE2 and AE6 (both from Angus Creek) were the only sites to have samples outside Quadrant 2 with two samples from each of these site having taxa richness values <15, placing these samples in Quadrant 4.
- Results in Quadrant 4 represent the lowest values of both the SIGNAL2 score and the number of macro-invertebrate families and types. Such results indicate severe urban, industrial or agricultural pollution, and severely de-pauparate macro-invertebrate communities. Both sites AE2 and AE6 had one sample from 2011; however these were from different seasons in that year.
- The majority of samples were assessed by AUSRIVAS to be severely impaired (Band C) and far fewer families were observed than expected, indicating impoverished macro-invertebrate communities.
- The average SIGNAL2 value of macroinvertebrate taxa expected to occur, but were not observed was 5.63. This indicates that sensitive taxa constitute a large proportion of taxa expected by the model, but these were not observed in the sample data.
- Two samples, both from AE5 were assessed to be significantly impaired (Band B) and six samples were outside the experience of the AUSRIVAS model.

Upon further investigation of the environmental variables, it was evident that all samples which were outside the experience of the AUSRIVAS model had high alkalinity, at or above 250 mg/L.

To force a result for these samples, alkalinity values were reduced to 200 mg/L and the AUSRIVAS model was re-run. Results of this analysis are provided in Table 11 and all samples were assessed to be severely impaired (Band C).

Table 10 Macroinvertebrate indices for combined season data and total for each monitoring site

Site Code	Year	Taxa Richness (Number of Families)	EPT Taxa Richness	SIGNAL 2 Score	AUSRIVAS O/E 50	AUSRIVAS Band
AE1	2009/09	21	1	3.16	*	*
	2010/11	16	0	2.86	0.23	C
	2011/11	18	0	3.06	0.23	C
	2011/12	18	0	3.19	0.24	C
	Total	28	1	3.12	N/A	N/A
AE2	2009/09	19	0	2.50	*	*
	2010/11	21	0	2.58	0.40	C
	2011/11	14	0	2.83	0.34	C
	2011/12	15	0	3.07	0.24	C
	Total	28	0	2.73	N/A	N/A
AE3	2009/09	21	0	3.00	*	*
	2010/11	21	1	2.89	0.35	C
	2011/11	18	0	2.81	0.18	C
	2011/12	19	0	2.53	0.23	C
	Total	34	1	2.78	N/A	N/A
AE4	2009/09	26	1	2.65	0.46	C
	2010/11	22	1	2.95	0.36	C
	2011/11	19	1	3.06	0.30	C
	2011/12	27	1	2.83	0.43	C
	Total	36	1	2.82	N/A	N/A
AE5	2009/09	26	4	3.08	0.52	B
	2010/11	25	2	3.22	0.47	C
	2011/11	22	1	3.05	0.29	C
	2011/12	29	2	2.85	0.66	B
	Total	39	5	3.31	N/A	N/A
AE6	2009/09	13	0	2.54	*	*
	2010/11	15	0	2.87	*	*
	2011/11	18	0	2.73	0.18	C
	2011/12	25	0	2.55	*	*
	Total	33	0	2.77	N/A	N/A

* Outside experience of AUSRIVAS model; N/A AUSRIVAS model not applicable

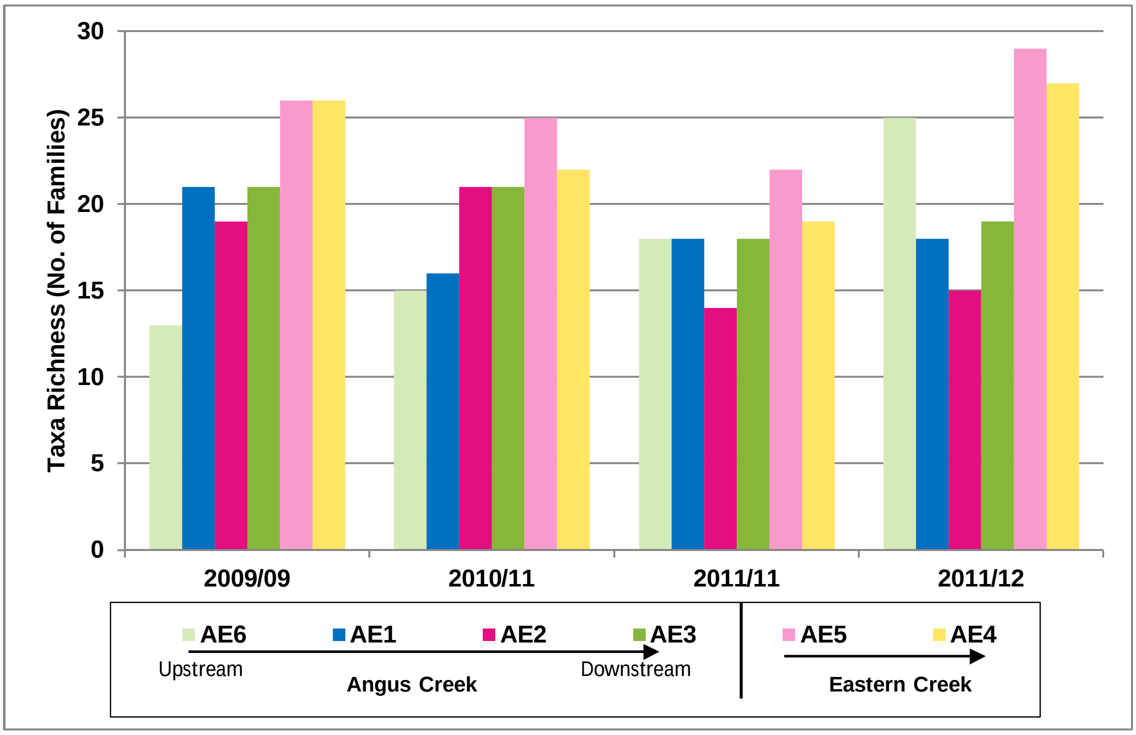

Figure 15 Taxa richness results for combined season macroinvertebrate data

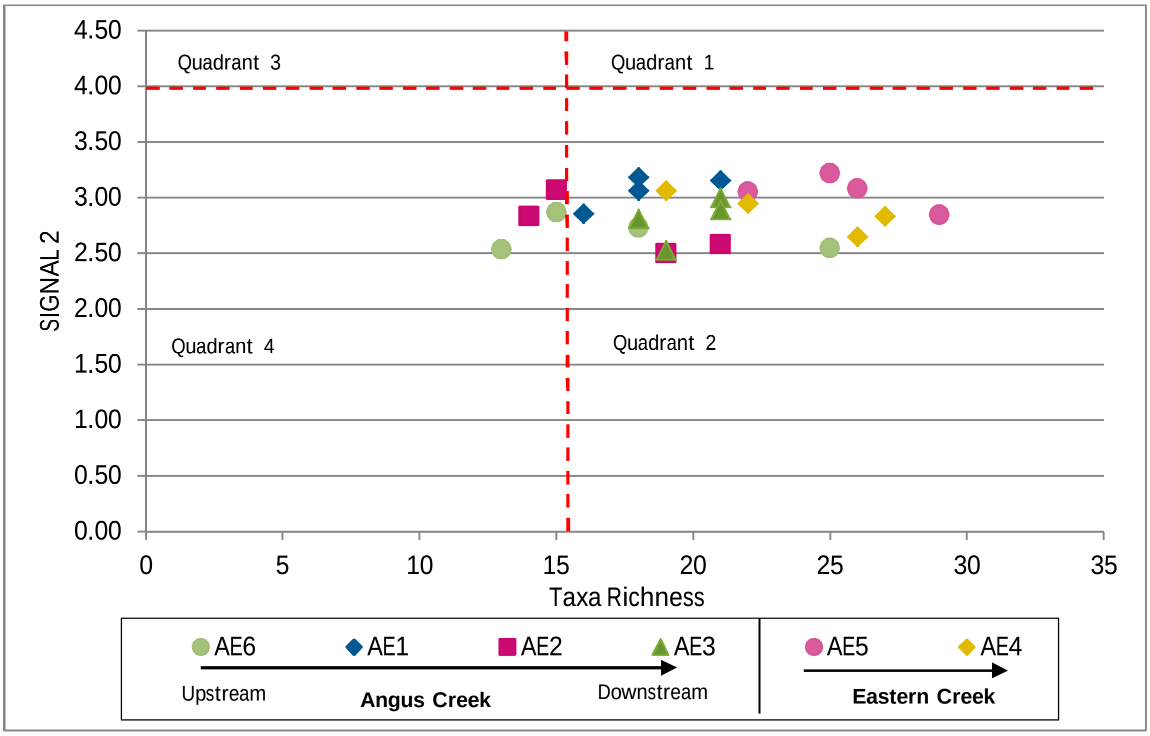

Figure 16 SIGNAL 2 bi-plot for all macroinvertebrate data

Note: The dashed red line indicates interim SIGNAL 2 boundaries for NSW (Chessman, 2001)

Table 11 Results for samples forced to run in the AUSRIVAS model by reducing alkalinity values

Site Code	Year	Taxa Richness	EPT Taxa Richness	SIGNAL 2 Score	AUSRIVAS O/E 50	AUSRIVAS Band
AE1	2009/09	21	1	3.16	0.18	C
AE2	2009/09	19	0	2.50	0.23	C
AE3	2009/09	21	0	3.00	0.37	C
AE6	2009/09	13	0	2.54	0.18	C
	2010/11	15	0	2.87	0.41	C
	2011/12	25	0	2.55	0.35	C

3.4.1 Multivariate Analysis

Analysis of macroinvertebrate community composition data generally showed few spatial or temporal trends when all sites were considered, for the duration of the study. The exception was the factor: influence of the creek sampled.

Cluster analysis of single season macroinvertebrate data showed the factor of creek best explained the macroinvertebrate community composition (Figure 17). The majority of Eastern Creek samples separated from the other data at 55% similarity. Two samples from AE4 were the only Eastern Creek samples not to separate from the Angus Creek data.

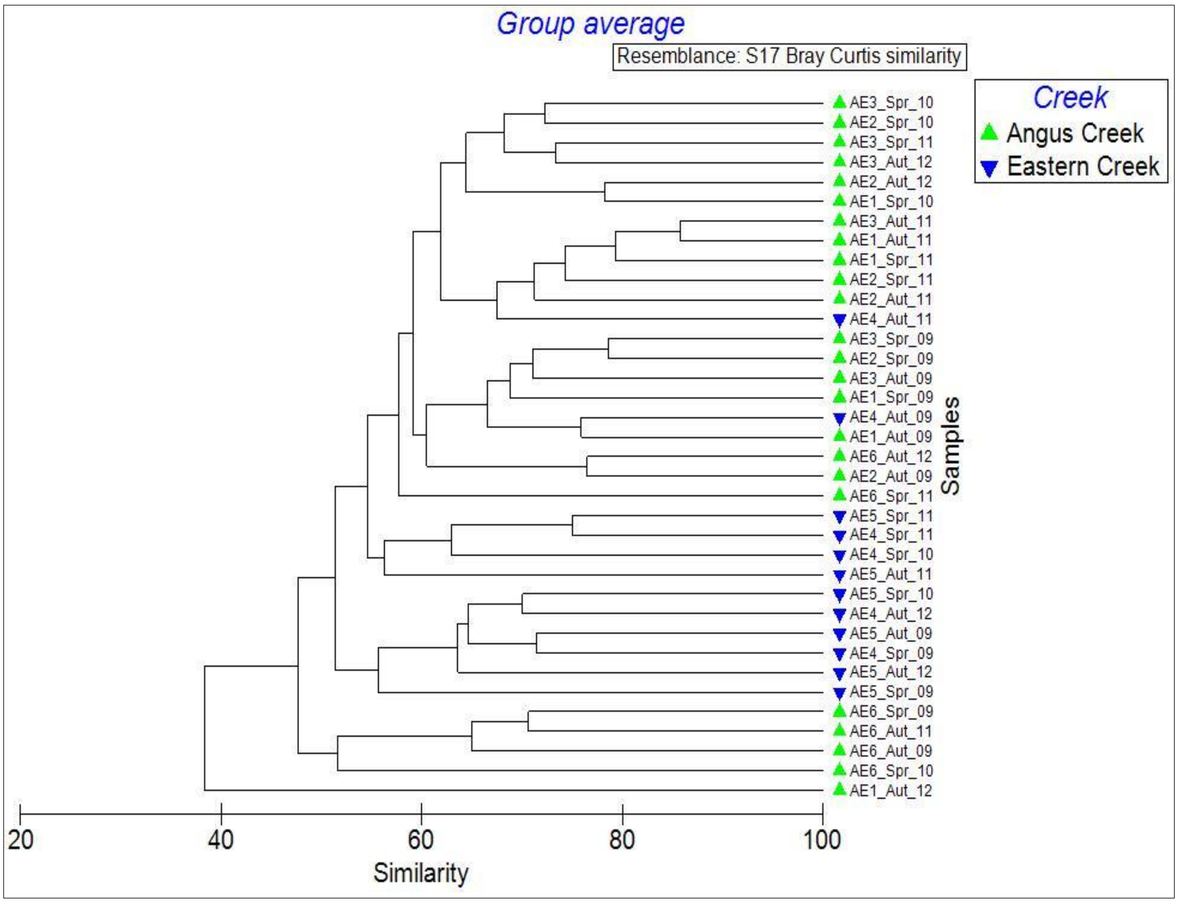

Figure 17 Cluster analysis of macroinvertebrate data showing the similarity of sites based on creek

- The ANOSIM analysis confirmed that the factor of Creek best explained the variation in macroinvertebrate community composition data across the study area (Global R=0.403, p=0.001). Site Code was also a factor that partly explained the variation in composition of samples, although the relationship was weak (Global R=0.323, p=0.001).
- ANOSIM indicated that there was no significant difference between seasons (Global R=0.016, p=0.279); or location relative to the RDC (upstream/downstream) (Global R=0.027, p=0.195).
- NMDS analysis also confirmed that the creek from which samples were collected was the most important factor explaining community composition data and there was clear seperation of Eastern Creek samples from the Angus Creek samples (Figure 18).

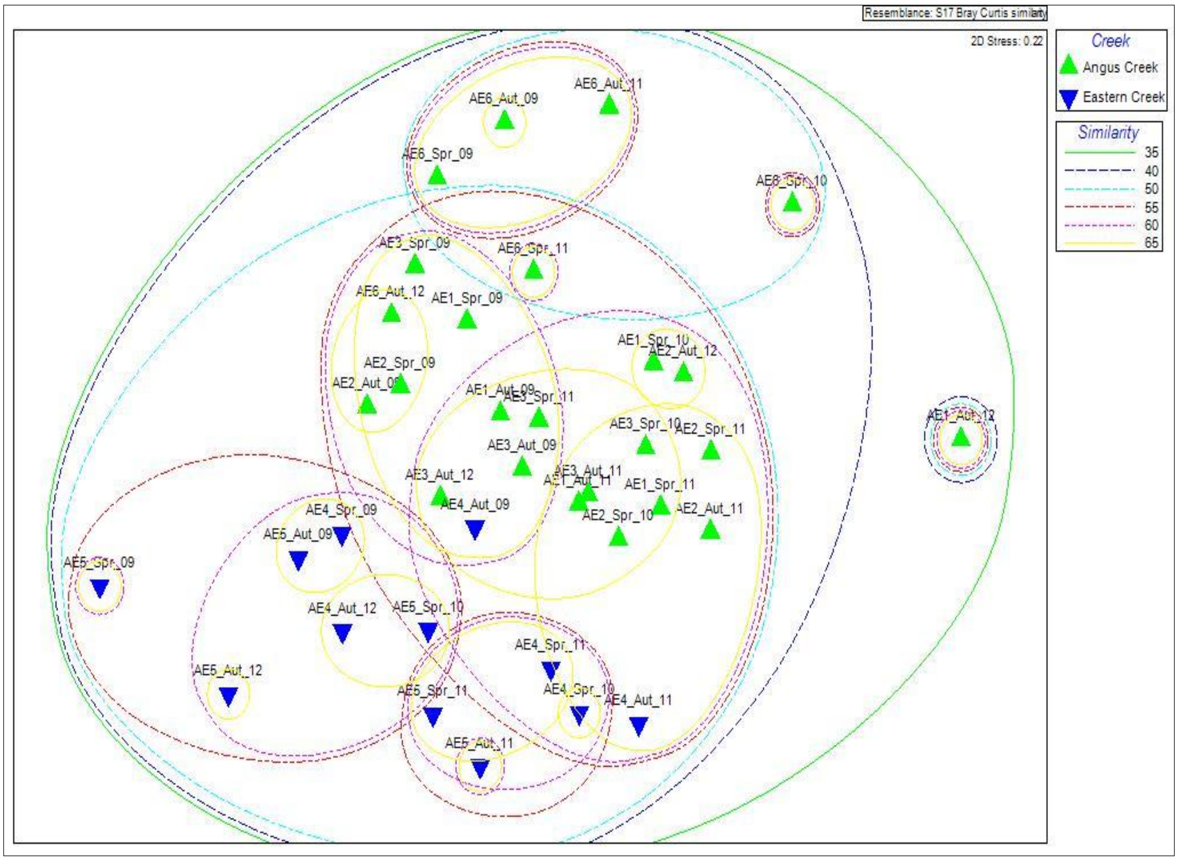

Figure 18 NMDS ordination of macroinvertebrate data showing the influence of creek on macroinvertebrate community composition

- SIMPER analysis of single season macroinvertebrate data showed Angus Creek sites to have a slightly higher average similarity (58.22%) than eastern Creek sites (57.08%) and the average dissimilarity between the two creek groups to be moderate (50.22%).
- SIMPER analysis also showed that the key taxa resposnible for the difference between the creek groups were quite varied taxonomicaly with the top 6 taxa contributing to over 25% of the difference between creek groups belonging to different macroinvertebrate Orders (Table 12).

Table 12 SIMPER results of the key macroinvertebrate taxa contributing to more than 55% of dissimilarity between creeks

Order	Family	SIGNAL 2 Score	Angus Creek Average Abundance	Eastern Creek Average Abundance	Av. Dissimi -larity	Diss/ SD	Contrib %	Cum.%
Hemiptera	Corixidae	2	0.04	0.83	2.56	1.94	5.09	5.09
Gastropoda	Hydrobiidae	4	0.92	0.33	2.1	1.29	4.18	9.26
Decapoda	Atyidae	3	0.04	0.67	2.02	1.34	4.03	13.3
Odonata	Isostictidae	3	0.38	0.92	1.99	1.2	3.97	17.26
Trichoptera	Leptoceridae	6	0	0.58	1.85	1.15	3.69	20.96
Crustacea	Cladocera	N/A	0.04	0.58	1.84	1.14	3.66	24.61
Crustacea	Copepoda	N/A	0.46	0.58	1.66	0.99	3.3	27.91
Odonata	Zygoptera	N/A	0.5	0.75	1.62	0.98	3.23	31.14
Crustacea	Ostracoda	N/A	0.54	0.67	1.58	0.95	3.15	34.29
Acarina	sp.	6	0.42	0.42	1.57	0.95	3.13	37.41
Collembola	Sp.	1	0.33	0.5	1.56	0.99	3.11	40.52
Gastropoda	Physidae	1	0.54	0.83	1.55	0.93	3.09	43.61
Diptera	Stratiomyidae	1	0.42	0.42	1.54	0.95	3.07	46.68
Turbellaria	Dugesiidae	2	0.58	0.75	1.49	0.9	2.96	49.64
Odonata	Megapodagrionidae	5	0.83	0.58	1.46	0.88	2.91	52.55
Coleoptera	Hydrophilidae	2	0.21	0.42	1.39	0.9	2.76	55.31

3.5 Aquatic Habitat

3.5.1 Angus Creek

The natural aquatic habitat in Angus Creek was severely restricted by the impacts and stresses of a heavily urbanised catchment. Large amounts of gross pollutants occurred within the stream and on riparian vegetation and snags, including general litter, car batteries and vehicle parts.

Anoxic sediment odour and the presence of algae blooms on several sampling occasions indicated poor, submerged habitat conditions. Iron precipitates were also observed in several areas, seeping out of banks and as build-up in slow moving water.

Evidence of high peak flows was present in Angus Creek. Some in-stream edge habitat and littoral vegetation had visible signs of scouring and there was little Coarse Particulate Organic Matter (CPOM) and in-stream debris for biological processing.

High velocity, peak flows of a short duration are probably a result of the nature of the primarily urbanised land-use within the catchment. The impervious surfaces and extensive stormwater interconnectivity are likely to increase the volume of runoff over a shorter period, when compared to a similar catchment in a more natural environment. These aspects have significant implications for the aquatic ecosystems within the study area.

Minimal stream bank, trailing vegetation and debris were present at most Angus Creek sites. Some submerged and emergent vegetation was present, although this was generally sparse.

A moderate amount of in-stream vegetation was present at the upstream site AE6, compared to other sites. This may be possibly due to a lower percentage of canopy cover and less shade at this site, relative to the other sites.

The substrate in Angus Creek was primarily silt and clay with limited sand and some areas of pebble and gravel build-up. The banks of the creek were generally steep and around 1-2 m high. The width of the creek varied between 0.5-5 m, with a mean width of around 1 m.

3.5.2 Eastern Creek

The aquatic habitat in Eastern Creek was similar to that of Angus Creek and deemed poor in quality, visibly disturbed by the impacts of urbanisation. Large amounts of gross pollutants were observed, as well as significant algal blooms, which covered large sections of the waterway on several sampling occasions.

The most obvious difference between the two creeks was the consistently low water visibility in Eastern Creek, due to high suspended solids, and a larger quantity of large woody debris within the stream channel. Evidence of high peak flows and associated scouring was present and little vegetation was present with 1 m of the normal waterline for the duration of the study.

Large woody debris generally remained in the channel, as well as a thick layer of Casuarina needles in some areas. No submerged macrophytes were observed in the creek and recruitment and growth of aquatic vegetation may be inhibited by the generally higher turbidity and limited light penetration through the water column.

The substrate in Eastern Creek was difficult to observe due to high turbidity and deeper channel habitat. Silt and clay were the dominant substrate category evident from sediment plumes and some large boulders were also noted protruding from the water at various places in the channel.

The channel widths in the assessed reaches of Eastern Creek were about 6-12 m; with an average width of approximately 10 m. Stream banks were higher and steeper than those of Angus Creek, with an average bank height closer to 4 m.

3.6 Vegetation

Results of the vegetation surveys are presented in Appendix A. Table 20 provide the complete flora list; and Table 21 provides the occurrence of species, recorded from two transects, at each of the AE sites.

The frequencies of occurrence of individual species were determined by the line intercept method and were used to indicate the % abundance of individual species and groups of plants.

The results are discussed in the sections below.

3.6.1 Significant (Listed) Species and Communities

As reported in the previous annual reports (Ecowise, 2010; ALS, 2011), two Endangered Ecological Communities (EECs) and a single vulnerable species, listed in the NSW *Threatened Species Conservation ACT* of NSW were recorded within the monitored sites (Table 13).

Table 13 Endangered Ecological Communities and Threatened Species in the vicinity of the RDC Site and Study area

Common Name (Species Name)	*TSC Act Status	*EPBC Act Status	Habitat Association	Likelihood of Occurring within assessed sites
Cumberland Plains Woodlands	E	E	Cumberland Plain Woodlands occur in the Auburn, Bankstown, Baulkham Hills, Blacktown, Camden, Campbelltown, Fairfield, Hawkesbury, Holroyd, Liverpool, Parramatta, Penrith and Wollondilly LGAs (NPWS, 2002a, NPWS, 2002b; NPWS, 2004a). The EEC has two forms — Shale hills woodland and Shale plains woodland. Shale Hills Woodland occurs mainly on the elevated and sloping southern half of the Cumberland Plain. The dominant canopy trees include grey box (*Eucalyptus moluccana*), forest red gum (*E. tereticornis*) and narrow-leaved ironbark (*E. crebra*). It has a shrub layer dominated by blackthorn (*Bursaria spinosa*), with other shrubs, such as *Acacia implexa*, *Indigofera australis* and *Dodonaea viscosa ssp cuneata* (Benson & Howell, 2000). Shale plains woodland is the most widely distributed form of Cumberland Plain Woodland. *Bursaria spinosa* is the dominant shrub species and there are canopy trees such as grey box (*E. moluccana*), forest red gum (*E. tereticornis*), spotted gum (*Corymbia maculata*) and thin leaved Stringybark (*E. eugenioides*). The diverse understorey layer is similar for both forms of the EEC. It is common to find grasses, such as kangaroo grass (*Themeda australis*), weeping meadow grass (*Microlaena stipoides var stipoides*) and herbs, such as kidney weed (*Dichondra repens*), blue trumpet (*Brunoniella australis*) and *Desmodium varians*. Clearing for agriculture and urban development is the greatest threat to Cumberland Plain Woodland. Because it exists now only in fragments, Cumberland Plain Woodland is vulnerable to disturbances, such as weed invasion, increased soil nutrients, rubbish dumping and frequent fire. Weeds, such as African lovegrass, African olive, bridal veil creeper and Rhodes grass are a major threat.	Unlikely to occur in their pre-European state, but remnants exist, along with appropriate habitat. Refer to Map (Figure 19)
Sydney Coastal River Flat Forest	E	E	Sydney Coastal River Flat Forest occurs along the extensive riverbanks and floodplain sites of the Cumberland Plain, particularly along the Hawkesbury-Nepean river system. The EEC is now reduced to 5446 ha, which is 13.9% of its original distribution (NPWS, 2002a, 2002b; 2004a). Remaining pockets occur in the Auburn, Bankstown, Baulkham Hills, Blacktown, Camden, Campbelltown, Fairfield, Hawkesbury, Holroyd, Hurstville, Liverpool, Parramatta, Penrith, Sutherland and Wollondilly LGAs. Two main forms of the EEC have been identified —Riparian Forest and Alluvial Woodland (Benson & Howell, 2000).	Unlikely to occur in their pre-European state, but remnants exist, along with appropriate habitat.

Table 13 (cont.) Endangered Ecological Communities and Threatened Species in the vicinity of the RDC Site and Study area

Common Name (Species Name)	*TSC Act Status	*EPBC Act Status	Habitat Association	Likelihood of Occurring within assessed sites
Sydney Coastal River Flat Forest (continued from overleaf)	E	E	Riparian Forest is a tall open forest community on alluvial soils adjacent to main river channels, with emergent trees, such as broad leaf apple (*Angophora subvelutina*), cabbage gum (*Eucalyptus amplifolia*), bangalay (*E. botryoides*) and river peppermint (*E. elata*). Alluvial Woodland occurs along minor watercourses and on terraces adjacent to riparian forest and commonly includes trees such as cabbage gum (*E. amplifolia*) forest red gum (*E. tereticornis*) and dense stands of Swamp Oak (*Casuarina glauca*). The medium to small tree layer and shrub layer comprises several Wattles (*Acacia floribunda; A. binervia*) and *Bursaria spinosa*. The EEC has an important role in maintaining aquatic ecosystems and riverbank stability. The plants are well adapted to flood, which disperses the seeds of some species. It is also highly significant as a wildlife corridor and includes several threatened species, such as Camden white gum (*E. benthamii*). The small and scattered remnants are under threat from woody weeds, such as privet (*Ligustrum spp*). Other threats include sand/soil mining, clearing, grazing, mowing, rubbish dumping and physical damage from recreational activities.	Unlikely to occur in their pre-European state, but remnants exist, along with appropriate habitat.
Grevillia juniperina [Proteaceae]	V	V	*Grevillea juniperina* ssp. *juniperina* is endemic to Western Sydney. Its distribution is centred on an area bounded by Blacktown, Erskine Park, Londonderry and Windsor with outlier populations at Kemps Creek and Pitt Town. Although relatively common within the core area most populations occur on private land or persist in marginal habitat along roadsides. There are at least 33 known populations of the species. *G. juniperina* ssp. *juniperina* grows on reddish clay to sandy soils derived from Wianamatta Shale and Tertiary alluvium. Soils are of the Blacktown and Berkshire Park soil landscapes and typically contain lateritic ironstone gravels. It is generally found in flat or gently sloping, low-lying sites between 30-70 m asl. Most populations are found in disturbed sites, particularly along roadsides, reflecting high levels of urbanisation in the region and a tendency for the species to colonise such areas. Degradation of habitat following clearing and fragmentation of native vegetation is a major threat to the species. Impacts may include direct loss of habitat and local populations, physical and genetic isolation of populations and reduced size and quality of habitat. The distribution of the species coincides with one of the main growth areas in Western Sydney. The gradual loss of small areas of habitat is likely to have a cumulative, adverse effect on the remaining populations of the species.	Significant populations occur within the RDC Site (see Figure 19)

*E - Endangered; CE - Critically Endangered; V - Vulnerable; N/A - Not Applicable; These Species and EECs require appropriate management in accordance with relevant statutory legislation: *Environment Protection & Biodiversity Act* (EPBC Act, 1999) and the *TSC Act* (1995).

The vegetation community characteristics of the site, surveyed in 2009/10 and 2011/12, are illustrated in Figure 19, with an ecological value assigned to provide context to the findings. Notes on key observations of the survey are provided below, with numbers corresponding to those on the map (Figure 19, pg. 39).

The following sections highlight relevant information on the vegetation in each of the areas identified and mapped in Figure 19.

<u>Grevillea juniperina</u>

Grevillea juniperina ssp. *juniperina* (see Table 13; Plate 1) is a vulnerable species listed in Schedule 2 of the *TSC Act* 1995. Fifteen (15) individuals were found on the north side of the creek (see Map; Figure 19), and seven (7) individuals were found on the south side of the creek.

Most plants were juveniles, clustered around one and several mature plants (south and north respectively). The populations on the north side of the creek are close to the current location of the HVAS1 and DD1 dust monitors. The plants of the south side are clustered around the fence line that separates the site from Nurragingy Reserve.

Plate 2 *Grevillea juniperina* ssp. *juniperina* found at the RDC site

<u>Area 1</u>

The critically endangered EEC - Cumberland Plain Woodland (Plate 3) exists on the site in the areas marked as Area 1 in Figure 19. The community consists of a tree cover of predominantly, *Eucalyptus amplifolia*, *E. moluccana* and other *Eucalyptus* spp. closer to the riparian boundary. The native tree Kurrajong - *Brachychiton populneus*, also occurs as part of the canopy.

As typical of Cumberland Plain Woodland, the understorey consists predominantly of *Bursaria spinosa* with *Acacia parramattensis* and *Acacia decurrens* also prominent in the shrub layer. The ground cover consists of a variety of grasses, herbs and small shrubs, including *Themeda australis*, *Dichondra repens*, *Lissanthe strigosa*, *Wurmbea dioica* and *Dichopogon fimbriatus*.

This vegetation community contains high quality habitat for native fauna, with many large hollow bearing trees present. A wide range of native mammalian fauna are known to inhabit the canopy vegetation within this community including numerous species of microbat (Threlfall et al., 2010).

During the ongoing monitoring (2009 to 2012), various birds, reptiles and invertebrates have also been noted on the site within this and the riparian community. Several introduced mammals were also noted during field visits, most significantly the European Red Fox (*Vulpes vulpes*) which appeared to have a den complex to the southwest of the HVAS1 site.

The EEC at the site degraded by various woody, perennials, invasive scramblers and annual weeds including: *Freesia* sp., Privets (*Ligustrum lucidum* and *L. sinense*), *Jasmine polyanthum*, *Asparagus asparagoides*, *Sida rhombifolia* and numerous other species.

Plate 3 Remnant Cumberland Plain Woodlands on the northwest side of Angus Creek

Area 2

Area 2 (Figure 19) is a *Eucalyptus amplifolia* woodland, which exists on the north western corner of the site. The vegetation community value assigned to this area was of lesser quality than the main bulk of the *Eucalyptus* dominated community in the centre of the site. This was due to the disconnection with other woodland vegetation and a weedier understory.

Figure 19 Vegetation Communities, significant species and assigned values at the RDC site

The understorey in Area 2 was dominated by introduced grasses, mainly Rhodes Grass (*Chloris gayana*). Large mature trees were not present at this location either, indicating more recent regrowth, which provides limited fauna habitat.

Area 3

An area dominated by *Casuarina glauca* (**Area 3**, Figure 19) exists on the north eastern side of the site, on low ground close to the creek line. This area borders the large patch of *Grevillea juniperina* (see below) and should be retained where possible as a buffer for the endangered plant population and as a riparian buffer for the nearby creek. Some minor clearing of his area was performed to provide the power line to the HVAS1 site.

Area 4

Patches of land to the south of the Angus Creek (labelled **Area 4;** Figure 19) contain stands of native grasses (primarily *Themeda australis*), which are of conservation value and should be retained where possible, because of potential for regrowth and expansion for the existing woodland community. Other small patches of native grasses also exist along the border of the woodland community further to the west. However, the grasslands on the north side of the railway line were noted as heavily weed infested within 20 m of the railway access road, although the composition improved with native grasses towards the woodland community.

Swampy ground exists within Area 4 in some depressions along the southern boundary of the woodland community. These areas contain moisture-loving plants including juvenile *Melaleuca decora*, *Casuarina glauca*, *Myriophyllum* sp., *Persicaria decipiens* and *Paspalum distichum.*

Area 5

The large expanses of grassland around the middle of the site, marked as **Area 5** (Figure 19), are dominated by introduced, annual grasses, including *Chloris gayana*, *Briza minor,* and numerous other annual weeds. This area and the area along the railway corridor were determined to be of low conservation value in its current state.

Area 6

The riparian vegetation along the creek line marked as **Area 6** (Figure 19), was heavily degraded (Plate 4). The community was dominated by a thick canopy of *Ligustrum* spp. and an understorey of the invasive species - *Tradescantia fluminensis*. A multitude of other weed species also made up the understorey of this community.

Some native tree cover was present in the form of scattered specimens of *Melaleuca* spp., *Casuarina* spp. and various *Eucalyptus* spp. Some native understorey plants (e.g. *Viola hederacea* and *Lomandra* sp.), and aquatic plants (e.g. *Potamogeton pectinasus*) were also observed at various locations.

The riparian vegetation community was considered to be of moderate to high value in terms of its function in bank stabilisation, buffering and as riparian habitat, yet had a reduced ecological value in terms of vegetation diversity. The riparian vegetation assemblage bears a strong resemblance to the pre-existing and endangered EEC – Sydney Coastal River-Flat Forest (see Table 13) on NSW Coastal Floodplains, albeit with a heavily modified, weed-infested shrub layer and ground cover (Plate 4).

Plate 4 Degraded Sydney Coastal River-Flat Forest along Angus Creek

3.6.2 Introduced vs. Native Species

The most significant invasive species, declared as 'noxious weeds', found at the sites, are listed in Table 14. These require on-going management.

In addition, the sites harbour infestations of several highly invasive shrubs (i.e. Privets- *Ligustrum* spp.); invasive scrambler vines (i.e. Moth Vine -*Araujia sericifera;* Turkey Rhubarb – *Acetosa sagittata*); and spreading, ground covers (i.e. Wandering Jew- *Tradescantia fluminensis*) and grasses (i.e. Rhodes Grass – *Chloris gayana*).

Figure 20 provides a comparison of the abundance of introduced species and native species, based on the frequencies of occurrence of individual species determined by the line intercept method. The dominance of introduced species at each of the sites is evident.

The results indicated the changes in abundance, which were most notable at sites AE3 and AE5. At these sites, introduced species significantly expanded in abundance between 2009 and 2012, at the expense of native species cover.

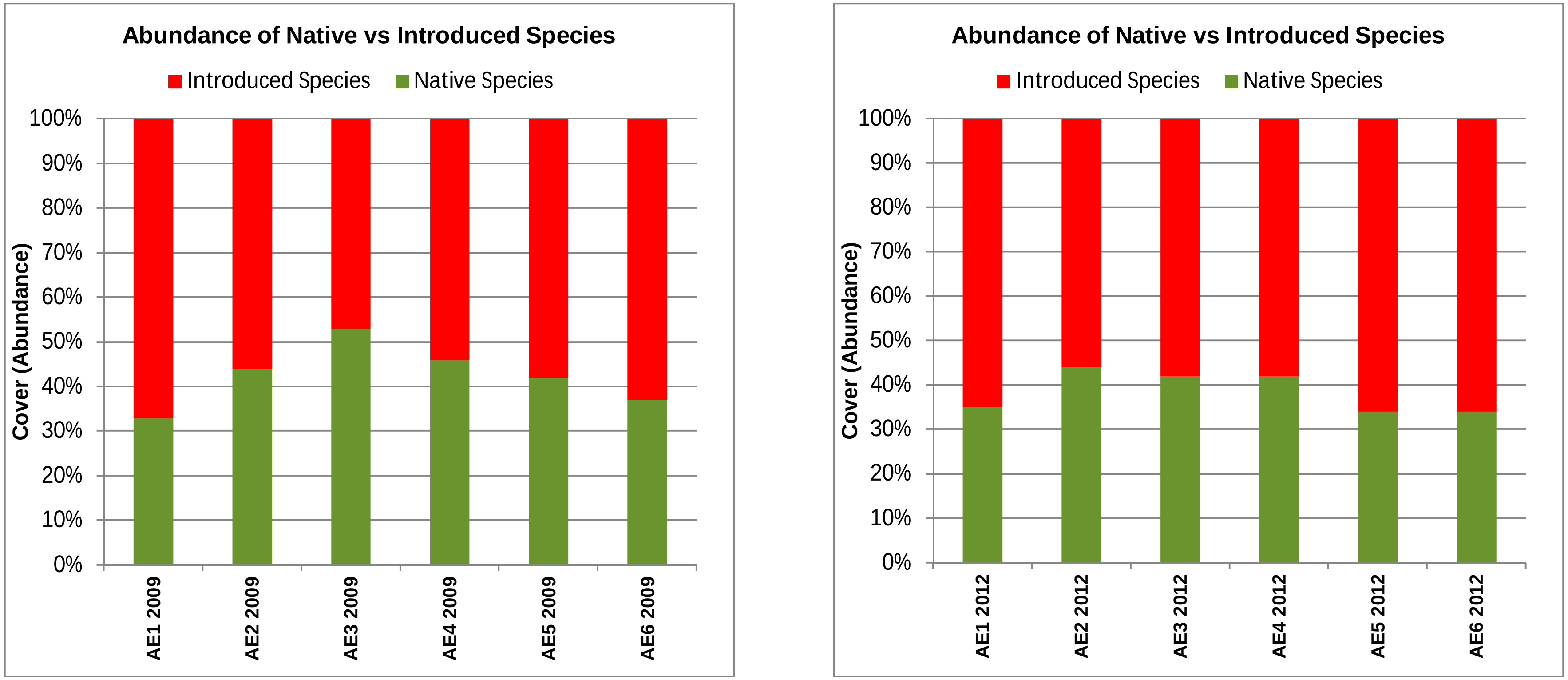

Figure 20 A comparison of the abundance of Native and Introduced Species at the monitored sites, 2009 and 2012

Table 14 Significant invasive species found during the 2009/10 and 2011/12 riparian vegetation assessments

Scientific Name	Common Name	Observed	Significance	Noxious Weed Class
Ageratina adenophora	Crofton Weed	AE5	Noxious Weed [2]	4
Bryophyllum delagoense	Mother of millions	AE2	Noxious Weed [2]	3
Cortaderia selloana	Pampas Grass	AE2	Noxious Weed [2]	3
Ligustrum lucidum	Broadleaf Privet	All AE sites	Noxious Weed [2]	4
Ligustrum sinense	Small leaf privet	All AE sites	Noxious Weed [2]	4
Asparagus asparagoides	Bridal Creeper	All AE sites	Noxious Weed [2 3]	5
Olea europea	European Olive	AE5	Noxious Weed [2]	4
Opuntia stricta	Prickly Pear	AE2	Noxious Weed [2]	4
Romulea rosea	Onion Grass	AE6	Noxious Weed [2]	5
Rubus fruiticosus	Blackberry	AE2, AE3	Noxious Weed [2 3]	4
Sonchus oleraceus	Sowthistle	AE6	Noxious Weed [2]	5
Tradescantia fluminensis	Wandering Jew	All AE Sites	Noxious Weed [2]	4

[1] NSW Threatened Species Act, 1995

[2] NSW Noxious Weed Act, 1993, database query for the Blacktown LGA

[3] Weed of National Significance, NSW Noxious Weed Act, 1993

3.6.3 Flora Quality and Habitat Assessments

Table 15 summarises the results of the general vegetation and habitat conditions of the assessed sites, discussed in the previous sections, in terms of the vegetation features (intactness, species diversity, history of disturbance, weed invasion and general health) and characteristics that were considered (**Section 4.2.1**).

Table 15 Summary of Flora Quality and Habitat Assessment

Site Code	Location	Description/Observations	Condition
AE1	Angus Creek at U/S boundary of RDC	Vegetation is dominated by exotic species. Some increase in abundance of invasive species occurred between 2009 and 2012	Currently Poor
AE2	Angus Creek at the D/S boundary of RDC	Heavily infested with invasive species; not much change in abundance of species between 2009 and 2012	Currently Poor
AE3	Angus Creek 150 m D/S of RDC boundary	Heavily infested with invasive species; a large decline in abundance of native species between 2009 and 2012	Currently Poor
AE4	Eastern Creek D/S of Angus Creek confluence	Heavily infested with invasive species; small increase in abundance of invasive species between 2009 and 2012	Currently Poor
AE5	Eastern Creek U/S of Angus Creek confluence	Heavily infested with invasive species; a notable decline in abundance of native species between 2009 and 2012; concurrent increased cover of weedy species	Currently Poor
AE6	Angus Creek 500 m upstream RDC	Heavily infested with invasive species; the abundance of invasive species increased slightly between 2009 and 2012	Currently Poor

4. Summary of Significant Results

This Report presents the environmental monitoring data collected from the RDC site during the monitoring period: November 2009 to August 2012, and determines compliance with conditions of approval for the site.

The monitoring program covered the elements that were required to be monitored, as part of the approval process, prior to construction activities (i.e. 'before' impact), and included: air quality, water quality, aquatic ecology and riparian vegetation.

Significant findings of the environmental monitoring program are summarised below.

4.1 Air Quality

Total Suspended Particulate matter (TSP) was monitored at two sites using High Volume Air Samplers (HVAS), in accordance with the Australian Standard: AS/NZS 3580.9.3 (2003).

- HVAS1 was not operational since 2009. Only six (6) samples were collected with an average TSP of 32.5 µg/m^3, which is well below the DECC air quality guideline level of 90 µg/m^3/day (annual average).
- HVAS2 collected 185 samples since site inception in February 2009, with an average TSP of 37.8 µg/m^3, which is also well below the DECC Guideline of 90 µg/m^3/day.
- During two brief periods (Feb 2011 and August 2011) TSP levels exceeded the DECC Guideline. However, the rolling averages of more than three years of collected TSP data indicated that the levels were well below the guideline (90 µg/m^3/day, annual average), which confirmed compliance with the air quality goal.

Depositional dust (Total Insoluble Solids) was measured at three al Dust Gauge (DDG) monitoring sites in accordance with the relevant Australian Standard: AS/NZS 3580.10.1 (2003).

- DD1 collected 36 months of depositional dust data, with a mean of 1.5 g/m^2/month.
- DD2 collected 38 months of depositional dust data, with a mean of 2.2 g/m^2/month.
- DD3 collected 38 months of depositional dust data, with a mean of 2.0 g/m^2/month.
- The annual means of the depositional dust were therefore well below the maximum allowable guideline value (4.0 g/m^2/month of total insoluble solids); and the maximum increase in annual mean permitted (2.0 g/m^2/month of total insoluble solids). These results indicate compliance with the air quality goal for depositional dust.
- However, during the monitoring period, there were a few instances of air quality samples exceeding the guidelines (i.e. all three sites in August and September 2009; at DD2 and DD3 during April and May 2010; at DD2 during December 2009 and January 2010). These periods were transient, and despite the exeedances, the annual averages in 2009 and 2010 for all three sites complied with the DECC guidelines for depositional dust.
- During the whole year 2011, and for the first six months in 2012, at all three sites, depositional dust levels were below the DECC Guidelines, achieving compliance.

4.2 Water Quality

Important physico-chemical water quality parameters were measured at the six sites selected for aquatic ecology monitoring, which included four sites located on Angus Creek (Sites AE1, AE2, AE3 and AE6), and two on Eastern Creek (Sites AE4 and AE5). Two of the sites (AE6 and AE5) were located upstream of the RDC and were considered as 'control' sites.

Sampling included both *in situ* measurements with a multi-parameter probe (for pH, Temperature; EC; DO; and Turbidity); and *ex situ* water sampling and laboratory analyses (for TN, TP, Alkalinity and Turbidity). Water quality data were evaluated against ANZECC (2000) Guidelines for 'slightly to moderately-disturbed' aquatic ecosystems for lowland rivers.

The highlights of the results are as follows:

- Elevated electrical conductivity (high ionic concentrations) characterised the upstream Angus Creek sites, and EC decreased moving downstream. These are likely to be due to the influence of groundwater and/or water percolation through calcified soils.
- The pH values of both creeks complied with the ANZECC (2000) Guideline values (pH 6.5 to 8.0) for the majority of sites and samples during much of the monitoring from February 2009 to July 2012.
- Mean total alkalinity was significantly higher at Angus Creek (244 mg/L) than in Eastern Creek (120 mg/L). The implication is that water in Angus Creek is better 'buffered' than in Eastern Creek, and will most likely resist pH changes, which could occur due to various discharges, or run-off, more favourably.
- Both creeks consistently recorded high TN and TP concentrations, above their respective ANZECC Guidelines. Such nutrient enrichment indicates highly productive environments, and eutrophic conditions, which are conducive to algal blooms, or blooms of floating aquatic plants, such as *Azolla*. The nutrient inputs are impacts of drainage from degraded, upstream, urban catchments.
- During the monitoring period, the two creeks also showed low to very low dissolved oxygen concentrations, below the ANZECC Guidelines. Low levels of DO are likely to be a major cause of an overall degraded quality of aquatic life and habitat within both creeks.
- High turbidity characterised both creeks. Turbidity levels were significantly higher in the Eastern Creek. Bank erosion and poor sediment control at various sites, upstream of the RDC site, are the likely causes of higher suspended solids loads in the Eastern Creek.

4.3 Aquatic Ecology

Macroinvertebrate communities were sampled using a rapid assessment protocol, and the organisms and their families identified, in order to study the ecological health of the two creeks. A range of univariate and multivariate routines were adopted to elucidate spatial trends in the data and to determine the underlying environmental factors responsible for the observed trends.

- Macroinvertebrate communities of the AE sites were generally poor in diversity and were dominated by taxa tolerant of physical and chemical stressors, characteristic of waterways in an urban catchment.

- Taxa richness values for Angus Creek sites indicated a slight trend in increased diversity with increasing distance downstream. In contrast, the Eastern Creek sites showed a decrease in taxa richness, moving from AE5, upstream of the Angus Creek confluence, to AE4, downstream of the confluence.
- AUSRIVAS showed that the majority of the AE sites monitored were consistently 'severely impaired'.
- Multivariate analysis showed significant differences in the macroinvertebrate community composition between the two creeks. The Eastern Creek sites generally scored higher taxa and EPT taxa richness, and higher SIGNAL 2 scores.
- The moderate to high number of macroinvertebrate taxa at some sites suggests that physical conditions are still benign and toxic chemicals are not present in large amounts to cause extreme degradation of the aquatic communities.
- Flows from Angus Creek into Eastern Creek are a likely to be a factor impacting on macroinvertebrate community composition. However, further studies, possibly with increased number of sites both upstream and downstream, are required to confirm the possible impacts of poor water and habitat quality in Angus Creek and more broadly across the study area.

4.4 Aquatic Habitat

- The aquatic habitat of both creeks was heavily degraded by the impacts of urbanisation.
- Abundant quantities of gross pollutants occur in the creeks; and varying degrees of bank scouring was noted at both sites.
- Algal blooms, observed in both creeks on several occasions during the past three years, confirm nutrient enrichment and poor water and habitat quality.
- High levels of turbidity, salinity and inflow of nutrients, are likely to be the results of disturbance upstream, due to human activities.

4.5 Vegetation

At all of the six sites and the vicinity, vegetation has been subject to high levels of disturbance and is significantly modified structurally, few shrubs and little of its original groundcover.

- Despite the presence of native tree canopies, in general, upper and lower riparian vegetation, as well as the adjacent terrestrial (upland) vegetation, is dominated by exotic species, which have replaced much of the indigenous ground cover.
- Ecologically valuable vegetation is present on site in the form of the EEC: *Cumberland Plain Woodland*. The quality of this vegetation community is degraded by the presence of invasive shrubs, trees, scrambler vines and an array of herbaceous weeds and exotic grasses in the understorey.
- The riparian vegetation associated with both Angus Creek and Eastern Creek resembles the pre-existing Sydney Coastal River Flat Forests, which is also a listed EEC. These forests were once prevalent on NSW Coastal Floodplains, including in the area and region surveyed.

- However, there are many native species, trees, shrubs, forbs and grasses in the vegetation assemblages, including the vulnerable TSC species: *Grevillea juniperina*.
- Several individuals (both adults and juveniles) of *Grevillea juniperina* ssp. *juniperina*, a species listed as vulnerable in the TSC Act (1995), occur within the RDC site. These individuals form more than one 'population' in two distinct areas.
- The presence of degraded EECS and the vulnerable species at the site dictates a bush regeneration approach to vegetation management planning. Accordingly, vegetation rehabilitation work at the site would require a plan approved by DECC. Such a plan should minimise habitat fragmentation during future construction work.
- Fragmentation of aquatic and terrestrial habitat should be limited where possible, and regeneration of land to offset losses should be appropriately located. Consideration should also be made for the passage for fauna where fragmentation has occurred.
- As part of landscape management, it would be appropriate to consider feral animal control (rabbits and foxes) through a controlled eradication program, to reduce the impacts on native animals, as well as to promote native plant regeneration.

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Appendices

Appendix A Macroinvertebrate Data 2009-2012

Table 16 Macroinvertebrate Data 2009

Taxa Code	Class/Order	Family/Sub-family	AE1 Autumn 2009	AE2 Autumn 2009	AE3 Autumn 2009	AE4 Autumn 2009	AE5 Autumn 2009	AE6 Autumn 2009	AE1 Spring 2009	AE2 Spring 2009	AE3 Spring 2009	AE4 Spring 2009	AE5 Spring 2009	AE6 Spring 2009
IF419999	Turbellaria	Temnocephalidae									1			
IF619999	Turbellaria	Dugesiidae	5	5	3	4	1			1		1		
KG029999	Gastropoda	Hydrobiidae	7		2	1		2	7		2	2		1
KG059999	Gastropoda	Lymnaeidae										1		
KG079999	Gastropoda	Planorbidae			1		1							
KG089999	Gastropoda	Physidae	3		4		4		9	1	6	8	6	1
LH019999	Hirudinea	Glossiphoniidae	3	2	2	5	1	6	3	13	1	9		13
LH059999	Hirudinea	Erpobdellidae			1				1	1	1			1
LO999999	Oligochaeta	Oligochaeta	8	4	8	6	1	4	10	7	3			12
MM999999	Acarina	sp.			1									
OG999999	Crustacea	Cladocera				1	2					1	1	
OH999999	Crustacea	Ostracoda			1	3			1					
OJ999999	Crustacea	Copepoda		1					1			7		
OR259999	Isopoda	Oniscidae		5										
OT019999	Decapoda	Atyidae					4					1	5	
QA999999	Collembola	sp.		2			1					3		

Table A16 (cont.) Macroinvertebrate Data 2009

Taxa Code	Class/Order	Family/Sub-family	AE1 Autumn 2009	AE2 Autumn 2009	AE3 Autumn 2009	AE4 Autumn 2009	AE5 Autumn 2009	AE6 Autumn 2009	AE1 Spring 2009	AE2 Spring 2009	AE3 Spring 2009	AE4 Spring 2009	AE5 Spring 2009	AE6 Spring 2009
QC099999	Coleoptera	Dytiscidae		1						1	5	1		
QC119999	Coleoptera	Hydrophilidae		1	1		2						3	
QC209999	Coleoptera	Scirtidae					1							
QCAN9999	Coleoptera	Curculionidae										1		
QD019999	Diptera	Tipulidae											1	
QD109999	Diptera	Simuliidae							1					
QD249999	Diptera	Stratiomyidae	2	2			1					1		2
QDAE9999	Diptera	Tanypodinae						1			1			
QDAF9999	Diptera	Orthocladiinae							3	1			2	
QDAJ9999	Diptera	Chironominae	11	37	52	33	33	86	14	66	45	32	49	47
QDAZ9999	Diptera	Chironomidae				1								
QE029999	Ephemeroptera	Baetidae					1							
QH569999	Hemiptera	Veliidae										4		
QH619999	Hemiptera	Nepidae											1	
QH659999	Hemiptera	Corixidae				3	3					2	10	
QH679999	Hemiptera	Notonectidae					1	1				1	3	
QL019999	Lepidoptera	Crambidae							1					

Table A16 (cont.) Macroinvertebrate Data 2009

Taxa Code	Class/Order	Family/Sub-family	AE1 Autumn 2009	AE2 Autumn 2009	AE3 Autumn 2009	AE4 Autumn 2009	AE5 Autumn 2009	AE6 Autumn 2009	AE1 Spring 2009	AE2 Spring 2009	AE3 Spring 2009	AE4 Spring 2009	AE5 Spring 2009	AE6 Spring 2009
QO029999	Odonata	Coenagrionidae	10	9	5	8	19	7	2	18	1	9	19	19
QO039999	Odonata	Isostictidae	7		3	22	12		4	2	6	27	4	
QO079999	Odonata	Megapodagrionidae	15	18	16	1	1		3	1	4	3	2	
QO099999	Odonata	Diphlebiidae							1					
QO129999	Odonata	Aeshnidae									1			
QO179999	Odonata	Libellulidae	2	1		2		1				1		
QO309999	Odonata	Hemicorduliidae	6	4	8	2	5	4	7	21	3	2	1	
QO999997	Odonata	Zygoptera	5	3	12	13	4	7	11	12	18	7	6	6
QO999998	Odonata	Epiproctophora			2									
QT039999	Trichoptera	Hydroptilidae							1				2	
QT089999	Trichoptera	Ecnomidae											1	
QT259999	Trichoptera	Leptoceridae				1							3	

Table 17 Macroinvertebrate Data 2010

Taxa Code	Class/Order	Family/Sub-family	AE1 Spring 2010	AE2 Spring 2010	AE3 Spring 2010	AE4 Spring 2010	AE5 Spring 2010	AE6 Spring 2010
IB029999	Hydrazoa	Clavidae				3	2	3
IF619999	Turbellaria	Dugesiidae			3	1	3	5
KG029999	Gastropoda	Hydrobiidae	12	36	4	9	23	
KG059999	Gastropoda	Lymnaeidae					1	1
KG089999	Gastropoda	Physidae		1	3	7		1
KG999999	Gastropoda	sp.					6	
LH019999	Hirudinea	Glossiphoniidae	11			7	23	2
LO999999	Oligochaeta	Oligochaeta	19	6	3	33	3	7
MM999999	Acarina	sp.	3	2	1	1		1
OG999999	Crustacea	Cladocera						12
OH999999	Crustacea	Ostracoda		1	12	15	3	6
OJ999999	Crustacea	Copepoda			2	1	1	
OT019999	Decapoda	Atyidae			3			
QA999999	Collembola	sp.		1	1	1	1	
QC099999	Coleoptera	Dytiscidae	2					
QC119999	Coleoptera	Hydrophilidae			1			
QC139999	Coleoptera	Hydraenidae	2			1		1
QC189999	Coleoptera	Staphylinidae						1
QC209999	Coleoptera	Scirtidae	1					
QD079999	Diptera	Culicidae	1			2	2	
QD249999	Diptera	Stratiomyidae					2	1
QDAJ9999	Diptera	Chironominae	77	6	52	59	65	72
QH529999	Hemiptera	Mesoveliidae			2			
QH569999	Hemiptera	Veliidae	1					
QH659999	Hemiptera	Corixidae			2			
QH679999	Hemiptera	Notonectidae			2			
QO029999	Odonata	Coenagrionidae	9	4	4	7	4	2
QO039999	Odonata	Isostictidae			9		3	7
QO079999	Odonata	Megapodagrionidae		2	1	12	4	
QO129999	Odonata	Aeshnidae						1
QO179999	Odonata	Libellulidae				1		
QO239999	Odonata	Synthemistidae				1		
QO309999	Odonata	Hemicorduliidae	2	14	4	14	10	3
QO999997	Odonata	Zygoptera			2			1
QO999999	Odonata	sp.	3					
QT039999	Trichoptera	Hydroptilidae				1		
QT259999	Trichoptera	Leptoceridae			3			5
QT999999	Trichoptera	sp.			1			

Table 18 Macroinvertebrate Data 2011

Taxa Code	Class/Order	Family/Sub-family	AE1 Autumn 2011	AE2 Autumn 2011	AE3 Autumn 2011	AE4 Autumn 2011	AE5 Autumn 2011	AE6 Autumn 2011	AE1 Spring 2011	AE2 Spring 2011	AE3 Spring 2011	AE4 Spring 2011	AE5 Spring 2011	AE6 Spring 2011
IF419999	Turbellaria	Temnocephalidae								3		1		
IF619999	Turbellaria	Dugesiidae		5		8	7	2		4	2	3	1	2
II999999	Nematoda	sp.						4	1					
KG029999	Gastropoda	Hydrobiidae	37	53		3	35		11	135		10	22	
KG059999	Gastropoda	Lymnaeidae	1											
KG089999	Gastropoda	Physidae		1	1			2			1	4		
LH019999	Hirudinea	Glossiphoniidae	49	4	2	7	25	1	5	5		4	9	3
LH059999	Hirudinea	Erpobdellidae	3											
LH999999	Hirudinea	sp.							1			2		
LO999999	Oligochaeta	Oligochaeta	50	13	3	39	33	10	15	16	5	34	12	5
MM999999	Acarina	sp.		1			1	1		1	1		1	1
OG999999	Crustacea	Cladocera							1		4			1
OH999999	Crustacea	Ostracoda		7	4	4		21	2	2	5	1	1	6
OJ999999	Crustacea	Copepoda		2	1	6	10	1	3	2	2	1		4
OP019999	Amphipoda	Talitridae								2				
OT019999	Decapoda	Atyidae			7						4			
QA999999	Collembola	sp.									2	1		
QC099999	Coleoptera	Dytiscidae					4							

Table A18 (cont.) Macroinvertebrate Data 2011

Taxa Code	Class/Order	Family/Sub-family	AE1 Autumn 2011	AE2 Autumn 2011	AE3 Autumn 2011	AE4 Autumn 2011	AE5 Autumn 2011	AE6 Autumn 2011	AE1 Spring 2011	AE2 Spring 2011	AE3 Spring 2011	AE4 Spring 2011	AE5 Spring 2011	AE6 Spring 2011
QC119999	Coleoptera	Hydrophilidae					1							
QCAN9999	Coleoptera	Curculionidae							3	3				6
QD249999	Diptera	Stratiomyidae		1			2							
QDAF9999	Diptera	Orthocladiinae							1					
QDAJ9999	Diptera	Chironominae	42	1	1	2	2	3	61	2	31	10	5	16
QH569999	Hemiptera	Veliidae		1	1	1	1	1						
QH659999	Hemiptera	Corixidae			2						5			1
QO029999	Odonata	Coenagrionidae	18	3	11	8	2	1	11	2	15	1	2	7
QO039999	Odonata	Isostictidae		2	4	4		3		2	8			3
QO079999	Odonata	Megapodagrionidae		18	2	27	16		1	10		14	4	
QO129999	Odonata	Aeshnidae			1									
QO139999	Odonata	Gomphidae			1									1
QO179999	Odonata	Libellulidae				3			1					
QO309999	Odonata	Hemicorduliidae	7	1		12			2	7	6	6		1
QO999997	Odonata	Zygoptera							1		2	2		2
QO999998	Odonata	Epiproctophora									1			
QT089999	Trichoptera	Ecnomidae									1			
QT259999	Trichoptera	Leptoceridae						1						

Table 19 Macroinvertebrate Data for 2012

Taxa Code	Class/Order	Family/Sub-family	AE1 Autumn 2012	AE2 Autumn 2012	AE3 Autumn 2012	AE4 Autumn 2012	AE5 Autumn 2012	AE6 Autumn 2012
IF619999	Turbellaria	Dugesiidae		3		1		1
II999999	Nematoda	sp.						1
KG029999	Gastropoda	Hydrobiidae	20	11		7	37	1
KG089999	Gastropoda	Physidae	1		1	1	2	1
LH019999	Hirudinea	Glossiphoniidae	31		1	23	2	2
LH059999	Hirudinea	Erpobdellidae	9					
LO999999	Oligochaeta	Oligochaeta	7	11	1		7	4
MM999999	Acarina	sp.		2			1	
OH999999	Crustacea	Ostracoda			2	1	1	
OJ999999	Crustacea	Copepoda	1					1
OP019999	Amphipoda	Talitridae		2				
OT019999	Decapoda	Atyidae			3	1		1
QA999999	Collembola	sp.	5		3	1	3	1
QC099999	Coleoptera	Dytiscidae	1		1			1
QC119999	Coleoptera	Hydrophilidae	1		1		1	2
QC209999	Coleoptera	Scirtidae			2			
QC349999	Coleoptera	Elmidae					1	
QD079999	Diptera	Culicidae	1	1		2		
QD109999	Diptera	Simuliidae		6				
QD249999	Diptera	Stratiomyidae	1	1	1	2	1	2
QDAF9999	Diptera	Orthocladiinae			1			
QDAJ9999	Diptera	Chironominae	33		2	1	2	1
QH529999	Hemiptera	Mesoveliidae			5			1
QH569999	Hemiptera	Veliidae			10			
QH619999	Hemiptera	Nepidae	1					
QH629999	Hemiptera	Belostomatidae						1
QH659999	Hemiptera	Corixidae			2	1		1
QH679999	Hemiptera	Notonectidae			1			
QH689999	Hemiptera	Pleidae			3			
QL019999	Lepidoptera	Crambidae			1			
QO029999	Odonata	Coenagrionidae	7		7	2		1
QO039999	Odonata	Isostictidae			1			
QO079999	Odonata	Megapodagrionidae	2	7		4	19	2
QO129999	Odonata	Aeshnidae	4					
QO179999	Odonata	Libellulidae	1					
QO309999	Odonata	Hemicorduliidae	2	3		5	6	
QO999997	Odonata	Zygoptera	6		1	1		
QT259999	Trichoptera	Leptoceridae			5			1

Appendix B Flora Species List

Table 20 Flora List from the Surveys

Plant Type: NM – Native Macrophyte; NGG – Native Graminoid (Grass); NGS – Native Graminoid (Sedge); NF – Native Forb; NV – Native Vine/Creeper; NS – Native Shrub; NT- Native Tree; IM – Introduced Macrophyte; IGG – Introduced Graminoid (Grass); IGS – Introduced Graminoid (Sedge); IF – Introduced Forb; IVC – Introduced Vine/Creeper; IS – Introduced Shrub; IT – Introduced Tree

Family	Taxon	Common Name	Plant Type
Amaranthaceae	*Alternanthera denticulata*	Lesser Joyweed	NF
Anthericaceae	*Dichopogon fimbriatus*	Nodding Chocolate Lily	NF
Apiaceae	*Foeniculum vulgare*	Fennel	IF
	Hydrocotyle peduncularis	Stinking Pennywort	F
Arecaceae	*Phoenix canariensis*	Canary Island Palm	IT
	Syagrus romanzoffiana	Cocos Palm	IT
Asclepiadaceae	*Araujia hortorum*	Moth Vine	IVC
Asparagaceae	*Asparagus asparagoides*	Bridal Creeper	IVC
	Asparagus officinalis	Asparagus	IF
	Lomandra sp.	Lomandra	NF
	Protoasparagus aethiopicus	Asparagus Fern	IF
Asteraceae	*Ageratina adenophora*	Crofton Weed	IF
	Bidens pilosa	Cobbler's Pegs	IF
	Cardus sp.	Thistle	IF
	Conyza bonariensis	Fleabane	IF
	Siegesbeckia orientalis	Sticky Weed	NF
	Senecio madagascariensis	Fireweed	IF
	Solvia sessilis	Bindi	IF
	Sonchus oleraceus	Common Sowthistle	IF
Basellaceae	*Anredera cordifolia*	Madeira Vine	IVC
Brassicaceae	*Brassica* sp.	Mustard	IF
Cactaceae	*Opuntia stricta*	Prickly Pear	IS
Campanulaceae	*Wahlenbergia gracilis*	Australian Bluebell	NF
Casuarinaceae	*Casuarina glauca*	Swamp She-Oak	NT
Chenopodiaceae	*Einadia trigonos*	Fishweed	IFG
Colchicaceae	*Wurmbea dioica ssp. dioica*	Early Nancy	NF
Commelinaceae	*Commelina cyanea*	Scurvy Weed	NVC
	Tradescantia fluminensis	Wandering Jew	IF
Convolvulaceae	*Dichondra repens*	Kidney Weed	NF
Crassulaceae	*Bryophyllum delagoense*	Mother-of-Millions	IF
	Crassula multicava	Shade Crassula	IF
Cyperaceae	*Baumea articulata*	Sedge	NM
	Bolboschoenus fluviatilis	Sedge	NM
	Cyperus eragrostis	Umbrella Sedge	NGS
Ericaceae	*Lissanthe strigosa*	Peach Heath	NF
Euphorbiaceae	*Ricinus communis*	Castor-Oil-Plant	IS
Fabaceae	*Acacia decurrens*	Wattle	NS
	Acacia parramattensis	Parramatta Wattle	NS

Table 20 (cont.) Flora List from the Surveys

Family	Taxon	Common Name	Plant Type
	Erythrina x sykesii	Indian Coral Tree	IT
	Glycine clandestina	Twining Glycine	NVC
	Glycine microphylla	Small-leaf Glycine	NVC
	Lotus angustissimus	Bird's Foot Trefoil	IF
	Lotus sp.	-	IF
	Senna sp.	Senna	IS
	Vicia sp.	Vetch	IF
Fumariaceae	*Fumaria* sp.	Fumitory	IF
Geraniaceae	*Geranium solanderi*	Native Geranium	NF
	Geranium sp.	Native Geranium	NF
Iridaceae	*Freesia sp.*	Freesia	IF
	Romulea rosea	Onion Grass	IF
Juncaceae	*Juncus bufonius*	Rush	NGS
	Juncus cognatus	Common Rush	NGS
	Juncus sp.	Rush	NGS
Malvaceae	*Brachychiton populneus*	Kurrajong	NT
	Modiola caroliniana	Carolina Mallow	IF
	Sida rhombifolia	Paddy's Lucerne	IF
Meliaceae	*Melia azedarach*	White Cedar	NT
Moraceae	*Morus alba*	Mulberry	IT
Myrtaceae	*Eucalyptus amplifolia*	Cabbage Gum	NT
	Eucalyptus crebra	Ironbark	NT
	Eucalyptus elata	River Peppermint	NT
	Eucalyptus moluccana	Grey Box	NT
	Eucalyptus sp.2	Stringybark Gum	NT
	Eucalyptus sp.3	Smoothbark Gum	NT
	Melaleuca decora	White feather Honey Myrtle	NT
	Melaleuca quinquenervia	Paperbark	NT
	Melaleuca styphelioides	Prickly Leaved Paperbark	NT
Ochnaceae	*Ochna serrulata*	Micky-mouse Bush	IS
Oleaceae	*Jasminum polyanthum*	White Jasmine	IVC
	Ligustrum lucidum	Broad-leaf Privet	IT
	Ligustrum sinense	Small-leaf Privet	IT
	Olea europea	European Olive	IT
Passifloraceae	*Passiflora edulis*	Passion Fruit	IVC
Phyllanthaceae	*Phyllanthus tenellus*	Hen and Chicken	IF
Pittosporaceae	*Bursaria spinosa*	Blackthorn	NS
	Pittosporum undulatum	Pittosporum	NT
Plantaginaceae	*Plantago lanceolata*	Lamb's Tongue	IF
Poaceae	*Axonopus affinis*	Carpet Grass	IGG
	Bromus catharticus	Prairie Grass	IGG
	Capillipedium spicigerum	Scented Top-grass	NGG
	Cortaderia selloana	Pampas Grass	IGG

Table 20 (cont.) Flora List from the Surveys

Family	Taxon	Common Name	Plant Type
	Chloris gayana	Rhodes Grass	IGG
	Cynodon dactylon	Couch Grass	NGG
	Echinopogon ovatus	Hedgehog Grass	NGG
	Ehrharta erecta	African Veldt Grass	IGG
	Eleusine indica	Crow's Foot Grass	IGG
	Eragrostis curvula	African Love Grass	IGG
	Panicum maximum	Guinea Grass	IGG
	Microlaena stipoides	Weeping Grass	NGG
	Oplismenus aemulus	Basket Grass	NGG
	Paspalum dilatatum	Caterpillar Grass	G
	Pennisetum clandestinum	Kikuyu Grass	IGG
	Phragmites australis	Common Reed	NGG
	Poa annua	Winter grass	IGG
	Themeda australis	Kangaroo Grass	NGG
	Setaria gracilis	Slender Pigeon Grass	IGG
Polygonaceae	*Acetosa sagittata*	Turkey Rhubarb	IVC
	Persicaria decipiens	Knotweed	NF
	Rumex crispus	Curly Dock	NF
Potamogetonaceae	*Potamogeton pectinasus*	Sago Pondweed	NM
Primulaceae	*Anagallis arvensis*	Scarlet Pimpernel	IF
Proteaceae	*Grevillea juniperina* ssp. *juniperina*	Grevillea	NS
Ranunculaceae	*Clematis glycinoides*	Headache Vine	NVC
	Ranunculus muricatus	Sharp Buttercup	NF
	Ranunculus sp.		NF
Rosaceae	*Rosa rubiginosa*	Sweet Briar	IVC
	Rubus fruiticosus sp. aggregate	Blackberry	IVC
Rubiaceae	*Galium aparine*	Cleavers, Bedstraw	IF
	Richardia stellaris		IF
Solanaceae	*Cestrum aurantiacum*	Orange Cestrum	NF
	Solanum chenopoidioides	White-tip Nightshade	IF
	Solanum mauritianum	Wild Tobacco Tree	IS
	Solanum nigrum	Purple Nightshade	IF
	Solanum prionophyllum	Forest Nightshade	NF
	Solanum pseudocapsicum	Jerusalem Cherry	IF
Typhaceae	*Typha orientalis*	Cumbungi	Se
Verbenaceae	*Verbena bonariensis*	Purpletop	F
Xanthorrhoeaceae	*Bulbine bulbosa*	Bulbine Lily	NF
	Dianella sp.	Flax Lily	NF

Table 21 Flora Species recorded from individual AE sites

Note: X – found in Transect; O – observed in the vicinity;

NM – Native Macrophyte; NGG – Native Graminoid (Grass); NGS – Native Graminoid (Sedge); NF – Native Forb; NV – Native Vine/Creeper; NS – Native Shrub; NT- Native Tree; IM – Introduced Macrophyte; IGG – Introduced Graminoid (Grass); IGS – Introduced Graminoid (Sedge); IF – Introduced Forb; IVC – Introduced Vine/Creeper; IS – Introduced Shrub; IT – Introduced Tree

Scientific Name	Common Name	AE1	AE2	AE3	AE4	AE5	AE6	N/I	Plant Type
Acacia parramattensis	Parramatta Wattle	x	x	x	x	o		N	NS
Acetosa sagittata	Turkey Rhubarb				x	x		I	IVC
Ageratina adenophora	Crofton Weed					x		I	IF
Alternanthera denticulata	Lesser Joyweed					x		N	NF
Anagallis arvensis	Pimpernel						x	I	IF
Anredera cordifolia	Madeira Vine	x					x	I	IVC
Araujia hortorum	Moth Vine		x	x	x	o	x	I	IVC
Asparagus asparagoides	Bridal Creeper	x	x	x	x		x	I	IVC
Asparagus offinalis	Asparagus						x	I	IF
Axonopus affinis	Carpet Grass					x		I	IGG
Baumea articulata	Jointed Twig-rush						x	N	NGS
Bidens pilosa	Cobbler's Pegs		x	x	x	x	x	I	IF
Bolboschoenus fluviatilis.	Sedge						x	N	NM
Brachychiton populneus	Kurrajong	o						N	NT
Brassica sp.	Mustard						x	I	IF
Bromus catharticus	Prairie Grass					x	x	I	IGG
Bryophyllum delagoense	Mother of millions		o					I	IF
Bulbine bulbosa	Golden Lily	o						N	NF
Bursaria spinosa	Blackthorn	x	x	x		x	x	N	NT
Melaleuca sp.	Paperbark			o	o			N	NT
Capillipedium spicigerum	Scented-top grass		x					N	NGG
Cardus sp.	Thistle	x	x		x		x	I	IF
Casuarina glauca	Swamp She Oak	x	x	x	x	x	x	N	NT
Cestrum aurantiacum	Orange Cestrum	x	x	x	x	x	x	I	NF
Chloris gayana	Rhodes grass		x	x	x		x	I	IGG
Clematis glycinoides	Headache Vine			x	x	x		N	NVC
Commelina cyanea	Scurvy Weed	x	x		x	x		N	NVC
Conyza sp.	Fleabane						x	I	IF
Cortaderia selloana	Pampas Grass		x					I	IGG
Crassula multicava	Shade Crassula	x						I	IF
Cynodon dactylon	Couch Grass					x			NGG
Cyperus eragrostis	Umbrella Sedge		x	x	x	x	x	I	IGS
Dianella sp.	Dianella		x					N	NF
Dichondra repens	Kidney Weed		o		x		x	N	NF
Dichopogon fimbriatus	Nodding Chocolate Lily	o						N	NF
Echinopogon ovatus	Hedgehog Grass					x		N	NGG
Ehrharta erecta	African veldt grass		x		x			I	IGG
Einadia trigonos	Fishweed						x		IF

Table 21 (cont.) Flora Species recorded from individual AE sites

Scientific Name	Common Name	AE1	AE2	AE3	AE4	AE5	AE6	N/I	Plant Type
Eleusine indica	Crab Grass					x		I	IGG
Eragrostis curvula	African lovegrass		x				x	I	IGG
Erythrina x sykesii	Indian Coral Tree		x		x	x		I	IT
Eucalyptus sp. 1	Ironbark		x					N	NT
Eucalyptus amplifolia	Cabbage Gum	x	x	x	x	x		N	NT
Eucalyptus elata	River Peppermint	x	x					N	NT
Eucalyptus moluccana	Grey Box	x	x	x	x	x	x	N	NT
Eucalyptus sp. 2	Stringybark Gum			x				N	NT
Eucalyptus sp. 3	Smooth Bark Gum	x		x				N	NT
Foeniculum vulgare	Fennel					o	x	I	IF
Fumaria sp.	Fumitory						x	I	IF
Galium aparine	Cleavers	x	x	x				I	IF
Geranium solanderi	Native Geranium				x	x		N	NF
Geranium sp.	Geranium					x		I	IF
Glycine clandestina	Twining Glycine		x					N	NVC
Glycine microphylla	Small-leaf Glycine		x	x				N	NVC
Grevillia juniperina	Grevillia		o					N	NS
Hydrocotyle peduncularis	Pennywort					x		N	NF
Juncus bufonius	Toad rush		x					N	NGS
Juncus cognatus	Juncus	x		x				I	NGS
Juncus sp.	Juncus					o		I	NGS
Ligustrum lucidum	Broadleaf Privet	x	x	x	x		x	I	IT
Ligustrum sinense	Small leaf privet	x	x	x	x	x	x	I	IS
Lomandra sp.	Lomandra	o		x	x			N	NF
Lotus angustissimus	Bird's foot trefoil		x				x	I	IF
Lotus sp.						x		I	IF
Melaleuca decora	White Feather Honeymyrtle	x					x	N	NT
Melaleuca stypheloides	Prickly Leaved Paperbark				x	x		N	NT
Melia azedarach	White Cedar		x			o		N	NT
Microlaena stipoides	Weeping Grass						x	N	NGG
Modiola caroliniana	Red flowered mallow	x							IF
Morus alba	Mulberry				o	x		I	IT
Ochna serrulata	Ochna	x						I	IS
Olea europea	European Olive	x			x	x		I	IT
Oplismenus aemulus	Basket Grass	x	x	x	x	x		N	NGG
Opuntia stricta	Prickly Pear		o					I	IS
Panicum maximum	Guinea Grass			x				I	IGG
Paspalum dilatatum	Caterpillar Grass		x		x	x	x	I	IGG
Passiflora edulis	Passionfruit		x					I	IVC
Pennisetum clandestinum	Kikuyu grass		x	x			x	N	IGG
Persicaria decipiens	Knotweed					x	x	N	NF
Phragmites australis	Common reed					o	x	N	NGG

Table 21 (cont.) Flora Species recorded from individual AE sites

Scientific Name	Common Name	AE1	AE2	AE3	AE4	AE5	AE6	N/I	Plant Type
Phyllanthus tenellus	Hen and Chicken				x			I	IF
Pittosporum undulatum	Pittosporum			x				N	NT
Plantago lanceolata	Lamb's Tongue						x	I	IF
Poa sp.	Poa				x			I	NGG
Potamogeton pectinasus	Sago pondweed	o	x				x	N	NM
Prostasparagus aethiopicus	Asparagus Fern			x				I	IF
Ranunculus muricatus	Sharp Buttercup						x	N	IF
Ranunculus sp.					x	x		NI	IF
Richardia stellaris			x						IF
Ricinus communis	Castor-Oil Plant		x	x			x	I	IS
Romulea rosea	Onion Grass						x	I	IF
Rosa rubiginosa	Sweet Briar		x					I	IVC
Rubus fruiticosus	Blackberry		x	x				I	IVC
Rumex crispus	Dock						x	I	IF
Senecio madagascariensis	Fireweed		x				x	I	IF
Senna sp.	Senna			o	x		x	I	IS
Setaria gracilis	Slender pigeon grass		x	x			x	I	IGG
Sida rhombifolia	Paddy's Lucerne	x	x	x	x	x	x	I	IF
Siegesbeckia orientalis	Sticky weed		x	x	x	x		N	NF
Solanum chenopodioides	White-tip Nightshade	x	x			x		I	IF
Solanum mauritianum	Wild tobacco tree		x	x	o	o		I	IS
Solanum nigrum	Blackberry Nightshade			x		x		I	IF
Solanum prionophyllum	Forest Nightshade	x						N	NF
Solanum pseudocapsicum	Jerusalem cherry	o	x	x	x	x		I	IF
Soliva sessilis	Bindi					x		I	IF
Sonchus oleraceus.	Sowthistle		x				x	I	IF
Syagrus romanzoffianum	Cocos palm	x	o				x	I	IT
Themeda australis	Kangaroo Grass		x					N	NGG
Tradescantia fluminensis	Wandering Jew	x	x	x	x	x	x	I	IF
Typha orientalis	Cumbungi						x	N	NGG
Verbena bonariensis	Purple Top		x		x		x	I	IF
Vicia sp.	Vetch						x	I	IF
Wahlenbergia gracilis	Australian bluebell						x	N	NF
Wurmbea dioica ssp. *dioica*	Early Nancy	o						N	NF
Phoenix canariensis	Canary Island Palm	x						I	IT
Poaceae Sp1*			x	x	x	x	x	-	-
Poaceae Sp2*			o			x	x	-	-
Poaceae Sp3*			x					-	-
Poaceae Sp4*		x						-	-

* *Unidentified Grass species*

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