3.0 Review of Historical Water Quality Data

Lake Richmond Reserve was included as part of the areas urban drainage scheme in the 1960's and subsequently the former Water Board constructed three inlet drains and one outlet drain in 1968 (Naragebup NRM Office 1998). The inlet drains are on the north east and south east areas of the reserve and the outlet drain is in the north-west area. These drains collect runoff from the surrounding urban area and there are reflux gates on the outlet drain to prevent seawater entering the lake.

Prior to the 1960s the lake was saline with salinity ranging from 2000 to 3500 mg/L total dissolved salts (TDS). After installation of the drains, salinity reduced to 300 – 400 mg/L TDS (Strategen 2006).

Water quality was considered to have deteriorated between 1998-2004 based on an increase in phytoplankton scums and epiphytic growth on the thrombolites. This is likely to affect the condition of the thrombolites due to smothering and therefore blocking light and changed water chemistry (Rose, Morgan & Gill 2004).

To date a number of water quality programs have been undertaken at Lake Richmond but a consistent and coordinated seasonal monitoring program has yet to be implemented. At present both the Department of Water (DoW) and the Water Corporation (WC) do not conduct water quality monitoring for Lake Richmond.

The following is a summary of the monitoring programs that have been undertaken to date:

- DoW – twice yearly monitoring from 1970 to 1986, then once in 1995 (DoW 1995)
- Naragebup NRM office – three month monitoring period in the winter months in 2002 (Naragebup NRM Office 2003)
- MWH – conducted monthly monitoring from January 2010 to March 2011 (MWH 2010)
- RPS – conducted quality monitoring from 2001-2008 at various sites including the drains at Lake Richmond as part of the Anchorage Estate groundwater and surface water monitoring program (RPS 2008).

With respect to groundwater, there is limited data in the areas with the nearest DoW bore being located approximately 3km east of Lake Richmond. This DoW bore has recorded water level data since the mid 1970's, and no significant water quality data.

Table 1 summarises the previous water monitoring that has been undertaken at Lake Richmond Reserve (adapted from MWH, 2010). Locations of these monitoring sites are shown on **Map 1.**

Table 1: Surface water monitoring at Lake Richmond Reserve

Site ID	Site Name	Type of Monitoring	Date	Number of Readings	Agency/Ref
13662	Lake Richmond	Water level	1945 – current[1]	330	Department of Water
13662	Lake Richmond	Water quality	1970 – 1986	35	Department of Water
23002414	Lake Richmond outlet drain	Water level	2002 – 2003	10	Department of Water
23002414	Lake Richmond outlet drain	Water quality	2003	10	Department of Water
23015714	Mangles Bay drain	Water quality	2003[2]	20	Cockburn Sound Management Council
23015717	Rockingham North drain	Water quality	2003	2	Cockburn Sound Management Council
23015718	Rockingham Central drain	Water quality	2003	5	Cockburn Sound Management Council
23015720	Lake Richmond	Water quality	2003	1	Cockburn Sound Management Council
23015721	Lake Richmond	Water quality	2003	1	Cockburn Sound Management Council
23018873	Safety Bay SW drain	Water quality	2003	9	Department of Water
DO (formerly D1)	Water Corp Drain	Water quality	1999-2007[2]	47	RPS (2008)
D2	Water Corp Drain	Water quality	1999-2003[2]	26	RPS (2008)
D3	Water Corp Drain	Water quality	1999-2000[2]	12	RPS (2008)
D4	Water Corp Drain	Water quality	1999-2000[2]	11	RPS (2008)
D5	Water Corp Drain	Water quality	1999-2004[2]	38	RPS (2008)
D6	Water Corp Drain	Water quality	2001-2003[2]	11	RPS (2008)
LI	Lake Richmond in flow drain	Water quality	2001-2008[2]	39	RPS (2008)
LO	Lake Richmond out flow drain	Water quality	2001-2008[2]	30	RPS (2008)
MP	Water Corp Drain	Water quality	2001-2008[2]	34	RPS (2008)
MPW	Water Corp Drain	Water quality	2003-2008[2]	26	RPS (2008)
LR1	Lake Richmond	Water quality	2010[3]	8	MWH (2010)
LR2	Lake Richmond	Water quality	2010[3]	8	MWH (2010)

[1] Water levels have been recorded consistently since 1978

[2] Monitoring conducted on a quarterly basis for multiple water quality parameters, occasionally samples were not taken when surface drains were dry. Number of readings refer to number of days sampled

[3] Monthly sampling undertaken from Jan-Aug 2010 for multiple water quality parameters. Number of reading refer to number of days sampled.

3.1 Naragebup Lake Richmond Drain Outlet Water Quality Study (2003)

The Naragebup NRM office (2003) conducted a study of the water quality of the outlet drain at Lake Richmond to determine the level of nutrients entering into Mangles Bay and Cockburn Sound.

Monitoring was conducted over a three month period after the winter months in 2002. Results indicated that:

- pH was between 8.26-8.79 which is alkaline but expected due to the limestone geology of the catchment
- dissolved oxygen was above recommended levels for lowland rivers
- all nitrogen samples were above recommended levels for freshwater lakes
- total phosphorus was above recommended levels for freshwater lakes and lowland rivers
- toxicants such as heavy metals, oils and pesticides were below recommended levels for freshwater ecosystems except for zinc
- algal blooms were obvious during the survey in September, with high levels of toxic blue-green algae (*Microcystis cyanobacteria*). Scum was also observed around the shallow lake edges, particularly in reed beds in the north-west area of the lake. There was no evidence of the algal bloom during a follow up survey about a month later in October 2002.

It was surmised that total nitrogen and phosphorus level would make a significant contribution to existing levels if they entered into Mangles Bay, as the levels were above recommended guidelines for freshwater ecosystems (Naragebup NRM Office 2003). These levels were noted to be higher than those collected from the previous year by the WC. Water quality samples did not indicate a significant contribution of herbicides and pesticides although a few samples with high levels of phosphorus could be attributed to lawn fertilisers entering into the drains via stormwater runoff.

Table 2 is a summary of water quality results at Lake Richmond from the 2003 survey as presented in the State of the Environment report (City of Rockingham 2005). The water quality at Lake Richmond is used as one of the environmental indicators of the health of inland waters within the City of Rockingham.

Table 2: Lake Richmond Water Quality Results 2003

Nutrients	Lake Richmond indicators of water quality tested in 2003 ($\mu g\ L^{-1}$)	ANZECC Guidelines ($\mu g\ L^{-1}$)		Results
		F/water lake	Wetlands	
Nitrogen	650 to 840	350	1500	Exceeds guidelines for freshwater lakes but not for wetlands
Reactive Nitrogen (Nox)	12 to 25	10	100	Exceeds guidelines for freshwater lakes but not for wetlands
Total Phosphorous	12 to 30	10	60	Exceeds guidelines for freshwater lakes but not for wetlands
Filterable reactive phosphorous (FRP)	7 to 12	5	30	Exceeds guidelines for freshwater lakes but not for wetlands

3.2 MWH Cape Peron Water Quality Study (2010)

MWH (2010) conducted a monthly monitoring program from January 2010 to March 2011, with an interim report released in September 2010. Monitoring was conducted at two sites within Lake

Richmond as part of the approvals process for the Mangles Bay Marina. The monitoring program consisted of:

- water level monitoring
- water sampling
- stratification monitoring
- depth transects.

Results of the monitoring program undertaken by MWH indicate that (Strategen 2011):

- the maximum depth of the lake is 14.4m
- water quality is fresh to slightly brackish at the surface with an increase in salinity and a drop in pH below 8 metres in depth
- nutrient levels are slightly above ANZECC guidelines
- water levels varied from 0.1m AHD in January 2010 to 0.8m in August 2010.

3.3 RPS Anchorage Estate Water Quality Monitoring (2008)

The Anchorage Estate groundwater and surface water monitoring program was also undertaken from 1999-2008 during the development of the estate by the Australand Property Group. The main focus of the program was to protect the water quality and subsequently the survival of the thrombolites surrounding the lake. Surface water monitoring was undertaken on a quarterly basis from sites located along Water Corporation drainage lines (RPS 2008).

Results indicate that groundwater levels fluctuated seasonally and did not show any irregular trends which suggests that the development associated with Anchorage Estate has had minimal impact on groundwater levels.

Surface water results indicated that Total Nitrogen (TN) and Total Phosphorus (TP) exceeded ANZECC criteria at some monitoring locations. Contributing factors are likely to be attributed to the following:

- construction activities associated with the Anchorage Estate
- seasonal fluctuation associated with warmer temperatures which are favourable to nitrogen production
- lawn fertiliser from surrounding gardens and Public Open Space (POS).

The surface water drains entering Lake Richmond extend beyond the Anchorage Estate area and therefore nutrient input is likely to be from a wide range of sources.

4.0 Water Quality Monitoring Program 2011

The management plan for the reserve prepared by Ecoscape (2009) for the CoR identified water quality monitoring as a high priority action. While monitoring of the lake had occurred sporadically over the years as discussed in Section 3, no consistent program had previously been implemented. Ecoscape (2009) identified a seasonal monitoring program as being beneficial for the reserve, particularly with increased urban development pressures such as the Mangles Bay Marina proposal.

As part of commencing a continuing, more coordinated monitoring program for the lake, monitoring from four locations within the Lake was undertaken as part of the ICMP.

Surface water monitoring for 2011 was undertaken by Ecoscape on two occasions, once during summer on February 28 2011, and once during winter on August 10, 2011.

Monitoring was conducted at four locations, shown in **Table 3** and **Map 1**. The locations monitored for water quality by MWH from January – March 2011 are also shown in **Table 3** and **Map 1**.

Table 3: Coordinates of water quality sampling locations (MGA50)

Location	Easting (X)	Northing (Y)	Consultant
EcoLR1	379234	6426700	Ecoscape
EcoLR2	379055	6427391	Ecoscape
EcoLR3	378703	6427545	Ecoscape
EcoLR4	378806	6426899	Ecoscape
LR1	378787	6427116	MWH
LR2	379059	6427057	MWH

The eastern and southern sides of Lake Richmond collect surface water and groundwater via the WC main drainage system which comprises of a network of open drainage channels and an outlet drain on the northern side to Mangles Bay (RPS 2008). The locations of the four monitoring sites were provided by the City of Rockingham and were positioned on the edges of all sides of the Lake. One was located at the end of the stormwater inlet on the southern edge, one was close to the stormwater outlet drain on the northern edge, and one was in front of the boardwalk on the eastern edge and one on the western edge north of another identified drain point. The two MWH monitoring sites were located to the centre of the Lake.

4.1 Monitoring Parameters

Water quality parameters selected for monitoring include those that are believed to be important for thrombolite function as well as indicators of potential for groundwater and surface water contaminants. These parameters are listed in **Table 4**.

Table 4: Parameters tested at Lake Richmond 2010-2011

Water Quality Parameters	
pH	conductivity
colour	salinity
chlorophyll a (Chlα)	dissolved oxygen (DO)
turbidity (NTU)	total nitrogen (TN)
oxides of nitrogen (NOx)	ammonium (NHx)
total phosphorus (TP)	filterable reactive phosphate (FRP)
total dissolve solids (TDS)	total recoverable hydrocarbons (TRH)
Sulphate	Sodium
Potassium	Calcium
Magnesium	Chloride
Carbonate	Bicarbonate
soluble Iron (Fe)	Nitrate
Fluoride (F)	soluble Manganese (Mg)
soluble Silica (Si)	cation/anion balance
soluble Arsenic (As)	soluble Cadmium (Cd)
soluble Chromium (Cr)	soluble Copper (Cu)
soluble Lead (Pb)	soluble Mercury (Hg)
soluble Nickel (Ni)	soluble Zinc (Zn(

4.1.1 PHYSICAL AND CHEMICAL STRESSORS

A number of naturally-occurring physical and chemical stressors can cause serious degradation of aquatic ecosystems when ambient values are too high and/or too low. The following physical and chemical stressors are typically considered during water quality assessments and were part of the water quality analysis for Lake Richmond; nutrients, , dissolved oxygen, turbidity, colour, total dissolved solids (TDS), temperature, salinity, conductivity, pH and chlorophyll a (ANZECC 2000).

An excess of nutrients within a waterbody can stimulate nuisance growths of aquatic plants and measuring this can indicate how eutrophied (nutrient polluted) a waterbody is and how susceptible it will be to nuisance plant growths occurring (ANZECC 2000)..

The dissolved oxygen (DO) concentration measured in a waterbody reflects the equilibrium between oxygen-consuming processes (e.g. respiration) and oxygen-releasing processes (e.g. photosynthesis and the physical transfer of oxygen from the atmosphere to the waterbody). Measures of DO indicate whether there is a disturbance to these competing processes and defines the living conditions for aerobic (oxygen requiring) organisms (ANZECC 2000)..

The turbidity or 'muddiness' of water is caused by the presence of suspended particulate and colloidal matter consisting of suspended clay, silt, phytoplankton and detritus. Increased turbidity can reduce the light climate and change an ecosystem significantly. Measures of turbidity indicate the extent of catchment and riverbank erosion, and how much the light regime is being affected. Some suspended particulate matter arises from point sources such as sewage outfalls, industrial wastes (e.g. from pottery and brick making plants) and stormwater drains, but most arises from diffuse land runoff due to soil erosion. Turbidity is highly dependent upon flow, with very large increases noted during flood events (ANZECC 2000)..

Salinity or electrical conductivity (EC) are measures of the total concentration of inorganic ions (salts) in the water. EC is used to measure the total ion concentration in fresh and brackish waters. Freshwaters are generally considered to have an EC of less than 1000 µS/cm. Measures of salinity and EC indicate whether the chemical nature of aquatic ecosystems is being altered and provides a warning of the potential loss of native biota. Salinity and electrical conductivity are relatively simple methods that can provide a broad characterisation of the amount of dissolved inorganic material in a particular waterbody.

Aquatic ecosystem functioning is very closely regulated by temperature. Biota, and physical and chemical processes like oxygen solubility and hydrophobic interactions are sensitive to temperature changes. Temperature changes can occur naturally as part of normal diurnal (daily) and seasonal cycles, or as a consequence of human activities. Measures of water temperature indicate how much an ecosystem's normal temperature regime is being disturbed by human activities (ANZECC 2000)..

pH is a measure of the acidity or alkalinity of water and has a scale from 0 (extremely acidic) to 7 (neutral), through to 14 (extremely alkaline). Low pH can cause direct adverse effects on fish and aquatic insects, while pH changes (particularly reduced pH) can result in the toxicity of several pollutants (e.g. ammonia, cyanide, aluminium) to significantly increase (ANZECC 2000).

4.1.2 TOXICANTS

Toxicants is a term used for chemical contaminants that have the potential to exert toxic effects at concentrations that might be encountered in the environment. These can include Metals and Metalloids (As, Cd, Cr, Cu, Fe, Hg, Pb, Mg, Ni, Si, Zn), Non Metallic Inorganics (Ammonia, Chloride, Nitrate), and Hydrocarbons (Total Recoverable Hydrocarbons (TRH) C6-C9) (ANZECC 2000).

Other measurements included the cation/anion balance which measure; cations (such as calcium, magnesium, sodium and potassium) and anions (such as chloride, bicarbonate, sulfate and bromide). These can be used as tracers to determine groundwater input to a stream during high flow and low flow periods (Australian Government 2006).

4.2 Sampling Method and Analysis

Water samples were collected from approximately 0.2m below the water surface before being stored in an esky for transport to SGS Australia Pty Ltd for analysis as soon as possible after sampling.

SGS Australia Pty Ltd provided the bottles and preservatives to store the samples and also conducted the laboratory analysis.

4.3 Results

4.3.1 PHYSICAL AND CHEMICAL STRESSORS

Across all sample locations and sample dates, total nitrogen (TN) and total phosphorus (TP) were below the ANZECC guidelines for wetlands in Western Australia. However, all sites exceeded the TN trigger value associated with Freshwater Lakes in Western Australia and some sites (ECOLR01 and ECOLR04) exceeded the TP values associated with Freshwater Lakes in Western Australia (**Table 5 and 6**). The following parameters were also recorded as being lower than the ANZECC guidelines during both sampling periods; Conductivity, chlorophyll a, TSS and Turbidity, while pH levels were higher than the recommended range (**Table 5 and 6**).

Table 5: Lake Richmond Water Quality Results for Physical and Chemical Stressors (28 Feb 2011)

Nutrients	Lake Richmond indicators of water quality tested in 2011 ($\mu g\ L^{-1}$)				ANZECC Guidelines ($\mu g\ L^{-1}$)	
	ECOLR01	ECOLR02	ECOLR03	ECOLR04	F/water lake	Wetlands
Chl a	9.4	3.7	14	2.2	3 to 5	30
Total Phosphorus	<10	<10	30	<10	10	60
FRP	<2	<2	<2	<2	5	30
Total Nitrogen	840	820	940	830	350	1500
Reactive Nitrogen (Nox)	11	<5	<5	<5	10	100
NH_4^+	53	12	22	18	10	40
pH	9.0	9.0	9.1	9.1	6.5 to 8.0	7.0 to 8.5
Electrical Conductivity (µg/cm)	1100	1000	1000	1000	n/a	300 to 1500
TSS (mg/L^{-1})	<5	<5	<5	12	n/a	80
Turbidity (NTU)	1.3	0.9	1.3	1.4	n/a	10 to 100

Table 6: Lake Richmond Water Quality Results for Physical and Chemical Stressors (10 Aug 2011)

Nutrients	Lake Richmond indicators of water quality tested in 2011 ($\mu g\ L^{-1}$)				ANZECC Guidelines ($\mu g\ L^{-1}$)	
	ECOLR01	ECOLR02	ECOLR03	ECOLR04	F/water lake	Wetlands
Chl a	<5	<0.5	2	3.4	3 to 5	30
Total Phosphorus	40	10	10	20	10	60
FRP	8	<2	<2	<2	5	30
Total Nitrogen	730	550	850	790	350	1500
Reactive Nitrogen (Nox)	230	51	48	38	10	100
NH_4^+	46	34	35	27	10	40
pH	7.9	8.7	8.7	8.6	6.5 to 8.0	7.0 to 8.5
Electrical Conductivity (µg/cm)	650	980	990	1000	n/a	300 to 1500
TSS (mg/L^{-1})	<5	<5	<5	<5	n/a	80
Turbidity (NTU)	0.9	2.8	1.1	0.9	n/a	10 to 100

4.3.2 TOXICANTS

Within the ANZECC guidelines the trigger values for toxicants is derived using the statistical distribution method and calculated at four different protection levels, 99%, 95%, 90% and 80%. The protection level signifies the percentage of species that is expected to be protected. The highest level of protection (99%) has been chosen as the default value for Lake Richmond as it is of high conservation value (ANZECC 2000).

4.3.2.1 Metals and metalloids

The following metals recorded readings above the ANZECC guidelines for those that had trigger values: Arsenic, Cadmium, Chromium, Copper, Lead and Zinc. However, it was also noticed that iron levels were very higher at ECOLR01 during the August sampling and nickel levels were high at ECOLR03 during the February sampling (**Tables 7 and 8**).

Table 7: Lake Richmond Water Quality Results for Metals and Metalloids (28 Feb 2011)

Metals and Metalloids	Lake Richmond indicators of toxicants tested in 2011 ($\mu g\ L^{-1}$)				ANZECC Guidelines Trigger Values for freshwater ($\mu g\ L^{-1}$)
	ECOLR01	ECOLR02	ECOLR03	ECOLR04	(Level of Protection 99%)
Arsenic	<20	<20	<20	<20	1.0
Cadmium	<1	<1	<1	<1	0.06
Chromium	<5	<5	<5	<5	0.01
Copper	<5	<5	<5	<5	1.0
Iron	<20	30	<20	<20	ID
Lead	<5	<5	<5	<5	1.0
Manganese	<5	<5	<5	<5	1200
Mercury	<0.05	<0.05	<0.05	<0.05	0.06
Nickel	<5	16	<5	<5	8
Zinc	40	70	100	240	2.4

ID=Insufficient data to derive a reliable trigger value

Table 8: Lake Richmond Water Quality Results for Metals and Metalloids (10 Aug 2011)

Metals and Metalloids	Lake Richmond indicators of toxicants tested in 2011 ($\mu g\ L^{-1}$)				ANZECC Guidelines Trigger Values for freshwater ($\mu g\ L^{-1}$)
	ECOLR01	ECOLR02	ECOLR03	ECOLR04	(Level of Protection 99%)
Arsenic	<20	<20	<20	<20	1.0
Cadmium	<1	<1	<1	<1	0.06
Chromium	<5	<5	<5	<5	0.01
Copper	<5	<5	<5	<5	1.0
Iron	120	<20	<20	<20	ID
Lead	<5	<5	<5	<5	1.0
Manganese	8	<5	<5	<5	1200
Mercury	<0.05	<0.05	<0.05	<0.05	0.06
Nickel	<5	<5	<5	<5	8
Zinc	<10	<10	<10	20	2.4

ID=Insufficient data to derive a reliable trigger value

4.3.2.2 Non Metallic Inorganics

Both Ammonia and Nitrate levels were below the ANZECC guidelines when recorded during the February sampling (**Table 9**). However, Nitrate readings from the August sampling period showed a large increase in amount and levels that were above the ANZECC guidelines (**Table 10**).

Table 9: Lake Richmond Water Quality Results for Non Metallic Inorganics (28 Feb 2011)

Non Metallic Inorganics	Lake Richmond indicators of toxicants tested in 2011 ($\mu g\ L^{-1}$)				ANZECC Guidelines Trigger Values for freshwater ($\mu g\ L^{-1}$)
	ECOLR01	ECOLR02	ECOLR03	ECOLR04	(Level of Protection 99%)
Ammonia	53	12	22	18	320
Nitrate	<5	<5	<5	<5	17

Table 10: Lake Richmond Water Quality Results for Non Metallic Inorganics (10 Aug 2011)

Non Metallic Inorganics	Lake Richmond indicators of toxicants tested in 2011 ($\mu g\ L^{-1}$)				ANZECC Guidelines Trigger Values for freshwater ($\mu g\ L^{-1}$)
	ECOLR01	ECOLR02	ECOLR03	ECOLR04	(Level of Protection 99%)
Ammonia	46	34	35	27	320
Nitrate	970	230	210	170	17

4.3.3 ANION-CATION BALANCE

The anion-cation balance is based on a percentage difference between the total positive charge and total negative charges based on the ions Na+, K+, Ca2+, Mg2+, SO42-, Cl-, HCO3- and CO32. A negative number means there is an excess of anions or a lack of cations while a positive number means an excess of cations or a lack of anions. Lake Richmond is predominantly showing a negative number which can be attributed to the higher combined amounts of the anions (Sulfate, Chloride, Carbonate and Bicarbonate), compared to cations (Calcium, Magnesium, Potassium and Sodium).

A reasonable balance for routine water quality analysis is generally considered to be less than 5% difference. If there is a higher number, further analysis is recommended. The anion-cation balances for Lake Richmond are shown in **Table 11**. The breakdown of the ions contributing to the calculation of these results is shown in **Table 12 and 13**.

Table 11: Lake Richmond Anion-Cation Balance

Sampling Data	Anion-Cation Balance 2011 (%)			
	ECOLR01	ECOLR02	ECOLR03	ECOLR04
28 February 2011	1	1	-1	0
10 August 2011	-1	-3	-3	-2

Table 12: Lake Richmond Ions contributing to Anion-Cation Balance (28 Feb 2011)

Anion-Cation Ions	Lake Richmond indicators of toxicants tested in 2011 (mg/L)			
	ECOLR01	ECOLR02	ECOLR03	ECOLR04
Sodium	120	120	120	120
Potassium	6.4	6.9	6.8	6.9
Calcium	28	24	23	24
Magnesium	58	59	58	58
Sulfate	71	71	71	71
Chloride	190	190	190	190
Carbonate	27	26	30	28
Bicarbonate	210	210	210	200

Table 13: Lake Richmond Ions contributing to Anion-Cation Balance (10 Aug 2011)

Anion-Cation Ions	Lake Richmond indicators of toxicants tested in 2011 (mg/L)			
	ECOLR01	ECOLR02	ECOLR03	ECOLR04
Sodium	52	100	100	100
Potassium	3.8	5.9	5.9	6.0
Calcium	53	28	28	28
Magnesium	25	52	53	53
Sulfate	41	72	75	67
Chloride	86	180	180	780
Carbonate	<1	13	14	13
Bicarbonate	230	250	240	240

4.3.4 AROMATIC HYDROCARBONS

Benzene, toluene, ethylbenzene and xylenes are the simplest C6−C9 aromatic hydrocarbons. They are important and common aromatic solvents used for adhesives, resins, fibres, pesticides and ink, and in the rubber industry, as industrial cleaners and degreasers and as thinners for paints and lacquers (ANZECC 2000).

The high volatility and relatively low water solubility of these chemicals indicates that they would be rapidly lost to atmosphere from a water body, with none of these compounds expected to bioaccumulate. Most of the sites recorded less than 40 µg L^{-1} with site EcoLR01 recording a slightly higher reading of 56 µg L^{-1}, these results are within the trigger values stated in the ANZECC guidelines (2000).

4.4 Comparison to Previous Water Quality Data

Table 14 provides a consolidated summary and comparison for a range of water quality parameters for different monitoring periods via the various monitoring programs.

The summary table highlights the difficulty in providing any conclusive finding in terms of any continuing long term water quality trend on the basis of existing monitoring data. With respect of nutrient for example, the table indicates TP and TN water quality data as having a similar range of values in the 2011 program as recorded in early programs.

This represents a key finding of the 2011 monitoring program, and highlights the need for additional seasonal monitoring as an ongoing program for at least three years to provide the necessary information to inform the assessment of water quality trends, and identify pollutant sources toward improving water quality outcomes for the lake.

This finding is reflected in the approach contained in the ICMP strategy together with identifying likely priority areas for future works based on existing land use.

Table 14: Comparison of 2003 and 2011 Lake Richmond Water Quality Results

Nutrients	Lake Richmond indicators of water quality tested in 2003 ($\mu g\ L^{-1}$)	Lake Richmond indicators of water quality tested in 2011 ($\mu g\ L^{-1}$)
Nitrogen	650 to 840	350-940
Reactive Nitrogen (Nox)	12 to 25	<5 to 230
Total Phosphorous	12 to 30	<10 to 40
Filterable reactive phosphorous (FRP)	7 to 12	<2 to 8