Report 15, to end of May 2010

Lower Lakes and Tributaries

Water Quality Report

Ambient and Response Monitoring

Environment Protection Authority

Observations at a Glance

- ***Areas of localised acidity have been identified at Boggy Lake and the western margins of Lake Albert. Boggy Lake was aerially dosed with limestone between the 28th May and the 2nd of June. This site is being monitored weekly to assess the effect the limestone addition has had.***
- ***pH and alkalinity remains satisfactory at all sites within the main water bodies of Lake Alexandrina and Lake Albert.***
- ***Upper Currency Creek saw a slight rise in alkalinity at the end of May to 20-25 mg/L as $CaCO_3$, but still remains a risk for potential acidification.***
- ***Salinity and nutrient levels remain very high at all sites.***

Background

The Environment Protection Authority (EPA), Department of Environment and Natural Resources (DENR), and the Department for Water (DFW) are monitoring to assess potential water quality impacts associated with water level decline and the oxidation of acid sulfate soils in the Lower Lakes. Ambient water quality sampling is undertaken fortnightly at 19 sites in Lake Alexandrina (including the Goolwa Channel, Currency Creek and Finniss River tributary regions), and Lake Albert (Figure 1). Response water quality sampling is also undertaken in selected regions that have experienced acidification or are at risk of acidification (Figure 1). Previous reports are contained on the EPA website[1].

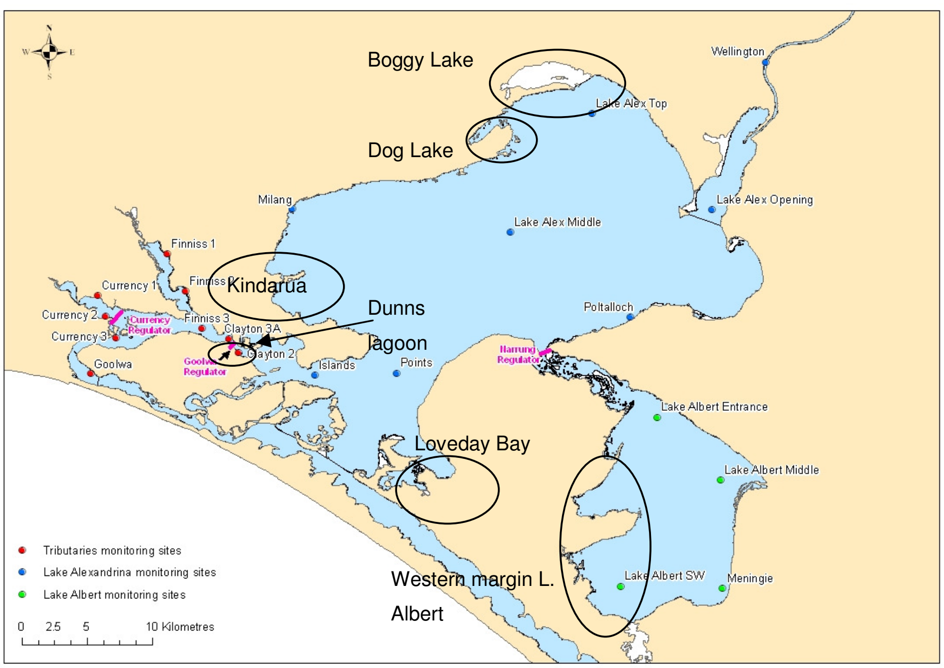

Figure 1 – Map of the ambient (points) and response (black ovals) monitoring sites

[1] See http://www.epa.sa.gov.au/environmental_info/water_quality/monitoring_programs_and_assessments/lower_lakes

Water Quality Parameters

A wide range of water quality parameters are monitored within the Lower Lakes with key parameters reported herein being pH, alkalinity, salinity, sulfate:chloride ratio, turbidity, nutrients and chlorophyll. A brief description of these parameters and typical historical (pre-drought) levels are provided below:

***pH* is an indicator of acidity or alkalinity. Neutral water has a pH of 7, acidic solutions have lower values and alkaline solutions have higher values. Prior to the current drought, the pH in the region was typically between 8.3 and 8.5.**

***Alkalinity* is a measure of the buffering capacity of water, or the capacity of the water to neutralise acids and resist pH change. Alkalinity within water bodies is consumed as acid is released from acid sulfate soils. Adding limestone contributes alkalinity to waters, helping to neutralise any acid released from the sediments. Historically, alkalinity levels within this region have been between 80 and 250 mg/L as $CaCO_3$.**

***Salinity* is a measure of the amount of dissolved salts in the water. Saline water conducts electricity more readily than freshwater, so electrical conductivity (EC) is routinely used to measure salinity. As salinity increases, it may become toxic to native freshwater organisms. Prior to drought conditions, salinity was on average less than 700 µS/cm (EC) in Lake Alexandrina (at Milang) and less than 1600 EC in Lake Albert (at Meningie).**

***Turbidity* is a measure of the cloudiness or haziness in water caused by suspended solids (e.g. sediment, algae). Turbidity is expressed in Nephelometric Turbidity Units (NTU) and is measured using a relationship of light reflected from a given sample. Turbidity is very variable in the Lower Lakes and influenced primarily by wind events. Prior to drought conditions, turbidity was on average about 60 NTU in Lake Alexandrina (at Milang).**

***Sulfate:chloride ratio* is used to give an indication of any sulfate inputs from acid sulfate soils. Chloride concentration is largely determined by evaporation and dilution. An increase in the ratio of sulfate:chloride indicates possible external sulfate inputs from acid sulfate soils. Prior to the drought, this ratio was about 0.06 (SO_4: Cl).**

***Nutrients - Total nitrogen (TN) and total phosphorus (TP)* are the total amount of nitrogen and phosphorus present in the water body. Nitrogen can be present in different forms (e.g. organic nitrogen in plant material, ammonia, nitrate and nitrite). Phosphorus can also be present in different forms (e.g. organic phosphorus, phosphate). High concentrations of phosphorus and nitrogen can result in excessive growth of aquatic plants such as phytoplankton, cyanobacteria, macrophytes and filamentous algae. Prior to drought conditions, TN was on average about 1.2mg/L in Lake Alexandrina (at Milang) and 1.6mg/L in Lake Albert (at Meningie) with TP on average about 0.15 mg/L in Lake Alexandrina (at Milang).**

***Chlorophyll a* is the main photosynthetic pigment in green algae. The concentration of chlorophyll gives an indication of the volume of aquatic plants present in the water column. Levels in excess of 15 µg/L are considered very high ("hyper-eutrophic") and nuisance algae and plant growth can occur. Prior to drought conditions, chlorophyll was on average about 24 µg/L in Lake Alexandrina (at Milang) and 35 µg/L in Lake Albert (at Meningie).**

Lake Alexandrina

Ambient water quality monitoring results are discussed below for selected sites and parameters in Lake Alexandrina.

pH

- pH levels are relatively stable and within ANZECC guideline levels (pH 6.5-9.5) at all sites in the main Lake Alexandrina water body (Figure 2).

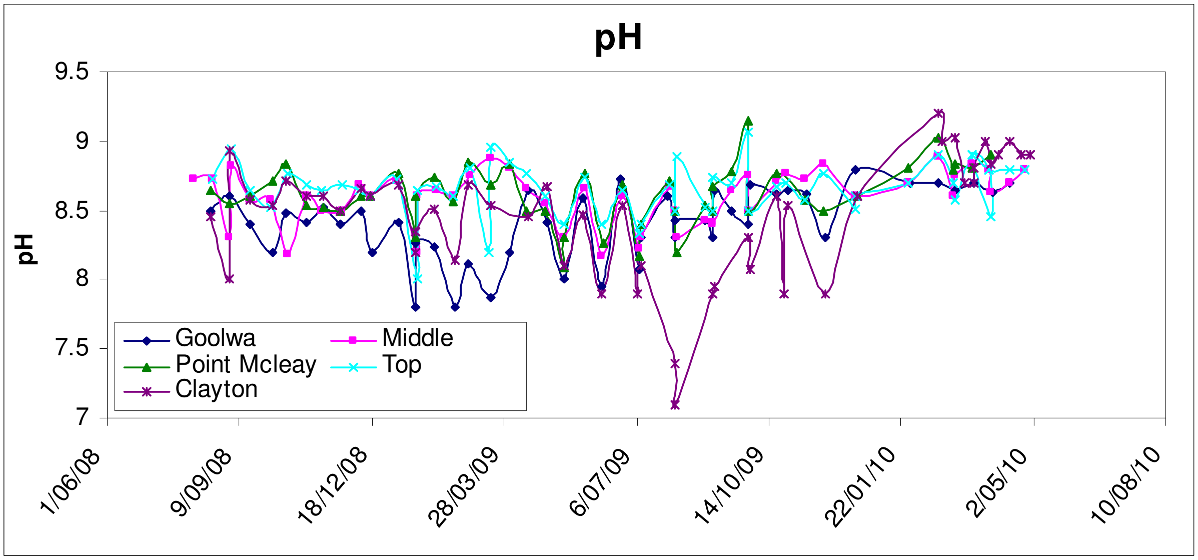

Figure 2 – pH at the Lake Alexandrina ambient monitoring sites

Alkalinity

- Alkalinity remains stable and satisfactory for all sites in the main areas of Lake Alexandrina (Figure 3).

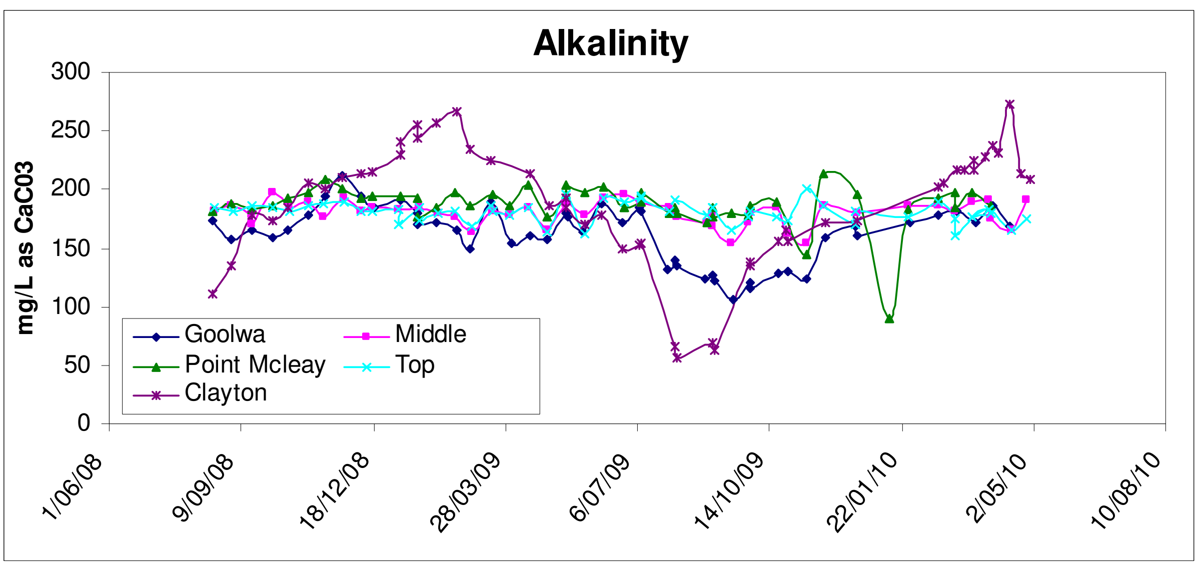

Figure 3 – Alkalinity at the Lake Alexandrina ambient monitoring sites

Salinity (EC)

Salinity levels (as measured by electrical conductivity) have slightly decreased at most sites recently (Figure 4). Autumn rainfall, increased River Murray Basin inflows, and cooler autumn weather has contributed to this decrease. Despite these minor decreases, salinity thresholds for freshwater species to live healthily in the Lower Lakes have already been exceeded in the entire Lower Lakes[2]. A current EPA macro-invertebrate survey of the Lower Lakes is confirming this assessment, with no or very few freshwater species remaining and very limited recolonisation of brackish-estuarine species. Salinity at the Goolwa site is very high and continues to increase, possibly due to leakage through the Goolwa barrage now that water levels have decreased below mean sea level in this region again.

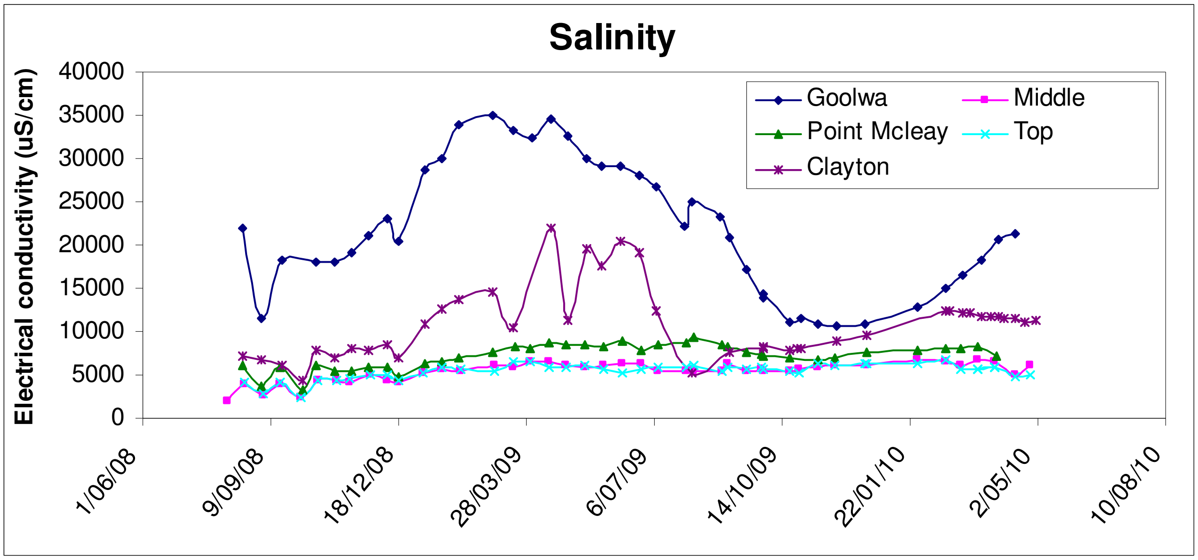

Figure 4 – Salinity at the Lake Alexandrina ambient monitoring sites

Sulfate:chloride ratio

- The sulfate:chloride ratio shows some variability, but is not showing any clear increasing trends that would suggest widespread acid sulfate soil influences (Figure 5). Some increases were seen at the Goolwa and Clayton sites, most likely as a result of localised acid flux in the Currency-Finniss region during the winter of 2009.

[2] Few freshwater species are predicted to remain above 8000 EC, but the diversity of freshwater ecosystems decrease rapidly above 5,000 EC. See Nielsen et al. (2008), *Marine and Freshwater Research*, 59, 549-559.

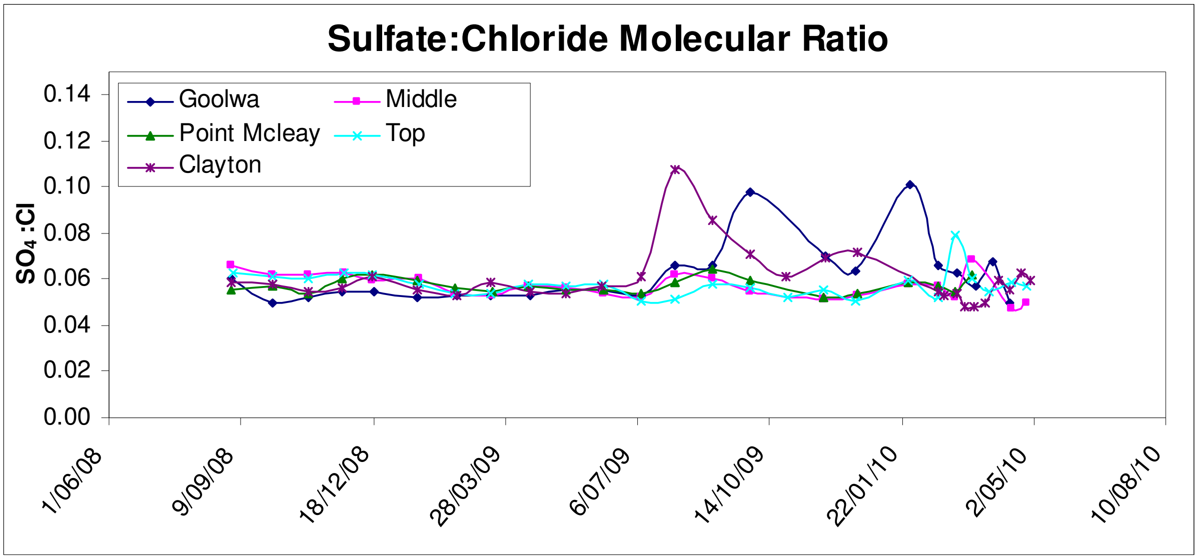

Figure 5 – Sulfate:chloride ratio at the Lake Alexandrina ambient monitoring sites

Turbidity

- Turbidity is very variable in Lake Alexandrina and influenced primarily by wind events (Figure 6). The sites at Goolwa and near Clayton appear to have much lower turbidity than the other sites at present. This is likely to be due to less current and wind-driven re suspension of sediment as a consequence of the Clayton regulator being in place. The aggregation and settling of suspended particles is also likely to be increased by the high salinities at these two sites (Figure 4).

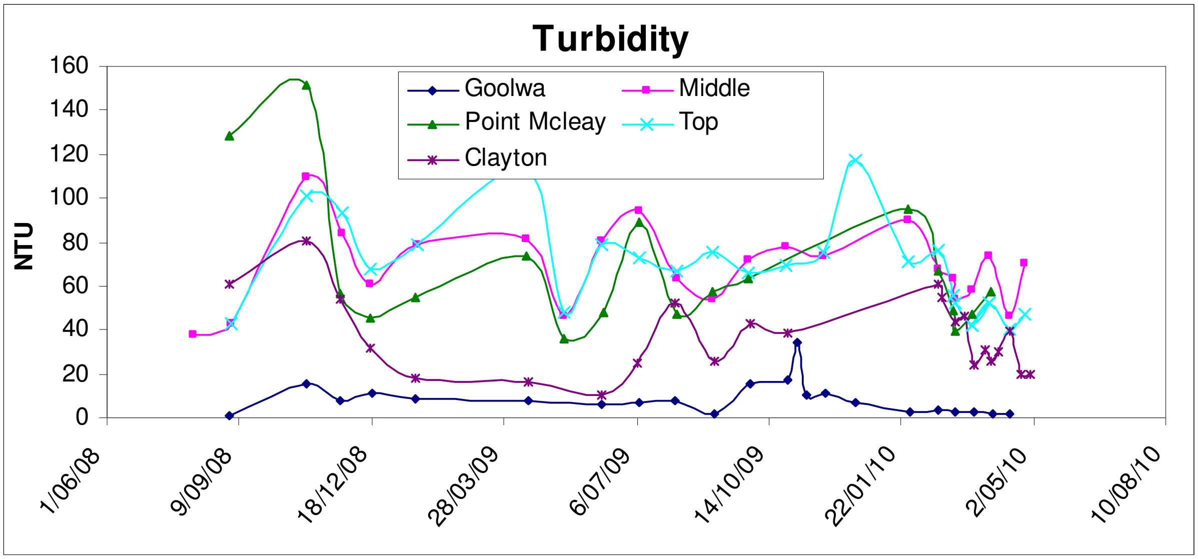

Figure 6 – Turbidity at the Lake Alexandrina ambient monitoring sites

Nutrients (total nitrogen and phosphorus)

- Total nitrogen and total phosphorus remain at very high levels in Lake Alexandrina (see Milang data in Figures 7 and 8). These levels are well in excess of the ANZECC guidelines (<1mg/L TN, <0.025 mg/L TP) and high compared to historical levels.

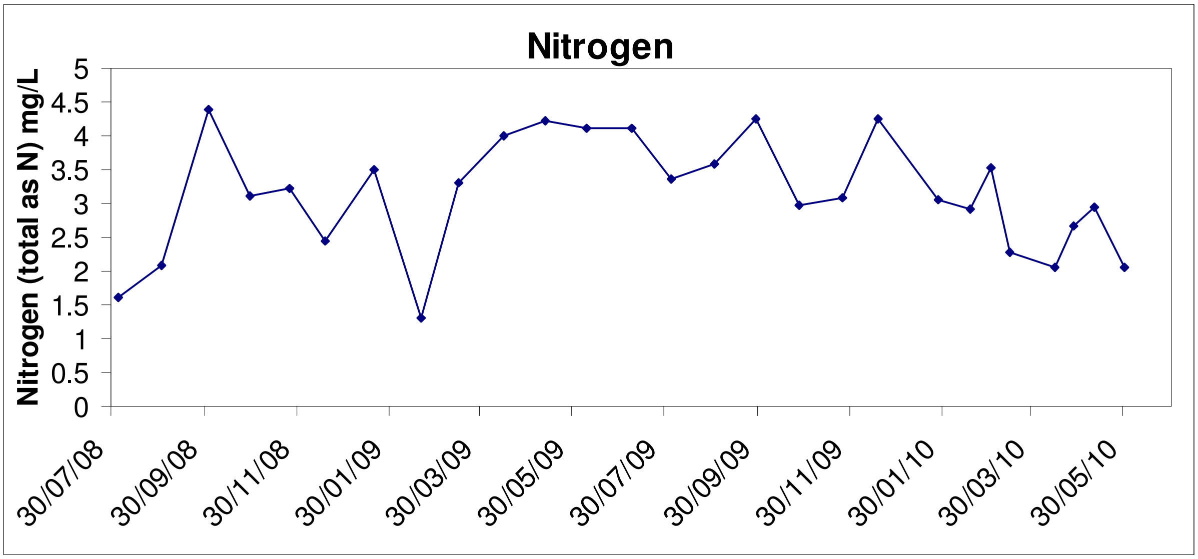

Figure 7 – Total Nitrogen at Milang

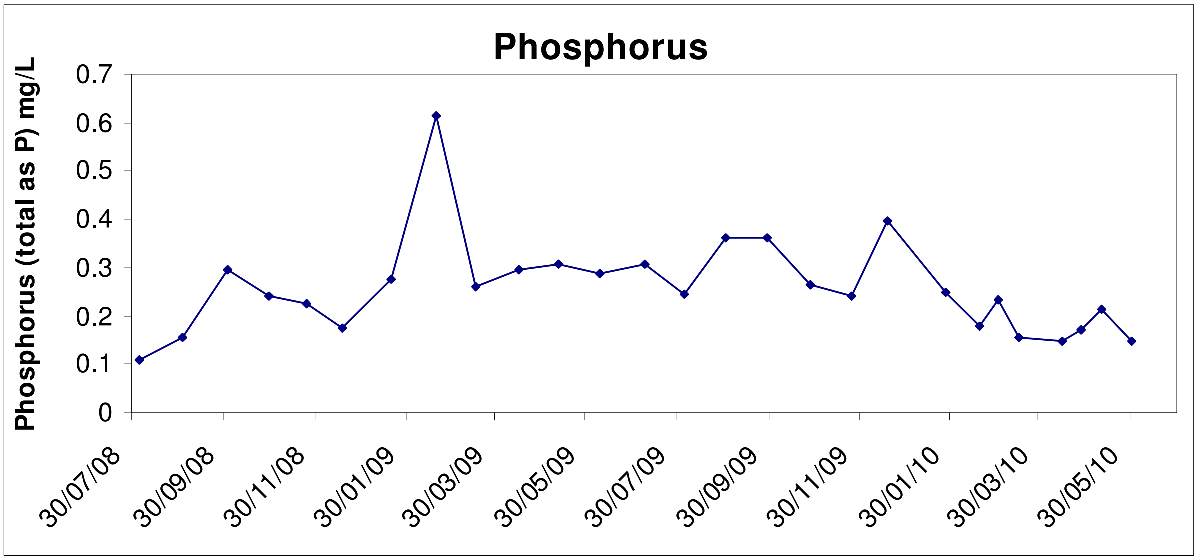

Figure 8 – Total Phosphorus at Milang

Chlorophyll and blue-green algae

- Chlorophyll *a* is also at very high levels in Lake Alexandrina (see Milang data in Figure 9). These levels are well in excess of historical values and the ANZECC guidelines (<15 µg/L) and indicate a highly nutrient enriched (hyper-eutrophic) system. While the chlorophyll levels in Lake Alexandrina are very high, no potentially toxic blue-green algal blooms are present.

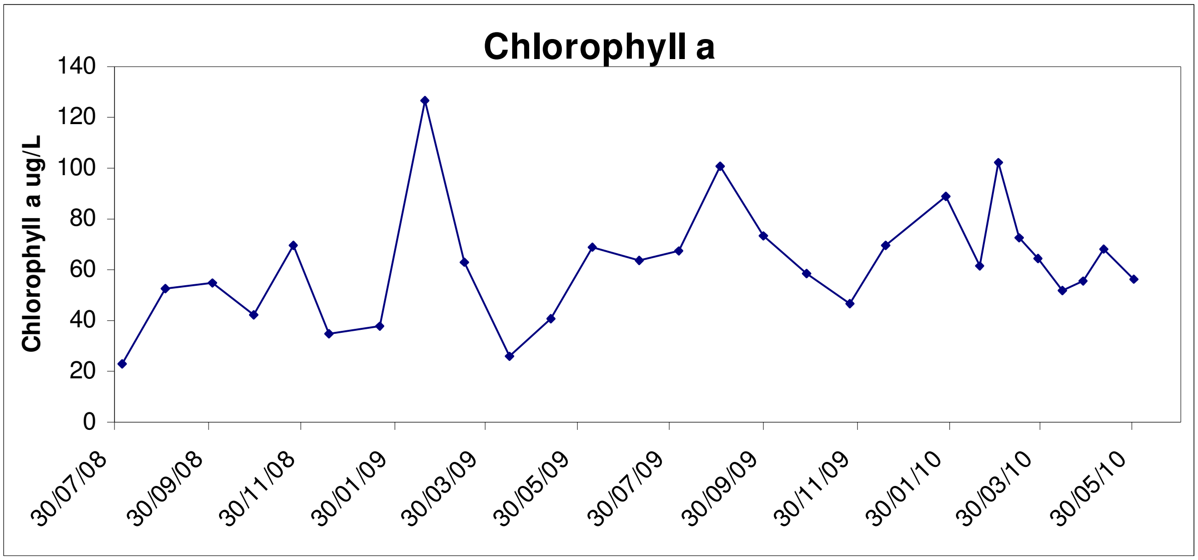

Figure 9 – Chlorophyll at Milang

Lake Albert Water Quality

Ambient water quality monitoring results are discussed below for selected sites and parameters in Lake Albert.

pH

- pH levels are stable and within ANZECC guideline levels (pH 6.5-9.0) at all sites in the main Lake Albert water body (Figure 10).

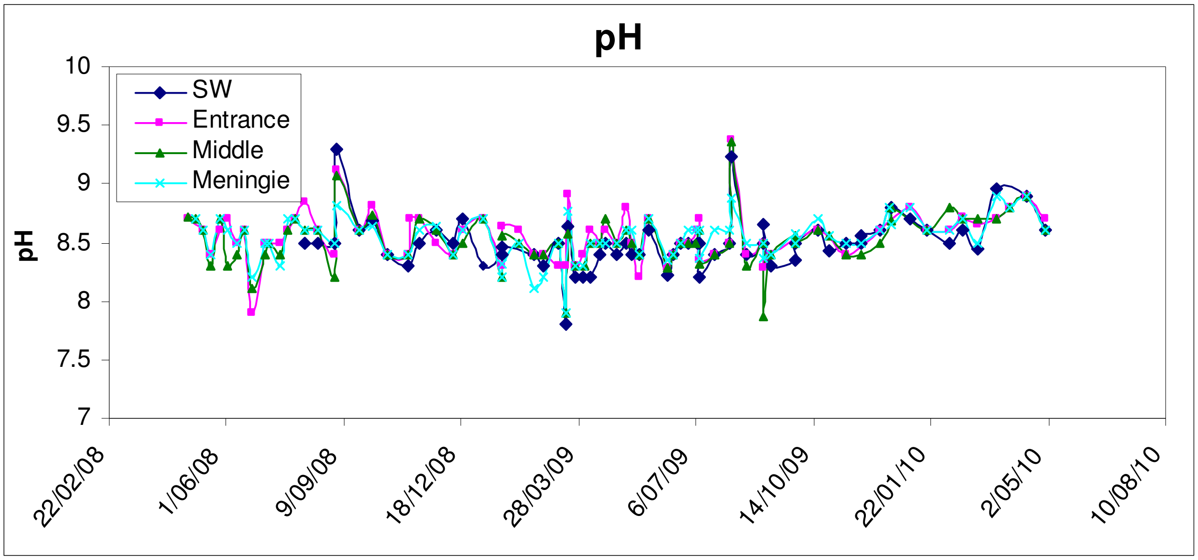

Figure 10 – pH at the Lake Albert ambient monitoring sites

Alkalinity

- Lake Albert alkalinity remains high and rapid increases were seen in January (270 - 310 mg/L as $CaCO_3$, Figure 11). The reason for this increase is unclear and the alkalinity levels now greatly exceed those in Lake Alexandrina. Alkalinity has been decreasing over the last month at all sites. This is presumably due to the increasing dilution from lower alkalinity water pumped from Lake Alexandrina with the entrance site recording the largest alkalinity decline.

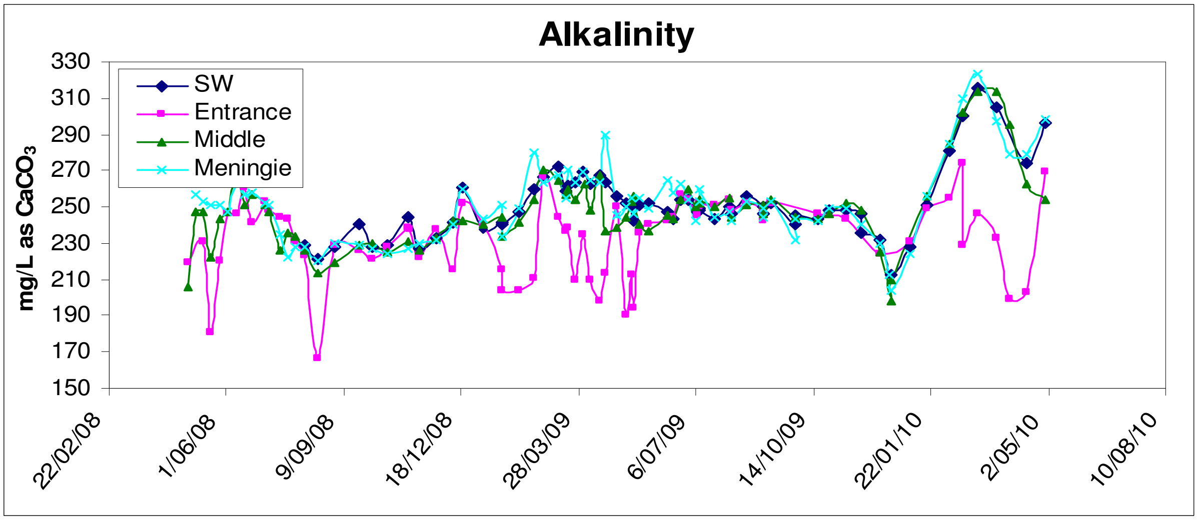

Figure 11 – Alkalinity at the Lake Albert ambient monitoring sites

Salinity (EC)

- Salinity remains very high compared to historical levels but has recently decreased at all sites with the exception of the enterance site. This site has experienced an increase in salinity due to the completion of pumping and mixing with more saline waters within the lake(Figure 12)..

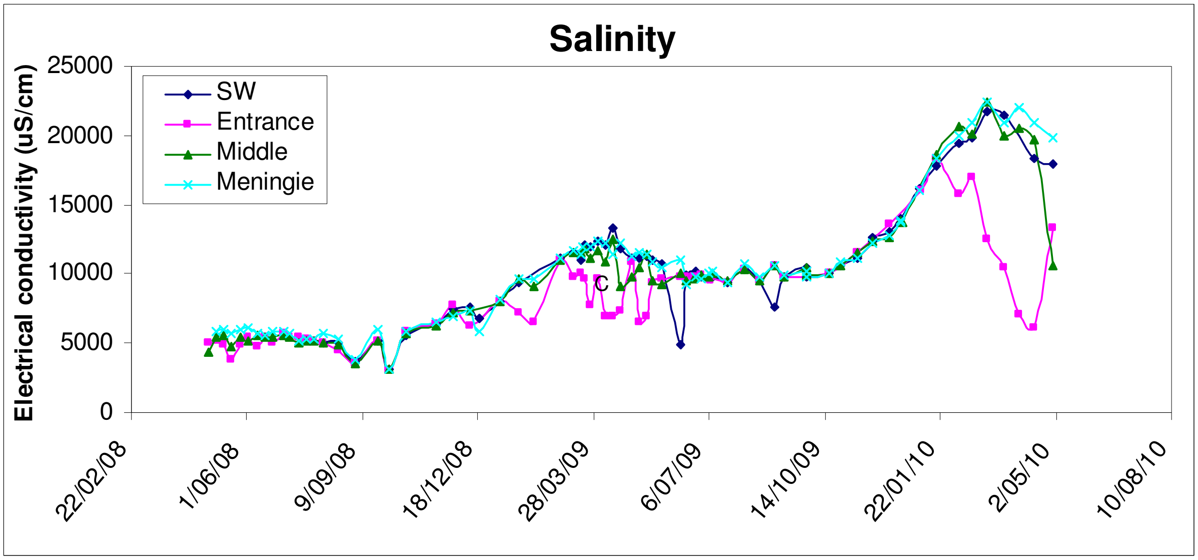

Figure 12 – Salinity at the Lake Albert ambient monitoring sites

Sulfate:chloride ratio

- The sulfate:chloride ratio has decreased over the last few months (Figure 13). This may be related to the dilution from Lake Alexandrina water pumped in (ratio is now similar to that in Lake Alexandrina, see Figure 5).

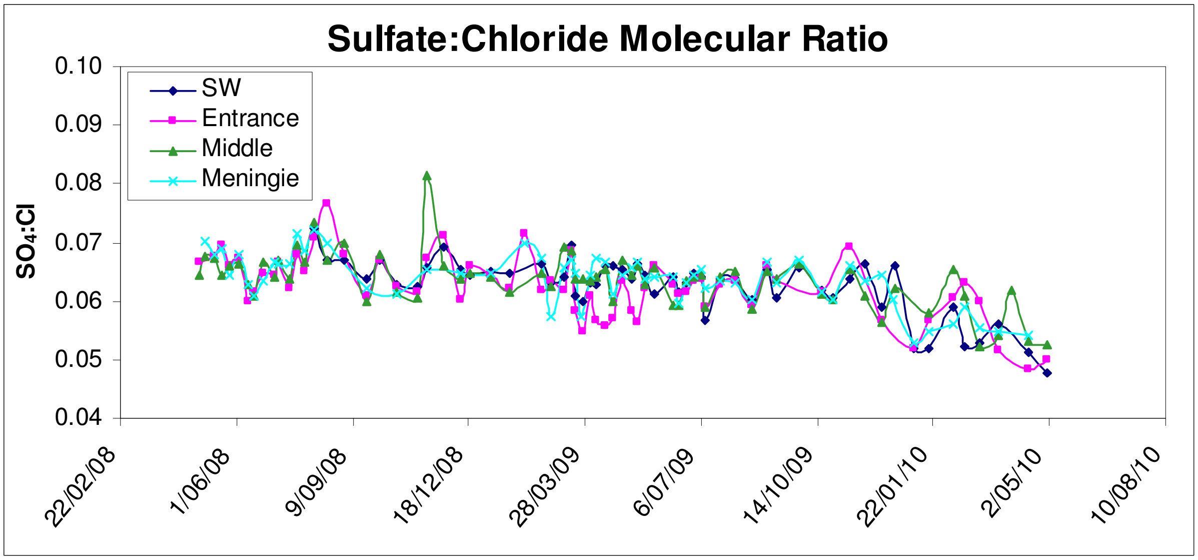

Figure 13 – Sulfate:chloride ratio at the Lake Albert ambient monitoring sites

Turbidity

- Turbidity in Lake Albert currently appears relatively low in comparison to levels in the last 2 years (Figure 14).

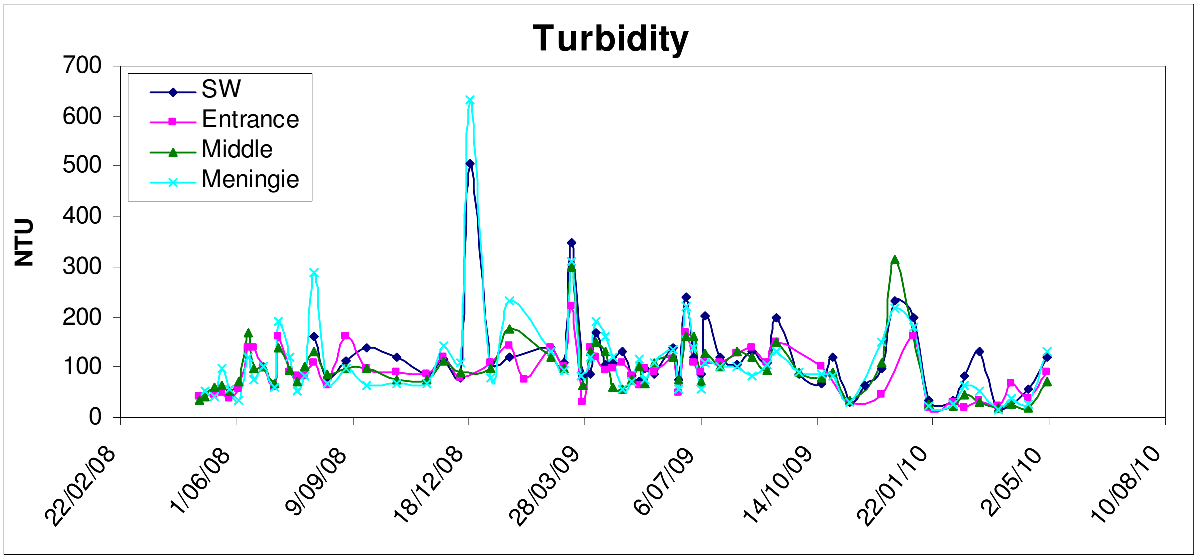

Figure 14 – Turbidity at the Lake Albert ambient monitoring sites

Nutrients (total nitrogen and phosphorus)

- Total nitrogen and total phosphorus are now at very high levels in Lake Albert (see Meningie data in Figures 15 and 16).). These levels are well in excess of the ANZECC guidelines (<1mg/L TN, <0.025 mg/L TP) and high compared to historical levels.

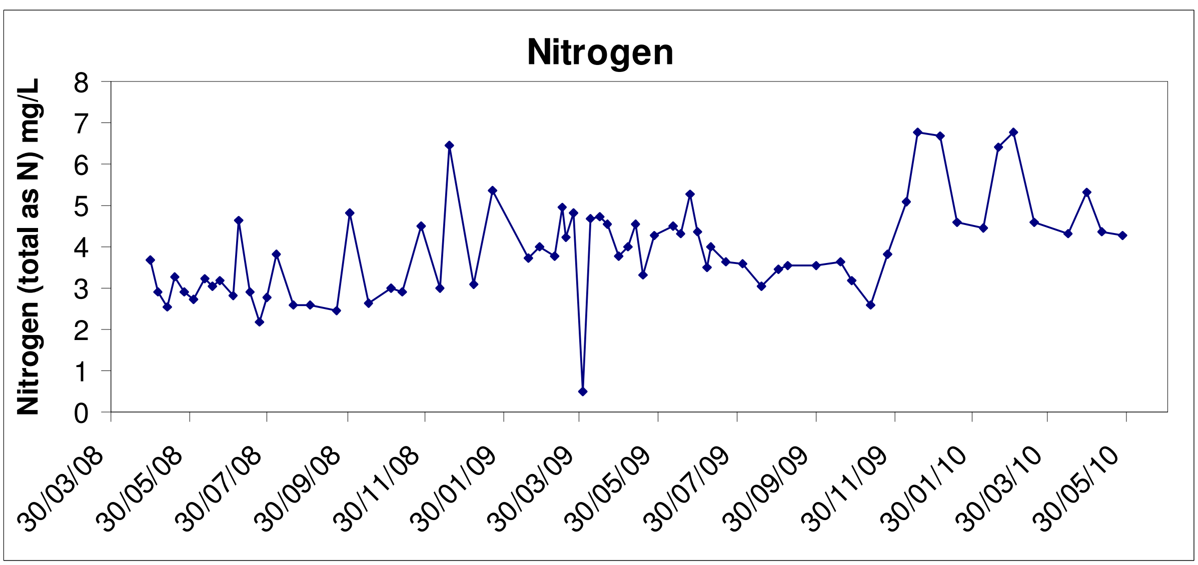

Figure 15 – Total Nitrogen at Meningie

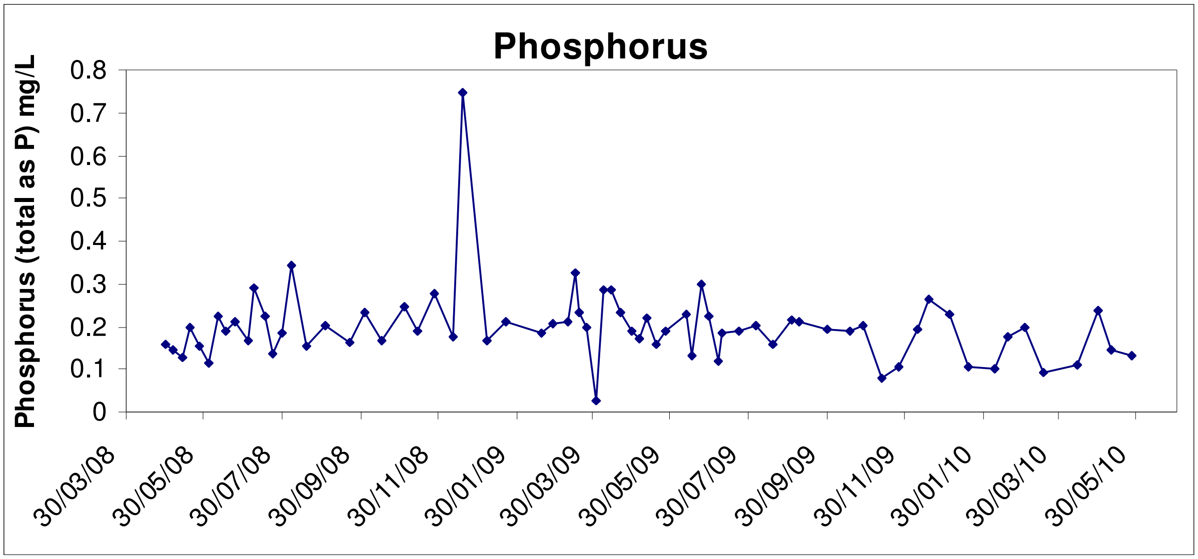

Figure 16 – Total phosphorus at Meningie

Chlorophyll and blue-green algae

- Chlorophyll *a* is variable but remains at very high levels in Lake Albert (see Meningie data in Figure 17). These levels are well in excess of the ANZECC guidelines (<15 µg/L) and indicate a very nutrient enriched system. No toxic blue-green algal issues are apparent at present, although this will be monitored closely over coming months as a large *Nodularia* (potentially toxic blue-green algae) bloom formed last winter.

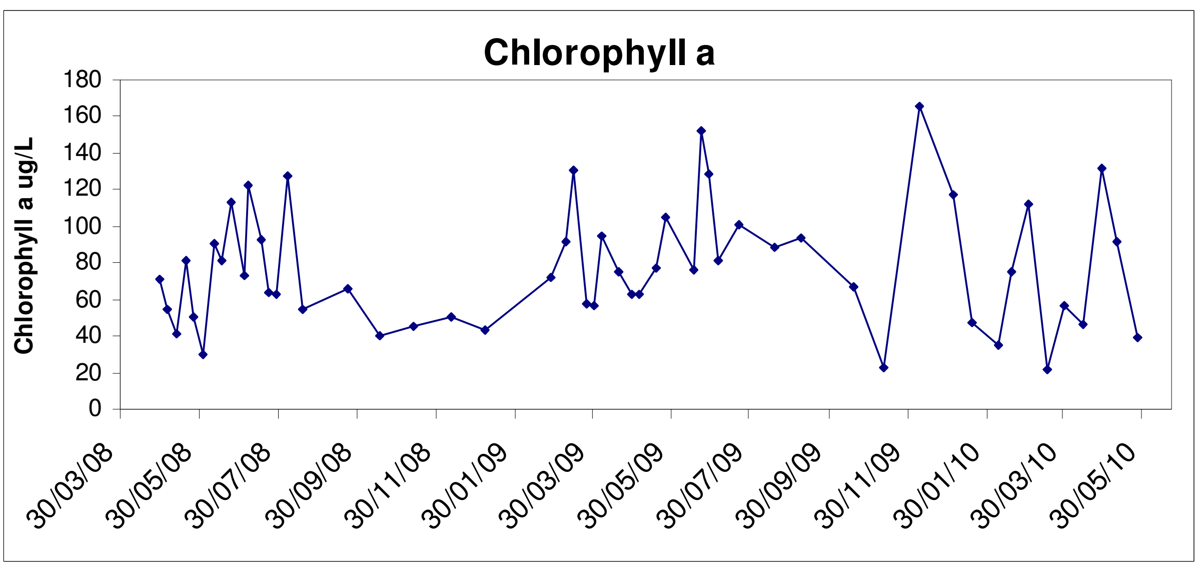

Figure 17 – Chlorophyll at Meningie

Tributaries Water Quality

Ambient water quality monitoring results are discussed below for selected sites and parameters in the Currency-Finniss tributaries region. See Figure 1 for sample site locations.

pH

- pH levels are stable and within ANZECC guideline levels (pH 6.5-9.5) at all sites in the tributaries (Figure 18).

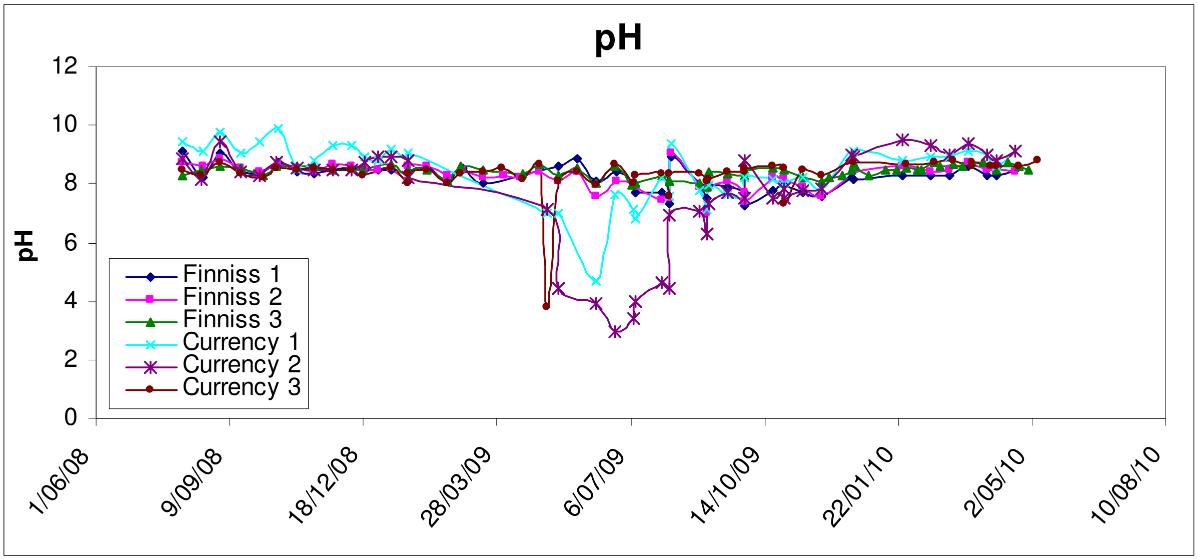

Figure 18 – pH at the Tributary ambient monitoring sites

Alkalinity

- Alkalinity at most of the tributary sites is satisfactory (Figure 19). The upper Currency Creek region has shown some alkalinity declines and the upper Currency pool now has very low alkalinity (see acidification response section).

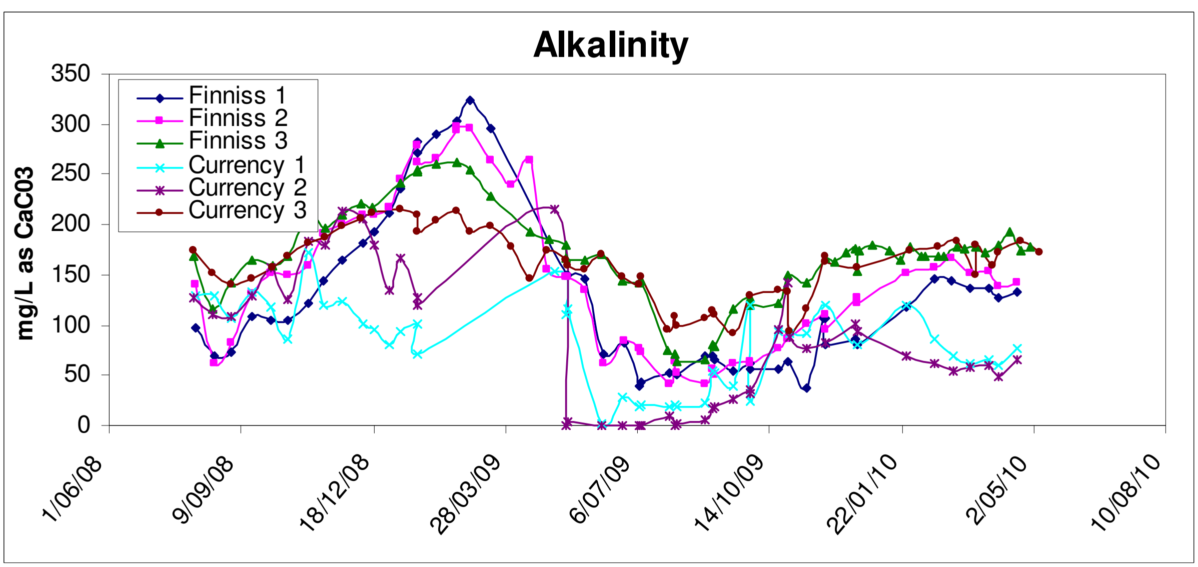

Figure 19 – Alkalinity at the Tributary ambient monitoring sites

Salinity (EC)

- Salinity is still increasing at all sites due to concentration by evaporation (Figure 20). This area is not receiving any dilution from the recent increased river inflows to Lake Alexandrina due to the physical restriction of the Goolwa Regulator.

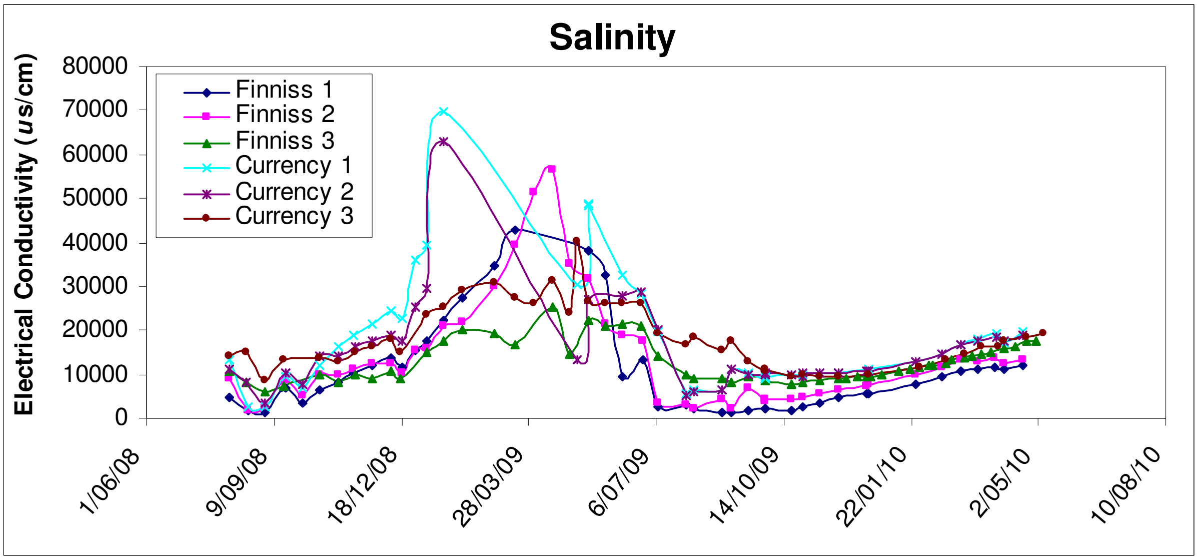

Figure 20 – Salinity at the Tributary ambient monitoring sites

Sulfate:chloride ratio

- The sulfate:chloride ratio shows some variability but is not showing any clear increasing trends that would suggest widespread acid sulfate soil inputs (Figure 21). Previously, during the winter of 2009, there were large increases in this ratio when the Currency region acidified.

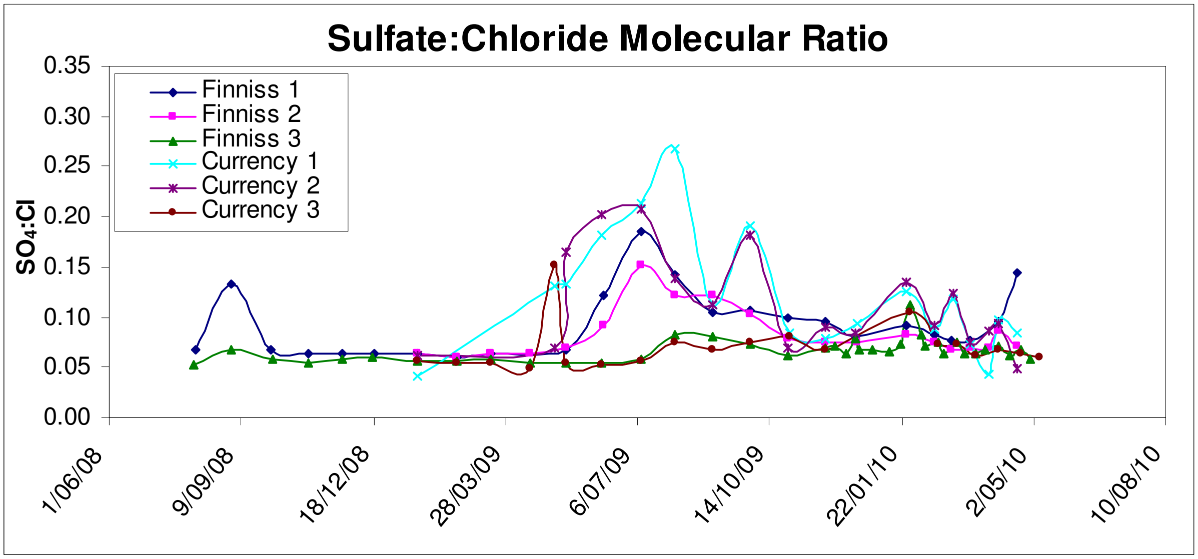

Figure 21 – Sulfate:chloride molecular ratio at the Tributary ambient monitoring sites

Turbidity

- Since pumping finished into the Goolwa Channel, the turbidity at all the tributary sites within the Clayton regulator has decreased markedly (Figure 22) and are at very low levels (<7NTU) in comparison to other sites in Lake Alexandrina (see Figure 6). The very low turbidity in this region is likely due to increased particle settling and reduced particle resuspension due to a reduction in wind-driven current flows following construction of the Clayton regulator. Salt-induced coagulation and settling of fine clay particles (colloids) is another likely reason for this outcome.

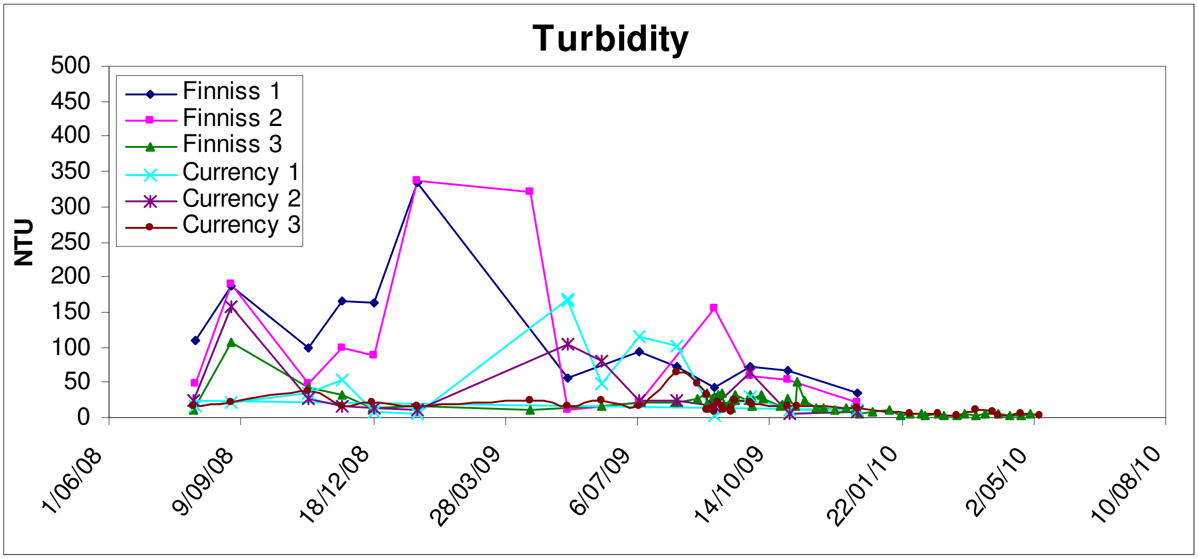

Figure 22 – Turbidity at the Tributary ambient monitoring sites

Nutrients (total nitrogen and phosphorus)

- Total nitrogen and phosphorus are at high levels in the tributaries, although levels are presently much lower than during last winter (Figures 23 and 24).

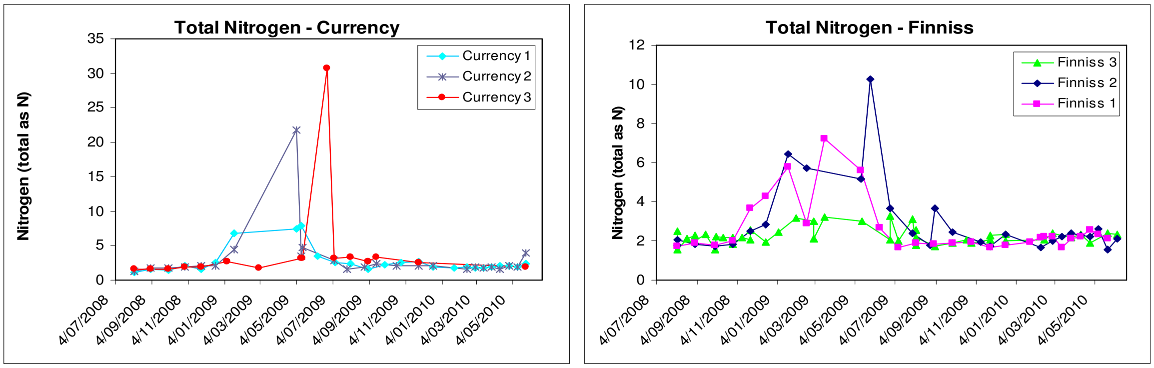

Figure 23 – Total Nitrogen at the Tributary ambient monitoring sites

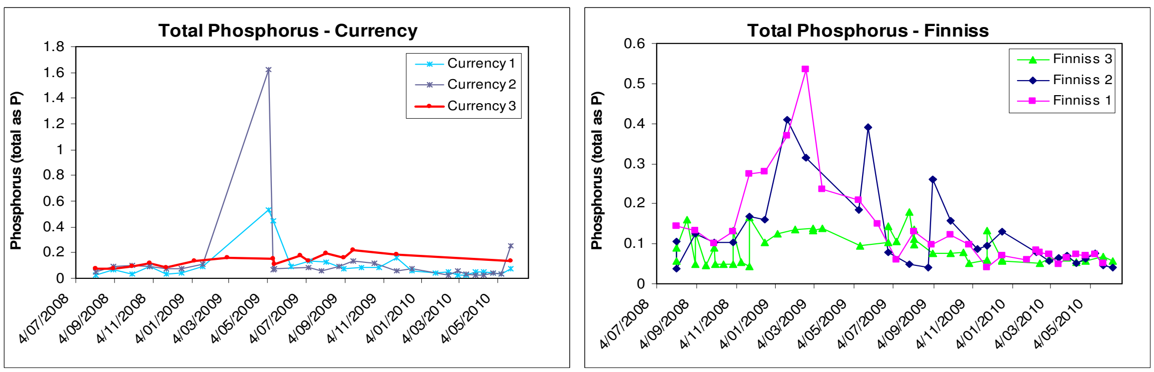

Figure 24 – Total phosphorus at the Tributary ambient monitoring sites

Chlorophyll and blue-green algae

- Chlorophyll *a* is at very high levels at the lower tributary sites (Figure 25). These levels are well in excess of the ANZECC guidelines (<15 µg/L) and indicate a very nutrient enriched system. No toxic blue-green algal issues are apparent at present. A large increase in filamentous (*Cladophora sp.)* and macro-algal growth (*Stuckenia pectinata*) was observed in this region over the summer of 2009/10, presumably as a result of the greater water clarity allowing more light to stimulate algal growth.

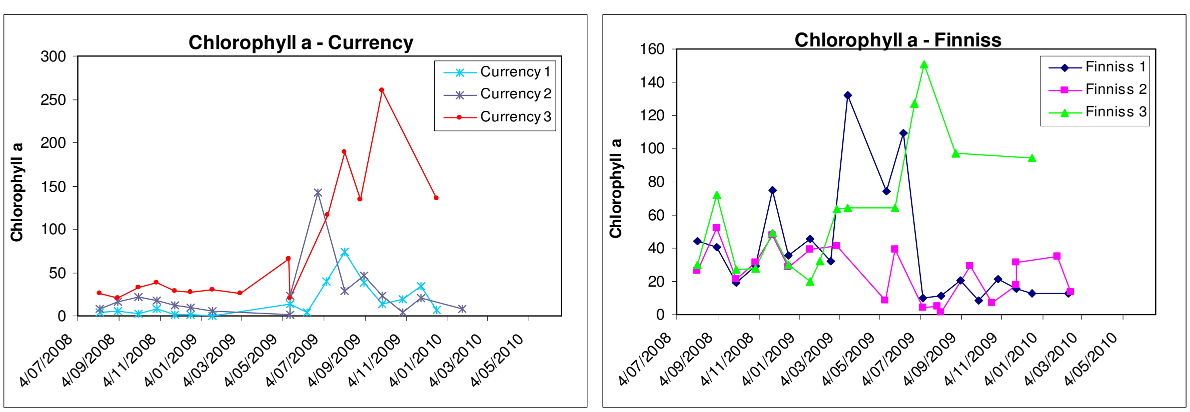

Figure 25 – Chlorophyll *a* at the Tributary ambient monitoring sites

Acidification response monitoring

Response water quality monitoring is being undertaken on an “as needs basis” to assess if any localised acidification is present. See Figure 1 for general sample site locations. The selection of sites was based upon perceived acid sulfate soil risk, in accordance with available data on the concentration and distribution of sulfidic and sulfuric materials. Each site was screened to identify the extent of acidity and frequency of monitoring was determined from these results. The information informs the need for management actions, such as limestone dosing, which has the capacity to reduce the acidity hazard and mitigate further metal release.

Boggy Lake

Boggy Lake is a shallow lagoon situated within the north-western corner of Lake Alexandrina. The lagoon is connected to the main water body on its eastern side. During the summer periods of 2008/09 and 2009/10 a large proportion of Boggy Lake dried, exposing acid sulfate soils (predominantly cracking clays) with high net acidity and access to atmospheric oxygen allowing the oxidation of pyrite to occur.

The oxidation of pyrite generates acidity (hydrogen ions, dissolved iron) in the soil. If severe acid conditions (pH<4) develop in the soil, precipitation of secondary acidic minerals (e.g. Jarosite) often occurs and weathering of alumino-silicate (e.g. clay) minerals is enhanced. High concentrations of soluble aluminium are a common outcome of this weathering process.

Following recent rainfall events and increased flows , Boggy Lake has been rewet and progressively inundated (Figure 26).

Figure 26 – Acidified surface water (pH 2-3) overlying cracked clay soils

As a result of the acidification risk, the EPA has been monitoring water quality in Boggy Lake on an approximately fortnightly basis. Parameters measured in the field include pH, temperature, dissolved oxygen, salinity, oxidation-reduction potential, alkalinity and acidity. Selected analyses for major ions (e.g. sulfate, chloride) and metals (e.g. dissolved and total iron, aluminium and arsenic) are performed in the laboratory.

Figure 27 shows a map of pH levels at 10 sites in Boggy Lake sampled on 18/5/2010. Very low pH (2-3, red dots on figure) is present in the south-western margins of the lagoon. Approximately 250ha of surface water is acidic (pH<6.5) at present. The acidic sections of the lagoon have low turbidity and high acidity (up to 2500 mg/L as $CaCO_3$). The waters in Boggy Lake increase in pH as they mix with the alkaline waters of Lake Alexandrina. Brown iron oxide precipitates are forming as the water is neutralised and precipitates (suspected to be Schwertmannite) are also forming in acidic areas. The area was subject to aerial limestone dosing from 28/5/2009 to 2/06/10 and follow up monitoring will occur on the completion of this program. Evaluation of the monitoring data will determine future actions.

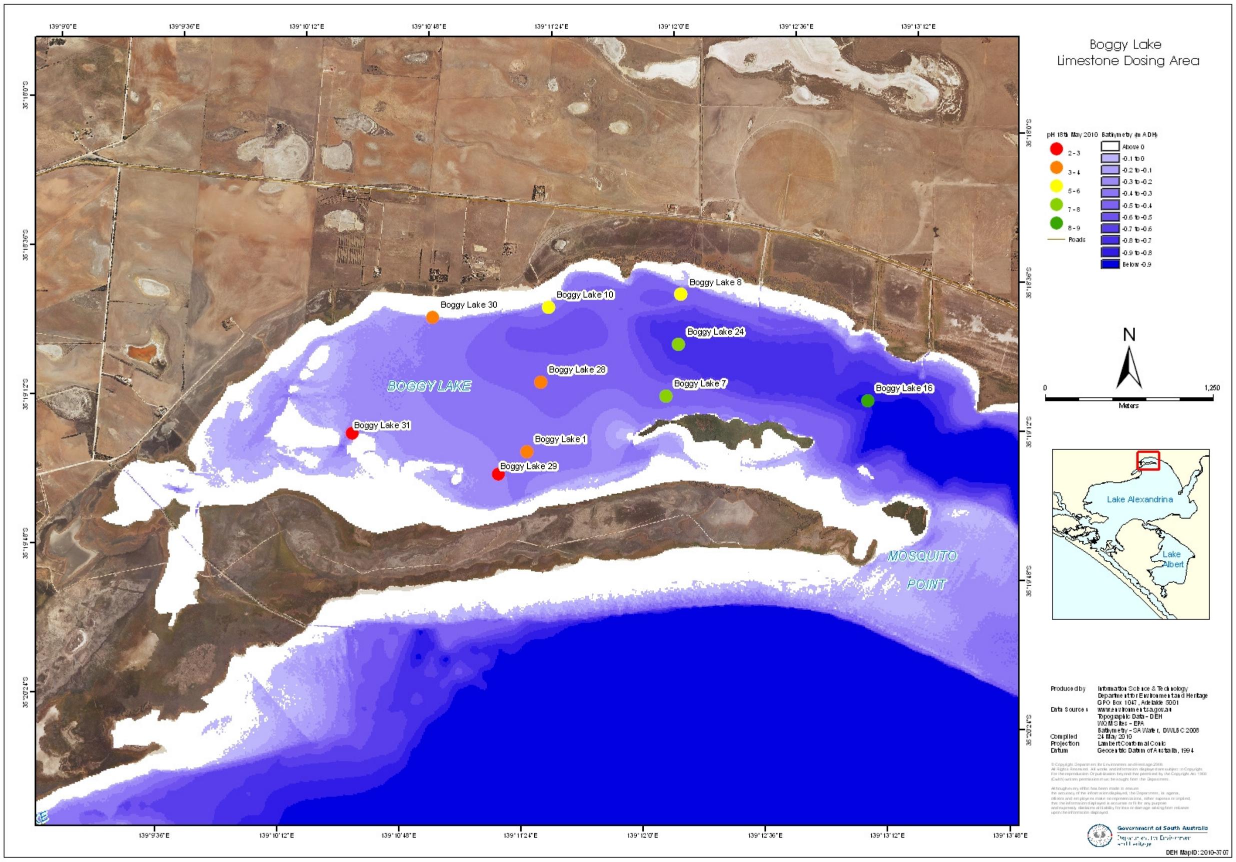

Figure 27 – Map of Boggy Lake pH levels on 18/5/2010

Dog Lake

Dog Lake is to the south of Boggy Lake in the north-western corner of Lake Alexandrina. Sampling has indicated that the water in the area currently rewet is not acidic (pH 7-9). However there were significant deposits of jarosite and other acidic minerals present. It is likely from field observations that lake mixing had flushed the immediately available surface acidity out of the margins and diluted it with the main lake water. There is a risk remaining in the area, particularly if the sill into the large dried area is overtopped, as there would be much more limited flushing in this instance. This area will continue to be monitored as the area refills over the winter period.

Upper Currency Creek

Upper Currency Creek is a large pool representing the transition from the narrow creek to the open waterbody. The pool is constrained by a narrow bottle neck which separates the pool from Goolwa channel (Figure 28). The pool completely dried out over the summer of 2008-09, exposing large areas of acid sulfate soils. Rainfall events in May 2009 allowed pooling over the acid sulfate soils, causing areas of localised acidification. In response to the acidification events, the area was aerial dosed with 1000 tonnes of fine grade limestone. Following the addition of limestone and the construction of a regulator to ensure sediments remain inundated with water, the area recovered somewhat with increasing pH and alkalinity (69 mg/L as $CaCO_3$ on 18/1/2010). However, after the 2009-10 summer, the alkalinity began to decrease again from 40 mg/L as $CaCO_3$ on 1/4/2010 to 11.5 mg/L as $CaCO_3$ on 17/5/2010. Large areas of orange/brown precipitate have been observed around the north-western side of the pool (see Figure 29) which is suspected to be an iron oxide precipitate indicating a significant acidification event. This site is currently being monitored twice weekly for decreases in alkalinity, the presence of acidity and metal release.

Figure 28 – Upper Currency Creek – CC291 indicates main monitoring location

Figure 29 – Red/orange precipitate on the shoreline of Upper Currency Creek near monitoring location

Western margin of Lake Albert

Water quality monitoring of Lake Albert's western shoreline on the12th May 2010 sought to map the extent of 3 sites that had previously been screened and found to have low pH values. Nine sites were monitored in the bay to the west of Reedy Point and all had pH below 7, ranging from 2.72-6.46 (Figure 30). Acidity was present at these sites with values ranging from 95-945 mg/L $CaCO_3$. Scum deposits were also visible (Figure 31). The previously tested pool to the west of Rumply Point had dried and results from the nearest water body to this site revealed pH of 8.28 and alkalinity of 240 mg/L $CaCO_3$. The pool south-west of Rumply Point previously tested had pH values ranging from 7.76-7.86 and alkalinity present at all sites, values ranging from 54-116 mg/L $CaCO_3$.

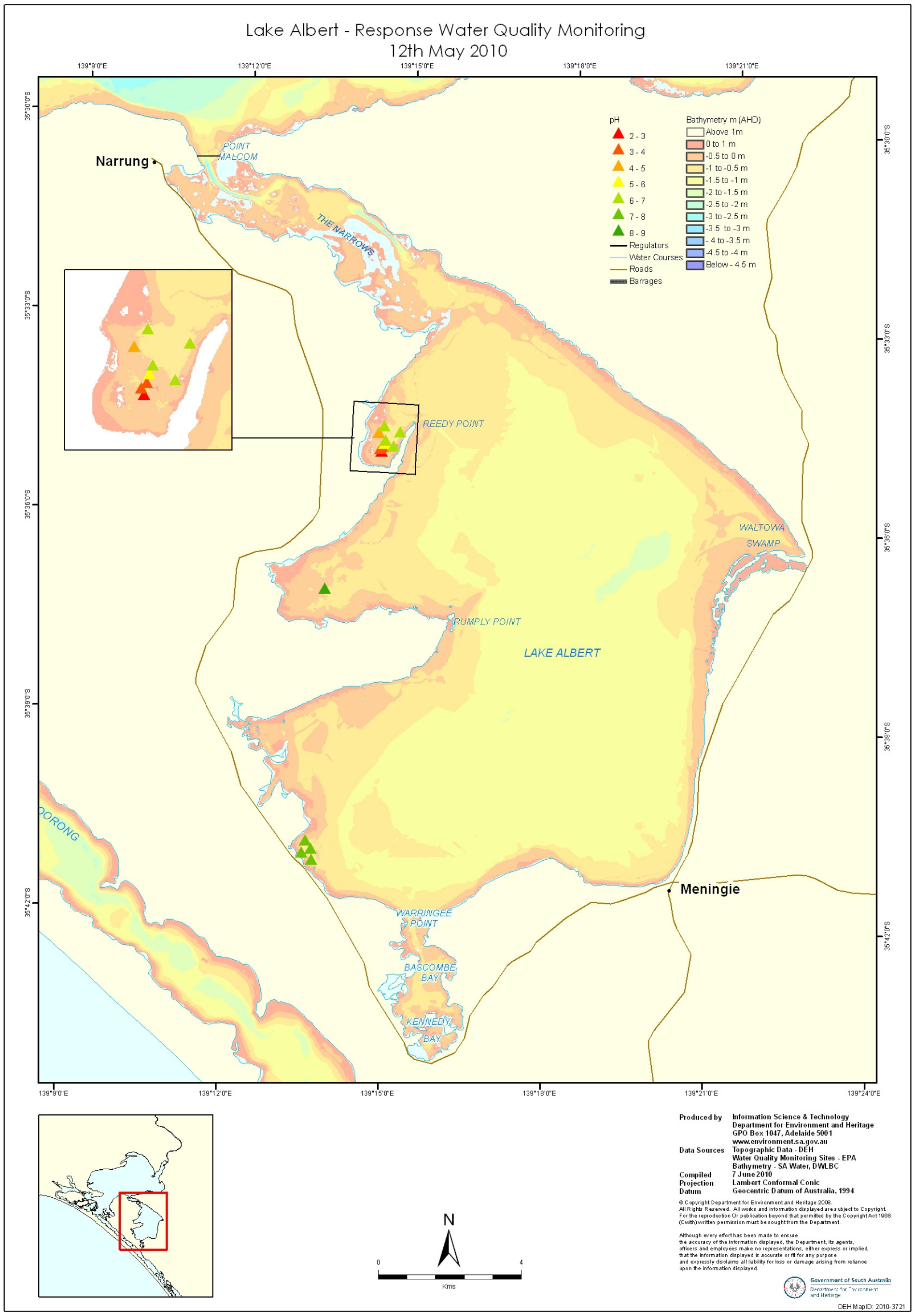

Figure 30 – Map of western Lake Albert pH levels in May 2010

Figure 31 - Photos of water acidification and scum deposits at Reedy Point, Lake Albert

Dunn's Lagoon

Dunn's Lagoon is near Clayton on the Goolwa Channel (Figures 1 and 32). This lagoon dried during 2008-09 but has been recently rewet as a result of the water level rise. In 2009, acidic surface water was found pooled following a rainfall event, however follow up sampling during March 2010 has found the lagoon pH is now neutral (pH 7-8) at all sites. Decreases in alkalinity have been observed away from the entrance, as the influence of alkaline Lake Alexandrina water reduces. The site closest to the channel entrance records alkalinity of 159-239 mg as $CaCO_3$, compared to the middle of the lagoon which records low to moderate alkalinities (86-150 mg/L as $CaCO_3$). This suggests there has been some release of acidity from the soil into the waterbody but currently this is able to be neutralised by dilution via exchange with Lake Alexandrina water. Water exchange has been occurring routinely from the channel near Clayton, but it has been noted that mixing with the main lake via the east channel has also occurred.

Figure 32: Aerial photo of Dunn's Lagoon near Clayton (foreground) in Lake Alexandrina

Loveday Bay

Loveday Bay is a shallow lagoon located at the south eastern shore of Lake Alexandrina (Figure 1 and 33). When water levels are below -0.3 AHD, the lagoon is separated from Lake Alexandrina by a natural sand barrier (Figure 33). There is periodic connection to the main water body during some large wind events which can raise water levels on the Lake Alexandrina side. Large areas of Loveday Bay dried in the summer of 2008-09 allowing the oxidation of acid sulfate soils. Following rewetting from winter rains, the lagoon displayed large areas of acidic water (pH < 3) and metal precipitates. Since this time the EPA has monitored Loveday Bay on a fortnightly basis and low pH and high acidity has been present at most sites since mid 2009. The area has again dried over the 2009-10 summer, exposing sediments to oxidation. Recent samples indicate the water body is now neutral pH after a second winter rainfall rewetting and partial connection to Lake Alexandrina. Sampling will continue over the coming months.

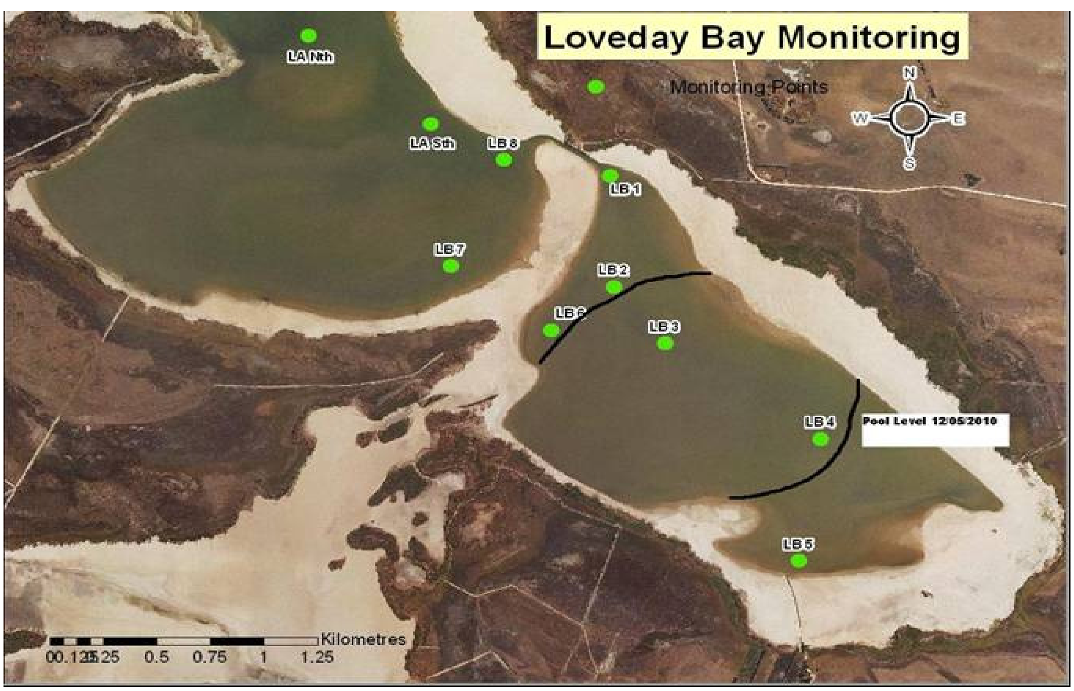

Figure 33 Map of Loveday Bay showing natural sand barrier

Further Information

Further information on water quality and quantity, and acid sulfate soils, can be found on the following websites:

- Department for Environment and Natural Resources www.environment.sa.gov.au/cllmm/
- River Murray Data http://data.rivermurray.sa.gov.au/ (real-time data)
- Environment Protection Authority www.epa.sa.gov.au or for specific Lower Lakes data see www.epa.sa.gov.au/environmental_info/water_quality/monitoring_programs_and_assessments/lower_lakes
- Department for Water www.dwlbc.sa.gov.au
- South Australian Murray–Darling Basin Natural Resource Management Board www.samdbnrm.sa.gov.au
- Murray–Darling Basin Authority www.mdba.gov.au
- Waterwatch www.waterwatch.org.au
- CSIRO acid sulfate soils www.clw.csiro.au/acidsulfatesoils/murray.html