Lakeshore erosion monitoring data analysis

Government of South Australia
Department of Environment, Water and Natural Resources

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Contents

List of figures

List of tables

1 Introduction

1.1 Background

Erosion of the Lower Murray Lake Alexandrina and Lake Albert lakeshores is a problem that has been observed and documented for many decades. The problem is believed to have arisen and/or been exacerbated as a result of anthropogenic changes to the management of the lakes, including:

- Elevated freshwater levels in the lakes since installation of the barrages in the 1940s, which separate the lakes from the Murray Mouth estuary. Artificially high and stable lake levels are noted to be a significant contributor to lakeshore erosion because they cause waterlogging of the highly dispersive Poltalloch soils which predominantly fringe the lakes. This also subjects these soils to water wave action, rather than allowing the dissipation of wave energy by the lakeshore sands[1].

- Changes in lakeshore land use. Most sections of the lakeshore have been grazed by stock (predominantly cattle) over the past century causing much of the natural riparian vegetation that protects the shoreline to be lost. Furthermore, the trampling of cattle has a direct destructive effect that can potentially accelerate erosion of the lakeshore.

A number of investigations and studies relating to lakeshore erosion around the Lower Murray lakes have been undertaken over the past 15 years. However, the first systematic monitoring of erosion at a number of sites along the shores of Lakes Alexandrina and Albert was undertaken by the Goolwa to Wellington Local Action Planning Board between 2006 and 2011. The first 22 monitoring sites were established in November 2006 and a further eight sites were established in April 2008. Monitoring data were collected during field observations taken every April and November until April 2011.

1.2 Purpose

The purpose of this report is to provide an analysis of data collected during the twice-yearly erosion monitoring conducted been 2006 and 2011. The results will also inform future decision-making regarding the feasibility or need for reinstating and continuing the on-ground lakeshore erosion monitoring and for targeting priority sites for erosion control on-ground works in future.

1.3 Supporting data and documentation

In preparing this report, the author has reviewed the following data sources:

- Monitoring data collected periodically in the field between 2006 and 2011 from 30 designated monitoring locations. Data include:
    - shoreline measurements from fixed monitoring markers
    - observations of soil type, shoreline structure and physical changes
    - comments on vegetation types, density and structure
    - grazing status
    - photography recorded at the three designated photo points at each monitoring site, during each monitoring visit throughout the monitoring period

[1] ID&A, 2001, *Lakeshore Erosion Control Around the Lower Murray Lakes, South Australia*, Document no. 5500511-R009, prepared for Coorong District Local Action Plan Committee, Goolwa to Wellington Local Action Planning Board Inc., Point Sturt and Districts Landcare Group, and the Department for Environment and Heritage

- Monthly average lake-level data obtained from Hydstra, measured during the monitoring period at six locations in Lake Alexandrina and three locations in Lake Albert
- Wind speed and direction data observed at the Pelican Point automatic weather station. All data were obtained from Hydstra with missing data from 2008-09 infilled with data observations from Lake Albert near Waltowa Swamp.

In addition, the author has reviewed the following reports:

- ID&A 2001, *Lakeshore Erosion Control Around the Lower Murray Lakes, South Australia*, Document no. 5500511-R009, prepared for the Coorong District Local Action Plan Committee, Goolwa to Wellington Local Action Planning Board Inc., Point Sturt and Districts Landcare Group, and the Department for Environment and Heritage
- Randall, T. 2006, *Soil Classification for the Lakes Alexandrina and Albert Lakeshore Erosion Monitoring Project*, produced by Rural Solutions SA for the Goolwa to Wellington Local Action Planning Board Inc., Coorong District Local Action Plan Committee, and South Australian Murray-Darling Basin Natural Resources Management Board

2 Methodology

2.1 Data collection

The systematic field data collection at each monitoring site was undertaken in April and November of each year during the monitoring period and included:

- measurements of lakeshore distances (Figure 2-1) at three points (Left, Centre and Right – see Figure 2-2 for explanation), relative to a base marker installed 10 m from the initial shoreline
- photography at the three photo points for each site (base marker and left and right shore points)
- noting of physical changes to the site, including morphology, vegetation, water level, land use and grazing status.

Only photographic data (i.e. no measurements of erosion or accretion) were collected during the November 2009 and April 2010 monitoring visits because the lake levels had severely receded due to drought conditions. Monitoring of two sites (Fischer01 and Fischer02) was ceased in 2010 after their monitoring point markers were destroyed by cultivation for cropping. Furthermore, no erosion observations were recorded for Cowan02, Lake Albert Station and Pitchford01 during the April 2011 monitoring round.

Lakeshore erosion measurement data for all of the monitoring sites are presented in Appendix A.

Figure 2-1. Measuring shoreline erosion from base marker

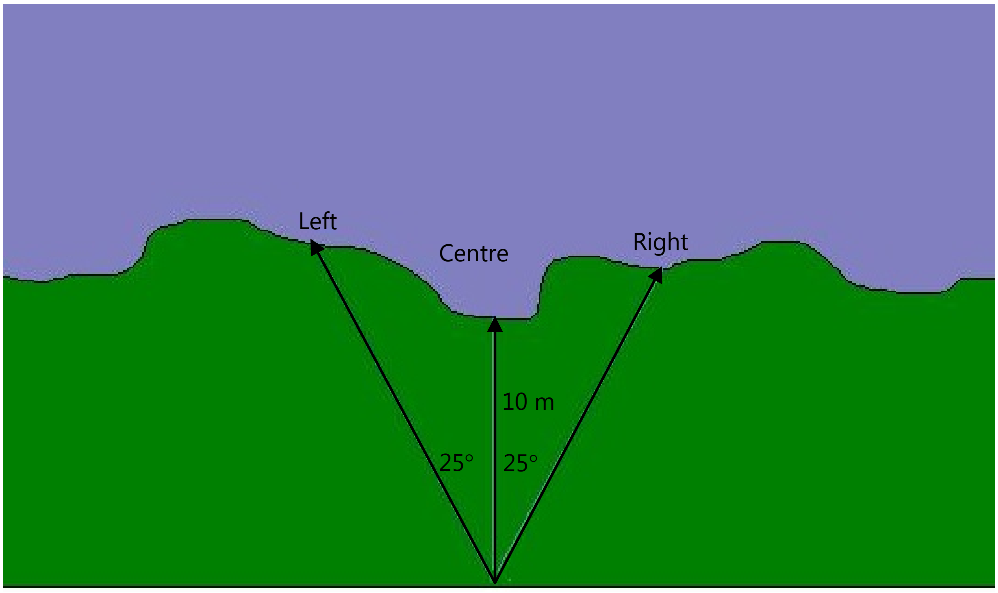


Figure 2-2. Shoreline distance measurements from a base marker located 10 m from the shoreline

2.2 Data collation

Monthly average lake water-level data were collated from the Hydstra database. These were used to calculate average lake levels for Lake Alexandrina and Lake Albert during the periods between erosion monitoring events. The collated monthly data are provided in Appendix B and include information about data quality. Lake level measurements were collated from the following sites:

- **Lake Alexandrina**

  A4260524 Lake Alexandrina at Milang Jetty

  A4261156 Lake Alexandrina 3 km west of Point McLeay

  A4261133 Lake Alexandrina (offshore Raukkan)

  A4260575 Lake Alexandrina at Poltalloch Plains

  A4261158 Lake Alexandrina 4 km west of Pomanda Point

  A4260574 Lake Alexandrina near Mulgundawa

- **Lake Albert**

  A4260630 Lake Albert at Meningie Sailing Club Jetty

  A4261153 Lake Albert near Causeway at Waltowa Swamp

  A4261155 Lake Albert 2 km north of Warringee Point

Local wind data for the periods between monitoring visits were collated in Hydstra and are displayed in the form of nine wind roses in Appendix C:

- November 2006 to March 2007 (Pelican Point AWS)
- April 2007 to October 2007 (Pelican Point AWS)
- November 2007 to March 2008 (Pelican Point AWS)
- April 2008 to October 2008 (near Waltowa Swamp)
- November 2008 to March 2009 (near Waltowa Swamp)
- April 2009 to October 2009 (near Waltowa Swamp)
- November 2009 to March 2010 (Pelican Point AWS)
- April 2010 to October 2010 (Pelican Point AWS)
- November 2010 to March 2011 (Pelican Point AWS)

Wind velocities indicated for each wind direction are average velocities (in km/h); these are further partitioned in the wind roses to indicate velocity ranges for each direction.

Wind runs have been calculated by multiplying the average velocity for a given direction by the number of hours the wind blew from that direction during the analysis period. Wind runs have been used to compare relative “windiness” and determine prevailing wind directions. It is considered likely that shorelines with an aspect toward prevailing winds are more susceptible to water erosion due to waves and seiching effects in the lakes, so this makes it possible to assess whether any correlations between wind and lakeshore erosion are evident from available monitoring data.

A map showing the locations of the erosion monitoring sites and the sources of Hydstra data used in the analyses is provided (Figure 2-3). The lakeshore erosion potential (low, medium, high) markings indicated on the map are derived from the ID&A (2001) report referred to in Section 1; they are not based on the field monitoring data analyses presented in this report.

Figure 2-3. Lakeshore erosion monitoring locations and Hydstra data source locations

3 Lake conditions

3.1 Water levels

Monitoring of lakeshore erosion commenced during a severe drought period, just prior to a rapid decline in water levels in Lake Alexandrina and Lake Albert (Figure 3-1). Water levels did not return to normal operating levels until spring 2010. As a result, the lakeshores were exposed to the effects of water erosion at normal operating lake levels for only about six months (11%) of the four and a half years of the monitoring period.

Water levels in the lakes were below mean sea level (0 m AHD) between December 2007 and August 2010, in many regions leaving hundreds of m of lakebed exposed. Some lakeshores exposed to prevailing winds were subjected to significant morphological and vegetation changes during this period, as a result of aeolian sand eroded from the lakebed during 2008 and 2009 being deposited in drifts that migrated tens of m inland. Wind erosion was reduced after this time, largely as a result of vegetation growth on the exposed lakebed, either from artificial plantings, or natural seed germination.

3.2 Wind conditions

During the warmer months of the year (November to March), the prevailing wind directions are invariably southerly, characterised by afternoon sea and lake breezes that occur almost without fail. During the other seven months of the year (April to October), the wind directions and velocities are far more variable, with prevailing wind directions varying from year to year. Data appear to indicate that the period April 2008 to October 2009 was characterised by higher average wind velocities than the rest of the monitoring period. However, it should be noted that wind data used for this period were obtained from a different wind gauge (Lake Albert, near Waltowa Swamp) due to incomplete data for the Pelican Point wind gauging station. The difference in observed "windiness" may therefore indicate that the gauge near Waltowa Swamp is more exposed than that at Pelican Point in the Coorong.

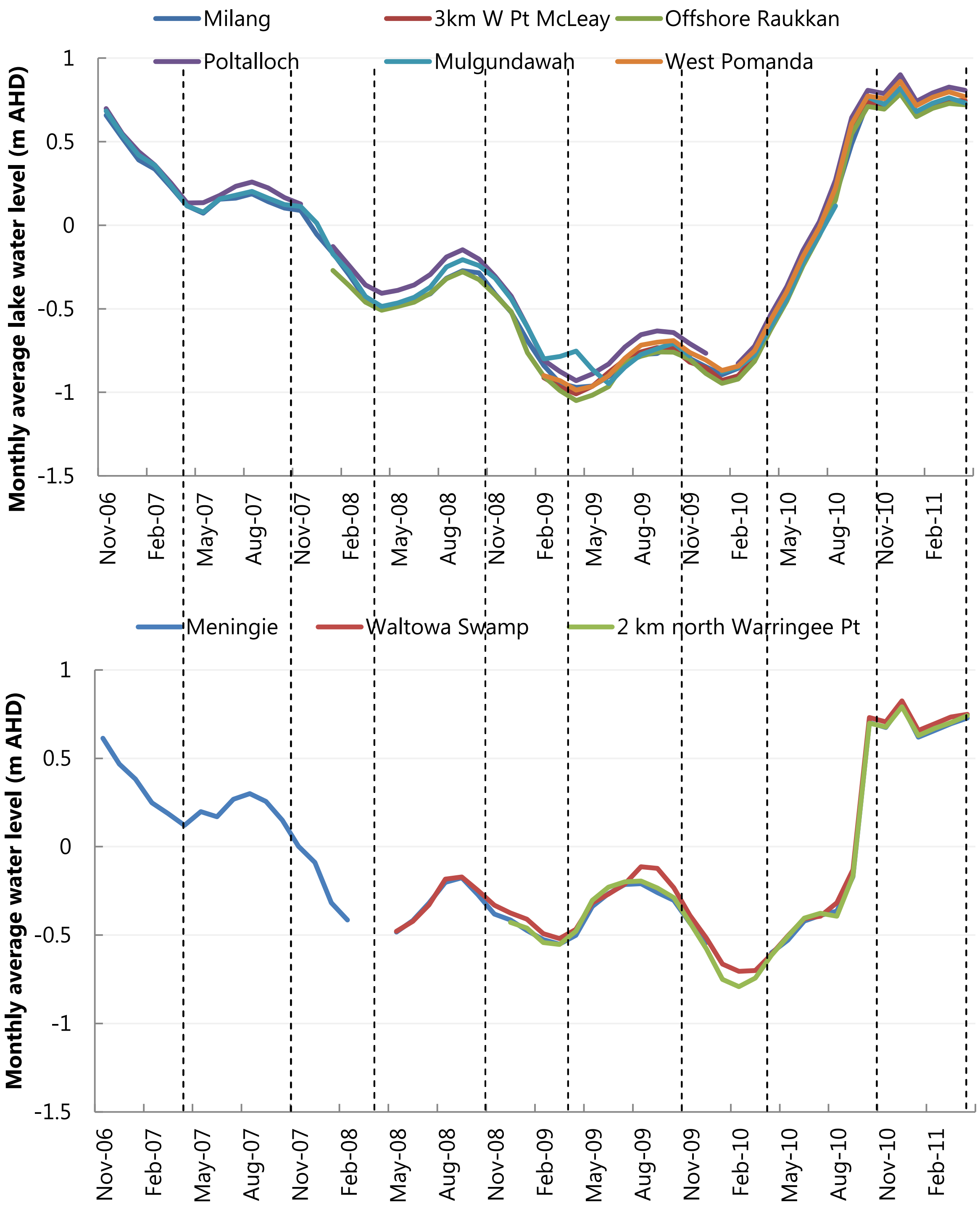


Figure 3-1. Observed monthly lake levels for Lake Alexandrina (top) and Lake Albert (bottom) during erosion monitoring period (monitoring dates indicated by vertical dashed lines)

4 Soil types of the Lower Lakes shoreline

Based upon the results of soil observations at the 30 monitoring sites, the shorelines of Lake Alexandrina and Lake Albert appear to be dominated by Poltalloch soils (observed at 23 of the 30 sites).The Poltalloch soil type, largely confined to the low-lying plains surrounding the Lower Lakes, is characterised by a 10–20 cm sand or sandy loam textured surface soil overlying a silty to medium clay B horizon, sometimes peaty in nature, of between 20 and 40 cm. This is underlain by a buried deep sand layer from an earlier depositional period. The soil is potentially eroded by water slaking of the sand and underlying B horizons, causing slumping and erosion. There is also the potential for direct water erosion of exposed layers prior to slumping. The erosion process is likely to be accelerated by trampling from grazing stock.

Three of the monitoring sites are characterised by high (~3 m) cliff shorelines. In two of these cases (Cowan01 and Nurra Nurra01), the cliffs consist of deep sand that is highly vulnerable to incremental erosion. Direct erosion and undercutting of the sandy cliff face occurs at the beach level, causing overlying sand to slump to the beach, where it is rapidly eroded and redistributed. The erosion process is typically exacerbated and accelerated where cattle are allowed to trample and break the shoreline dune edge. The third monitoring site (Pitchford02) consists of a limestone rubble cliff, with a deep sand shoreline at the base of the cliff. This shoreline is far less vulnerable to erosion than the sandy cliff shorelines.

Other observed shoreline soil types include a sandy loam overlying limestone at Dodd02 on the southern shore of Lake Albert, calcareous sand overlying clay at Lloyd01 and McFarlane (Lake Alexandrina) and sand overlying clay loam on buried deep sand at Withers (Lake Alexandrina). Of these, those sites with calcareous sands overlying clay appear to be relatively resistant to erosion, due to the presence of a sandy beach or high sandy bank that builds up at or above lake pool level. Although sandy beaches or banks are potentially subject to erosion, their ability to absorb wave energy provides some erosion protection to the shoreline.

In the following section, the lakeshore erosion observations for each of the 30 monitoring sites are presented. As soil type is known to be an important indicator of erosion potential and behaviour, Section 5 has been subdivided into three subsections, separately presenting the results for:

1. sites with Poltalloch soils
2. those characterised by deep sands
3. those with other soil types.

Where referred to in the following section, soil dispersion refers to the disaggregation of soil particles and thus the breakdown of the soil's original structure, resulting from local environmental processes.

5 Results

5.1 Poltalloch soil sites

5.1.1 Browns Beach

Site average erosion# (m)	Vegetation	Grazing status	Aspect
0.183	Kikuyu and lignum. Phragmites bed planted in front of site in 2010 and establishing well. Kikuyu sprayed in 2011 for revegetation	Not grazed	W

#Site average erosion is defined as the average of the erosion measured at the centre, left and right monitoring points, from the start to the end of the monitoring period.

Browns Beach is a very unevenly eroded shoreline forming part of an ungrazed council reserve north of Meningie on Lake Albert. The shoreline has a westerly aspect and received a substantial amount of sand drift from the exposed dry lake bed during 2008–09. The bank height at the monitoring site is 0.4 m. Poltalloch soil is present and soil dispersion is observed to be strong in both the A and B horizons. The site is located in a section of lakeshore with a high erosion risk rating.

The site has a well-established vegetation cover of primarily kikuyu and lignum. A phragmites reed bed was planted in front of the site in 2010 and was observed to be establishing well in 2011. The kikuyu was sprayed in 2011, achieving an extensive kill, in readiness for a revegetation project.

This site experienced minor erosion during the monitoring period, with net erosion at the left (L), centre (C) and right (R) monitoring points found to be 0.25 m, 0 m, and 0.3 m, respectively (average of 0.183 m across the three points). Erosion of 0.4 m and 0.6 m was measured following the April – October 2007 period at L and R, respectively, when the average lake level was 0.209 m AHD, and prevailing winds were from the NNE, WNW, W and S.

However, accretion was also apparent at some other monitoring visits; possible reasons for this include measurement inaccuracy as a result of kikuyu spreading along the bank, sand deposition (0.3 m accretion was observed at R during the April 2008 monitoring visit) and later establishment of the nearshore reed bed. No erosion was observed in April 2011 after lake water levels had returned to normal; in fact, a small amount of accretion was noted, possibly as a result of the phragmites reed bed establishment (Figure 5-1).

Figure 5-1. Browns Beach right photo point in April 2007 (l) and November 2011 (r)

5.1.2 Cowan02

Site average erosion (m)	Vegetation	Grazing status	Aspect
0.567	Paspalum, kikuyu, strawberry clover	Regularly grazed by cattle and Cape Barren Geese	NNW

Although Cowan02 is located very near Cowan01 on Lake Alexandrina, also with a NNW aspect, its shoreline characteristics are very different. The shoreline consists of a Poltalloch soil and has a bank height of 0.4 m (Figure 5-2). No soil dispersion is present in the soil profile. The shoreline is vegetated with paspalum, kikuyu and strawberry clover, and is regularly grazed by cattle and Cape Barren geese.

No erosion measurements were made at this site after November 2010. Moderate total shoreline erosion losses of 0.7, 0.2 and 0.8 m were measured at L, C and R, respectively. Minimal erosion was recorded between 2007 and 2009 – most of the shoreline loss was recorded in the November 2010 monitoring visit, immediately after lake levels had returned to normal operating levels after the drought.

Figure 5-2. Cowan02 right photo point in April 2007 (l) and April 2011 (r)

5.1.3 Dodd01

Site average erosion (m)	Vegetation	Grazing status	Aspect
0.150	Paspalum down bank, reedbeds establishing, spiny rush in water	Regularly grazed by cattle	N

Dodd01 is located on the south-western shore of Lake Albert, with a northerly aspect and in lakeshore zone with a medium erosion risk rating. The eroded shoreline consists of a 0.4 m high Poltalloch soil bank, vegetated with paspalum and regularly grazed by cattle (Figure 5-3). Reed beds and rushes are established offshore.

The monitoring site was established in April 2008. Erosion at this site was very minor over the monitoring period, with shoreline losses ranging between 0.1 and 0.2 m across the three measured points (L, C & R). When lake operating levels had returned to normal, bank erosion was only recorded at L and C, whereas the erosion at R occurred when the waterline was well offshore due to the drought and was due to the crumbling of dry bank soil.

Figure 5-3. Dodd01 right photo point in April 2008 (l) and April 2011 (r)

5.1.4 Fischer01

Site average erosion (m)	Vegetation	Grazing status	Aspect
-0.117	Paspalum and strawberry clover	Regularly grazed by cattle	SSE

Fisher01 is also located on the south-western shore of Lake Albert. The shoreline has a SSE aspect and has a medium erosion risk rating. The 0.4 m high Poltalloch soil bank was overlain by sand drift from the exposed lake bed during 2008-09 (Figure 5-4). The shoreline is vegetated with paspalum and strawberry clover and regularly grazed by cattle.

The monitoring site was established in April 2008 with erosion monitoring ceased in 2010 when the monitoring point markers were destroyed by cultivation for cropping. Erosion measurements were undertaken only in November 2008 and April 2009. During this time, lake levels were very low due to the drought and no net erosion occurred. However, some accretion was recorded due to the windblown lakebed sand that was deposited onto the shore. The deposition of aeolian sand from the dry lakebed during 2008 and 2009 is unsurprising since the shoreline directly faces the prevailing wind of the drier summer months (November to March).

Figure 5-4. Fischer01 right photo point in May 2008 (l) and April 2010 (r)

5.1.5 Fischer02

Site average erosion (m)	Vegetation	Grazing status	Aspect
-0.033	Paspalum	Regularly grazed by cattle	E

Fischer02 is also located on the south-western shore of Lake Albert, approximately 1 km NNW of Fischer01. The shoreline has an easterly aspect and has a medium erosion risk rating. The 0.6 m high Poltalloch soil shoreline is vegetated with paspalum and regularly grazed by cattle (Figure 5-5).

The monitoring site was established in April 2008 with erosion monitoring ceased in 2010 when the monitoring point markers were destroyed by cultivation for cropping. Erosion measurements were undertaken only in November 2008 and April 2009. During this time, lake levels were very low due to the drought and no net erosion occurred.

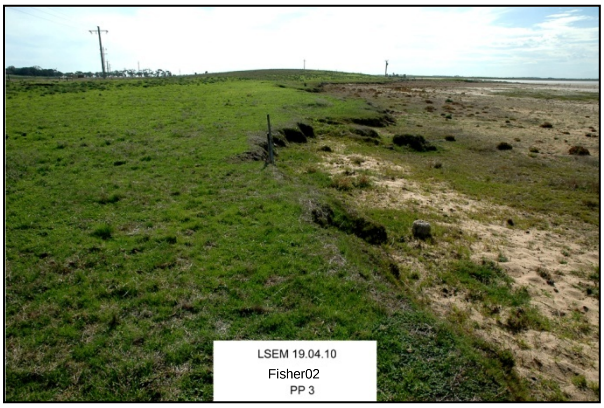


Figure 5-5. Fischer02 right photo point in May 2008 (l) and April 2010 (r)

5.1.6 Griffen01

Site average erosion (m)	Vegetation	Grazing status	Aspect
0.900	Kikuyu	Recently grazed by cattle	SE

Griffen01 is located on an eroded shoreline with a high erosion risk rating, on the southern shore of Point Sturt in Lake Alexandrina. The shoreline has a south-easterly aspect and consists of a 0.5 m high deep Poltalloch soil bank, vegetated with dense kikuyu matting and subject to cattle grazing (Figure 5-6). Soil dispersion is slight in the soil surface layer, but strong at depth. A sandbag groyne has been located north of this site in an attempt to control erosion.

Erosion at this site was moderate. At the April 2007 monitoring visit, 0.5 m of bank loss was observed at the left (L) transect. At the April 2011 monitoring visit, following the return of normal lake levels, further erosion of 0.3, 0.8 and 0.9 m was measured at L, C and R, respectively. The average shoreline loss measured at this site was 0.9 m, with almost all of the erosion occurring during the period when lake levels were at or near normal operating levels. Given the site's south-easterly aspect, it is likely that the prevailing summer-period winds (typically ranging SSW to SSE) were a contributing factor to wave erosion of the shoreline.

Figure 5-6. Griffen01 right photo point in April 2007 (l) and May 2011 (r)

5.1.7 Griffen02

Site average erosion (m)	Vegetation	Grazing status	Aspect
0.133	Kikuyu	Regularly grazed by cattle	SE

The characteristics of Griffen02 are almost identical to those of Griffen01 (Figure 5-7). Griffen02 is located approximately 80 m NNW of Griffen01, on the northern side of the groyne. Erosion at this site was minor. No erosion was observed at L or C during the monitoring period, however 0.4 m of net shoreline loss was measured at R following the restoration of normal operating lake levels after the drought.

Figure 5-7. Griffen02 right photo point in April 2007 (l) and May 2011 (r)

5.1.8 Hartnett

Site average erosion (m)	Vegetation	Grazing status	Aspect
-0.427	Kikuyu	Controlled grazing – some on lakebed and shoreline	N

Hartnett is located on an eroded shoreline with a northerly aspect, with a medium erosion risk rating, on the northern side of Point Sturt in Lake Alexandrina. The 0.4 m high shoreline bank consists of Poltalloch soil; it is vegetated with kikuyu and subject to controlled grazing by cattle (Figure 5-8). Some offshore establishment of rushes and other water plants occurred following the restoration of normal lake levels. Soil dispersion was not detected at the surface, but was found to be slight at depth within the soil profile.

No erosion was recorded at this site; in fact net shoreline accretion was observed at all three transects (L, C and R), varying between 0.03 and 0.85 m. The shoreline growth at this site is attributable to the spreading of the kikuyu cover across the sandy beach. Furthermore, the shoreline does not face a commonly-prevailing wind direction (although northerly winds are frequent during some winter (April – October) periods).

Figure 5-8. Hartnett right photo point in April 2007 (l) and May 2011 (r)

5.1.9 Lake Albert Station

Site average erosion (m)	Vegetation	Grazing status	Aspect
0.083	Paspalum and kikuyu, heavy algal growth at shoreline with return of water	Regularly grazed by cattle, shoreline excluded from 2010	SW

Lake Albert Station is a dairy property located on the severely eroded north-eastern shoreline of Lake Albert and has a south-westerly aspect. The shoreline has a high erosion risk rating and consists of a 0.4 m high Poltalloch soil bank. No soil dispersion is evident in the soil at this site. The shoreline is vegetated with paspalum and kikuyu and was regularly grazed by cattle until an exclusion fence was constructed 15 m from the shoreline in 2010.

During the summer of 2008, a large amount of sand, blown from the exposed lakebed by the prevailing southerly and SSW winds, was deposited in drifts up to 30 m inland, making the lake edge difficult to define. Following the restoration of normal lake levels after the drought, heavy algal growth and deposition also occurred along the shoreline.

No erosion measurements were taken at this site after November 2010 due to the base marker having been broken off and monitoring pegs having been buried in sand. No erosion was observed following the restoration of normal lake levels after the drought, presumably due in part to the thick blanket (up to 20 cm deep) of dried algae that was deposited along the shoreline, protecting the bank from physical erosion by water waves. Between setup in November 2006 and April 2009, the net erosion observed was estimated to be 0.7 and 0.5 m at the L and C transects, respectively, whereas net accretion of approximately one m was observed at the R transect.

Figure 5-9. Lake Albert Station right photo point in April 2007 (l) and May 2011 (r)

5.1.10 Lighthouse

Site average erosion (m)	Vegetation	Grazing status	Aspect
0.467	Kikuyu and paspalum	Regularly grazed by cattle	S

Lighthouse is located on an eroded shoreline of Lake Alexandrina at the north-west end of the Narrung Narrows, adjacent to the Point Malcolm lighthouse. The shoreline has a southerly aspect and a high erosion risk rating.

The 0.6 m high Poltalloch soil lake shoreline is vegetated with kikuyu and paspalum and was regularly grazed by cattle until 2010 when exclusion fencing was constructed. When the lake levels were restored to normal levels in late 2010 after the drought, the lake edge was noted to be covered with kikuyu, algae and other plants. The kikuyu was sprayed for weed control in April 2011, as can be seen from Figure 5-10.

Erosion at this site was moderate. However, all erosion during the monitoring period was observed to be a result of crumbling of the dry bank and trampling by cattle. At the time of the site setup, the water level was already too low to produce any water erosion and no erosion was observed after normal lake operating water levels were restored in late 2010. Shoreline loss at this site was 0.95, 0.4 and 0.05 m, measured at L, C and R, respectively.

Figure 5-10. Lighthouse right photo point in April 2007 (l) and April 2011 (r)

5.1.11 Lloyd02

Site average erosion (m)	Vegetation	Grazing status	Aspect
0.617	Paspalum, lignum, dense kikuyu after cattle exclusion	Regularly grazed by cattle, shoreline excluded from 2010	NE

Lloyd02 (Figure 5-11) is located approximately 700 m east of Lloyd01, at the western entrance to the Narrung Passage in Lake Alexandrina. The site has a north-easterly aspect and is located along a shoreline with a high erosion risk rating. The 0.4 m high Poltalloch soil shoreline is vegetated with kikuyu, paspalum and lignum and was regularly grazed by cattle until an exclusion fence was constructed in 2010.

Some of the erosion at this site is attributable to cattle trampling of the dried and cracked bank during the drought period. Overall erosion at this monitoring site was moderate, with shoreline losses of 0.6, 0.9 and 0.35 m respectively, measured at L, C and R. All the erosion at C occurred following the restoration of normal lake operating levels. The site does not directly face a prevailing wind direction. However, due to its location at the entrance of the Narrung Passage, the shoreline is nevertheless likely to be affected by wave and current action due to wind-driven flow between the lakes.

Figure 5-11. Lloyd02 right photo point in April 2007 (l) and April 2011 (r)

5.1.12 Marles

Site average erosion (m)	Vegetation	Grazing status	Aspect
1.037	Kikuyu, Paspalum, heavy algal growth with return of water	Regularly grazed by cattle	SW

The Marles monitoring site is located on the eroded north shore of Lake Albert, with a south-westerly aspect and a high erosion risk rating. The 0.6 m high Poltalloch soil bank is vegetated with paspalum and kikuyu and grazed by cattle (Figure 5-12). Soil dispersion at this site is not detected at the surface and is only slight at depth within the soil profile.

This site directly faces the prevailing wind for the warm months of the year, with a wave fetch up to 17 km. As a result, shoreline losses averaging one m were measured across all transects (L, C and R) within the first few months following setup in November 2006. During 2008, when the dry lakebed was exposed, significant onshore sand drift occurred, with sand being deposited up to 55 m inland of the shoreline. Stock trampling of the dry cracked shoreline contributed to some erosion during the drought. Following the return of normal operating lake levels, a large amount of algae and mulch material was washed onshore (visible in the second photograph in Figure 5-12), protecting the shoreline from significant erosion for at least the first few months.

Erosion at this site was significant, with total shoreline losses of 1.02, 0.97 and 1.12 m measured across L, C and R, respectively, almost all of which occurred during the first few months of monitoring before the waterline had receded well south of the shoreline.

Figure 5-12. Marles right photo point in April 2007 (l) and April 2011 (r)

5.1.13 McAnanney

Site average erosion (m)	Vegetation	Grazing status	Aspect
1.583	Paspalum and cereal rye	Grazed by sheep and cattle	S

The south-facing McAnanney monitoring site is located on the eroded north shore of Mosquito Point in Lake Alexandrina, which has a high erosion risk rating. The severely pugged 0.5 m high Poltalloch soil shoreline is vegetated with paspalum and cereal rye (Figure 5-13). It was grazed continuously by cattle and sheep until a shore exclusion fence was constructed in 2010. Soil dispersion at this site is not detected at the surface and is only slight at depth within the soil profile.

The monitoring site was established in December 2006, at which time the lake water level was approximately 0.3 m below normal operating pool level, so erosion at this site was minimal prior to the return of normal lake levels in late 2010. The shoreline directly faces the prevailing wind direction, with the result that during 2008 and 2009, the shoreline was buried in half a metre of sand blown up to 40 m inland from the exposed dry lakebed, repeatedly burying the base monitoring marker.

Erosion at this site was significant. Shoreline losses of 2.3, 1.1 and 1.35 m respectively were measured at the L, C and R transects, with practically all of the erosion occurring during the final months of the monitoring period, after normal lake levels were restored.

Figure 5-13. McAnanney right photo point in April 2007 (l) and May 2011 (r)

5.1.14 Nurra Nurra02

Site average erosion (m)	Vegetation	Grazing status	Aspect
1.767	Kikuyu and phragmites	Early grazing by sheep, later excluded	SE

The Nurra Nurra02 monitoring site is located approximately 100 m south of Nurra Nurra01 in Lake Albert. However, the shoreline at this site is very different to that of Nurra Nurra01, consisting of 0.8 m high deep Poltalloch soil bank, vegetated with kikuyu and phragmites (Figure 5-14). Soil dispersion was found to be slight to moderate throughout the soil profile. Some sheep grazing occurred during 2007 and the bank was observed to contain active swamp rat burrows.

Erosion at this site was severe. Although negligible erosion occurred during the initial drought period, significant shoreline losses were observed at the November 2010 and April 2011 monitoring visits, following the restoration of normal lake operating levels. Total erosion losses of 2.1, 2.0 and 1.2 m were measured at the L, C and R transects, respectively. Having a south-easterly aspect, the shoreline does not face a prevailing wind direction.

Figure 5-14. Nurra Nurra02 right photo point in April 2007 (l) and April 2011 (r)

5.1.15 Pitchford01

Site average erosion (m)	Vegetation	Grazing status	Aspect
0.000	Kikuyu, reedbeds establishing offshore	Regularly grazed by cattle, shoreline excluded from 2010	W

The Pitchford01 monitoring site was established in April 2008 when the waterline was already well offshore due to the drought conditions. No shoreline measurements were taken after November 2010 as the base marker had been removed. The site is located on an eroded western shore of Lake Albert, on the northern side of Rumpley Point. The shoreline has a northerly aspect and a medium erosion risk rating. The shoreline consists of a 0.7 m high Poltalloch soil bank, vegetated with kikuyu and was grazed by cattle until an exclusion fence was constructed in 2010 (Figure 5-15). Following the restoration of normal lake levels, phragmites and rushes rapidly became established up to 80 m offshore.

No erosion was observed at this site.

Figure 5-15. Pitchford01 right photo point in May 2008 (l) and April 2011 (r)

5.1.16 Raukkan01

Site average erosion (m)	Vegetation	Grazing status	Aspect
-0.350	Kikuyu	Regularly grazed by cattle	NW

Raukkan01 is located on an eroded southern shoreline of Lake Alexandrina, with a north-westerly aspect and a high erosion risk rating. The 0.4 m high Poltalloch soil shoreline is protected by a small sandy foreshore dune that is vegetated with kikuyu on the landward side (Figure 5-16) and regularly trampled and grazed by cattle. Soil dispersion is slight in the A and upper B horizons, but strong in the lower B horizon.

Stock trampling of the foreshore dune caused some erosion during the drought period, but within a few months of the return of normal lake levels, the shoreline had been restored, such that net accretion averaging 0.35 m from the original baseline measurements was observed across all three transects. The shoreline does not face a prevailing wind direction.

Figure 5-16. Raukkan01 right photo point in April 2007 (l) and April 2011 (r)

5.1.17 Raukkan02

Site average erosion (m)	Vegetation	Grazing status	Aspect
1.233	Kikuyu	Regularly grazed by cattle	N

Raukkan02 is located approximately 1.8 km WNW of Raukkan01 and has a northerly aspect. This site lacks the foreshore dune present at Raukkan01, with the result that the lake edge was subject to damage and erosion from a combination of sand drift and stock trampling of the dry and crumbling 0.4 m high Poltalloch soil bank during the drought period (Figure 5-17). With the restoration of normal lake levels, significant erosion occurred across all transects – 1.0, 1.5 and 1.2 m respectively at L, C and R. The shoreline at this monitoring site does not face a prevailing wind.

Figure 5-17. Raukkan02 right photo point in April 2007 (l) and April 2011 (r)

5.1.18 Secomb01

Site average erosion (m)	Vegetation	Grazing status	Aspect
0.100	Kikuyu and paspalum, pungens inshore, phragmites offshore	Not recently grazed	NE

The Secomb01 monitoring site was established in April 2008 when the lake waterline was hundreds of metres from the shoreline. Secomb01 is east-facing and located on the eroded south-western shore of Lake Albert, along a shoreline with a medium erosion risk rating. The 0.5 m Poltalloch soil bank is vegetated with kikuyu and paspalum and following the restoration of lake levels, rushes regenerated inshore and phragmites offshore (Figure 5-18). Grazing is excluded from the shoreline.

No erosion occurred at this site. Some minor variations in shoreline measurements were noted during 2008 and 2009, but were attributable to changes in the dense kikuyu matting on the lake edge. No erosion occurred following the restoration of normal lake levels. The shoreline does not face a prevailing wind direction.

Figure 5-18. Secomb01 right photo point in May 2008 (l) and May 2011 (r)

5.1.19 Secomb02

Site average erosion (m)	Vegetation	Grazing status	Aspect
-2.800	Kikuyu, paspalum, typha, phragmites	Grazing excluded from shoreline	NE

The Secomb02 monitoring site was established in April 2008, approximately 50 m inshore of the bank, which has a self-established reed bed (Figure 5-19). The site is located approximately 360 m north-west of Secomb01 along the south-western shore of Lake Albert. This monitoring site has a north-easterly aspect and is located on a shoreline with a medium erosion risk rating. The shoreline is vegetated with kikuyu, paspalum, typha and phragmites and grazing is excluded.

Figure 5-19. Secomb01 right photo point in May 2008 (l) and May 2011 (r)

The reed bed has stopped bank erosion at this site and measurements were taken to the nearest typha and furthest paspalum to give an indication of land reclamation. By April 2009, much of the typha was dead due to the prolonged lake level recession. The dormant reed beds rapidly re-established during the spring and summer of 2010-11, following the return of normal lake levels.

By April 2011, the net distances to the nearest typha had increased by 0.8, 2.4 and 5.2 m at the L, C and R transects. By contrast, distances to the furthest paspalum had increased by 7.0 and 4.7 m along the L and C transects, but decreased by 2.8 m at the R transect.

5.1.20 South

Site average erosion (m)	Vegetation	Grazing status	Aspect
2.367	Paspalum	Controlled cattle grazing	SW

The South monitoring site is located on the eroded south-western shoreline of Point Sturt in Lake Alexandrina and has a south-westerly aspect and a high erosion risk rating. The 0.4 m Poltalloch soil bank is vegetated with paspalum and subject to controlled cattle grazing (Figure 5-20).

Figure 5-20. South right photo point in April 2007 (l) and May 2011 (r)

Heavy aeolian sand deposition from the exposed lake bed occurred along this shoreline during 2008 and 2009. Although some erosion also occurred at this site even during a period when the waterline was up to 200 m offshore, presumably exacerbated by cattle trampling, most of the shoreline losses were incurred during the few months after the lake had returned to normal operating water levels.

Erosion at this site was severe. Net erosion measured was 2.65, 2.5 and 1.95 m at the L, C and R transects, respectively. The site faces the prevailing winds for this region.

5.1.21 Strother01

Site average erosion (m)	Vegetation	Grazing status	Aspect
0.100	Kikuyu, juncus on lakebed, phragmites plantings established offshore	Grazing excluded from shoreline	SE

The SSE-facing Strother01 monitoring site is located along the eroded western shoreline of Lake Albert, which has a high erosion risk rating. The 0.4 m Poltalloch soil bank is vegetated with kikuyu and grazing is excluded from the shoreline (Figure 5-21). A phragmites reed bed was established approximately 60 m offshore in 2006 as a wave barrier to stop shoreline erosion. Rushes became established on the lakebed during the monitoring period. Soil dispersion is not detectable in the surface horizon and is only slight at depth within the soil profile.

Although this shoreline faces a prevailing wind, erosion at this site was negligible as a result of the established reed bed. Very minor erosion (0.1–0.2 m) occurred at the L and R transects shortly after the monitoring site was set up in November 2006, but no erosion occurred subsequently, even with the return of normal operating lake levels.

Figure 5-21. Strother01 right photo point in April 2007 (l) and April 2011 (r)

5.1.22 Strother02

Site average erosion (m)	Vegetation	Grazing status	Aspect
0.117	Paspalum, phragmites plantings established offshore	Grazing excluded from shoreline	SE

Strother02 is located approximately 1.9 km WSW of Strother01 and has a south-easterly aspect. The 0.4 m Poltalloch soil bank is vegetated with paspalum and grazing is excluded from the shoreline (Figure 5-22). A phragmites reed bed was established in 2006, between the shoreline and an island 200 m offshore, as a wave barrier to stop shoreline erosion. Rushes became established on the lakebed during the monitoring period. Soil dispersion is strong in the B horizon, but only slight in lower horizons.

Although this shoreline has exposure to a prevailing wind, erosion at this site was negligible as a result of the established reed bed. Minor erosion (0.15–0.3 m) occurred at the L and R transects shortly after the monitoring site was set up, but no erosion occurred subsequently, even with the return of normal operating lake levels.

Figure 5-22. Strother02 right photo point in April 2007 (l) and April 2011 (r)

5.1.23 Teringie

Site average erosion (m)	Vegetation	Grazing status	Aspect
-0.217	Kikuyu	Not recently grazed	NW

Teringie is located on the southern shoreline of Lake Alexandrina. The monitoring site is located on a shoreline section with a north-westerly aspect and a high erosion risk rating. The 0.6 m high Poltalloch soil bank is densely vegetated with kikuyu and has not been recently grazed (Figure 5-23). Soil dispersion is not present, or only very slight. Although this site does not face a prevailing wind direction, sand from the exposed dry lakebed was blown inland up to 18 m during 2008 and 2009, during which time the waterline was up to 2.5 km from the shore. This helped to establish a 4 m wide sandy beach that protected the shoreline from erosion.

No net erosion occurred at this site. Net shoreline growth of 0.25 and 0.4 m, at the L and R monitoring points respectively, was measured at the April 2011 monitoring visit, with almost all of this occurring after the return of normal lake operating levels.

Figure 5-23. Teringie right photo point in April 2007 (l) and April 2011 (r)

5.2 Deep sand soil sites

5.2.1 Cowan01

Site average erosion (m)	Vegetation	Grazing status	Aspect
1.800	Marram grass, vetch, blue lupins on exposed lake bed	Regularly grazed by cattle	NNW

Cowan01 is characterised by a 3 m high sandy cliff face (Figure 5-24). It is located north-east of Pt McLeay in Lake Alexandrina, in a shoreline section with a NNW aspect and high erosion risk rating. Erosion typically occurs at this site as a result of slumping of 0.5–1 m wide sections, due to direct erosion and undercutting of the sand at beach level. As the site is regularly grazed by cattle, the erosion can be exacerbated by stock trampling and breaking of the dune edge. Bundled tyres have been packed against the base of the cliff to the east of the site to try to control the shoreline erosion. The site is vegetated with marram and other grasses and during the drought blue lupins were observed growing on the exposed lake bed.

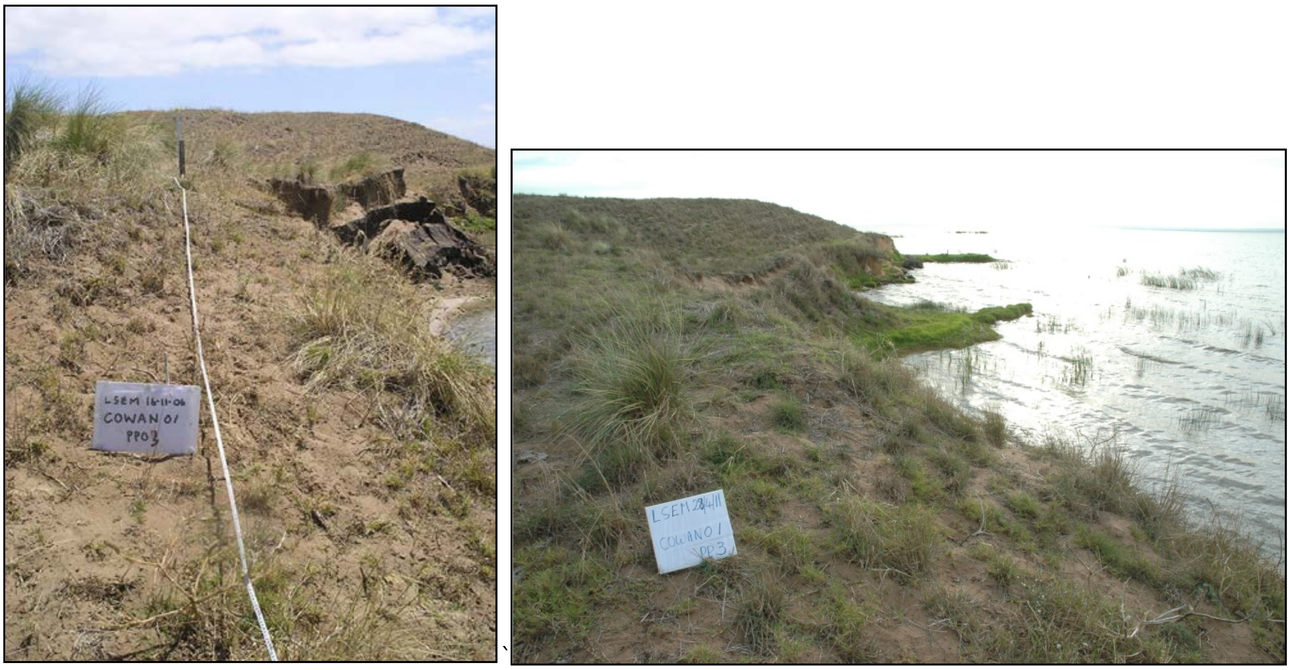


Figure 5-24. Cowan01 right photo point in November 2006 (l) and April 2011 (r)

This shoreline is not directly exposed to a locally prevailing wind. All three measured points (L, C & R) at this site experienced severe erosion, ranging between 1.5 and 2.0 m over the monitoring period. Minimal erosion occurred during the drought period when the lake levels were very low. The most substantial erosion was recorded during the 2007 and November 2010 monitoring visits, with shoreline losses of 0.5 to 1.5 m. However, the shoreline erosion measured in April 2011, when the lake levels were the highest for the entire monitoring period, was surprisingly low, with 0.35 m measured at L and no erosion at either C or R.

5.2.2 Nurra Nurra01

Site average erosion (m)	Vegetation	Grazing status	Aspect
0.463	Grasses, offshore reedbed planting regenerating after return of water	Early grazing by sheep, later excluded	SE

The south-east facing Nurra Nurra01 monitoring site is located on the eroded north-western shore of Lake Albert, near the entrance to the Narrung Passage, on a shoreline with a medium erosion risk rating. The shoreline consists of a 3 m high grassy deep sand cliff that is subject to erosion by undercutting and slumping (Figure 5-25). The shoreline was grazed by sheep during 2007. A planted reed bed is located just offshore and began to re-establish following the return of normal lake operating levels.

Erosion at this site was relatively minor, with total shoreline losses of 0.35, 0.3 and 0.74 m measured at the L, C and R transects, respectively. Given that cliff slumping occurred even when the water was hundreds of m from the shoreline during the drought, there is little evidence from the limited available data to indicate a direct link between water level and shoreline erosion at this site. No erosion was observed at the April 2011 monitoring visit, when lake levels were at their highest for the monitoring period.

Figure 5-25. Nurra Nurra01 right photo point in April 2007 (l) and November 2010 (r)

5.2.3 Pitchford02

Site average erosion (m)	Vegetation	Grazing status	Aspect
-0.017	Kikuyu	Regularly grazed by cattle, shoreline excluded from 2010	NW

Pitchford02 is located approximately 900 m WNW of Pitchford01 and was established at the same time as Pitchford01. The shoreline has a north-westerly aspect, and consists of a 4 m high deep sand and limestone rubble cliff (Figure 5-26). The shoreline is vegetated with kikuyu and was grazed by cattle until an exclusion fence was constructed in 2010.

No erosion was observed at this site.

Figure 5-26. Pitchford02 right photo point in May 2008 (l) and April 2011 (r)

5.3 Sites with other soil types

5.3.1 Dodd02

Site average erosion (m)	Vegetation	Grazing status	Aspect
-0.033	Kikuyu and buffalo grass on bank, phragmites establishing offshore	Not grazed	N

Dodd02 is located approximately 2.2 km east of Dodd01, along an eroded shoreline west of Warrengie Woolshed on the south-western shore of Lake Albert (Figure 5-27). It has a northerly aspect and is situated along a shoreline with a high erosion risk rating. The 0.7 m high bank consists of sandy loam over limestone, with the potential for direct water erosion of the sandy soil at beach level causing undercutting and slumping. The shoreline is ungrazed and vegetated with kikuyu and buffalo grass. Phragmites reed beds are becoming established offshore.

The monitoring site was established in April 2008. No erosion was measured at this site during the monitoring period; in fact slight accretion (0.1 m) was measured at R during the April 2011 monitoring visit.

Figure 5-27. Dodd02 right photo point in May 2008 (l) and April 2011 (r)

5.3.2 Lloyd01

Site average erosion (m)	Vegetation	Grazing status	Aspect
-0.767	Kikuyu	Regularly grazed by cattle, shoreline excluded from 2010	N

Lloyd01 is located on the eroded southern shoreline of Lake Alexandrina, with a northerly aspect, in a section of shoreline with a high erosion risk rating. This site is unique, with respect to the other monitoring sites, in that the shoreline consists of calcareous sand overlying a clay layer, with the result that a sandy beach builds up at or below normal lake pool level (Figure 5-28). The 0.4 m high bank is vegetated with kikuyu and was regularly grazed by cattle until a shoreline exclusion fence was constructed in 2010.

Sand deposition on the shoreline from the exposed lakebed was observed during 2008 and 2009. Shoreline measurements were taken to the edge of the kikuyu cover. The kikuyu retreated during the period when the lake levels were very low, but returned with the restoration of normal lake levels in 2010. No erosion was observed following the restoration of lake levels. No net erosion occurred at this monitoring site, with shoreline growths of 0.55, 1.1 and 0.65 m recorded at L, C and R, respectively.

Figure 5-28. Lloyd01 right photo point in April 2007 (l) and April 2011 (r)

5.3.3 McFarlane

Site average erosion (m)	Vegetation	Grazing status	Aspect
0.467	Couch grass, offshore reedbed planted 2007	Grazing excluded with 20 m of shore	W

The McFarlane monitoring site is located on the eroded north-eastern shore of Lake Alexandrina opposite Pomanda Point, on a section of shoreline with a westerly aspect and low erosion risk rating. The shoreline consists of a calcareous sand bank, 0.8 m high, overlying a clay soil (Figure 5-29). The shoreline is vegetated with couch grass and protected from grazing by an exclusion fence constructed 20 m from the shoreline. Offshore reed beds were established in early 2007 and regenerated following the return of normal lake levels after the drought.

Figure 5-29. McFarlane right photo point in April 2007 (l) and May 2011 (r)

Some aeolian sand from the exposed dry lakebed was deposited onshore between 2007 and 2009. Winds from westerly directions were common during each of the April–October periods, however, there is no indication from the limited available data that erosion occurs mainly during these parts of the year – lake water level seem to be the main predictor of erosion potential at this site. The re-establishing offshore reed bed does not appear to have prevented erosion following the restoration of normal lake levels.

Erosion at this site was relatively minor. Net shoreline losses of 0.3, 0.2 and 0.9 m were measured at the L, C and R transects, respectively, with almost all erosion occurring during periods when lake levels were at or near normal operating levels.

5.3.4 Withers

Site average erosion (m)	Vegetation	Grazing status	Aspect
-0.233	Kikuyu, juncus, typha and phragmites	Grazed by cattle	SW

The south-westerly facing Withers monitoring site is located on the north-eastern shoreline of Lake Alexandrina, which has a high erosion risk rating. The 0.5 m high shoreline bank consists of sand overlaying a clay loam on a deep buried sand layer and is vegetated by kikuyu, which is subject to cattle grazing (Figure 5-30). Offshore, dense beds of rushes, typha and phragmites became established during the monitoring period. Soil dispersion at this site is slight to negligible throughout the soil profile.

Although this site is exposed to a prevailing wind, no erosion was observed. However some minor erosion of the bank was observed along the L transect during the period that the lakebed was dry, with the waterline located 350 m offshore, due to the trampling of cattle grazing the lakebed. Shoreline growths of 0.6 and 0.2 m, respectively, were measured at the C and R transects.

Figure 5-30. Withers right photo point in April 2007 (l) and May 2011 (r)

5.4 Summary

Table 5-1. Summary of site and erosion characteristics

Location	Lake	Aspect		Net erosion (m)	Site average erosion (m)	ID&A Erosion Hazard Rating	Soil type	Site description	Vegetation	Grazing status
Poltalloch soil shorelines										
Browns Beach	Albert	W	L	***0.25***	0.183	High	Poltalloch soil	Council reserve north of Meningie, very unevenly eroded shoreline. Sand drift off lakebed during drought	Kikuyu & lignum. Phragmites bed planted in front of site in 2010 and establishing well. Kikuyu sprayed in 2011	Not grazed
			C	***0***						
			R	***0.3***						
Cowan 02	Alexandrina	NNW	L	***0.7***	0.567	High	Poltalloch soil	Poltalloch soil eroded lake edge NE of Pt Malcolm	Paspalum, Kikuyu, Strawberry Clover	Regularly grazed by cattle and Cape Barren Geese
			C	***0.2***						
			R	***0.8***						
Dodd 01	Albert	N	L	***0.2***	0.150	Medium	Poltalloch soil	Eroded shoreline with some established reedbeds on SW shore	Paspalum down bank, reedbeds establishing, spiny rush in water	Regularly grazed by cattle
			C	***0.1***						
			R	***0.15***						
Fischer 01	Albert	SSE	L	***-0.1***	-0.117	Medium	Poltalloch soil with recent drift sand from exposed lakebed	Eroded shoreline on S Lake Albert. Monitored from 2008 until 2010 when site destroyed by cultivation for cropping	Paspalum & strawberry clover	Regularly grazed by cattle
			C	***0***						
			R	***-0.25***						
Fischer 02	Albert	E	L	***-0.15***	-0.033	Medium	Poltalloch soil	Eroded shoreline on S Lake Albert. Monitored from 2008 until 2010 when site destroyed by cultivation for cropping	Paspalum	Regularly grazed by cattle
			C	***0***						
			R	***0.05***						
Griffen 01	Alexandrina	SE	L	***0.8***	0.900	High	Deep Poltalloch soil	Eroded shoreline on southern shore of Pt Sturt, south of sandbag groyne, dense kikuyu matting	Kikuyu	Recently grazed by cattle
			C	***0.8***						
			R	***1.1***						
Griffen 02	Alexandrina	SE	L	***0***	0.133	High	Deep Poltalloch soil	Eroded shoreline on south side of Pt Sturt, north of groyne, which has made no difference to rate of erosion	Kikuyu	Regularly grazed by cattle
			C	***0***						
			R	***0.4***						
Hartnett	Alexandrina	N	L	***-0.85***	-0.427	Medium	Poltalloch soil	Eroded shoreline on north side Pt Sturt, controlled grazing, samphire flat fenced off	Kikuyu	Controlled grazing - some on lakebed and shoreline
			C	***-0.4***						
			R	***-0.03***						
Lake Albert Station	Albert	SW	L	***0.7***	0.083	High	Poltalloch soil	Severely eroded shoreline on NE shore of Lake Albert. In summer of 2008 sand drift from exposed lakebed drifted 30 m inland, making lake edge hard to define.	Paspalum & kikuyu, heavy algal growth at shoreline with return of water	Regularly grazed by cattle, shoreline excluded from 2010
			C	***0.5***						
			R	***-0.95***						
Lighthouse	Alexandrina	S	L	***0.95***	0.467	High	Poltalloch soil	Eroded shoreline at the NW end of the Narrung Narrows, adjacent to Pt Malcolm lighthouse	Kikuyu	Regularly grazed by cattle
			C	***0.4***						
			R	***0.05***						
Lloyd 02	Alexandrina	NE	L	***0.6***	0.617	High	Poltalloch soil	Eroded shoreline on S shore of Lake Alexandrina, among lignum on approaches to Albert Passage	Paspalum, lignum, dense kikuyu after cattle exclusion	Regularly grazed by cattle, shoreline excluded from 2010
			C	***0.9***						
			R	***0.35***						
Marles	Albert	SW	L	***1.02***	1.037	High	Poltalloch soil	Eroded shoreline on NW shore of Lake Albert. Erosion on all transects within 3 months of monitoring. 55 m inland drift of sand from exposed lakebed in 2008	Paspalum, heavy algal growth with return of water	Regularly grazed by cattle
			C	***0.97***						
			R	***1.12***						
McAnanney	Alexandrina	S	L	***2.3***	1.583	High	Poltalloch soil	Eroded shoreline on northern shore of Mosquito Point. Severely pugged bank with sand drifting inland from lakebed	Paspalum	Grazed by sheep and cattle
			C	***1.1***						
			R	***1.35***						
Nurra Nurra 02	Albert	SE	L	***2.1***	1.767	Medium	Deep Poltalloch soil	Eroded shoreline on north-west side of Lake Albert	Kikuyu & phragmites	Early grazing by sheep, later excluded
			C	***2***						
			R	***1.2***						
Pitchford 01	Albert	W	L	***0***	0.000	Medium	Poltalloch soil	Eroded shoreline, western side of Lake Albert	Kikuyu, reedbeds establishing offshore	Regularly grazed by cattle, shoreline excluded from 2010
			C	***0***						
			R	***0***						
Raukkan 01	Alexandrina	NW	L	***-0.3***	-0.350	High	Poltalloch soil	Eroded shoreline of Lake Alexandrina with small foreshore dune	Kikuyu	Regularly grazed by cattle
			C	***-0.4***						
			R	***-0.35***						
Raukkan 02	Alexandrina	N	L	***1***	1.233	High	Poltalloch soil	Eroded shoreline of Lake Alexandrina. Dry crumbled lake edge, sand drift & trampling by cattle	Kikuyu	Regularly grazed by cattle
			C	***1.5***						
			R	***1.2***						
Secomb 01	Albert	NE	L	***0.3***	0.100	Medium	Poltalloch soil	Eroded shoreline on Lake Albert	Kikuyu & paspalum, pungens inshore, phragmites offshore	Not recently grazed
			C	***0***						
			R	***0***						
Secomb 02	Albert	NE	L	***-0.8***	-2.800	Medium	Poltalloch soil	Shoreline on Lake Albert with self-established reedbed, 50 m from bank, which has stopped erosion and assisted land reclamation	Kikuyu, typha, phragmites	Grazing excluded from shoreline
			C	***-2.4***						
			R	***-5.2***						
South	Alexandrina	SW	L	***2.65***	2.367	High	Poltalloch soil	Eroded shoreline on southern shoreline of Pt Sturt. Onshore sand drifts from exposed lakebed during 2008 and 2009	Paspalum	Controlled cattle grazing
			C	***2.5***						
			R	***1.95***						

Location	Lake	Aspect		Net erosion (m)	Site average erosion (m)	ID&A Erosion Hazard Rating	Soil type	Site description	Vegetation	Grazing status
Strother 01	Albert	SE	L	***0.1***	0.100	High	Poltalloch soil	Eroded shoreline on Lake Albert. Reeds established 2006 as wave barrier to stop shoreline erosion	Kikuyu, juncus on lakebed, phragmites plantings established offshore	Grazing excluded from shoreline
			C	***0***						
			R	***0.2***						
Strother 02	Albert	SE	L	***0.15***	0.117	High	Poltalloch soil	Eroded shoreline on Lake Albert. Reeds established 2006 as wave barrier to stop shoreline erosion	Paspalum, phragmites plantings established offshore	Grazing excluded from shoreline
			C	***0***						
			R	***0.2***						
Teringie	Alexandrina	NW	L	***-0.25***	-0.217	High	Poltalloch soil	Eroded shoreline on Lake Alexandrina. Sand blown inland 18 m from exposed lakebed during 2009	Kikuyu	Not recently grazed
			C	***0***						
			R	***-0.4***						
Deep sand shorelines										
Cowan 01	Alexandrina	NNW	L	***2***	1.800	High	Deep sand	Sandy cliff face NE of Pt Malcolm, with slumping of 0.5 to 1 m at a time. Star post placed 1 m from edge at setup. Bundled tyres to east of site	Marram grass, vetch, blue lupins on exposed lake bed	Regularly grazed by cattle
			C	***1.5***						
			R	***1.9***						
Nurra Nurra 01	Albert	SE	L	***0.35***	0.463	Medium	Deep sand	High sandy cliff just before entrance to Albert Passage	Grasses, offshore reedbed planting regenerating after return of water	Early grazing by sheep, later excluded
			C	***0.3***						
			R	***0.74***						
Pitchford 02	Albert	NW	L	***0***	-0.017	Medium	Deep sand	Limestone rubble cliff on north-west side of Rumpley Point, Lake Albert. Shoreline is at rocky base of cliff	Kikuyu	Regularly grazed by cattle, shoreline excluded from 2010
			C	***0***						
			R	***-0.05***						
Other soil type shorelines										
Dodd 02	Albert	N	L	***0***	-0.033	High	Sandy loam over limestone	Eroded shoreline west of Warrengie Woolshed on SW Lake Albert. Fenced 20 m back from shore	Kikuyu & buffalo grass on bank, phragmites establishing offshore	Not grazed
			C	***0***						
			R	***-0.1***						
Lloyd 01	Alexandrina	N	L	***-0.55***	-0.767	High	Calcareous sand over clay	Eroded shoreline on southern shore of Lake Alexandrina. A sandy beach builds up at or below pool level	Kikuyu	Regularly grazed by cattle, shoreline excluded from 2010
			C	***-1.1***						
			R	***-0.65***						
McFarlane	Alexandrina	W	L	***0.3***	0.467	Low	Calcareous sand over clay	Eroded shoreline on northern shore of Lake Alexandrina, high sandy bank fenced 20 m from shore	Couch grass, offshore reedbed planted 2007	Grazing excluded within 20 m of shore
			C	***0.2***						
			R	***0.9***						
Withers	Alexandrina	SW	L	***0.1***	-0.233	High	Sand over clay loam on buried deep sand	Eroded shoreline on Lake Alexandrina	Kikuyu, juncus, typha and phragmites	Grazed by cattle
			C	***-0.6***						
			R	***-0.2***						

Key to colours used:

Net erosion

-0.65	Net shoreline accretion
0	No net measured change
0.3	Net shoreline loss <0.5 m
2	Net shoreline loss >0.5 m

Site average erosion

-0.767	Average accretion >0.5 m
-0.233	Average accretion <0.5 m
0.000	No net measured change
0.467	Average shoreline loss <0.5 m
0.900	Average shoreline loss between 0.5 and 1 m
1.800	Average shoreline loss >1 m

6 Summary and conclusions

The lakeshore erosion monitoring program, established by the Goolwa to Wellington Local Action Planning Board between 2006 and 2011, was undertaken to enable assessment of the factors affecting rates of Lake Alexandrina and Lake Albert shoreline erosion. A total of 30 shoreline monitoring sites was established (22 in November 2006, and a further eight in April 2008), and observational data were collected every April and November until April 2011. Data collected as a part of the systematic monitoring program included shoreline measurements from fixed monitoring markers, and written and photographic observations of vegetation, land use, soil type, shoreline structure and physical changes that occurred during the monitoring period. This report presents a review of the monitoring data, along with relevant lake water level data and wind speed and direction data. The timing of the monitoring program unfortunately resulted in lake levels being at normal operating levels for only about six months of the entire monitoring period. Nevertheless, it has been possible to draw some valuable conclusions regarding the factors which influence lakeshore erosion potential.

Shoreline vegetation appears to be the strongest overall indicator of erosion risk. Even if the shoreline is exposed to a prevailing wind, established offshore reed beds can limit or even reverse the effects of erosion. This was observed at Browns Beach, Dodd01, Dodd02, McFarlane, Pitchford01, Secomb02, Strother01 and Strother02. Erosion control and reversal are achieved because the reed beds act as a wave barrier and encourage the deposition of sediment along the shoreline. Ungrazed densely growing shoreline grasses such as kikuyu also help to stabilise the bank and trap sand, reducing water-induced erosion, as was observed at Teringie.

Where implemented, the exclusion of grazing appears to have had multiple benefits in the control of lakeshore erosion. The Poltalloch soils and deep sands are particularly vulnerable to damage and collapse as a result of cattle trampling, as occurred at a number of sites (Lighthouse, McAnanney, Raukkan02 and South), particularly during the drought period when stock were allowed to graze on the exposed lakebed. Furthermore, stock exclusion has allowed the regeneration of both shoreline and offshore vegetation which are essential for shoreline stabilisation.

This study has revealed the shoreline soil type is an important factor in bank stability. The Poltalloch soil type, which fringes a large part of the Lakes, is particularly vulnerable to water erosion. Except where the shoreline was protected by offshore reed beds (Dodd01, Secomb02, Strother01 and Strother02) or a foreshore dune (Raukkan01), almost every site characterised by Poltalloch soils was subject to moderate to severe erosion. Although some of this erosion was attributable to stock trampling, the majority was due to water erosion while the lakes were at or near normal operating levels.

The presence of a sandy beach (Lloyd01) or foreshore dune (Raukkan01) appears to be a highly effective barrier to shoreline erosion – overall shoreline growth rather than erosion was observed in both instances. By contrast, high sandy cliffs (Cowan01, Nurra Nurra01) were subject to significant erosion, ranging from moderate to severe. Erosion along such shorelines typically occurs in an incremental fashion due to undercutting and subsequent collapse of bank sections, even when not exposed to water erosion.

The aspect of a particular shoreline is also a key factor in determining the shoreline erosion risk. Shorelines that are unprotected (e.g. by offshore vegetation or a sandy beach or dune) and that face prevailing wind directions SE–SW or NW-N appear to be the most vulnerable to erosion. Examples of such sites which have experienced significant erosion during the monitoring period are Cowan01, Cowan02, Griffen01, Marles, McAnanney, Nurra Nurra02, Raukkan02 and South. Wave fetch distance is also an important consideration, with shorelines exposed to the greater fetch distances being predictably more vulnerable. Exposure to prevailing winds both increases the wind and wave energy that contribute to shoreline erosion, and increases average water levels along these shorelines, due to wind-induced water set-up and seiching.

From data collected in the study, bank height does not appear to be an indicator of erosion risk – the study has indicated that soil type, local vegetation and shoreline aspect appear to be the main risk indicators.

7 Recommendations

Due to the concurrent drought conditions, unfortunately the monitoring period assessed in this report included only about half a year during which lake water levels were at or near normal operating levels. As a result, this lakeshore erosion monitoring study does not provide an adequate reflection of normal conditions, nor a clear picture of the longer-term erosive effects of typical water level conditions. There may be value in repeating the erosion monitoring project over consecutive years during which lake levels are at or near normal operating levels.

Given anecdotal reports by local landholders that lakeshore erosion appears to be accelerated by elevated lake operating levels, there may also be value in using future monitoring to determine whether any linkages can be drawn between erosion rates and different lake level management strategies. However, the feasibility of carrying out such a study may be limited by the following factors:

- Lake water levels are typically varied over relatively short periods (weeks or months) rather than years. To account for this, the monitoring frequency may need to be increased significantly (e.g. up to four or six times a year).
- Erosion can occur incrementally, such as after storm events. Only high frequency monitoring is likely to be able to attribute erosion that occurred to these types of events.
- Erosion can also occur over longer time periods where there are many factors changing, such as wind direction, lake level, grazing status, etc. For these reasons, it will always be difficult to differentiate the relative effects of these different influences.

If any future monitoring is to be undertaken, but it is not feasible to increase monitoring frequency (e.g. to assess relationships between water levels and erosion), it would be appropriate to continue the previous timing (April and November of each year) of monitoring visits. These months represent the typical start/end timings of seasonal patterns in wind, temperature and rainfall periods, so monitoring at these times gives an indication of the seasonal patterns and any linked erosion trends. Furthermore, if monitoring is carried out at the same times of the year as in the period covered by this report, it will be easier to compare results between this and any future studies.

There may be value in undertaking future monitoring and analysis to provide a comparison of geographically similar sites (or those with same soil types) with different shoreline management regimes (e.g. stock grazing or exclusion, reedbed establishment). The results could aid local land managers and planning groups by providing a clear indication and measure of the impacts of altered land management practices.

Appendix A – Lakeshore erosion measurements

		Lakeshore measurements (m from baseline marker)										Lakeshore erosion								
Location		**Setup**	**Apr-07**	**Nov-07**	**Apr-08**	**Nov-08**	**Apr-09**	**Nov -09**	**Apr-10**	**Nov-10**	**Apr-11**	**Apr-07**	**Nov-07**	**Apr-08**	**Nov-08**	**Apr-09**	**Nov-10**	**Apr-11**	**Net erosion (m)**	**Site average erosion (m)**
Browns Beach	L	12.2	12.3	11.9	11.9	11.8	11.8			11.8	11.95	-0.1	0.4	0	0.1	0	0	-0.15	**0.25**	0.183
	C	10	10	10	10	10	10	N/R	N/R	10	10	0	0	0	0	0	0	0	**0**	
	R	15	14.9	14.3	14.6	14.6	14.6			14.6	14.7	0.1	0.6	-0.3	0	0	0	-0.1	**0.3**	
Cowan 01	L	11.4	10.4	10.1	9.75	9.75	9.75			9.75	9.4	1	0.3	0.35	0	0	0	0.35	**2**	1.800
	C	11	10.1	9.6	9.65	9.6	9.55	N/R	N/R	9.5	9.5	0.9	0.5	-0.05	0.05	0.05	0.05	0	**1.5**	
	R	13	12.8	12.75	12.8	12.75	12.6			11.1	11.1	0.2	0.05	-0.05	0.05	0.15	1.5	0	**1.9**	
Cowan 02	L	13.6	13.5	13.5	13.6	13.4	13.4			12.9		0.1	0	-0.1	0.2	0	0.5		**0.7**	0.567
	C	10	9.95	10	9.95	9.95	9.95	N/R	N/R	9.8	N/R	0.05	-0.05	0.05	0	0	0.15		**0.2**	
	R	12	12.2	12	12	11.8	11.9			11.2		-0.2	0.2	0	0.2	-0.1	0.7		**0.8**	
Dodd 01	L				11.5	11.5	11.5			11.5	11.3				0	0	0	0.2	**0.2**	0.150
	C				10	10	10	N/R	N/R	10	9.9				0	0	0	0.1	**0.1**	
	R				12.05	11.9	11.9			11.9	11.9				0.15	0	0	0	**0.15**	
Dodd 02	L				11.7	11.7	11.7			11.7	11.7				0	0	0	0	**0**	-0.033
	C				10	10	10	N/R	N/R	10	10				0	0	0	0	**0**	
	R				11.4	11.4	11.4			11.4	11.5				0	0	0	-0.1	**-0.1**	
Fischer 01	L				10.8	10.7	10.9								0.1	-0.2			**-0.1**	-0.117
	C				10	10	10	N/R	N/R						0	0			**0**	
	R				10.65	10.8	10.9								-0.15	-0.1			**-0.25**	
Fischer 02	L				10.95	11.1	11.1								-0.15	0			**-0.15**	-0.033
	C				10	10	10	N/R	N/R						0	0			**0**	
	R				11.75	11.7	11.7								0.05	0			**0.05**	
Griffen 01	L	12.5	12	12.1	12.05	12.1	12			12	11.7	0.5	-0.1	0.05	-0.05	0.1	0	0.3	**0.8**	0.900
	C	10	10	10	10	10	10	N/R	N/R	10	9.2	0	0	0	0	0	0	0.8	**0.8**	
	R	11.4	11.35	10.6	11.3	11.1	11.3			11.2	10.3	0.05	0.75	-0.7	0.2	-0.2	0.1	0.9	**1.1**	

		Lakeshore measurements (m from baseline marker)										Lakeshore erosion								
Location		Setup	Apr-07	Nov-07	Apr-08	Nov-08	Apr-09	Nov -09	Apr-10	Nov-10	Apr-11	Apr-07	Nov-07	Apr-08	Nov-08	Apr-09	Nov-10	Apr-11	Net erosion (m)	Site average erosion (m)
Griffen 02	L	12	12.35	12.5	12.6	12.55	12.4			12.2	12	-0.35	-0.15	-0.1	0.05	0.15	0.2	0.2	**0**	0.133
	C	10	10	10	10	10	10	N/R	N/R	10	10	0	0	0	0	0	0	0	**0**	
	R	11.3	11.55	11.6	11.4	11.5	11.5			11.1	10.9	-0.25	-0.05	0.2	-0.1	0	0.4	0.2	**0.4**	
Hartnett	L	10.05	9.95	10.1	9.9	9.95	9.9			9.7	10.9	0.1	-0.15	0.2	-0.05	0.05	0.2	-1.2	**-0.85**	-0.427
	C	10	10	10	10	10	10	N/R	N/R	10	10.4	0	0	0	0	0	0	-0.4	**-0.4**	
	R	11.97	11.9	11.95	11.9	11.95	11.95			11.8	12	0.07	-0.05	0.05	-0.05	0	0.15	-0.2	**-0.03**	
Lake Albert Station	L	11.9	11.9	11.6	12	11.6	11.2			11.2		0	0.3	-0.4	0.4	0.4	0		**0.7**	0.083
	C	10	9.6	9.65	9.6	9.5	9.5	N/R	N/R	9.5	N/R	0.4	-0.05	0.05	0.1	0	0		**0.5**	
	R	11.15	11.1	12.1	12.1	12.15	12.1			12.1		0.05	-1	0	-0.05	0.05	0		**-0.95**	
Lighthouse	L	13.65	13.6	12.85	12.8	12.9	12.8			12.7	12.7	0.05	0.75	0.05	-0.1	0.1	0.1	0	**0.95**	0.467
	C	10	10	10	10	10	10	N/R	N/R	9.6	9.6	0	0	0	0	0	0.4	0	**0.4**	
	R	13.1	13.1	13.1	13	13.05	13.05			13.05	13.05	0	0	0.1	-0.05	0	0	0	**0.05**	
Lloyd 01	L	10.95	10.8	11	9.9	10.8	10.8			10.8	11.5	0.15	-0.2	1.1	-0.9	0	0	-0.7	**-0.55**	-0.767
	C	10	10	10	8.9	8.9	8.9	N/R	N/R	8.9	11.1	0	0	1.1	0	0	0	-2.2	**-1.1**	
	R	11.55	10.85	11.8	10.6	11.1	11.3			11.3	12.2	0.7	-0.95	1.2	-0.5	-0.2	0	-0.9	**-0.65**	
Lloyd 02	L	11.45	11.35	11.1	11	10.95	10.95			10.85	10.85	0.1	0.25	0.1	0.05	0	0.1	0	**0.6**	0.617
	C	10	10	10	10	10	10			9.3	9.1	0	0	0	0	0	0.7	0.2	**0.9**	
	R	11.55	11.15	11.6	11.5	11.4	11.3			11.3	11.2	0.4	-0.45	0.1	0.1	0.1	0	0.1	**0.35**	
Marles	L	11.1	10.05	10.05	10.1	10.05	10.1			10.1	10.08	1.05	0	-0.05	0.05	-0.05	0	0.02	**1.02**	1.037
	C	10	9.1	9.15	9.15	9.05	9.05	N/R	N/R	9.05	9.03	0.9	-0.05	0	0.1	0	0	0.02	**0.97**	
	R	11.2	10.2	10	10.05	10.3	10.1			10.1	10.08	1	0.2	-0.05	-0.25	0.2	0	0.02	**1.12**	
McAnanney	L	11.5	11.5	11.5	11.45	11.5	11.5			10.15	9.2	0	0	0.05	-0.05	0	1.35	0.95	**2.3**	1.583
	C	10	10	10	10	10	10	N/R	N/R	9.15	8.9	0	0	0	0	0	0.85	0.25	**1.1**	
	R	10.8	10.75	10.75	10.8	10.9	10.9			9.7	9.45	0.05	0	-0.05	-0.1	0	1.2	0.25	**1.35**	
McFarlane	L	11.9	11.5	11.7	11.6	11.6	11.6			11.6	11.6	0.4	-0.2	0.1	0	0	0	0	**0.3**	0.467
	C	10	10	10	10	10	10	N/R	N/R	10	9.8	0	0	0	0	0	0	0.2	**0.2**	
	R	11.4	11.2	11	10.9	10.9	10.9			10.9	10.5	0.2	0.2	0.1	0	0	0	0.4	**0.9**	

		Lakeshore measurements (m from baseline marker)										Lakeshore erosion								
Location		Setup	Apr-07	Nov-07	Apr-08	Nov-08	Apr-09	Nov -09	Apr-10	Nov-10	Apr-11	Apr-07	Nov-07	Apr-08	Nov-08	Apr-09	Nov-10	Apr-11	Net erosion (m)	Site average erosion (m)
Nurra Nurra 01	L	12.65	12.6	12.2	12.2	12.3	12.3			12.3	12.3	0.05	0.4	0	-0.1	0	0	0	**0.35**	0.463
	C	11	10.95	10.65	10.65	10.7	10.7	N/R	N/R	10.7	10.7	0.05	0.3	0	-0.05	0	0	0	**0.3**	
	R	10.54	10.5	10.2	10.15	10.1	10.1			9.8	9.8	0.04	0.3	0.05	0.05	0	0.3	0	**0.74**	
Nurra Nurra 02	L	11.4	11.4	11.3	11.4	11.3	11.3			9.75	9.3	0	0.1	-0.1	0.1	0	1.55	0.45	**2.1**	1.767
	C	10	10	10	9.95	10	10	N/R	N/R	8.4	8	0	0	0.05	-0.05	0	1.6	0.4	**2**	
	R	8.7	8.7	8.7	8.8	8.8	8.8			7.7	7.5	0	0	-0.1	0	0	1.1	0.2	**1.2**	
Pitchford 01	L				11.2	11.25	11.2			11.2					-0.05	0.05			**0**	0.000
	C				10	10	10	N/R	N/R	10	N/R				0	0			**0**	
	R				13	13	13			13					0	0			**0**	
Pitchford 02	L				12.8	12.8	12.8			12.8	12.8				0	0	0	0	**0**	-0.017
	C				10	10	10	N/R	N/R	10	10				0	0	0	0	**0**	
	R				11.4	11.45	11.45			11.45	11.45				-0.05	0	0	0	**-0.05**	
Raukkan 01	L	11.2	11.4	11.35	11	11.1	11			11	11.5	-0.2	0.05	0.35	-0.1	0.1	0	-0.5	**-0.3**	-0.350
	C	10	10	10	9.9	10	9.15	N/R	N/R	9.15	10.4	0	0	0.1	-0.1	0.85	0	-1.25	**-0.4**	
	R	11.65	11.3	11.7	11.7	11.6	11.6			11.6	12	0.35	-0.4	0	0.1	0	0	-0.4	**-0.35**	
Raukkan 02	L	10.3	10.25	10.2	10.1	10.15	10.15			9.5	9.3	0.05	0.05	0.1	-0.05	0	0.65	0.2	**1**	1.233
	C	10	9.95	9.8	9.8	9.4	9.4	N/R	N/R	9.2	8.5	0.05	0.15	0	0.4	0	0.2	0.7	**1.5**	
	R	11.1	11.15	10.95	10.8	10.8	10.8			10.6	9.9	-0.05	0.2	0.15	0	0	0.2	0.7	**1.2**	
Secomb 01	L				12.1	11.8	11.8			11.8	11.8				0.3	0	0	0	**0.3**	0.100
	C				10	10	10	N/R	N/R	10	10				0	0	0	0	**0**	
	R				11.8	11.65	11.8			11.8	11.8				0.15	-0.15	0	0	**0**	
Secomb 02	L				10.2	10.3	10.3			19.7	11				-0.1	0	-9.4	8.7	**-0.8**	-2.800
	C				7.6	8.9	8.9	N/R	N/R	12.4	10				-1.3	0	-3.5	2.4	**-2.4**	
	R				8.9	8.9	8.9			26.3	14.1				0	0	-17.4	12.2	**-5.2**	
South	L	10.8	10.1	10.1	9.1	9.4	9.4			9.4	8.15	0.7	0	1	-0.3	0	0	1.25	**2.65**	2.367
	C	10	10	10	9.15	9.2	10	N/R	N/R	9	7.5	0	0	0.85	-0.05	-0.8	1	1.5	**2.5**	
	R	10.3	9.7	9.8	9.6	9.5	9.5			9.5	8.35	0.6	-0.1	0.2	0.1	0	0	1.15	**1.95**	

		Lakeshore measurements (m from baseline marker)										Lakeshore erosion								
Location		**Setup**	**Apr-07**	**Nov-07**	**Apr-08**	**Nov-08**	**Apr-09**	**Nov -09**	**Apr-10**	**Nov-10**	**Apr-11**	**Apr-07**	**Nov-07**	**Apr-08**	**Nov-08**	**Apr-09**	**Nov-10**	**Apr-11**	**Net erosion (m)**	**Site average erosion (m)**
Strother 01	L	10.2	10.2	10.1	10.2	10.1	10.1			10.1	10.1	0	0.1	-0.1	0.1	0	0	0	**0.1**	0.100
	C	10	10	10	10	10	10	N/R	N/R	10	10	0	0	0	0	0	0	0	**0**	
	R	10.8	10.6	10.5	10.6	10.6	10.6			10.6	10.6	0.2	0.1	-0.1	0	0	0	0	**0.2**	
Strother 02	L	10.2	10.2	10.2	10.15	10.05	10.05			10.05	10.05	0	0	0.05	0.1	0	0	0	**0.15**	0.117
	C	10	10	10	10	10	10	N/R	N/R	10	10	0	0	0	0	0	0	0	**0**	
	R	9.9	9.65	9.65	9.6	9.6	9.6			9.6	9.7	0.25	0	0.05	0	0	0	-0.1	**0.2**	
Teringie	L	10.95	10.9	11	10.9	11	11			11	11.2	0.05	-0.1	0.1	-0.1	0	0	-0.2	**-0.25**	-0.217
	C	10	9.9	10	10	10	10	N/R	N/R	10	10	0.1	-0.1	0	0	0	0	0	**0**	
	R	11.1	11.1	11.3	11	11	11.1			11.1	11.5	0	-0.2	0.3	0	-0.1	0	-0.4	**-0.4**	
Withers	L	11.8	11.7	11.8	11.6	11.75	11.6			11.6	11.7	0.1	-0.1	0.2	-0.15	0.15	0	-0.1	**0.1**	-0.233
	C	10	10	10	10	10	10	N/R	N/R	10	10.6	0	0	0	0	0	0	-0.6	**-0.6**	
	R	11.4	11.4	11.45	11.5	11.5	11.5			11.5	11.6	0	-0.05	-0.05	0	0	0	-0.1	**-0.2**	

Appendix B – Lake level data

Lake Albert

	A4260630 Lake Albert at Meningie Sailing Club Jetty (Recorder)		A4261153 Lake Albert Near Causeway at Waltowa Swamp		A4261155 Lake Albert 2km North Warringee Point				
	Water level (m AHD)	Data Quality	Water level (m AHD)	Data Quality	Water level (m AHD)	Data Quality	Average all stations	Data Quality	Average for period
Nov-06	0.613	Missing days					0.613		
Dec-06	0.468						0.468		
Jan-07	0.382						0.382		0.380
Feb-07	0.249	Poor					0.249		
Mar-07	0.187	Poor					0.187		
Apr-07	0.121	Missing days					0.121		
May-07	0.198	Poor					0.198		
Jun-07	0.17	Fair					0.170		
Jul-07	0.268						0.268	Meningie data only	0.209
Aug-07	0.3						0.300		
Sep-07	0.256						0.256		
Oct-07	0.149						0.149		
Nov-07	0.002						0.002		
Dec-07	-0.089						-0.089		
Jan-08	-0.318	Missing days					-0.318		-0.205
Feb-08	-0.415	Missing days					-0.415		
Mar-08		Out of recordable range						No data	
Apr-08		Out of recordable range						No data	
May-08	-0.483	Missing days	-0.479	Missing days			-0.481	Missing days	
Jun-08	-0.417	Missing days	-0.423				-0.420	Missing days	
Jul-08	-0.319		-0.33				-0.325		-0.309
Aug-08	-0.201		-0.183				-0.192		
Sep-08	-0.176		-0.171				-0.174		
Oct-08	-0.272		-0.248				-0.260		
Nov-08	-0.381		-0.331				-0.356		
Dec-08	-0.415		-0.375		-0.429	Missing days	-0.406	Missing days	
Jan-09	-0.474		-0.41		-0.461		-0.448		-0.455
Feb-09	-0.526	Missing days	-0.492		-0.543		-0.520	Missing days	
Mar-09	-0.552	Missing days	-0.52		-0.553	Fair	-0.542	Missing days	
Apr-09	-0.501		-0.468		-0.479	Fair	-0.483		
May-09	-0.338		-0.318		-0.304		-0.320		
Jun-09	-0.266		-0.269		-0.229		-0.255		
Jul-09	-0.214	Fair	-0.211	Poor	-0.199		-0.208	Poor	-0.274
Aug-09	-0.209	Fair	-0.113	Poor	-0.194	Fair	-0.172	Poor	
Sep-09	-0.259	Fair	-0.123	Poor	-0.233		-0.205	Poor	
Oct-09	-0.304	Fair	-0.232	Poor	-0.288		-0.275	Poor	
Nov-09	-0.431		-0.389	Fair	-0.43		-0.417	Fair	
Dec-09	-0.543	Missing days	-0.516	Fair	-0.578		-0.546	Missing days	
Jan-10		No data	-0.664		-0.751		-0.708		-0.628
Feb-10		No data	-0.705		-0.792		-0.749		
Mar-10		No data	-0.701		-0.743		-0.722		
Apr-10	-0.6	Missing days	-0.609		-0.614		-0.608	Missing days	
May-10	-0.528		-0.505		-0.508		-0.514		
Jun-10	-0.42		-0.407	Fair	-0.404		-0.410	Fair	
Jul-10	-0.389		-0.394	Fair	-0.376		-0.386	Fair	-0.246
Aug-10	-0.365		-0.318	Fair	-0.394		-0.359	Fair	
Sep-10	-0.17		-0.13	Fair	-0.165		-0.155	Fair	
Oct-10	0.701		0.73		0.699		0.710		
Nov-10	0.675		0.706		0.678		0.686		
Dec-10	0.8		0.825		0.792		0.806		
Jan-11	0.619		0.658		0.629		0.635		0.702
Feb-11	0.657		0.695		0.669		0.674		
Mar-11	0.695		0.733		0.702		0.710		
Apr-11	0.728		0.749		0.741		0.739		

Lake Alexandrina

	A4260524 Lake Alexandrina at Milang Jetty (Recorder)		A4261156 Lake Alexandrina 3km West Point McLeay		A4261133 Lake Alexandrina (Offshore Raukkan)		A4260575 Lake Alexandrina at Poltalloch Plains		A4261158 Lake Alexandrina 4km West Pomanda Point		A4260574 Lake Alexandrina near Mulgundawa				
	Water level (m AHD)	Data Quality	Water level (m AHD)	Data Quality	Water level (m AHD)	Data Quality	Water level (m AHD)	Data Quality	Water level (m AHD)	Data Quality	Water level (m AHD)	Data Quality	Average all stations	Data Quality	Average for period
Nov-06	0.657						0.698				0.683		0.679		
Dec-06	0.522						0.548	Poor			0.54		0.537	Poor	
Jan-07	0.39						0.441				0.419		0.417		0.445
Feb-07	0.336						0.36				0.358		0.351		
Mar-07	0.228						0.252				0.238		0.239		
Apr-07	0.115						0.134	Missing days			0.116	Missing days	0.122	Missing days	
May-07	0.072						0.135				0.078	Missing days	0.095	Missing days	
Jun-07	0.156						0.178				0.157		0.164		
Jul-07	0.162						0.233				0.18		0.192		0.156
Aug-07	0.188						0.258				0.202		0.216		
Sep-07	0.142						0.223				0.162		0.176		
Oct-07	0.102						0.166	Missing days			0.124	Missing days	0.131	Missing days	
Nov-07	0.088						0.126	Missing days			0.112		0.109	Missing days	
Dec-07	-0.055							No data			0.012	Missing days	-0.022	Missing days	
Jan-08	-0.167				-0.271	Missing days	-0.127	Missing days			-0.173	Missing days	-0.185	Missing days	-0.163
Feb-08	-0.3				-0.362		-0.244	Missing days			-0.28		-0.297	Missing days	
Mar-08	-0.439				-0.46		-0.357				-0.426		-0.421		
Apr-08	-0.499	Missing days			-0.509		-0.408				-0.486		-0.476	Missing days	
May-08	-0.472				-0.487		-0.39				-0.465		-0.454		
Jun-08	-0.449				-0.46		-0.357				-0.431		-0.424		
Jul-08	-0.411				-0.408		-0.295				-0.37		-0.371		-0.355
Aug-08	-0.317				-0.321		-0.19				-0.25		-0.270		
Sep-08	-0.272				-0.279		-0.146				-0.207		-0.226		
Oct-08	-0.285	Poor			-0.326		-0.203				-0.241		-0.264	Poor	
Nov-08	-0.412				-0.417		-0.306				-0.318		-0.363		
Dec-08	-0.522				-0.519		-0.425				-0.442		-0.477	Missing days	
Jan-09	-0.69				-0.763	Missing days	-0.609				-0.61		-0.668	Missing days	-0.657
Feb-09	-0.841	Missing days	-0.912	Missing days	-0.905		-0.808		-0.899	Missing days	-0.8	Fair	-0.861	Missing days	
Mar-09	-0.945	Missing days	-0.969		-0.99		-0.875		-0.931		-0.785	Poor	-0.916	Missing days	
Apr-09	-0.971	Missing days	-1.01		-1.049	Poor	-0.93		-0.987		-0.754	Poor	-0.950	Missing days	
May-09	-0.963	Missing days	-0.964		-1.018	Poor	-0.89	Fair	-0.964		-0.862	Missing days	-0.944	Missing days	
Jun-09	-0.907	Missing days	-0.881		-0.966	Missing days	-0.831	Missing days	-0.9		-0.948		-0.906	Missing days	
Jul-09	-0.834	Missing days	-0.805		-0.821	Missing days	-0.73	Missing days	-0.797		-0.85		-0.806	Missing days	-0.826
Aug-09	-0.775	Missing days	-0.758		-0.784	Fair	-0.656		-0.718		-0.775		-0.744	Missing days	
Sep-09	-0.768	Missing days	-0.732		-0.758	Fair	-0.633		-0.701		-0.739		-0.722	Missing days	
Oct-09	-0.717	Missing days	-0.74		-0.759	Fair	-0.643		-0.69		-0.706		-0.709	Missing days	
Nov-09	-0.797	Missing days	-0.819		-0.801	Missing days	-0.709		-0.761		-0.783	Missing days	-0.778	Missing days	
Dec-09	-0.846	Missing days	-0.853		-0.887	Missing days	-0.766	Missing days	-0.807			No data	-0.832	Missing days	
Jan-10	-0.895	Fair	-0.928		-0.947	Missing days		No data	-0.869		-0.879	Missing days	-0.904	Missing days	-0.830
Feb-10	-0.856	Fair	-0.902		-0.92		-0.827	Missing days	-0.844		-0.852		-0.867	Fair	
Mar-10	-0.749	Fair	-0.788		-0.815		-0.725		-0.751		-0.777		-0.768	Fair	
Apr-10	-0.596	Missing days	-0.593		-0.626		-0.536		-0.567		-0.608		-0.588	Missing days	
May-10	-0.416	Fair	-0.421		-0.454		-0.367		-0.398		-0.443		-0.417	Fair	
Jun-10	-0.211	Fair	-0.211		-0.243		-0.151		-0.187		-0.227	Fair	-0.205	Fair	
Jul-10	-0.031	Fair	-0.025		-0.061		0.021		-0.014		-0.059	Fair	-0.028	Fair	0.039
Aug-10	0.175	Fair	0.17		0.151		0.27		0.223		0.115	Missing days	0.184	Missing days	
Sep-10	0.485	Missing days	0.574		0.547		0.643		0.607			No data	0.571	Missing days	
Oct-10	0.737		0.735		0.711		0.808		0.774		0.767	Missing days	0.755	Missing days	
Nov-10	0.725		0.719		0.694		0.788		0.758		0.724		0.735		
Dec-10	0.792		0.806		0.787		0.901		0.861		0.821		0.828		
Jan-11	0.668		0.672		0.65		0.741		0.715		0.68		0.688		0.751
Feb-11	0.718		0.723		0.7		0.791		0.766		0.73		0.738		
Mar-11	0.741	Missing days	0.747		0.728		0.827		0.798		0.762		0.767	Missing days	
Apr-11	0.726		0.747		0.721		0.807		0.768		0.732		0.750		

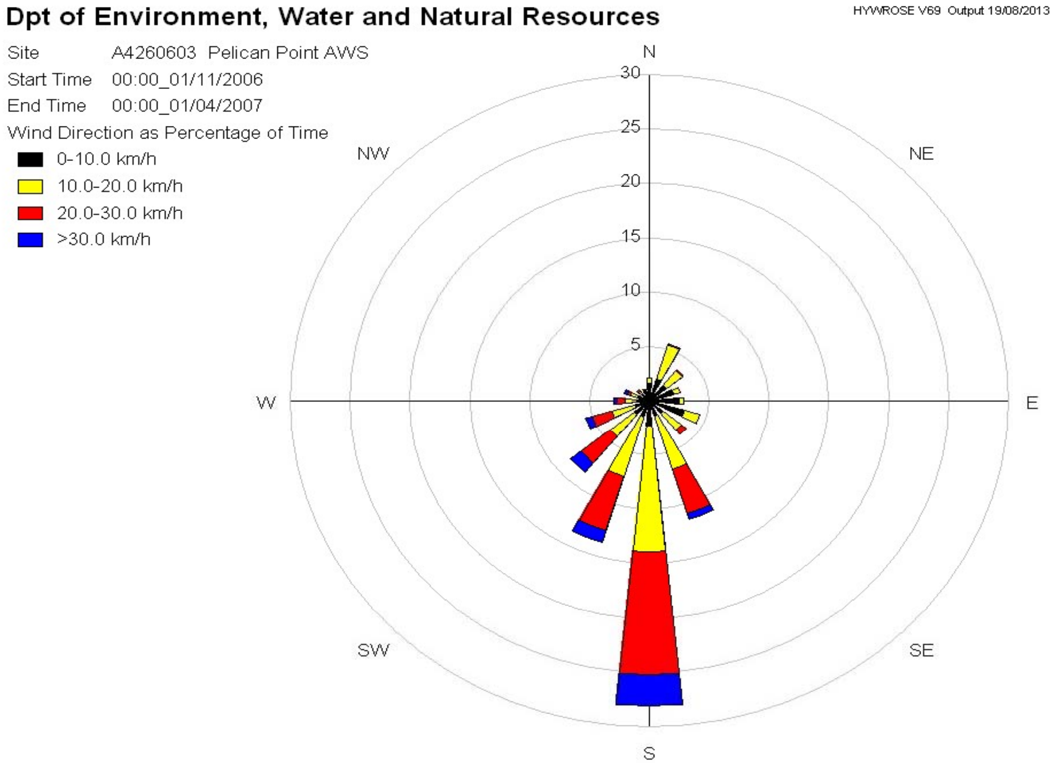
Appendix C – Wind data summaries

Dpt of Environme Water and Natural Resources HYWROSE V69 Output 19/08/2013

Site Pelican Point AWS
Start Time 00:00_01/11/2006
End Time 00:00_01/04/2007

Direction (deg)	Time (%)	Velocity (km/h)	Wind run (km)	Dir	% wind run
348.8 - 11.3	2.14	6.563	509	N	0.87%
11.3 - 33.8	5.44	10.625	2095	NNE	3.57%
33.8 - 56.3	3.63	9.334	1228	NE	2.09%
56.3 - 78.8	2.69	6.435	627	ENE	1.07%
78.8 - 101.3	2.9	4.771	501	E	0.85%
101.3 - 123.8	4.42	7.408	1187	ESE	2.02%
123.8 - 146.3	4.01	12.139	1764	SE	3.00%
146.3 - 168.8	11.43	18.656	7728	SSE	13.16%
168.8 - 191.3	28.01	20.142	20446	S	34.82%
191.3 - 213.8	13.59	19.417	9563	SSW	16.29%
213.8 - 236.2	8.47	19.619	6022	SW	10.26%
236.2 - 258.8	5.54	17.992	3612	WSW	6.15%
258.8 - 281.3	3	15.48	1683	W	2.87%
281.3 - 303.8	2.19	13.435	1066	WNW	1.82%
303.8 - 326.3	1.35	9.355	458	NW	0.78%
326.3 - 348.8	1.18	5.368	230	NNW	0.39%
			58718		

	1/11/2006
	1/04/2007
No days	151

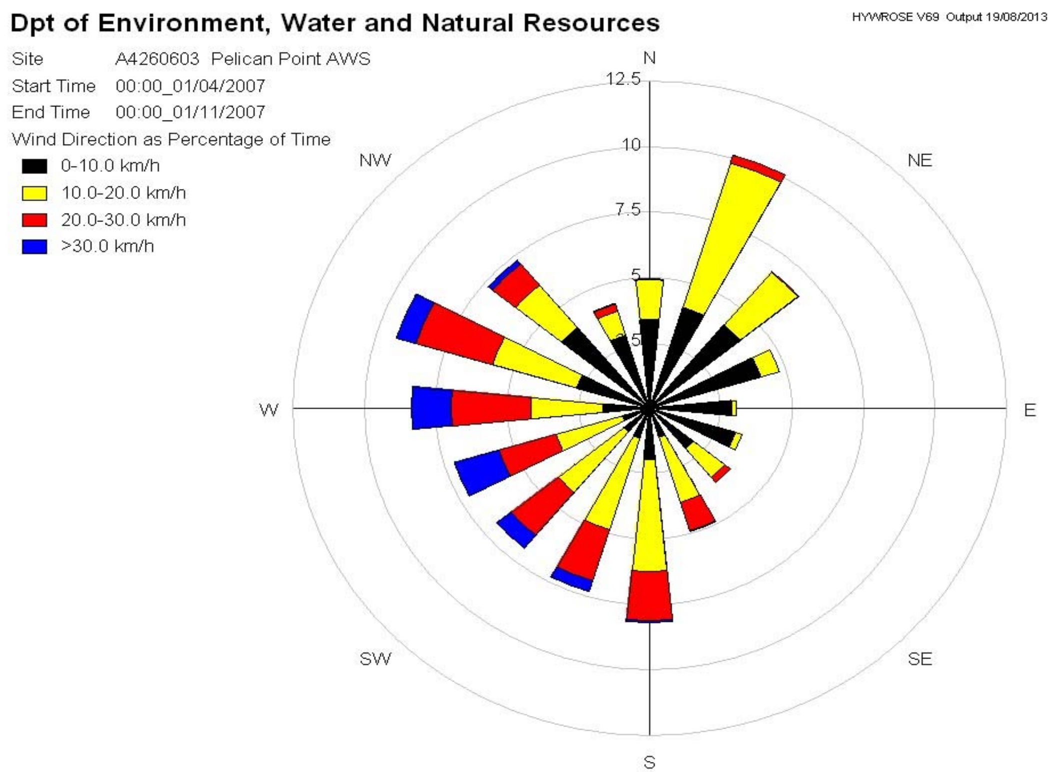


Dpt of Environmen Water and Natural Resources HYWROSE V69 Output 19/08/2013

Site Pelican Point AWS
Start Time 00:00_01/04/2007
End Time 00:00_01/11/2007

Direction (deg)	Time (%)	Velocity (km/h)	Wind run (km)	Dir	% wind run
348.8 - 11.3	4.94	8.229	2088	N	3.03%
11.3 - 33.8	10.08	11.041	5716	NNE	8.28%
33.8 - 56.3	6.74	8.57	2967	NE	4.30%
56.3 - 78.8	4.74	6.036	1469	ENE	2.13%
78.8 - 101.3	3.02	3.717	577	E	0.84%
101.3 - 123.8	3.38	5.073	881	ESE	1.28%
123.8 - 146.3	3.65	9.629	1805	SE	2.62%
146.3 - 168.8	4.9	14.952	3763	SSE	5.45%
168.8 - 191.3	8.16	15.117	6335	S	9.18%
191.3 - 213.8	7.28	17.436	6519	SSW	9.45%
213.8 - 236.2	6.88	18.295	6465	SW	9.37%
236.2 - 258.8	7.13	21.23	7774	WSW	11.27%
258.8 - 281.3	8.35	19.913	8540	W	12.38%
281.3 - 303.8	9.27	16.835	8015	WNW	11.62%
303.8 - 326.3	7.3	11.262	4222	NW	6.12%
326.3 - 348.8	4.19	8.695	1871	NNW	2.71%
			69008		

	1/04/2007
	1/11/2007
No days	214

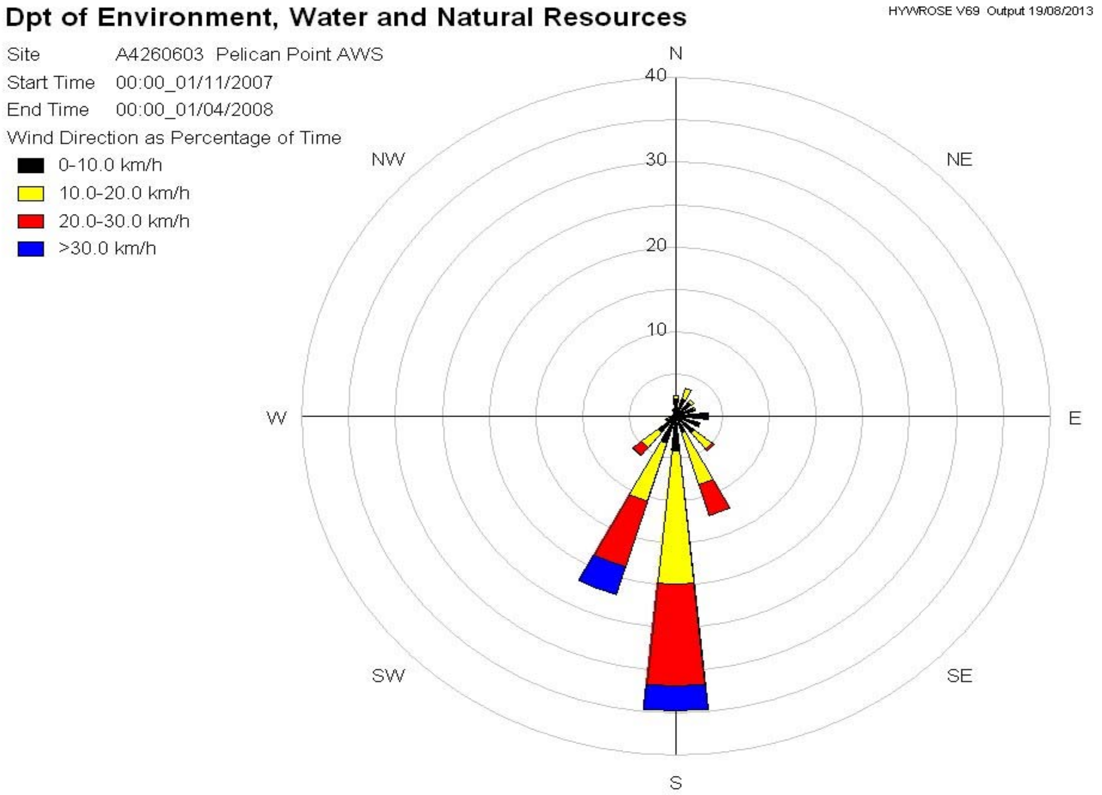


Dpt of Environr Water and Natural Resources HYWROSE V69 Output 19/08/2013

Site Pelican Point AWS
Start Time 00:00_01/11/2007
End Time 00:00_01/04/2008

Direction (deg)	Time (%)	Velocity (km/h)	Wind run (km)	Dir	% wind run
348.8 - 11.3	2.43	6.458	572	N	1.03%
11.3 - 33.8	3.44	8.598	1079	NNE	1.93%
33.8 - 56.3	2.43	6.022	534	NE	0.96%
56.3 - 78.8	2.21	4.056	327	ENE	0.59%
78.8 - 101.3	3.47	2.657	336	E	0.60%
101.3 - 123.8	2.73	4.199	418	ESE	0.75%
123.8 - 146.3	5.26	9.426	1809	SE	3.24%
146.3 - 168.8	12.2	16.2	7210	SSE	12.91%
168.8 - 191.3	34.69	18.736	23710	S	42.46%
191.3 - 213.8	22	20.264	16263	SSW	29.13%
213.8 - 236.2	6	12.84	2810	SW	5.03%
236.2 - 258.8	1.14	10.13	421	WSW	0.75%
258.8 - 281.3	0.29	3.917	41	W	0.07%
281.3 - 303.8	0.36	5.018	66	WNW	0.12%
303.8 - 326.3	0.42	3.681	56	NW	0.10%
326.3 - 348.8	0.94	5.303	182	NNW	0.33%
			55836		

	1/11/2007
	1/04/2008
No days	152

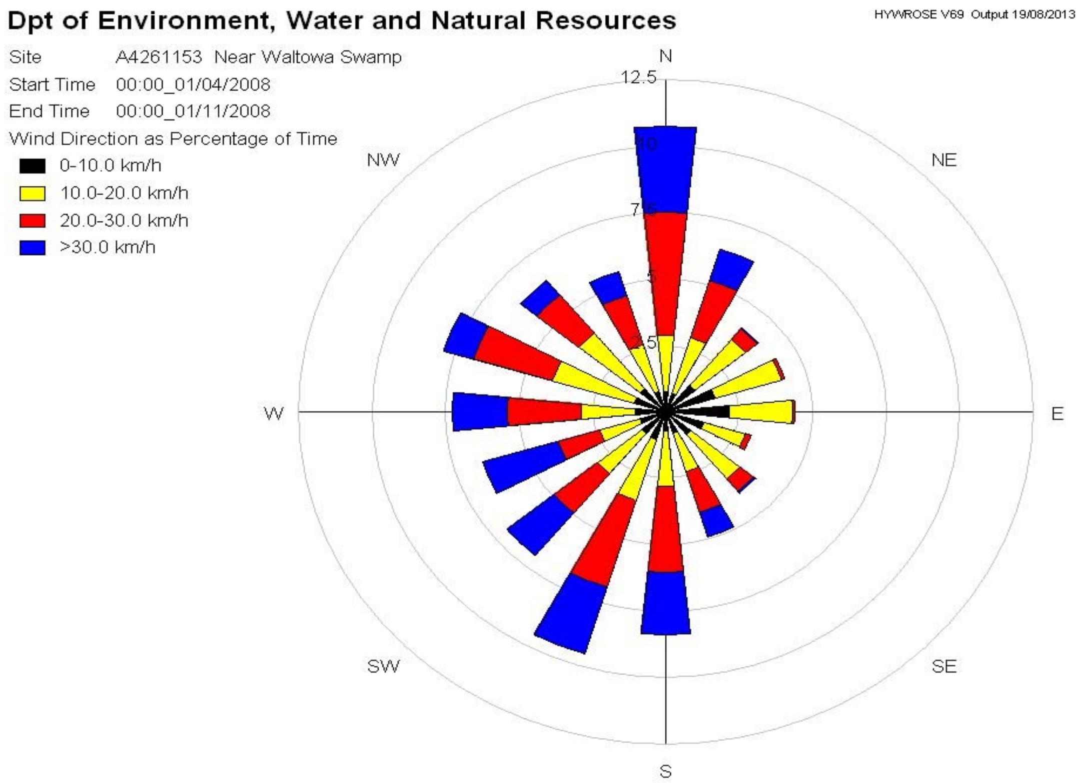


Dpt of Environm Water and Natural Resources HYWROSE V69 Output 19/08/2013

Site Near Waltowa Swamp
Start Time 00:00_01/04/2008
End Time 00:00_01/11/2008

Direction (deg)	Time (%)	Velocity (km/h)	Wind run (km)	Dir	% wind run
348.8 - 11.3	10.73	25.104	13835	N	12.50%
11.3 - 33.8	6.38	21.442	7026	NNE	6.35%
33.8 - 56.3	4.07	13.133	2745	NE	2.48%
56.3 - 78.8	4.23	11.232	2440	ENE	2.20%
78.8 - 101.3	4.37	10.211	2292	E	2.07%
101.3 - 123.8	3.03	11.419	1777	ESE	1.61%
123.8 - 146.3	3.93	14.036	2833	SE	2.56%
146.3 - 168.8	4.88	20.729	5195	SSE	4.69%
168.8 - 191.3	8.36	25.241	10838	S	9.79%
191.3 - 213.8	9.47	24.534	11933	SSW	10.78%
213.8 - 236.2	6.99	24.85	8921	SW	8.06%
236.2 - 258.8	6.49	30.341	10113	WSW	9.14%
258.8 - 281.3	7.26	28.212	10520	W	9.50%
281.3 - 303.8	7.91	20.209	8210	WNW	7.42%
303.8 - 326.3	6.38	18.52	6069	NW	5.48%
326.3 - 348.8	5.52	20.976	5947	NNW	5.37%
			110694		

	1/04/2008
	1/11/2008
No days	214

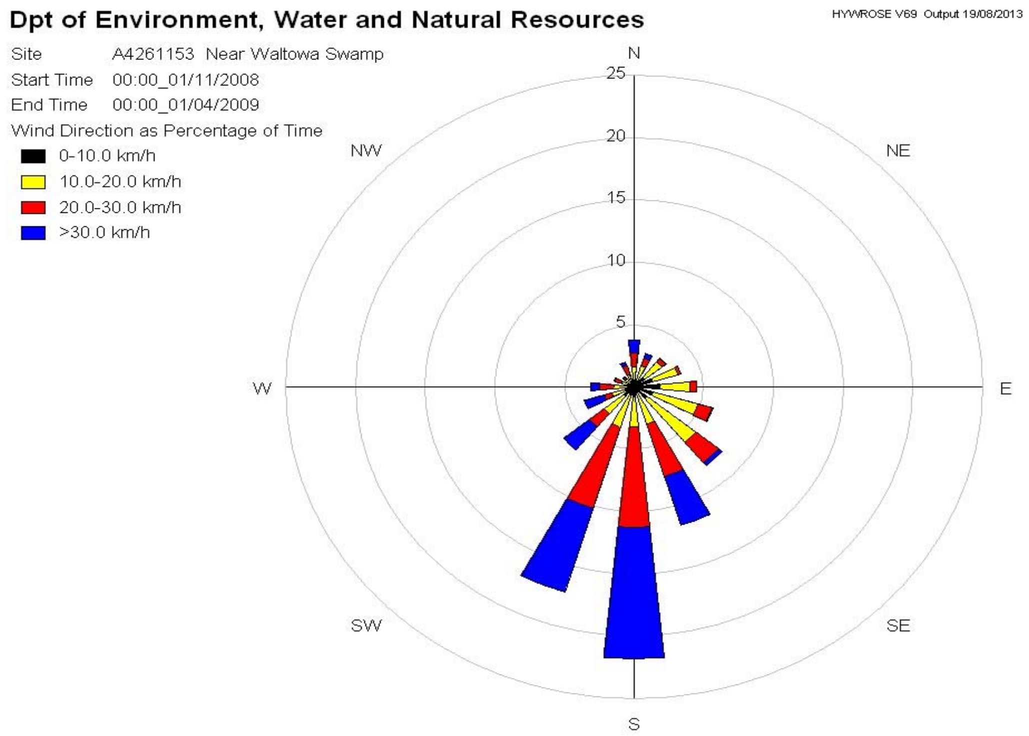


Dpt of Environme Water and Natural Resources HYWROSE V69 Output 19/08/2013

Site Near Waltowa Swamp
Start Time 00:00_01/11/2008
End Time 00:00_01/04/2009

Direction (deg)	Time (%)	Velocity (km/h)	Wind run (km)	Dir	% wind run
348.8 - 11.3	3.78	23.254	3186	N	3.78%
11.3 - 33.8	2.8	18.838	1912	NNE	2.27%
33.8 - 56.3	2.92	13.489	1427	NE	1.69%
56.3 - 78.8	3.51	12.764	1624	ENE	1.93%
78.8 - 101.3	4.46	12.049	1947	E	2.31%
101.3 - 123.8	5.91	14.757	3161	ESE	3.75%
123.8 - 146.3	8.16	17.063	5046	SE	5.99%
146.3 - 168.8	11.57	26.083	10937	SSE	12.98%
168.8 - 191.3	21.76	28.755	22676	S	26.91%
191.3 - 213.8	17.11	28.014	17371	SSW	20.62%
213.8 - 236.2	6.5	25.016	5893	SW	6.99%
236.2 - 258.8	3.77	26.017	3555	WSW	4.22%
258.8 - 281.3	3.11	22.183	2500	W	2.97%
281.3 - 303.8	1.5	17.007	925	WNW	1.10%
303.8 - 326.3	1.03	14.921	557	NW	0.66%
326.3 - 348.8	2.09	20.292	1537	NNW	1.82%
			84251		

	1/11/2008
	1/04/2009
No days	151

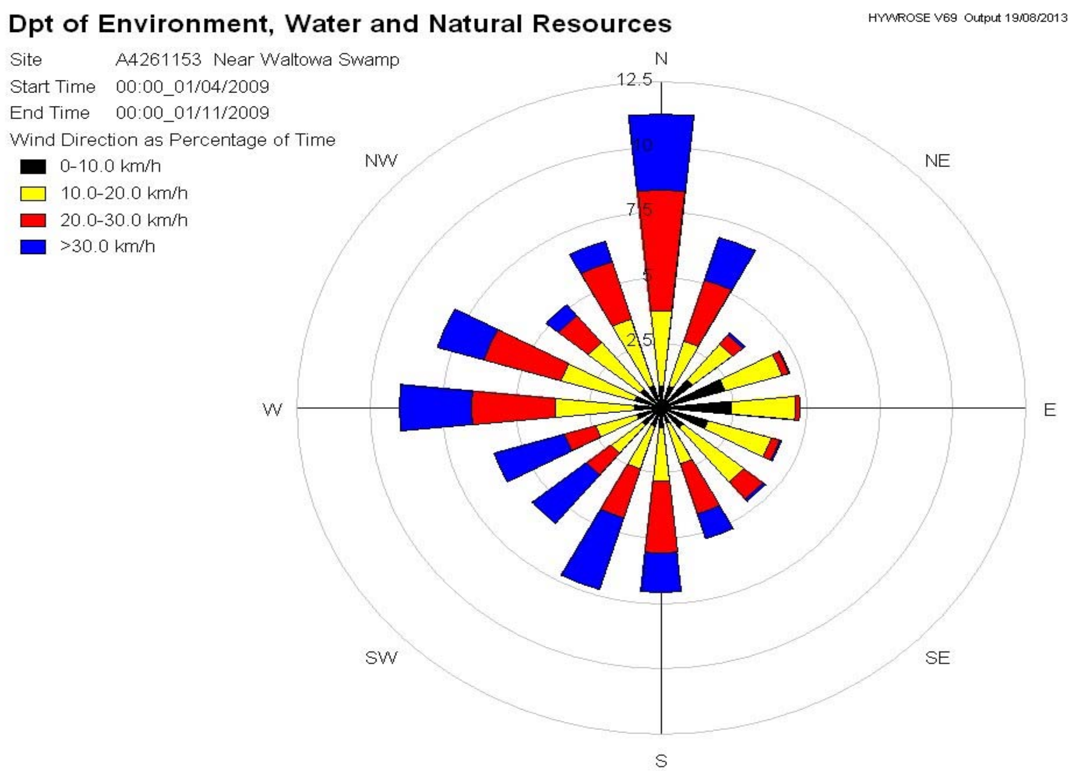


Dpt of Environm Water and Natural Resources HYWROSE V69 Output 19/08/2013

Site Near Waltowa Swamp
Start Time 00:00_01/04/2009
End Time 00:00_01/11/2009

Direction (deg)	Time (%)	Velocity (km/h)	Wind run (km)	Dir	% wind run
348.8 - 11.3	11.65	24.063	14398	N	13.26%
11.3 - 33.8	6.8	22.562	7880	NNE	7.25%
33.8 - 56.3	3.68	13.28	2510	NE	2.31%
56.3 - 78.8	4.55	10.975	2565	ENE	2.36%
78.8 - 101.3	4.74	10.558	2570	E	2.37%
101.3 - 123.8	4.27	12.437	2728	ESE	2.51%
123.8 - 146.3	4.6	15.071	3561	SE	3.28%
146.3 - 168.8	5.2	21.792	5820	SSE	5.36%
168.8 - 191.3	7.03	22.578	8152	S	7.51%
191.3 - 213.8	7.21	26.067	9653	SSW	8.89%
213.8 - 236.2	5.68	26.61	7763	SW	7.15%
236.2 - 258.8	5.96	27.649	8464	WSW	7.79%
258.8 - 281.3	8.91	25.231	11546	W	10.63%
281.3 - 303.8	7.97	22.969	9402	WNW	8.66%
303.8 - 326.3	5.09	18.341	4795	NW	4.41%
326.3 - 348.8	6.64	19.976	6812	NNW	6.27%
			108617		

	1/04/2009
	1/11/2009
No days	214

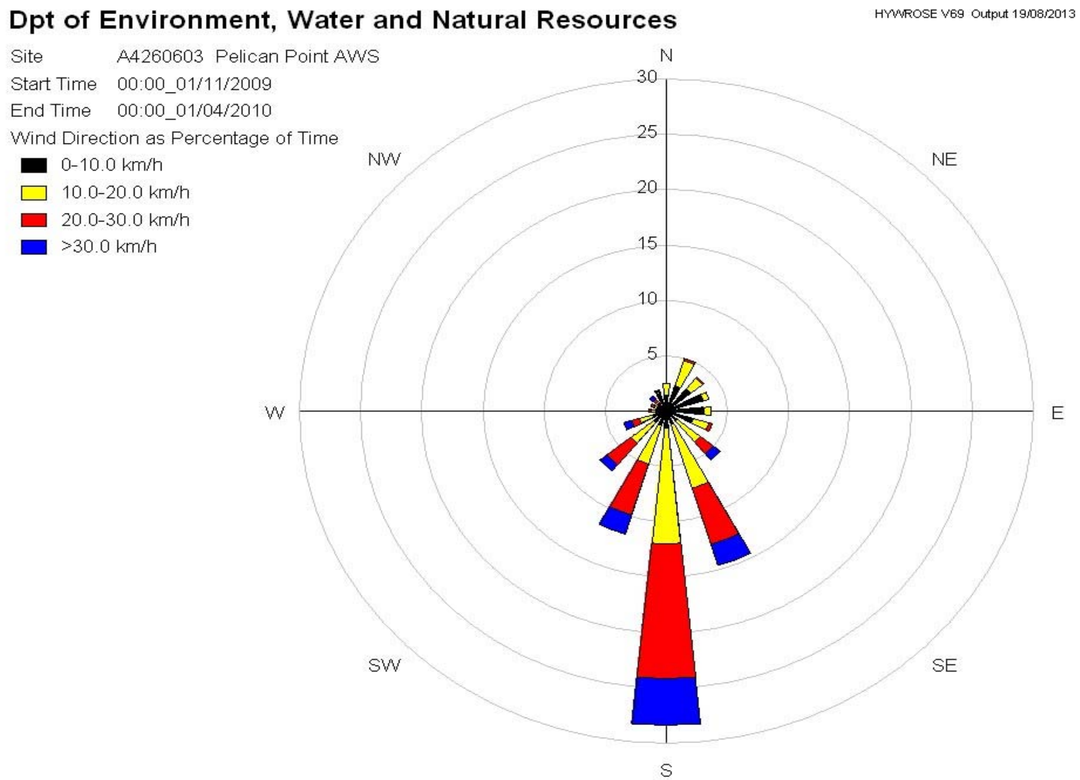


Dpt of Environr Water and Natural Resources   HYWROSE V69 Output 19/08/2013

Site   Pelican Point AWS
Start Time 00:00_01/11/2009
End Time   00:00_01/04/2010

Direction (deg)	Time (%)	Velocity (km/h)	Wind run (km)	Dir	% wind run
348.8 - 11.3	2.53	9.241	847	N	1.34%
11.3 - 33.8	4.93	10.178	1818	NNE	2.87%
33.8 - 56.3	3.96	8.803	1263	NE	1.99%
56.3 - 78.8	3.63	6.711	883	ENE	1.39%
78.8 - 101.3	3.67	7.661	1019	E	1.61%
101.3 - 123.8	3.91	10.055	1425	ESE	2.25%
123.8 - 146.3	5.77	18.104	3786	SE	5.97%
146.3 - 168.8	14.53	20.73	10916	SSE	17.22%
168.8 - 191.3	28.33	21.881	22465	S	35.44%
191.3 - 213.8	11.55	21.295	8913	SSW	14.06%
213.8 - 236.2	7.02	19.234	4893	SW	7.72%
236.2 - 258.8	3.62	18.138	2380	WSW	3.75%
258.8 - 281.3	1.47	11.639	620	W	0.98%
281.3 - 303.8	1.33	11.019	531	WNW	0.84%
303.8 - 326.3	1.72	15.634	975	NW	1.54%
326.3 - 348.8	2.03	8.781	646	NNW	1.02%
			63380		

	1/11/2009
	1/04/2010
No days	151

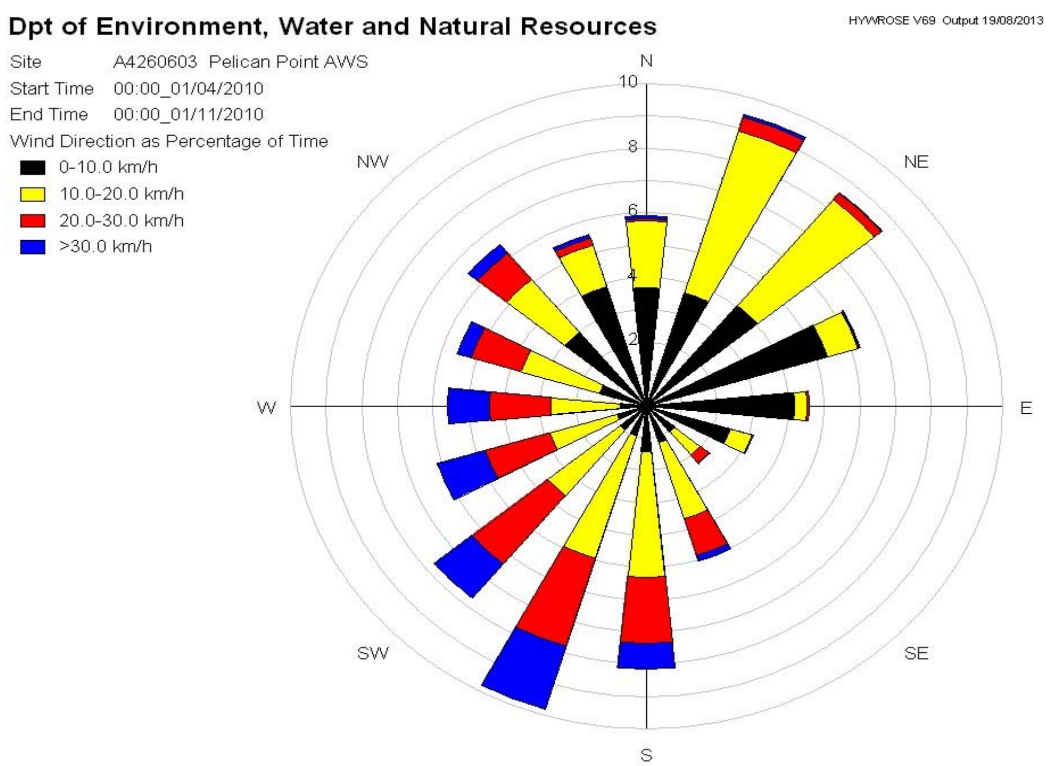


Dpt of Envirc Water and Natural Resources HYWROSE V69 Output 19/08/2013

Site Pelican Point AWS
Start Time 00:00_01/04/2010
End Time 00:00_01/11/2010

Direction (deg)	Time (%)	Velocity (km/h)	Wind run (km)	Dir	% wind run
348.8 - 11.3	5.89	9.339	2825	N	3.73%
11.3 - 33.8	9.43	11.638	5637	NNE	7.43%
33.8 - 56.3	8.54	10.655	4673	NE	6.16%
56.3 - 78.8	6.26	7.425	2387	ENE	3.15%
78.8 - 101.3	4.56	6.66	1560	E	2.06%
101.3 - 123.8	3.13	7.831	1259	ESE	1.66%
123.8 - 146.3	2.29	12.248	1441	SE	1.90%
146.3 - 168.8	5.02	16.036	4135	SSE	5.45%
168.8 - 191.3	8.13	18.054	7539	S	9.94%
191.3 - 213.8	9.79	21.891	11007	SSW	14.52%
213.8 - 236.2	7.7	21.479	8494	SW	11.20%
236.2 - 258.8	6.11	21.76	6828	WSW	9.01%
258.8 - 281.3	5.58	21.205	6077	W	8.01%
281.3 - 303.8	5.54	16.948	4822	WNW	6.36%
303.8 - 326.3	6.49	13.415	4472	NW	5.90%
326.3 - 348.8	5.54	9.375	2668	NNW	3.52%
			75823		

	1/04/2010
	1/11/2010
No days	214

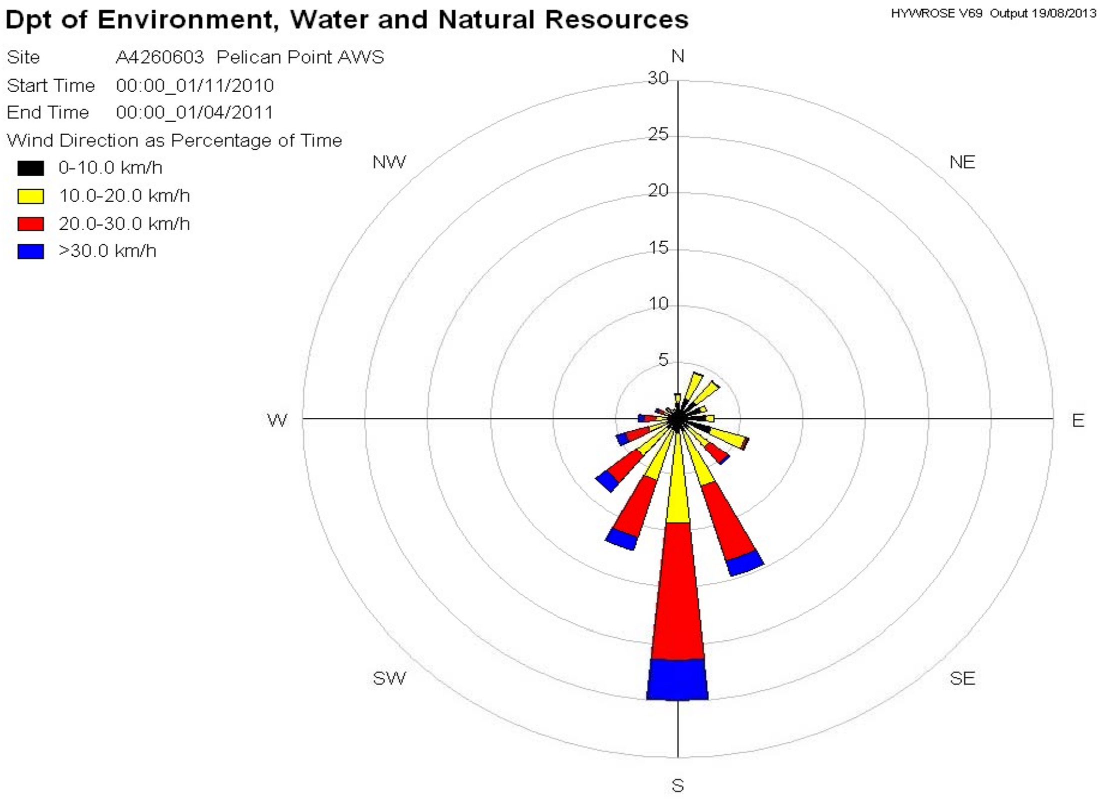


Dpt of Enviro Water and Natural Resources HYWROSE V69 Output 19/08/2013

Site Pelican Point AWS
Start Time 00:00_01/11/2010
End Time 00:00_01/04/2011

Direction (deg)	Time (%)	Velocity (km/h)	Wind run (km)	Dir	% wind run
348.8 - 11.3	2.2	9.878	788	N	1.18%
11.3 - 33.8	4.29	10.996	1710	NNE	2.56%
33.8 - 56.3	4.27	10.894	1686	NE	2.52%
56.3 - 78.8	2.38	7.679	662	ENE	0.99%
78.8 - 101.3	2.89	8.084	847	E	1.27%
101.3 - 123.8	5.92	11.4	2446	ESE	3.66%
123.8 - 146.3	5.36	17.496	3399	SE	5.09%
146.3 - 168.8	14.66	21.072	11195	SSE	16.76%
168.8 - 191.3	24.92	22.726	20524	S	30.73%
191.3 - 213.8	12.23	21.097	9351	SSW	14.00%
213.8 - 236.2	8.5	20.371	6275	SW	9.39%
236.2 - 258.8	5.17	20.456	3833	WSW	5.74%
258.8 - 281.3	3.2	19.098	2215	W	3.32%
281.3 - 303.8	1.88	16.053	1094	WNW	1.64%
303.8 - 326.3	1.27	10.855	500	NW	0.75%
326.3 - 348.8	0.85	8.834	272	NNW	0.41%
			66794		

	1/11/2010
	1/04/2011
No days	151



Government of South Australia

Department of Environment,
Water and Natural Resources