Reedy Lake Groundwater and Ecology Investigation

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ECOLOGICAL ASSOCIATES REPORT BX003-B

Reedy Lake Groundwater and Ecology Investigation

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1.1 Introduction

Ecological Associates Pty Ltd was engaged by Corangamite Catchment Management Authority and Parks Victoria to assist with investigations into the role of groundwater in the ecology of Reedy Lake.

Also engaged to assist the CMA and Parks Victoria in this project were:

- Peter Dalhous, Hydrogeologist; and
- Tony Miner, Geotechnical Engineer.

Further assistance was provided by the Geelong Branch of the Victoria Field and Game coordinated by Ian McLachlan LS, with further professional assistance from Ian.

1.2 Scope of Work

The overall objective of this project was to establish a groundwater monitoring program and to interpret the role of groundwater in the distribution and health of plant communities in Reedy Lake.

Ecological Associates contributed to project by:

- advising on the likely interaction between groundwater and vegetation health;
- advising on expected groundwater trends; and
- assisting with the planning and interpretation of groundwater data.

1.3 Background

Reedy Lake is a floodplain wetland of the Barwon River within the Barwon River estuary. As a component of the Lake Connewarre Game Reserve, the wetland is recognised as a wetland of national significance for the number of breeding waterbirds it supports and the integrity and diversity of its vegetation. The wetland is a component of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site (DSE 2003).

The conservation value of the site depends to a large degree to the integrity of the plant communities. Since first documented (Yugovic and Gowans 1984), the extent and condition of plant communities has changed considerably. In particular, the extent of reed beds, which comprise *Typha* sp. (Cumbungi) and *Phragmites australis* (Common Reed), has fluctuated. At times important aquatic habitats for waterbirds and other plant communities have been displaced or degraded.

An initial assessment of the role of surface and groundwater in the wetland ecosystem (Lloyd Environmental 2005) suggested that groundwater salinity is important in determining the distribution of reeds.

This study reports on initial groundwater investigations where the objectives were to describe:

- the shallow stratigraphy within the water table aquifer;
- the groundwater environment beneath the lake and its salinity;
- the relationship between the groundwater environment and plant communities;
- the effect of surface water management on the groundwater environment; and
- how surface water could be managed to manipulate plant communities.

2.1 Hydraulics and Water Management

Except where otherwise noted, the following information was provided by Ian McLachlan (Barwon Water).

Reedy Lake is a floodplain wetland of the Barwon River located at the upstream limit of the Barwon River estuary. The wetland is shallow basin of 550 ha within the sedimentary embayment of the estuary. The wetland is largely circular in shape and is enclosed to the east, north and west by a steep slope rising to the general landscape level of 5 m AHD. The wetland has a small local catchment of 27 km^2 (DSE 2003) but is flooded almost entirely by spill from the Barwon River.

The Barwon River channel flows from north-west to south-east on the southern margin of Reedy Lake, and discharges to the tidal, open water environment of Lake Connewarre. The river is separated from the Reedy Lake by a natural levee.

Under low-flow conditions, flow is contained within the Barwon River channel and discharges directly to Lake Connewarre. Significant peaks in flow cause water to spill from the river to the floodplain and thence to Lake Connewarre. The floodplain comprises Reedy Lake to the north-east and the wetlands, samphire and Lignum flats of Sparrowvale Farm and Hospital Swamp to the south.

Prior to settlement, the spill of water from the river to Reedy Lake was controlled by the natural levee of the river bank. Water spilled to the wetland several times a year in response to winter and spring freshes. The wetland was normally continuously flooded in winter and spring and then dried over summer and autumn. Inflows regularly exceeded the lake's capacity and discharged to Lake Connewarre to the south. The sill between the wetland and Lake Connewarre allowed saline estuarine water to enter the wetland during high tides.

The hydraulics of the system have been altered since settlement, significantly changing the water regime of the wetland. In the l860s a weir (the lower breakwater) was constructed where the Barwon River discharges to Lake Connewarre to raise the river level upstream and prevent the incursion of saline estuarine water. The weir raised the river level adjacent to Reedy Lake and presumably promoted inflow events.

In the 1920s the lower breakwater was re-constructed and relocated to its current location as a fixed-crest weir, 100 m upstream of the original site. This structure was converted to the current variable-level outlet structure in the 1960s. The structure was designed to prevent sea water from entering the river even when estuary levels exceed river levels. However, it effectively functions as a fixed crest weir.

The flow path between the Barwon River and Reedy Lake, upstream of the lower breakwater, was excavated in 1953. The details of further modifcations are unclear. Two 300 mm pipes with flap gates were installed, probably in the 1960s. These were replaced in the 1970s by three 1200 mm box culverts fitted with flap gates that allowed river water to enter the lake but preventing estuarine water to enter the river via the lake. At this time, or prior to this time, the sill of the connection was lowered below the level of the river, allowing continuous inflow to the lake.

Most water entering the lake drained rapidly to the estuary. Following the 1967-1968 drought, an earthen bank was constructed to 0.7 or 0.8 m AHD between Reedy Lake and Lake Connewarre, increasing the wetland's volume, depth, area and permanence. The bank largely eliminated the inflow of tidal water.

These arrangements remained in place until 2006 with the exception of two modifications which allowed greater control of lake water levels.

In 1996 the wetland was drained to eradicate the carp population that had developed and to improve the facility to drain the wetland. The flow path from the Reedy Lake to Lake Connewarre was excavated to a level of approximately 0.1 m AHD, allowing the wetland to be drained when estuary levels permit.

In 1997 the connection between the Barwon River and the lake was modified to provide better control over lake levels and carp. Two of the box culverts were closed and a penstock regulator and fish screen replaced the flap gates on the third.

In 2006 the lake was dried out and the channel from the inlet structure the central lake bed was excavated to 0.1 m AHD. The outlet channel was also cleaned out to a level of 0.1 m AHD.

2.2 Levels

The lowest point of the lake bed lies to the south-east of the centre at -0.1 m AHD (sometimes termed 'the Big Hole'). At a level of 0.4 m 356 ha is inundated which is approximately 63% of the wetland area. The outlet structure allows water to be retained to 0.8 m AHD, at which level the lake is entirely flooded (565 ha) and overland flow from the lake to Lake Connewarre commences.

The level of the Barwon River weir pool is 0.82 m AHD. The invert of the inlet culvert lies at 0.0 m AHD, which is below the pool level and allows the wetland to be filled at any time.

The invert of the outlet structure is 0.1 m AHD, allowing all but the last 0.2 m of water to be drained from the wetland.

2.3 Water Regime

Prior to settlement, the lake was flooded and dried seasonally. The lake was regularly over-filled by river water and spilled to Lake Connewarre. The retention level of the lake is not known but can be estimated from the shape of the lake. The lake's outer perimeter lies at approximately 0.5 m AHD and this may represent the limit of regular inundation. Lake Connewarre exceeded this level from time to time, so that the lake would have experienced saline events between more regular fresh conditions.

The construction of the lower breakwater would have promoted fresh water inflows. By reducing the margin between the river level and the inlet sill, smaller peaks would be required to spill water into the wetland. This would have promoted fresher conditions in the lake.

Fresh conditions were further promoted by the excavation of the inlet channel from the Barwon River to the wetland in the 1950s. While sea water could still enter the wetland when tides exceeded the outlet sill, the wetland received more persistent freshwater inflows.

The salinity of the wetland was reduced again by construction of the bank across the outlet to a level of 0.8 or 0.9 m AHD in the late 1960s. The bank prevented sea water inflows and, by increasing the retention level, increased the extent, depth and duration of freshwater inundation.

A largely constant level of approximately 0.8 m AHD was maintained from around 1970 to 1990.

Until 1990, the Barwon River received 10 ML/d of brackish (4,500 EC) groundwater pumped from a quarry site upstream. This contributed to baseflow in the lower Barwon and increased the likelihood of water spilling into Reedy Lake. The lake became marginally more likely to dry out when this inflow ceased.

The wetland was dried in 1996 and 1997 when carp were eliminated and regulators were modified.

In response to advice by PPK (2000), a managed water regime was introduced with the objective of promoting a diverse vegetation community (Table 1)

Table 1. Recommended Water Regime (PPK 2000)

Month	Water Level (m AHD)
May	0.5
June	0.6
July	0.6
August	0.7
September	0.75
October	0.8
November	0.8
December	0.6
January	0.4
February	0.2
March	0.2
April	0.4
May	0.5

3.1 Ecological History

Pre-settlement to 1970

Prior to settlement, it is likely that Reedy Lake supported a combination of fresh and salt-tolerant plant communities. The lower retention level of the lake would have allowed a greater influence of regional saline groundwater. Intermittent marine inflows may have recharged the aquifer below the lake and have contributed to the salt balance. The lake most likely represented an environment similar to, but more saline than, Hospital Swamp. The outer perimeter of the lake, which was only flooded by peaks in flow, may have supported *Gahnia* sedgelands and Lignum shrublands. The central lake bed may have supported aquatic macrophytes that grow in shallow fresh water but tolerate periods of high salinity, such as *Baumea arthrophylla, Juncus kraussii* and *Scheonoplectus validus.* Due to the lower retention level, it is likely that emergent macrophytes extended to the lowest areas of the lake.

1970 to 1990

The first detailed description of the lake vegetation was prepared by Yugovic and Gowans (1984). This was conducted in a period when the lake ecosystem was considered to be in good condition and in a steady state.

The authors describe Reedy Lake as having a particularly rich flora. At this time, the lake featured open water in the central, deep part of the lake (elevation less than 0.0 m AHD) and at the eastern, northern and western perimeter of the lake, between lake bed elevations between 0.4 and 0.5 m AHD. Large stands and smaller patches of *Phragmites, Typha, Eleocharis sphacelata* and *Schoenoplectus validus* occupied the lake bed where the elevation lies between 0.0 and 0.4 m AHD. The aquatic habitat in and around the reed beds supported abundant semi-emergent aquatic macrophytes including *Myriophyllum* spp., *Potamogeton* spp., *Ruppia maritima* and *Vallisneria gigantea*.

The shallow plain to the south of Reedy Lake and Lake Connewarre, which forms the outlet flow path, was occupied by Lignum and grassland / herbfield species. Notably, the south-western part of the lake and the southern bank, where the elevation lies between 0.3 and 0.5 m AHD, featured several large patches of *Eleocharis acuta*. The vegetation of this area has since changed.

The outer perimeter of the lake, at the base of the scarp, where the elevation lies between 0.5 and 1 m AHD supported salt-tolerant herbland species such as *Sarcocornia quinqueflora, Scheonoplectus pungens,* Lignum and *Distischlis distichophylla*.

Also of interest is the presence of *Phragmites* and *Typha* at high elevations (greater than 0.8 m AHD) on the natural levee between the Barwon River and the lake. These areas were flooded much less frequently than the other areas occupied by this vegetation, but presumably provided access to fresh groundwater recharging from the river.

The vegetation data collected reported by Yugovic and Gowans (1984) suggests the following groundwater interactions:

- the perimeter of the lake at the base of the scarp, to the north-west, north and east, is subject to shallow saline groundwater that promotes the growth of plants tolerant of high salinities and waterlogging;
- the high abundance of *Eleocharis acuta* at an equivalent elevation (and flooding regime) on the southern boundary of the wetland results from less saline conditions; and
- the presence of *Phragmites* and *Typha* at higher elevations near the inlet channel results from the presence of shallow, fresh groundwater.

From first settlement up to the 1985, Reedy Lake was grazed, suppressing the growth of reeds and promoting pasture grasses, notably *Cynodon dactylon* (Couch). When grazing licences were revoked, reeds replaced the *C. dactylon*, particularly near the outlet channel, where they impeded outflow.

European Carp were first observed in the Barwon River in 1979. Carp were reported in Reedy Lake soon after and gradually increased in abundance.

1990 to 1993

From 1990 to 1993 a rapid change in the vegetation was observed. The extent of emergent reeds rapidly declined with large clumps of vegetation displaced. Semi-emergent aquatic plants, which were reported to be abundant in 1984, declined. Turbidity is also reported to have increased.

The cause of this rapid change is not clear. The carp population, which first arrived in the lake around 1979, was very large and included large individuals. The fish may have contributed to the decline in vegetation by disturbing plant roots and re-suspending sediment.

1994 to 2005

In 1994 the lake was dried out for the first time since the early 1970s. An estimated 5,000 to 10,000 carp were stranded.

The lake was reflooded in 1996 after the outlet channel had been excavated and the inlet structure had been modified.

From 1996 to 2005 a general increase in the extent of *Typha* and *Phragmites* occurred. The reeds re-colonised all of the areas mapped in 1984 and colonised additional area in the south-west of the lake, towards the bank of the Barwon River. There was little additional area colonised in the lake areas below the scarp. This resulted in a significant loss of open water habitat

In contrast to 1984, little semi-emergent vegetation was observed.

To arrest the spread of reeds and to restore the diversity of habitats reported in 1984, the PPK (2000) water management plan was applied. However the plan has not achieved these objectives. A constraint on implementing the plan has been the choking effect of reeds on the inlet and outlet channels which prevent the small-scale water level manipulations required by the plan. The effectiveness of the proposed water regime in affecting the vegetation has also been questioned (Lloyd Environmental 2005).

2005 to 2006

In 2005 the lake was drained. On this occasion an estimated 2,500 large carp were stranded in the lake.

Excavations in the dry lake bed exposed the roots and rhizomes of *Phragmites* and *Typha*. Near the outlet channel roots appeared to only penetrate the shallow silt sediments, to a depth of approximately 0.3 m (Figure 1.). Near the inlet channel, roots appeared to penetrate depths of more than 1.0 m (Figure 2).

Figure 1. *Typha* roots and rhizomes exposed by the excavations for the outlet channel. The surface layer of black silt is approximately 0.3 m thick.

Figure 2. ***Phragmites*** **roots and rhizomes exposed by excavations for the inlet channel. The channel is approximately 1 m deep.**

While the lake was dry, some stands of reeds collapsed. The shoots of these plants may have been supported by the water column when flooded, and may have become unstable when the wetland was drained. Shallow roots may also have contribute to the instability of the plants.

3.2 Vegetation Mapping

The extent of reeds (*Phragmites australis* and *Typha* sp.) in Reedy Lake was measured from three historical images. Detailed mapping by Yugovic and Gowans (1984) provided the earliest image and is considered the benchmark for the ideal range and quality of habitats in the lake. The authors mapped the lake in detail from a combination of aerial photograph interpretation and field inspection. Their mapping was converted to a digital file. The extent of reeds was digitised from aerial photographs from 1995 and 2004.

The 1984 vegetation mapping is presented in Figure 3. The extent of reeds in 1984, 1995 and 2004 are presented in Figures 4 to 6.

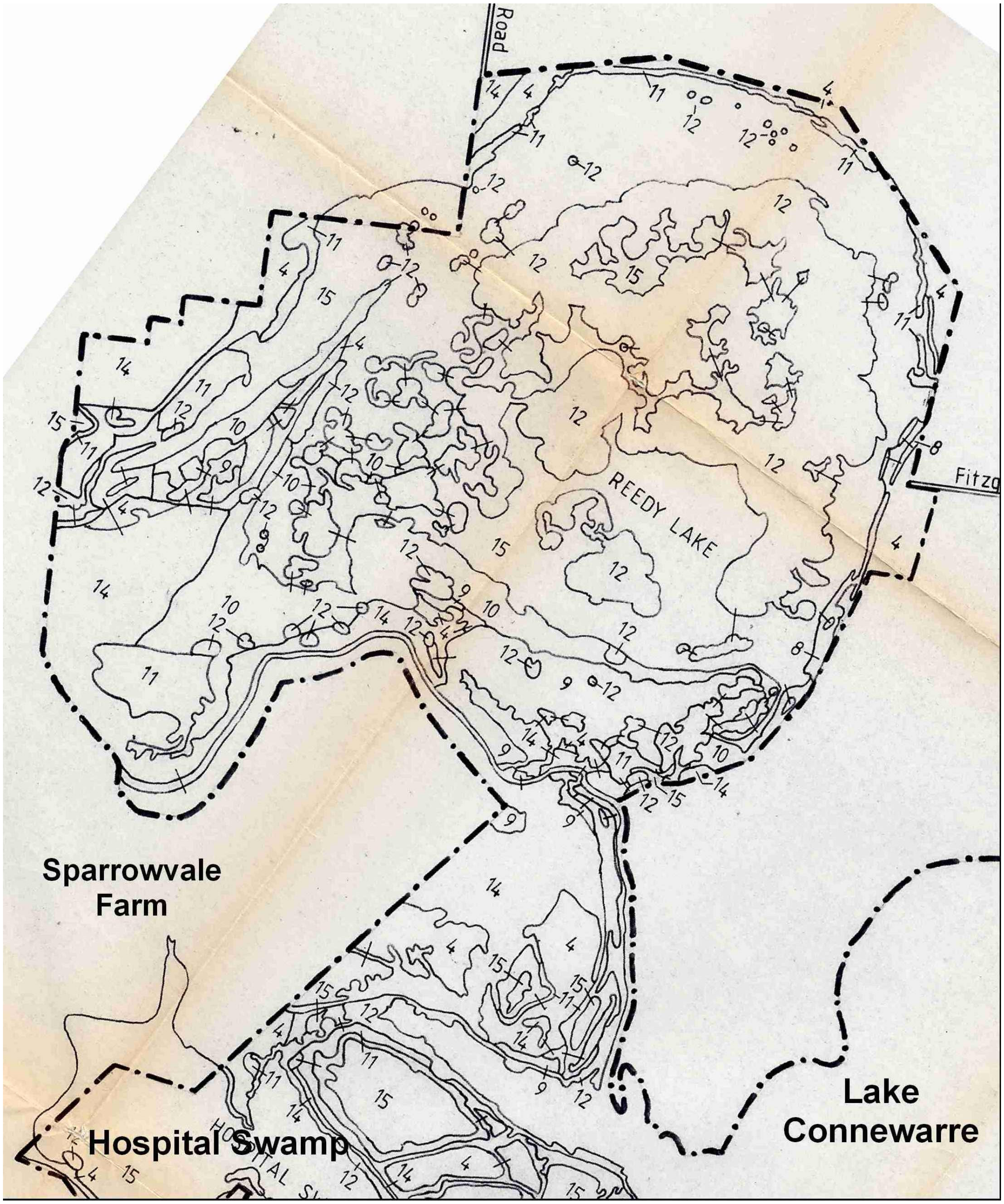

Figure 3. Vegetation Mapping from Yugovic and Gowans (1984). Plant associations: 4 – *Sarcocornia quinqueflora* herbfield, 9 – *Muehlenbeckia florulenta* (Lignum) shrubland, 10 – *Eleocharis acuta* sedgeland, 11 – *Scheonoplectus pungens* sedgeland, 12 – *Phragmites australis* / *Typha orientalis* grassland / sedgeland, 14 – variable grassland / herbfield, 15 – open water / submerged aquatic macrophytes.

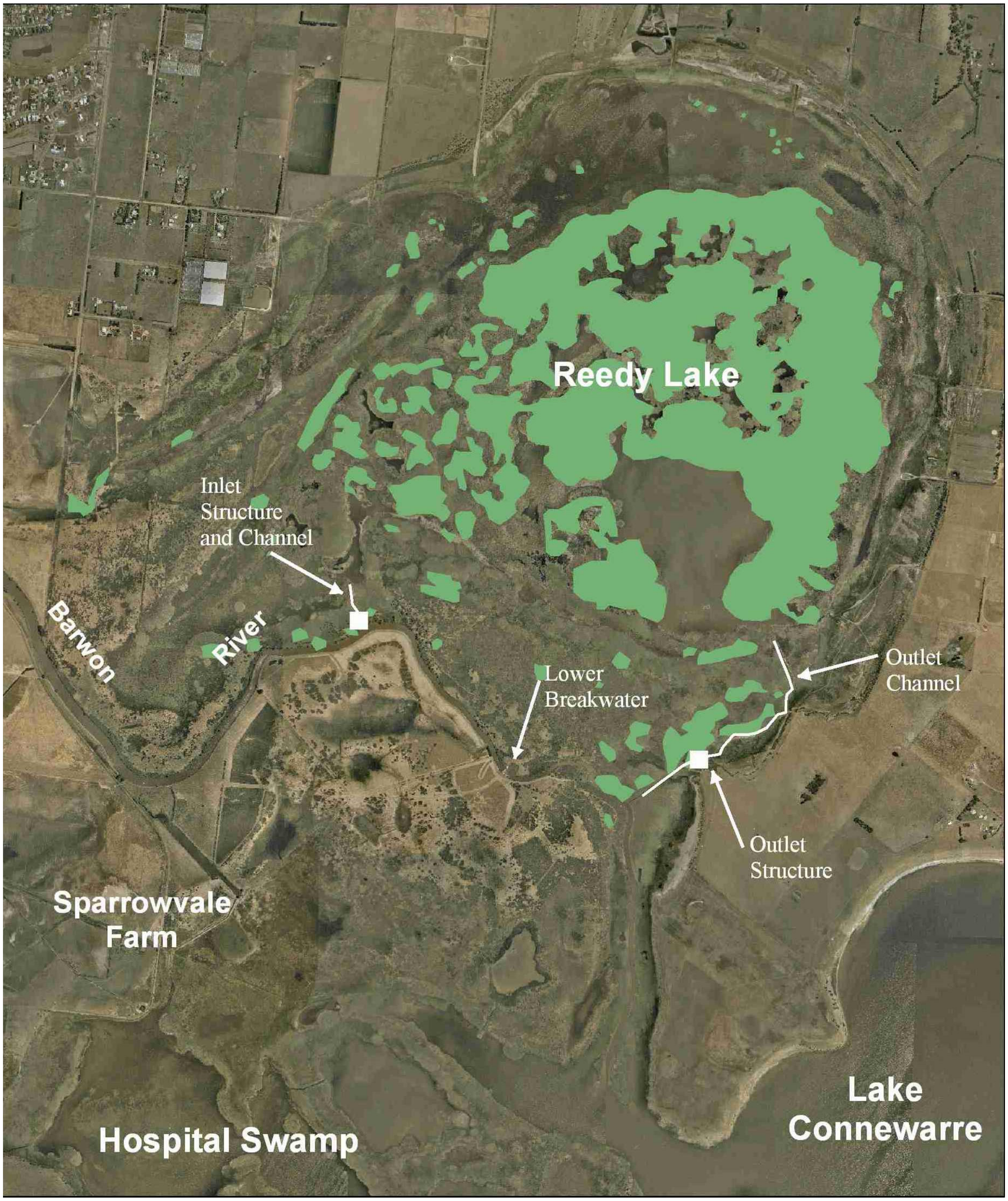

Figure 4. The extent of reeds (*Phragmites* and *Typha*) in 1984 overlayed on 2004 photography.

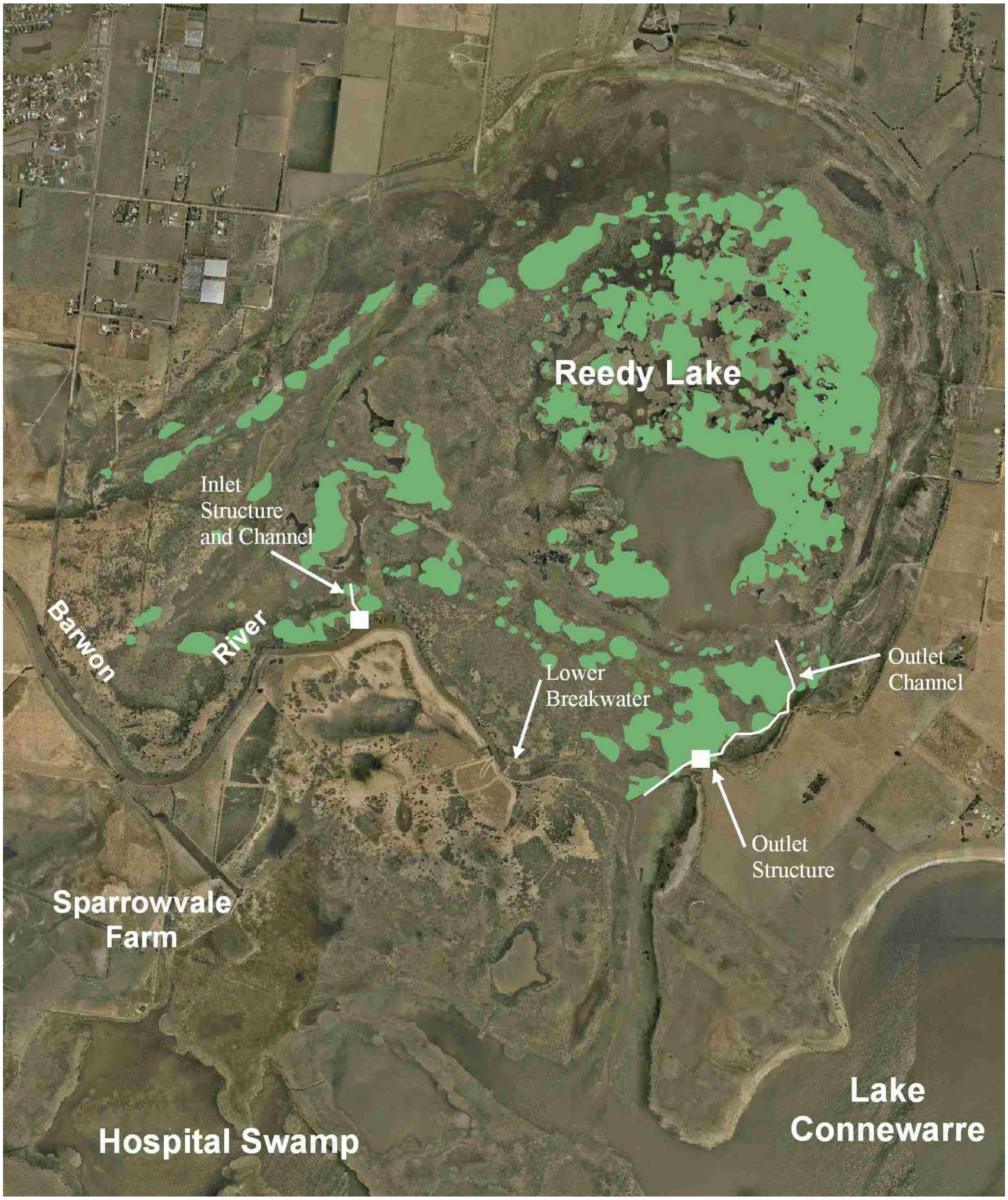

Figure 5. The extent of reeds (*Phragmites* and *Typha*) in 1995 overlayed on 2004 photography.

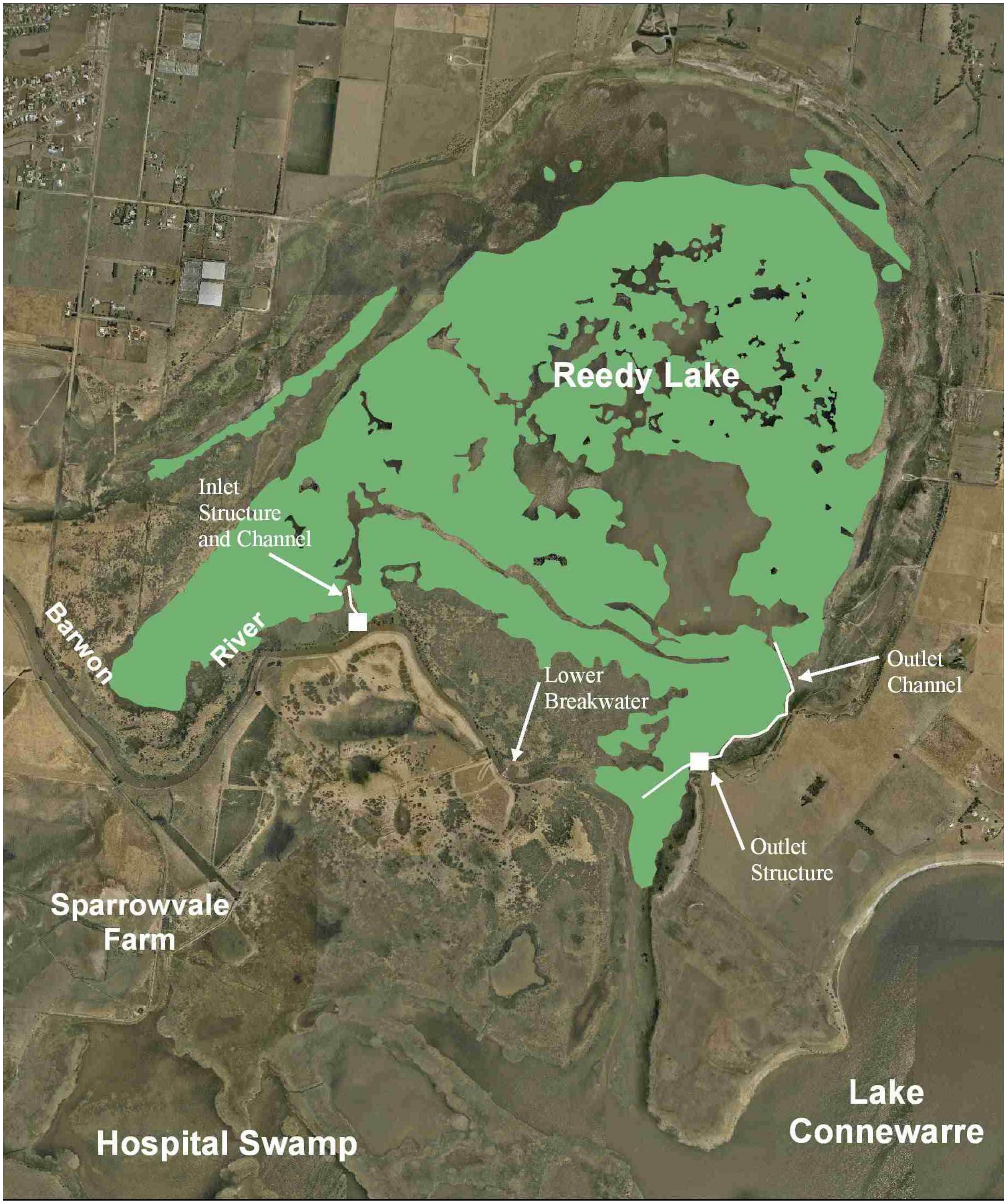

Figure 6. The extent of reeds (*Phragmites* and *Typha*) in 2004 overlayed on 2004 photography.

4.1 Groundwater Investigations

Hydrostratigraphy

Stratigraphy has been described from cores taken for four new groundwater bore sites in Reedy Lake (Miner 2006) and previous bores (Coulson 1933). The bore locations are presented in Figure 7.

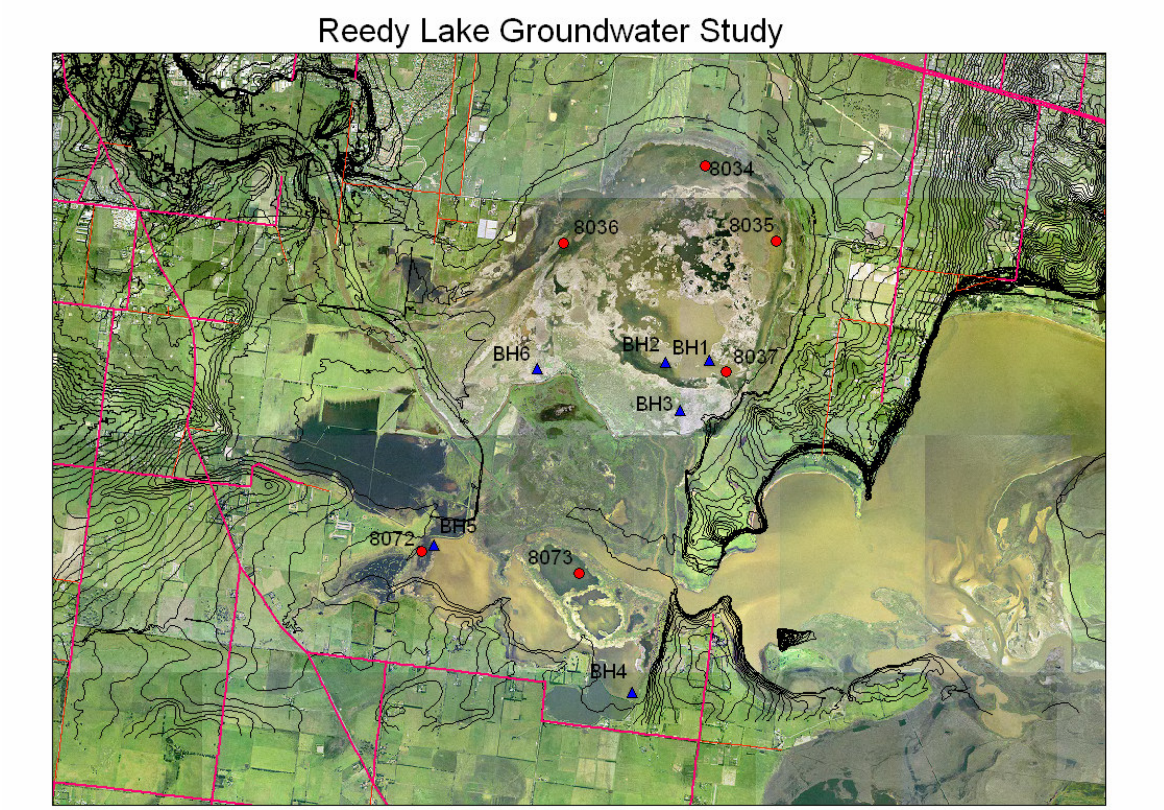

Figure 7. Locations of monitoring bores (BH1 to BH6 this study) and previous cores taken by Coulson 1933 – 8034,8035, 8072, 8073).

The lake bed comprises a veneer of silt 0.1 to 0.2 m thick (Figure 8). This is underlain by a bed of sands and shells, generally 1 to 2 m thick. Siltier sediments lie below these sands to a depth of 4 to 6 m. Below this lies a layer of highly plastic clay, more than 4 m thick.

Figure 8. Excavations of the Reedy Lake bed showing the shallow surface silt and underlying shelly sands – from Miner (2006).

The sands and shells are very porous. Together with the underlying silts, they form an aquifer, perched above the clay. The surface silts are not expected to significantly impede the hydraulic connection between the lake water and the aquifer. However, the underlying clays are likely to prevent any significant exchange with deeper regional aquifers below the lake bed.

Because it is porous, the aquifer (particularly the upper sandy part) is likely to respond quickly to changes in hydrostatic pressure.

The regional geology suggests that the extent of the lake bed aquifer is restricted to the almost circular basin in which the wetland lies (1:250,000 Queenscliff Geology Sheet).

The upper surface of the confining layer (the clay) lies at approximately -2.0 m AHD. This is below the surface of the Barwon River (0.82 m AHD upstream of the lower breakwater) and Lake Connewarre and would be subject to recharge from both these sources. The surface of the regional aquifer in the vicinity of the lake is not known, but the presence of salt-tolerant vegetation at the base of the scarp indicates discharge from this source to the lake bed aquifer as well.

Groundwater Levels and Salinity

Groundwater levels and salinity was sampled in May 2005. Levels at this time were influenced by the drawdown of the lake and excavation works. The wetland was gradually drawndown from its stable long-term level of 0.8 m AHD (largely constant since 1996) between August 2005 and February 2006. The lake bed was dry through the autumn 2006, during which time the inlet channel was excavated to 0.1 m AHD. The inlet channel required a channel approximately 1 m below the natural surface near the inlet structure on the Barwon River and became gradually shallower towards the lake centre. The outlet channel, in the south-west part of the lake, was excavated to a level of -0.1 m AHD, also requiring a channel exceeding 1 m depth in places.

Schematic diagrams of the groundwater results are presented in Figures 9 to 12.

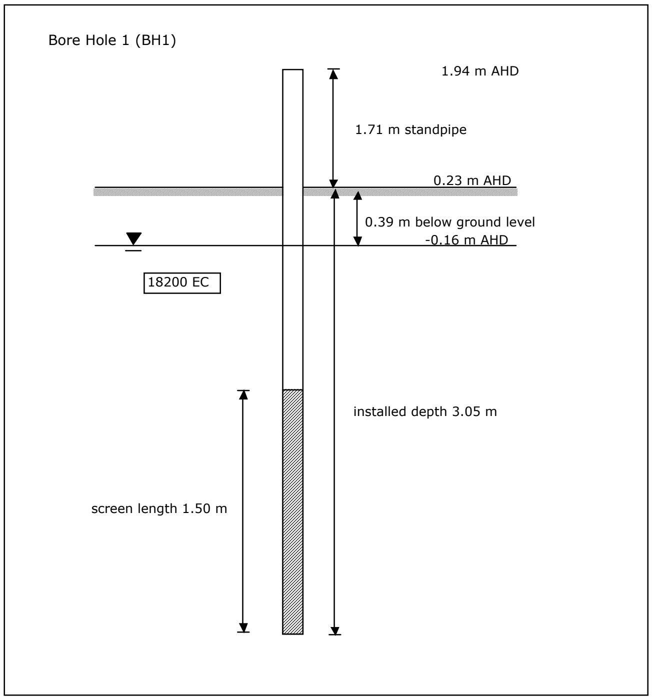

Figure 9. Bore Hole 1

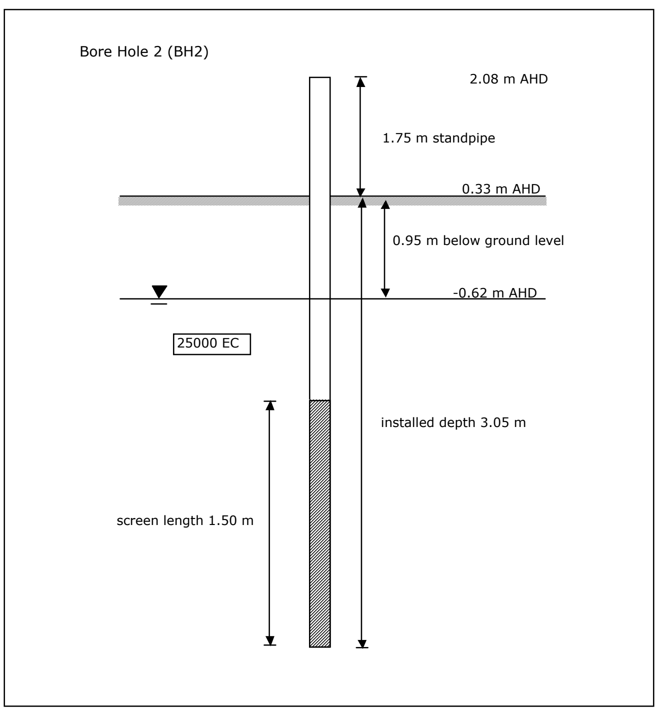

Figure 10. Bore Hole 2

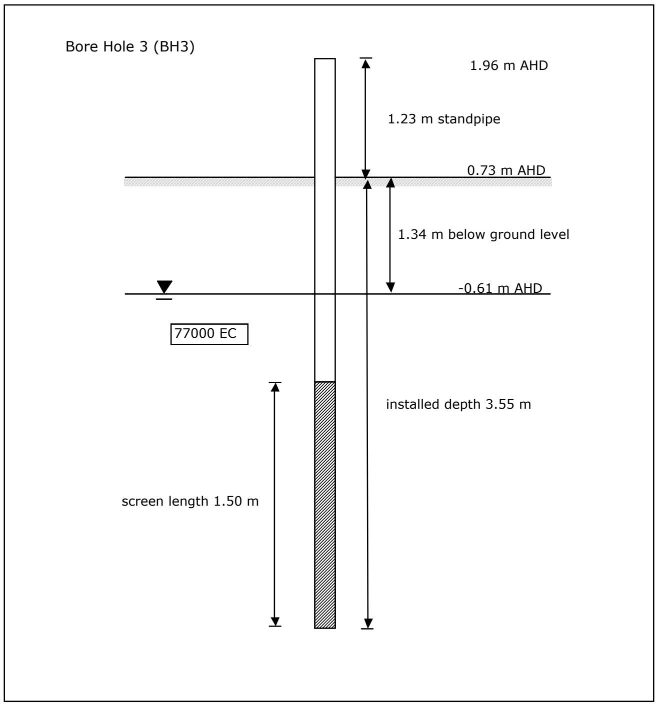

Figure 11. Bore Hole 3

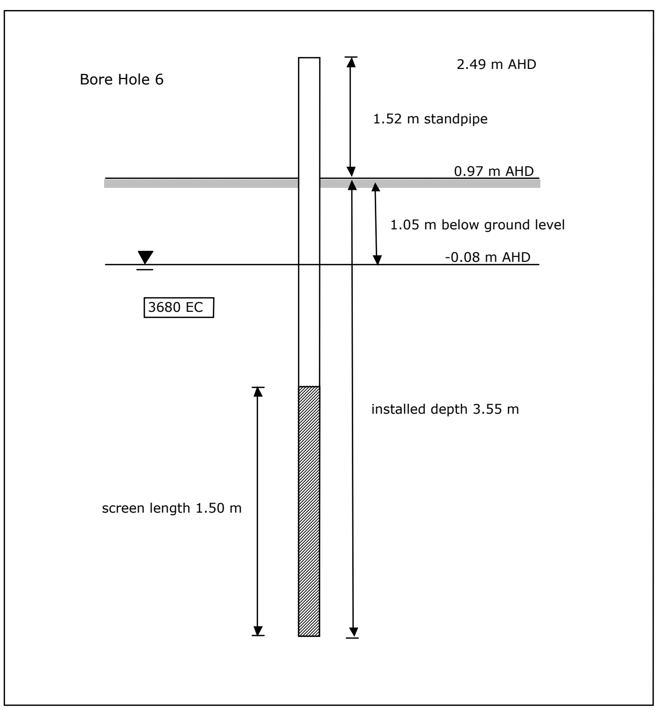

Figure 12. Bore Hole 6

Bore Holes 1 and 2 are located in the central part of the lake bed, near the deepest, open water area. They are located at the boundary between the deepest, open water area and the lower extent of reed beds. The surface elevation at these locations is 0.23 m AHD (BH1) and 0.33 m AHD (BH2). The water table was 0.39 m below the surface at BH1 and 0.95 m below the surface at BH2. These levels correspond to elevations of -0.16 and -0.62 m AHD for BH1 and BH2, respectively. The groundwater conductivity at both sites was similar, and high with conductivities of 18,200 EC and 25,000 EC reported at BH1 and BH2, respectively.

Bore Hole 3 is located at the southern perimeter of the wetland at an elevation of 0.73 m AHD, near the normal high water level. This site is located near the upper limit of reed growth. At higher elevations (up to 1.0 m AHD) Lignum and samphire species are the dominant vegetation types in this area. The water table was 1.34 m below the surface, with an elevation of -0.61 m AHD. The groundwater was extremely saline, 77,000 EC.

Bore Hole 6 is located near the inlet channel close to the Barwon River, above the lower breakwater. The bore is located on high ground at 0.97 m AHD, above the full supply level of the wetland. The watertable was reported at -0.08 m AHD, similar to the bed level of the nearby inlet channel. The groundwater conductivity was significantly lower than the other sites, 3,680 EC.

The wetland was gradually re-filled between May and July. Groundwater levels were taken on September 11, 2006 and are presented for comparison with levels in May when the lake was dry (Table 2).

Table 2. Groundwater levels when the lake was dry (May) and full (September) in m AHD.

Location	May	September
Lake Level	dry (-0.01)	0.80
BH1	-0.16	0.83
BH2	-0.62	0.84
BH3	-0.61	0.71
BH6	-0.08	0.83

In May the potentiometric head in all bores was essentially equivalent to the lake level in all bores. The data indicate that the lake bed aquifer was rapidly recharged as the lake filled. The slightly lower level reported in BH6 indicates the southerly flow of groundwater from the lake to Lake Connewarre. The lower levels reflect the lower level in Lake Connewarre than Reedy Lake and evapotranspiration losses from the soil.

5.1 Reed Distribution

The distribution of plant communities in Reedy Lake appears to reflect the combined effects of groundwater salinity and flooding history. Groundwater salinity appears, in general, to be close to the limit tolerated by both *Typha* and *Phragmites* under normal growing conditions. Both species tolerate salinities of up to 20,000 EC (Lissner and Schierup 1999), a conductivity similar to that reported in the deepest areas of the lake by BH1 and BH2.

Growth is likely to be supported primarily by low-salinity surface water and shallow soil water, rather than saline deep soil water. Both species can produce aquatic roots that access water and nutrients from the water column and avoid toxic salinities in the soil. Furthermore, flooding will apply pressure to the aquifer, possibly reducing the salinity of soil water near the surface. Where earthworks for the inlet and outlet channels had exposed the root system, they appeared to only penetrate the upper silt layer, to a depth of less than 0.3 mm (Figure 1).

A much higher salinity of 77,000 EC was reported by BH3, near the upper limit of normal wetland levels and near the boundary between reed and lignum vegetation. Shallow groundwater is subject to evaporative concentration when water, rising from the water table by capillary action, evaporates and deposits salts. Over time, rainfall recharge returns these salts to the aquifer, increasing groundwater salinity. This process could account for the much higher salinity in BH3 than BH1 and BH2, even though they are less than 300 m distant. At the elevation of this bore, 0.73 m AHD, this area is subject to shallow and intermittent flooding. There is less potential for any freshening affect by surface water and more potential for evaporation from the soil surface. Between 1994 and 2006 the area of reeds in the southern area increased towards the limit of flooding. However, high groundwater salinities are likely to prevent reeds spreading to higher elevations in the area below the lower breakwater.

In contrast, reeds have colonised significant areas above the full supply level to the west and south-west of the lake. The groundwater salinity is much lower in this area, with a reported conductivity of 3680 EC. This is likely to reflect the freshening effects of the Barwon River above the lower breakwater on the Reedy Lake aquifer. The breakwater maintains the river level at or above the normal level of Reedy Lake, creating a hydraulic gradient away from the river. Fresh river water recharging the banks will displace saline groundwater and will create a flushed zone. The contrast between the low salinity reported at BH6 and higher salinities reported at BH1 and BH2 is strong evidence of this process. The natural surface between the river and the bank above the breakwater is approximately 1.0 m AHD and a normal groundwater depth (when the lake is full) of 0.2 to 0.3 m can be assumed. Shallow, fresh groundwater is likely to have supported the spread of reeds in this area, even though it is not subject to inundation.

The spread of reeds in this area was much greater between 1992 and 2006 than between 1984 and 1992 and may reflect the continuing freshening of the system. Processes that have reduced groundwater salinity include the construction of the lower breakwater, exclusion of tidal inflows from the lake, the creation of permanent freshwater inflows and the permanent storage of water in the lake.

Reeds are largely absent at elevations between 0.3 and 0.5 m AHD in the north-western, northern and north-eastern areas of the lake bed. In contrast there as been a significant increase in the extent of reeds at equivalent elevations (and therefore water regimes) in other parts of the lake. This distribution may be related to the discharge of saline groundwater from a regional aquifer. The foot of the scarp that encloses the wetland to the north-east, north and west appears to be a discharge zone for saline groundwater. Although no groundwater data was collected in this area, high groundwater salinities are indicated by the presence of halophytes including *Sarcocornia quinqueflora, Schoenoplectus pungens, Bolboschoenus caldwellii* and *Distichlis distichophylla*. It is likely that the influence of saline groundwater discharge will extend into the lake, and may explain the absence of reeds, even though the surface water regime provides favourable conditions for growth. Groundwater data is required from the centre of the lake to the foot of the scarp to test this hypothesis.

Reeds have spread significantly to the south of the lake in the areas adjacent to the outlet channel. Yugovic and Gowans (1984) reported this area was occupied by communities dominated by the halophytes *Sarcocornia quinqueflora* and *Scheonoplectus pungens*. The spread of *Typha* into halophyte habitat along freshwater drains has previously been reported in Western Australia where the spread of *Typha* from stormwater drains into *Juncus kraussii* rushlands was promoted by the freshening effect of the drain. (Zedler et al. 1990).

The groundwater data appears to provide a reasonable basis to explain the spread of reeds from 1992 to 2006 and their current distribution. However, it does not explain the decline in reeds from 1990 to 1992. Over this period the extent of reeds rapidly declined from the area mapped by Yugovic and Gowans (1984) and clumps of reeds were reported to have been displaced. This decline coincided with a very high abundance of large carp. It is possible that at very high densities carp were disturbing the lake sediments sufficiently to destabilise reeds. Vegetation in Reedy Lake may be prone to destabilisation if saline groundwater prevents deep root systems developing. When the lake was drained in 1994 very high numbers of large carp were reported. In 2005/2006 fewer carp were reported, possibly because the lake had only been full for 10 years (as opposed to the 16 years since carp were introduced in 1979) and screens had been installed to reduce recolonisation by large fish. If carp numbers again reached the levels reported in 1994, a similar impact could be expected. Periodic drying events will effectively eradicate carp from the lake and provides an effective means to control the population.

5.2 Scope to Manage Reed Distribution

Groundwater salinities in the bed of Reedy Lake and at the lake perimeter to the south appear to exceed the tolerance of *Typha* and *Phragmites*. These species ideally grow in salinities of less than 5,000 EC and their dense growth in Reedy Lake appears to be supported by fresh surface water.

An approach to control the spread of reeds may be to expose the plants to existing saline groundwater over the course of one or more growing seasons. The high salinities will not support significant growth and are likely to lead to the widespread death of rhizomes.

5.3 Monitoring Recommendations

A better understanding of surface and groundwater interactions with vegetation are important to develop a water management plan for Reedy Lake. However, these processes affect and sometimes threaten, wetland communities much more widely. Information gained at Reedy Lake has important implications for groundwater and surface water management in many wetlands in south-eastern Australia. The lake is unusual in that it appears to have provide a wide range of groundwater salinities in areas where other factors important to vegetation (surface water regime and stratigraphy) are constant. This provides a valuable experimental basis to assess the effects of salinity on plant communities. Of particular interest is the potential to achieve a significant, widespread change in reed health by reducing the depth and duration of surface water flooding.

The following further investigations are recommended.

The vegetation mapping undertaken by Yugovic and Gowans (1984) should be repeated. This study as digitised their *Phragmites* and *Typha* mapping, but all their mapped associations should be mapped for comparison with current conditions. It is expected that this will reveal significant losses in some plant associations, particularly *Eleocharis acuta* sedgeland.

A vegetation monitoring program should be established. The program should attempt to relate the surface water flooding regime and groundwater depth and salinity to the structure and composition of plant communities. Vegetation data should be collected from sites where groundwater data is available or between those sites so that groundwater conditions to be interpolated.

Historical aerial photographs, at intervals of approximately 10 years, should be compiled and vegetation associations mapped. The primary objective should be to map reed beds, but other plant associations should be mapped if possible. This information will provide a better understanding of the evolution of the lake vegetation over the twentieth century and will test the interpreted evolution of the lake described in this report.

The importance of the mapped plant associations to plants of conservation significance is well described by Yugovic and Gowans (1984). However the importance of vegetation change to fauna is not documented. Waterbird monitoring data held by Field and Game and the Field Naturalists Society should be compiled and related to changes in vegetation. The methods used in the existing surveys should be reviewed to identify opportunities to strengthen linkages to management.

The structure and health of *Typha* and *Phragmites* stands should be assessed along gradients of groundwater salinity. Observations could be made of shoot height and density. Pits could be dug to measure rhizome and root size, density and depth. Data would be required on soil salinity.

Two additional bores are required to better describe the expected groundwater salinity gradient between the inlet (BH6) and the centre of the lake. Ideally, vegetation monitoring sites should be established along this transect.

Two additional bores are required between the foot of the scarp, in the saline herbfield, and the open area in the east of the lake which is unoccupied by reeds. This will better describe the expected groundwater salinity gradient. Vegetation monitoring sites should be established along this transect.

One new bore should be established each in Hospital Swamp and Salt Swamp. Cores from previous investigations should be reviewed before drilling to identify sites with corresponding stratigraphy to Reedy Lake. Data from these lakes will verify the conceptual model developed for Reedy Lake and will help describe the possible ecological outcomes of altered water regimes.

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