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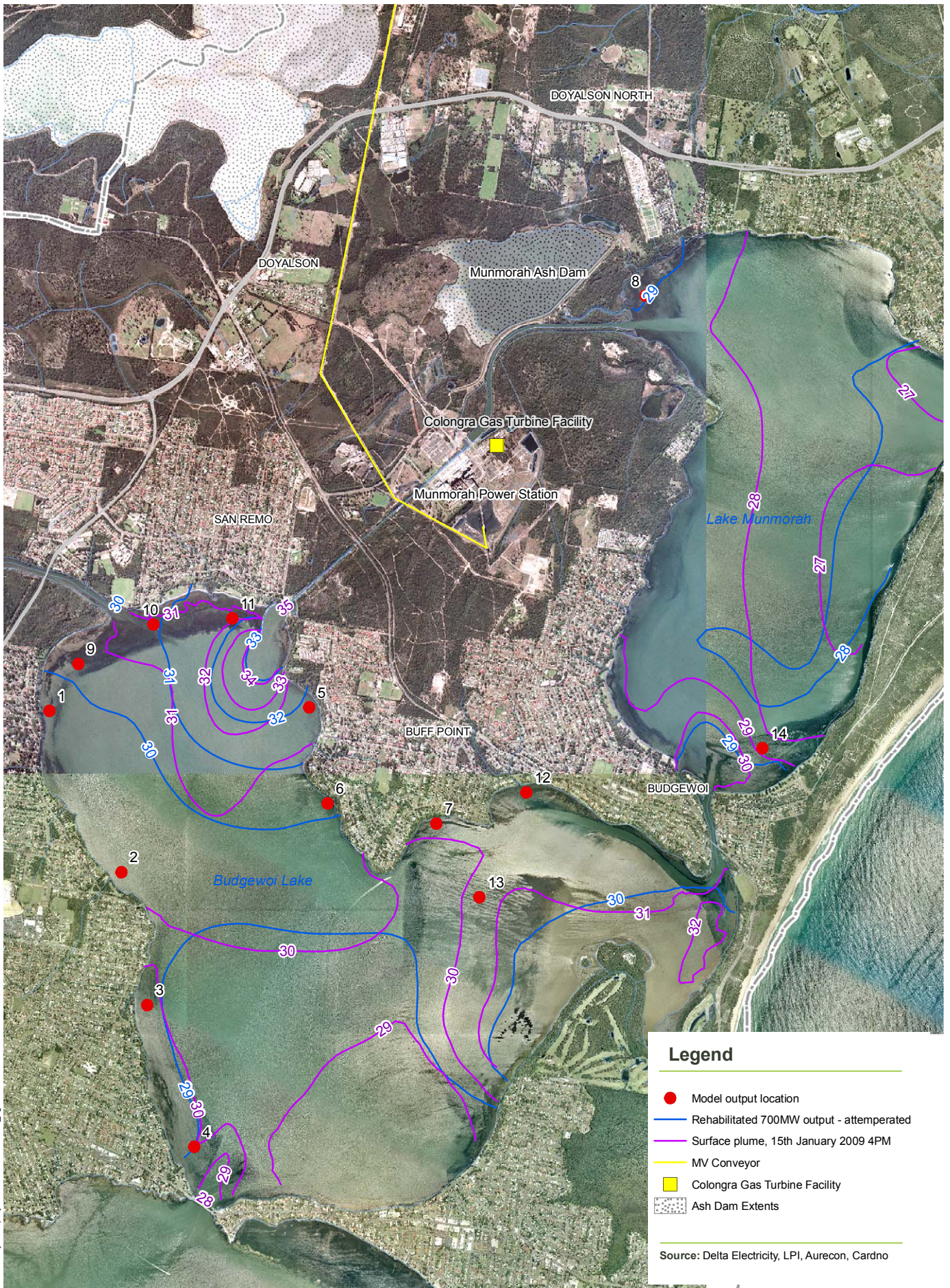
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Projection: MGA

Munmorah Power Station **Rehabilitation Environmental Assessment**

FIGURE 8.10: Modelled Refurbishment 700MW Attemperated Cooling Water Plume

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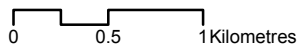
Legend

- Model output location
- Rehabilitated 700MW output - attempered
- Surface plume, 15th January 2009 4PM
- MV Conveyor
- Colongra Gas Turbine Facility
- Ash Dam Extents

Source: Delta Electricity, LPI, Aurecon, Cardno



SCALE 1:40,000 @ A4



Projection: MGA

Munmorah Power Station **Rehabilitation Environmental Assessment**

FIGURE 8.11: Modelled Refurbishment 700MW Attempered Cooling Water Plume compared to the current surface plume

Impact assessment

The rehabilitated plant would be more efficient and have less reject heat. The temperature increase at the cooling water outlet at full load is predicted to be 8°C with an average about 6.4°C for 80% capacity over a year. The modelled worst case inlet temperatures indicate recirculation would be increased by only 0.3°C over the current recirculation up to < 2°C.

With two units operating at base-load, the rehabilitation of the plant and average temperature increase is expected to be about 6°C, which is lower than that the 7°C reported in Roberts (2001). This is due to the expected increase in efficiency of the plant. With the downgrade to two units, modelling showed the plume size is reduced compared to the original, 'as built' four units and the refurbished, unattemperated and attemperated plumes are smaller than the 'as built' two unit plumes.

In terms of changes from the current plant, the plume measured in January, 2009 at 522 MW was larger and warmer than the modelled attemperated rehabilitated plume (Figure 8.11). This means the area of seagrass exposed to the elevated temperatures would be smaller for the rehabilitated plant.

8.5 Water Quality

8.5.1 Existing monitoring

Delta Electricity, in accordance with the requirements of the power station's EPL, routinely monitors the water quality at three ambient sites in the Tuggerah Lakes system. These sites are: M1 off the cooling water inlet in Lake Munmorah, B1 off the cooling water outlet in Lake Budgewoi and site T2 in the middle of Lake Tuggerah (Figure 8.12).

Water quality and trace elements are measured at the point at which water from the ash dam is discharged into the inlet canal (Figure 8.12).

Continuous monitoring of water temperature is also undertaken within the cooling water inlet and outlet canals.

The following water quality characteristics are monitored monthly at the ambient sites:

- temperature, salinity and dissolved oxygen profiles from the water surface to the lake bottom
- water clarity, as measured by Secchi depth
- zooplankton in surface waters (See Section 8.6).

The monitoring and frequency of measurements undertaken, as required by the power station's EPL, for the ash dam discharge is presented Table 8.7.

Table 8.7 – Ash dam discharge monitoring requirements listed in the EPL (DECCW License No 759)

| Pollutant | Frequency |
|---|---|
| Nutrients | |
| Nitrate + nitrite (oxidised nitrogen) Total Phosphorus Reactive Phosphorus Time | Yearly |
| Elements | |
| Cadmium Copper Lead Manganese Zinc | Required yearly as per the EPL, however, Delta Electricity samples twice per year |
| Selenium | Quarterly |
| Other | |
| TSS | Fortnightly |
| pH | Monthly |

8.5.2 Ambient water quality

The ambient water quality in the Tuggerah Lakes is determined by contributions from catchment runoff, from the ocean, from the power station, along with recycling processes within the lakes and between the sediments and water.

Previous studies of the water quality of the lakes were reviewed and more recent monitoring of the power station discharge provides information on the power station contribution to the lake water quality.

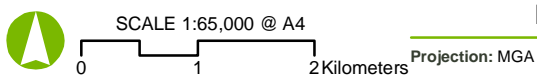


Legend

- ▲ Ash Dam Discharge
- ▲ Ambient Water Monitoring Points
- Munmorah Power Station

Source: Aurecon

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Previous investigations

The general water quality of the Tuggerah Lakes system has been the subject of a number of investigations two years sampling from 1996 for the Estuary Processes Study (Roberts, 2001). The Estuary Processes Study reports the average results and range for some characteristics in the three lakes, which are summarised here. Additional sampling was undertaken by Wyong Shire Council between 2000 and 2004 to examine hierarchical variability among replicates and sites to provide an overview of water quality data collected at a number of locations within

the Tuggerah Lakes estuary (Roberts and Barnes 2004).

Relevant findings from the Estuary Process Study with input from the 2000/04 study report are summarised in Table 8.8.

It should be noted that these investigations were carried out over a period when Munmorah Power Station was operating at low output (average about 150 MW).

Table 8.8 – Summary of Tuggerah Lakes water quality

| Variable | Summary |
|------------------|--|
| Temperature | <p>Roberts (2001) reported that temperature fluctuated through time with similar trends observed between locations. Report indicated only a minor increase in temperature in Lake Budgewoi.</p> <p>Roberts and Barnes (2004) reported that differences between the lakes were on average very small and unlikely to be of a magnitude to have ecological or biological consequences.</p> <p>In general, seasonal changes were similar in the lakes. Overall temperatures in the lakes reached maxima in late summer of approximately 25- 26°C and minima in winter of approximately 12-13°C.</p> |
| Salinity | <p>Roberts (2001) found no significant differences in salinity between the three lakes or over the 12 month period. Lake Munmorah averaged 25±1.7 ppt and Budgewoi 26±1.7 ppt. No average was give for Lake Tuggerah but the Entrance averaged 29±1.8 ppt</p> <p>Roberts and Barnes (2004) found the overall lakes salinity varied from a maximum of approximately 35‰ to a minimum of approximately 18‰.</p> <p>Changes in salinity were consistent among locations with periodic small gradients in salinity observed with distance from the Entrance, which changed direction from time to time.</p> |
| Dissolved oxygen | <p>Roberts (2001) found surface waters were well oxygenated and above saturation during winter 1998, probably due to phytoplankton photosynthetic activity.</p> <p>Roberts and Barnes (2004) observed the overall concentrations were very similar among the lakes. Seasonal trends for concentrations of dissolved oxygen had maxima of 9-10 mg/L in winter and minima of 5-6 mg/L in summer. Differences detected between lakes were small and concluded to be unlikely of a magnitude to be of ecological or biological importance. Neither study reported percent saturation which now forms the basis of the ANZECC (2000) guideline criterion.</p> |
| pH | <p>Roberts (2001) and the subsequent work of Roberts and Barnes (2004) found that pH showed little variation between the lakes and over time.</p> |
| Turbidity | <p>Roberts (2001) found turbidity varied between the lakes and over time with the highest overall levels in November, 1998. Lake Munmorah had the lowest turbidity at 4.7±1 NTU.</p> <p>Roberts and Barnes (2004) found similar variability of the data with little consistency between the sampling locations. Overall, periods of lowest turbidity occurred during winter and highest turbidity during summer. Tuggerah Lake was on average generally the most turbid of the three lakes and experienced the largest maxima each year.</p> |
| Total nitrogen | <p>Roberts (2001) found total nitrogen varied over time and was not consistent between locations. Lake Munmorah was consistently higher at 578±98 µg/L than other locations. The lowest of 375±41 µg/L occurred at the Entrance.</p> <p>Roberts and Barnes (2004) found similar variability. General, overall seasonal trends were observed against this background of variability, with maxima of 600 to 800 µg/L in late summer and minima of 200 to 400 µg/L in winter. On average, there was more total nitrogen in Budgewoi Lake and Lake Munmorah than at The Entrance and in Tuggerah Lake.</p> |

| Variable | Summary |
|---|---|
| Oxidisable nitrogen (Nitrate and Nitrite) NO _x | <p>Roberts (2001) found oxidised nitrogen (nitrate and nitrite) concentrations varied over time and was not consistent between locations. Generally concentrations were below the detection limit of 10 µg/L. Lake Munmorah was higher than the other locations once (15.6±1.9 µg/L) and Tuggerah Bay was higher once (27.8±9.5 µg/L).</p> <p>Roberts and Barnes (2004) found NO_x was generally at the laboratory detection limit of 5 µg/L at most locations at most times. Significant peaks in the concentration were observed five times out of 24 were sampling events at different times and locations through out the lakes.</p> |
| Ammonium | <p>Roberts (2001) found ammonium concentrations were much more variable than total nitrogen or oxidised nitrogen and varied over time and were not consistent between locations. Particularly high levels occurred at all the locations in January 1998. Lake Munmorah had significantly higher concentrations once in June, 1998 of 74.4±1.9 µg/L.</p> <p>Roberts and Barnes (2004) found similar variability. Overall concentrations had no obvious seasonal trends and ranged on average from 5 to 25 µg/L. One very large peak occurred in Lake Munmorah in November 2004.</p> |
| Total phosphorous | <p>Roberts (2001) reported that total phosphorus varied over time and was not consistent between locations. Overall concentrations ranged from 2±0.3 µg/L to 41±2 µg/L with no consistent seasonal or rainfall patterns.</p> <p>Roberts and Barnes (2004) found similar variability. Seasonal trends were evident and relatively consistent among locations. Overall, maxima were observed in late summer of 35 µg/L and minima in winter of 10 µg/L but some variability from this was observed from February 2001 to February 2002.</p> |
| Ortho-phosphate | <p>Roberts (2001) found ortho-phosphate varied over time and was not consistent between locations. Overall concentrations were generally low, ranging from 0.3±0.2 µg/L to 11±10.1 µg/L and were significantly higher in January 1998.</p> <p>Roberts and Barnes (2004) found similar variability. Relatively high concentrations were recorded in Lakes Munmorah and Budgewoi in August and September 2001 but not in Lake Tuggerah or at the Entrance. Lake Tuggerah had relatively high concentrations once. Overall concentrations of ortho-phosphate ranged from approximately 1 to 11 µg/L, and the range of levels was similar in each location.</p> |

Power Station water quality monitoring

Tuggerah Lakes system

Data collected during the period 2004 to 2008 has been used to characterise the water quality during operation of the existing power station (Table 8.9). The review is based on monitoring data that is reported to the EPA by Delta Electricity as part of the EPL reporting conditions.

The data indicates that the three lakes have similar water quality, although on average Lake Budgewoi is slightly warmer. The monitoring at the Lake Budgewoi outlet is in the immediate outlet area where the ANZECC (2000) guidelines do not apply.

The maximum dissolved oxygen in all lakes was higher than the ANZECC guideline maximum of 110% at all the sites

The secchi depth readings as low as 0.2 m indicates that the lakes are frequently turbid.

Salinity in the lakes is naturally highly variable due to the effects of catchment rainfall runoff and tidal exchange with the ocean.

While additional heat rejected to the lake causes further evaporation, this impact on salinity variation in the lakes has been assessed as being marginal when compared to local rainfall and consequent runoff being the dominant factor (CSIRO 1990).

Table 8.9 – Summary of Tuggerah Lakes ambient water quality (2004 to 2008)

| Element | Lake Tuggerah (background) | | | Lake Munmorah (inlet) | | | Lake Budgewoi (outlet) | | | ANZECC (2000) |
|---------------------------------|----------------------------|--------------|------|-----------------------|--------------|------|------------------------|--------------|------|---------------|
| | Avg | Max | Min | Avg | Max | Min | Avg | Max | Min | |
| Temperature (°C) | 19.0 | 26.7 | 11.1 | 19.7 | 26.9 | 11.3 | 22.1 | 30.3 | 10.7 | (1) |
| Salinity (‰) | 30.7 | 38.0 | 15.6 | 29.5 | 39.4 | 17.0 | 29.1 | 38.8 | 16.8 | - |
| Dissolved Oxygen (sat. %) | 101.9 | 129.3 | 90.0 | 102.7 | 125.0 | 83.9 | 99.5 | 120.2 | 85.5 | 80 – 110 |
| Secchi Depth (m) | 1.1 | 2.6 | 0.2 | 1.3 | 3.0 | 0.5 | 1.0 | 1.8 | 0.3 | - |
| Zooplankton (#/m ³) | 1317 | 15,671 | 4 | 628 | 6306 | 12 | 1,276 | 26,086 | 12 | |

Source: Delta Electricity Annual Reports to DECCW

Table 8.10 – Summary of water quality and trace elements in the Munmorah Ash Dam discharge (2004 to 2008)

| Element | Discharge Concentrations | | | Wallarah Creek Concentrations | ANZECC (2000) |
|-----------------------|--------------------------|--------------|---------|-------------------------------|----------------------|
| | Avg | Max | Min | | |
| mg/L | | | | Avg | |
| Water Quality | | | | | |
| Nitrate + Nitrite | 0.054 | 0.641 | <0.001 | | 0.015 |
| Total Phosphorous | 0.024 | 0.14 | 0.004 | 0.05 | 0.030 |
| Reactive Phosphorus | 0.008 | 0.08 | <0.001 | 0.015 | 0.005 |
| TSS ⁽¹⁾ | 11.0 | 36.0 | 1.0 | | 10.0 |
| pH | 8.1 | 9.4 | 6.8 | | 7.0-8.5 |
| Trace elements | | | | | |
| Cadmium | <0.0003 | <0.002 | <0.0002 | | 0.0007 |
| Copper | 0.0024 | 0.013 | <0.0001 | | 0.0013 |
| Lead | <0.0004 | 0.0014 | <0.0002 | | 0.0044 |
| Manganese | 0.069 | 0.33 | 0.0088 | | - |
| Selenium | <0.0015 | <0.005 | <0.001 | | 0.003 ⁽³⁾ |
| Zinc | 0.007 | 0.016 | 0.001 | | 0.015 |

NOTE: ⁽¹⁾ TSS – Total suspended solids
⁽²⁾ Measured at screens downstream of ash dam discharge
⁽³⁾ Interim guideline

Munmorah Ash Dam discharge

This section considers ash dam discharges from Munmorah Ash Dam. Table 8.10 lists the average, maximum and minimum for the water quality and trace element data collected at the Munmorah Ash Dam discharge point derived from the last five years of available data (2004 to 2008).

Roberts and Barnes (2004) reports average concentrations in Wallarah Creek, shown in Table 8.10. The ash dam discharge nutrient concentrations are lower than the Wallarah Creek inflow to Lake Budgewoi.

The ash dam discharges at 17 ML/d into the cooling water inlet canal where the flow of Lake Munmorah is 2,350 ML/d or a dilution factor of greater than 100.

Average metal concentrations in the ash dam discharge are generally less than the ANZECC guidelines except for copper which exceeds the guidelines some of the time. To provide greater resolution of the actual metal concentrations Delta electricity conducted a sampling exercise with analyses using high resolution metal detection procedures

Trace element loads

Delta Electricity data for ultra-trace element analyses for copper, cadmium, nickel and zinc discharged from the power station cooling water system was also analysed. Samples were collected at the cooling water outlet, inlet and in the middle of Lake Budgewoi, in April 2005. At the time, one unit was operating

between 180 MW and 300 MW. As the cooling water flow rate per unit does not change with rehabilitation, the trace element concentrations would remain the same for two unit operation. Trace element mass emissions for two units were estimated using the measured concentrations and the two unit flow rate of 2,350 ML/day.

The data provided in Table 8.11 demonstrates the low trace element concentrations at the cooling water outlet. Concentrations at the Lake Budgewoi and at the inlet sampling sites were lower than the ANZECC (2000) guidelines for the protection of aquatic life.

Mass emissions for the increase in metals, from the cooling water inlet to the outlet, for the proposed two unit operation following rehabilitation are also shown in Table 8.11. The zinc concentration from the ultra-trace element analysis at the inlet was higher than the outlet or in Lake Budgewoi so the mass emission was not calculated.

In the period from 2004 to 2009, electricity generation the annual generation from the power station varied between 912 GWh and 2,110 GWh. The estimated annual furnace ash production from 2004 to 2009 varied between 5,272 tonnes and 30,217 tonnes (average 20,018 t/year).

Delta Electricity has indicated the rehabilitated two units would be attemperated for only about 24 days per year. This means the trace element mass emissions would be reduced by nearly half compared to as built the four unit operation and similar to the recent operation.

Table 8.11 – Ultra trace elements in the Munmorah Power Station cooling water discharge and estimated mass emissions for two units

| Element | Outlet | Inlet | Lake Budgewoi | ANZECC (2000) | Estimated Discharge |
|---------|-----------------|-------|---------------|---------------|---------------------|
| | $\mu\text{g/L}$ | | | | kg/day |
| Copper | 1.9 | 1.1 | 1.1 | 1.3 | 1.88 |
| Cadmium | 0.02 | 0.01 | 0.01 | 0.7 | 0.02 |
| Nickel | 0.9 | 0.7 | 0.6 | 7.0 | 0.47 |
| Zinc | 1.2 | 1.8 | 0.2 | 15.0 | Inlet > outlet |

8.5.3 Groundwater

Section 8.2.6 identifies the ash dam as a potential source of input to ground water. The system of water management would minimise effects of the saline ash slurry lake water on the local groundwater. The ash dam water quality (Table 8.10) shows it has low levels of trace elements and low to moderate levels of nutrients, so effects on the local groundwater are not expected.

As the ash dam is constructed on a wetland, the local groundwater quality is typical of acid sulphate soils with low pH, high iron and moderate levels of manganese and zinc. Delta Electricity monitors the toe drains for these characteristics with the following results: pH (average 5.0), iron (average 16.9 to 46.6 mg/L) manganese (average 0.28 mg/L) and zinc (average 0.03 mg/L), which are one to three orders of magnitude higher than in the ash dam water (Table 8.10). Note that Delta Electricity measured iron concentrations in the ash dam for comparison with the toe drain data and found an average of about 0.06 mg/L.

A recent survey of vegetation in the power station property examined the wetlands, including the SEPP wetland along the edge of Lake Munmorah, and the forest between the dam wall and the edge of the lake (Robert Payne, Ecological Survey and Management, 2002). The wetland and forest condition recently satisfied the DECCW/DOP requirements for the area to be established as a green offset.

As the rehabilitation of the power station would not cause any major changes to the operation of the power station wastewater flows or systems and the water level in the ash dam is expected to remain unchanged, seepage and the quality of seepage to the local groundwater is not expected to change.

8.5.4 Assessment of rehabilitation impacts

Ambient water quality characteristics are not expected to be affected by the Proposal.

The ash dam discharge of nutrients, suspended solids and trace elements and the cooling water discharge of trace elements with the rehabilitated two units operating would be the same as the 'as built' power station equivalent of two units at 700 MW because the amount of coal burnt and furnace ash produced would be equivalent or slightly lower due to the improved efficiencies of the rehabilitated system.

The concentration increases in the inlet canal would remain well below the ANZECC guidelines (Table 8.10). As the mass emissions would remain the same or less than the 'as built' units, the sediment trace element concentrations are predicted to continue to be below the ANZECC (2000) guidelines for the rehabilitated plant.

8.6 Aquatic Ecosystems

This section provides a brief discussion of the Tuggerah Lakes ecosystems and the role of the power station operations.

The main assemblages of aquatic plants in the Tuggerah Lakes are the seagrasses. Other aquatic plants include emergent species along the lake edge including *Juncus kraussii* (sea rush), *Phragmites australis* (Common reed) and various other saltmarsh species.

Algae (Phytoplankton and Benthic algae) are also a natural part of the lakes ecology and along with the seagrasses, are the lake systems other main primary producers.

In addition, the Tuggerah Lakes Estuary is home to at least six species of the Syngnathids family which includes White's Seahorse - *Hippocampus whitei* and several species of pipefish. The flora and fauna in the Tuggerah Lakes is discussed in Chapter 12.


8.6.1 Seagrass

Existing environment

The aquatic flora of the Tuggerah Lakes is dominated by a fringing seagrass community. The seagrass beds are a key feature in the ecology of coastal lagoons because they provide habitat and nursery grounds for juvenile fish and prawns and support benthic populations (shellfish, snails and worms). They are also grazed by local swan populations.

The growth of aquatic plants in the lake is affected by a number of environmental factors which may also interact with each other. The plant populations show a high degree of natural variability, both spatially and temporally. The large variability of seagrass distributions and abundance shows effects of catchment rainfall runoff inputs and its effects on factors such as salinity, turbidity and nutrients (CSIRO 1990).

The dominant seagrass is *Zostera capricorni*, which provides an important nursery habitat for juvenile fish (Roberts, 2001). They grow in silty, sandy sediments



that extend around the perimeter of the lakes. In some cases, such as on the Budgewoi sandbank, these sediments, and hence the seagrasses, extend up to 500 m from shore and grow in water up to about 1.5 m depths.

The other dominant seagrass, *Ruppia maritima*, grows in protected, shallow water inshore of the *Zostera* beds. *Halophila* sp. is another small-leafed seagrass species that tends to grow in areas where there is little competition for light with *Zostera* and *Ruppia*.

Lake Budgewoi is also surrounded by fringing seagrass beds. A review by the CSIRO indicated that effects of the operating power station on seagrasses extended along the northern shore of Lake Budgewoi (CSIRO, 1990). The Tuggerah Lakes Processes Study concluded that the power station has substantial impacts on seagrass and associate fauna within 1 km of the cooling water outlet (Roberts, 2001).

A training wall was installed during construction of the original plant in the 1960s to increase mixing with cooler lake water in the discharge area. The wall directs the plume away from the seagrass beds on the western side of the wall in the north of the lake and generally away from the beds on the western side of Lake Budgewoi.

Seagrass distribution

The various seagrass distribution maps prepared throughout the life of the power station (shown and discussed in the following sections) illustrate the effects of the power station from the outlet to Buff Point (the main area of impact), under varying operating conditions, and its interaction with the naturally varying conditions due to catchment inputs.

The series of seagrass maps (Figures 8.13 to 8.16) show the consistent depletion of *Zostera* in the outlet area and the variability in abundance of *Halophila*

Detailed information on the hourly electricity generation in the 1980s was unavailable but the annual generation in 1980/81 averaged 675 MW and may have reached 1,200 MW. The seagrass survey undertaken in the summer of 1980/1981 shows no *Zostera* (Z) and only patches of *Halophila* (H) growing from the cooling water outlet to Buff Point. This 1981 seagrass distribution (Figure 8.13) corresponds with the 'worst case' operation of the 'as built' station operating at maximum capacity of 1,200 MW with three to four units in operation at the time of the plume survey.

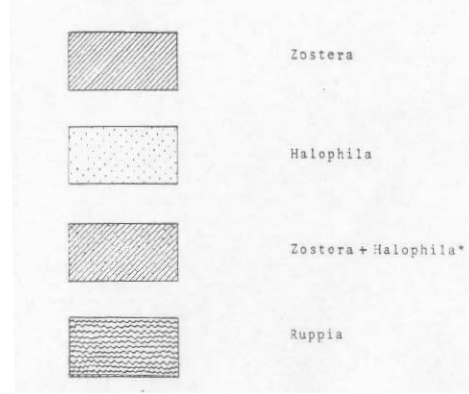
The seagrass surveys in 1985 and 1986 (Figure 8.14) are believed to represent with the 'worst case' scenario for the operation up to 700 MW. Electricity generation from 1996, after the power station was downgraded to a two unit station, is too low to represent the effects on the seagrass distribution for operation at 700 MW.

At the time of the plume survey in 1987, three units were operating at between 573 MW and 649 MW. This is also equivalent to two units operating with attemperament flows. However, the average annual electricity generation for 1986/87 was 420 MW. The seagrass map recorded in January/February 1987 is shown in Figure 8.15.

The latest seagrass distribution was mapped in 2003 (Figure 8.16) when the generation was at its lowest point with an average generation of about 150 MW. The 2003 map shows *Zostera* is present in the outlet area and this occurred because the power station did not operate in January and February, 2003. *Zostera* was also present in bays along the Buff Point Peninsula (Figure 8.16). Since 2003, the generation was increased by about 90 MW and recent visual observation found the *Zostera* in the immediate outlet area was depleted.

Scale of Abundance

- 1 - sparse growth (<20%)
- 2 - moderate growth (20%-50%)
- 3 - abundant growth (>50%)
- a - individual strands or clumps
- b - patches of growth up to 10m diameter
- c - beds of relatively even distribution
- e.g. 1(a) means a sparse bed of individual strands or clumps

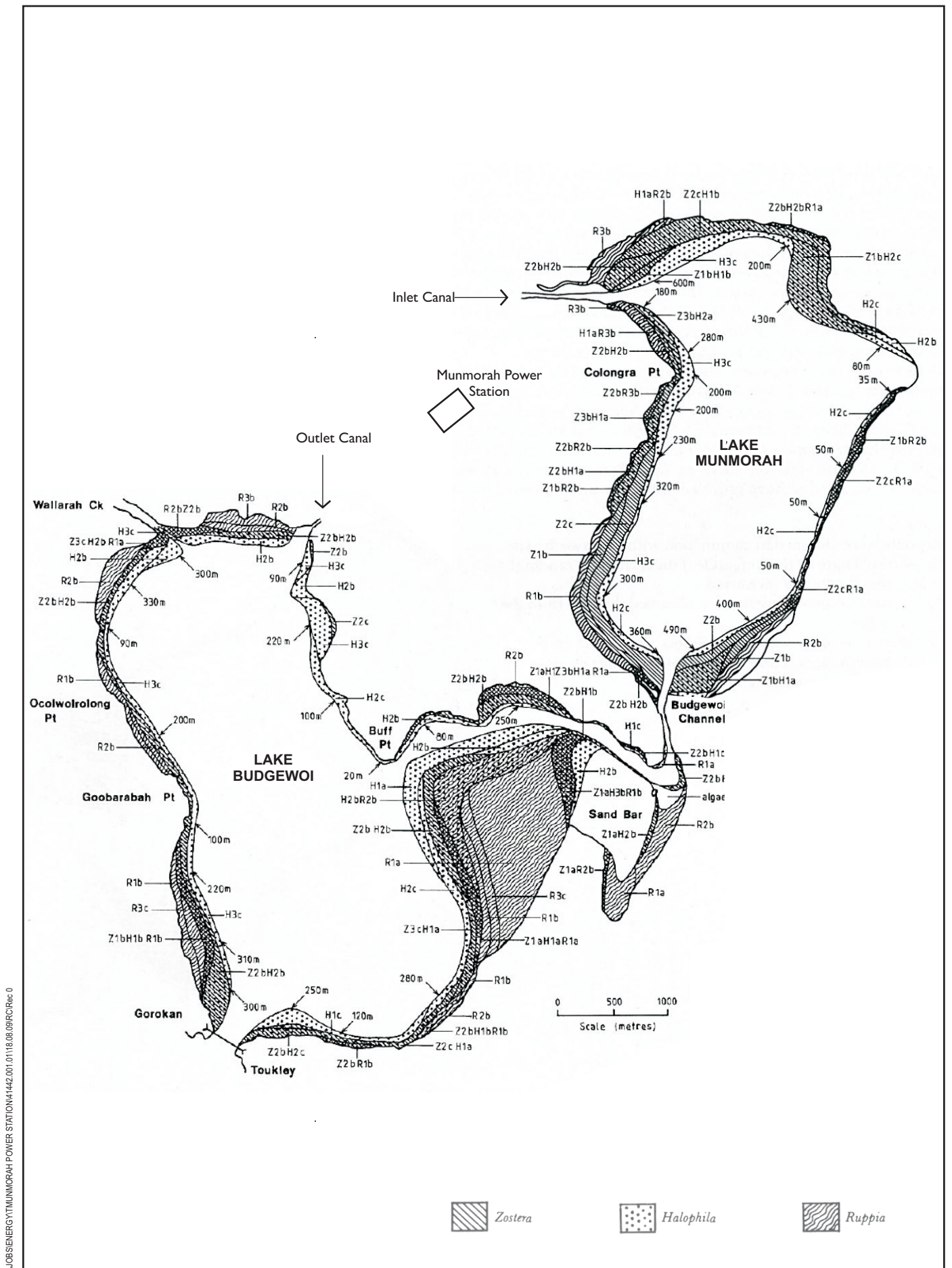


* Where this occurs abundance marked Z(for Zostera) followed by the scale (as above) then H(for Halophila) followed by its scale. e.g. Z3(b) H1(a)



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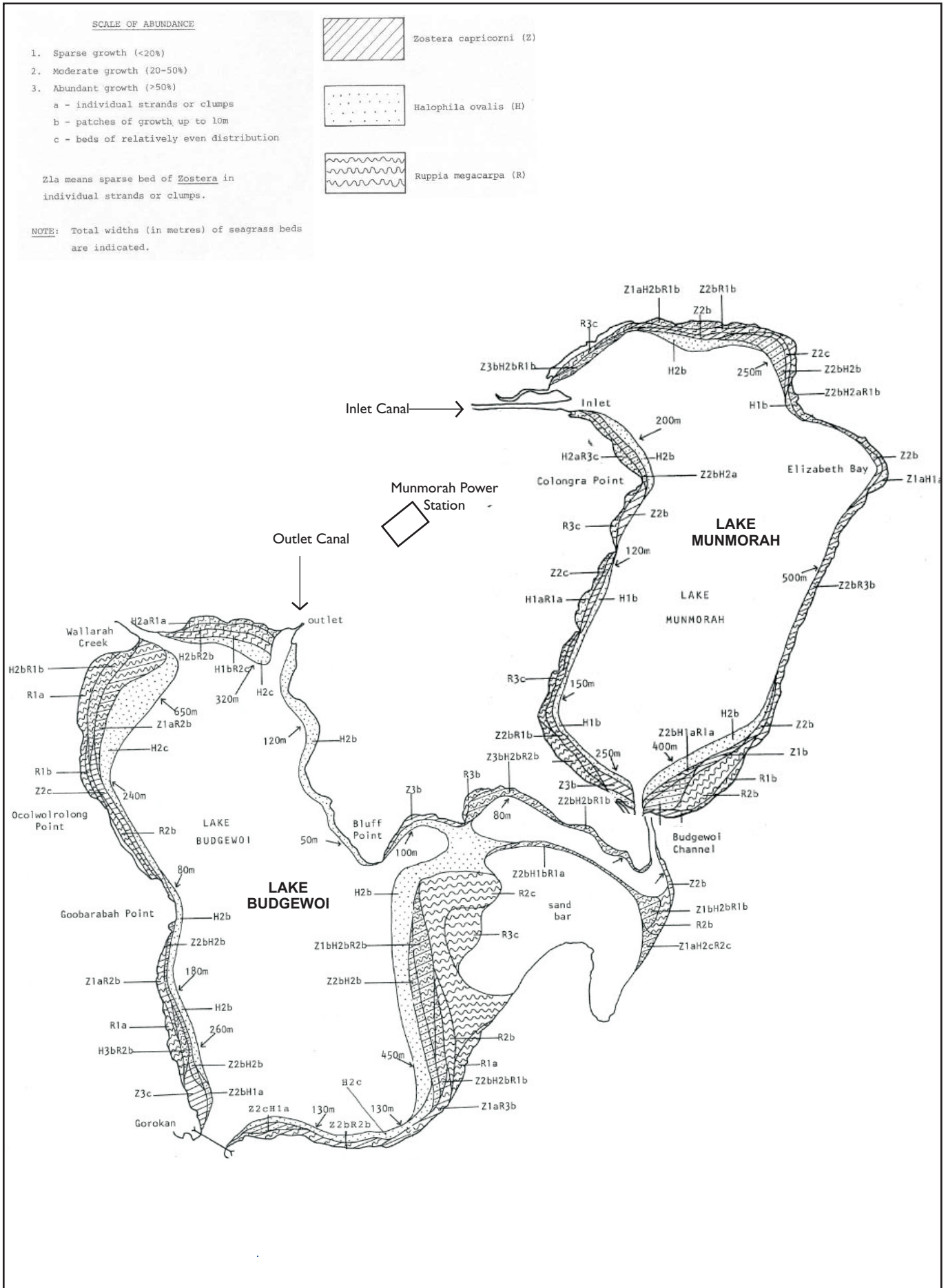
FIGURE 8.13: Seagrass Distribution Lake Munmorah and Lake Budgewoi January 1981



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Munmorah Power Station **Refurbishment Environmental Assessment**
FIGURE 8.14: Seagrass Distribution Lake Munmorah and Lake Budgewoi January 1985

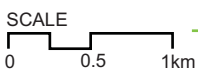
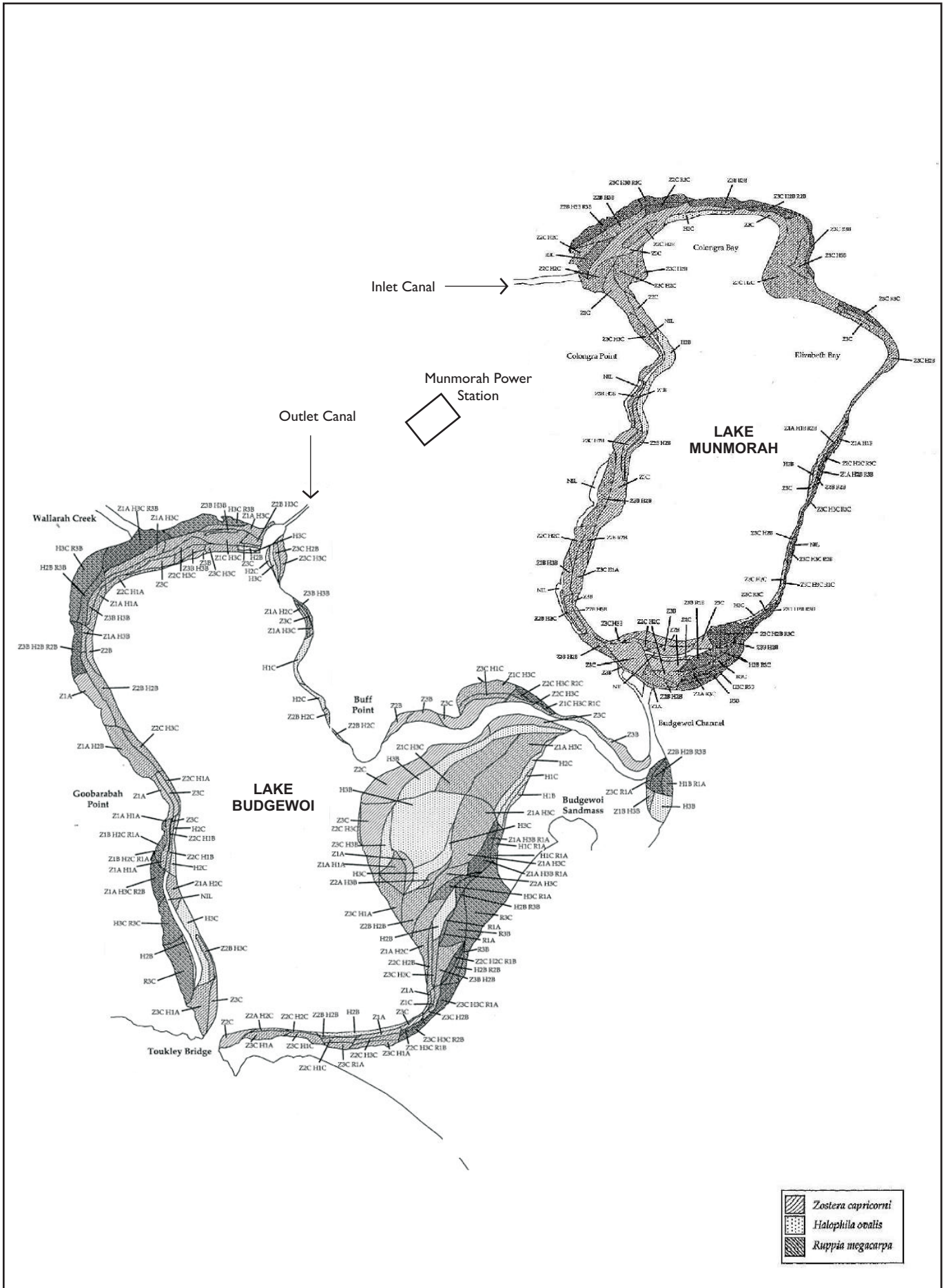


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Munmorah Power Station **Refurbishment Environmental Assessment**
FIGURE 8.15: Seagrass Distribution Lake Munmorah and Lake Budgewoi January 1987

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Temperatures in seagrass beds

Water quality monitoring by Delta Electricity showed that, due to the buoyancy of the warm water outside the immediate outlet area, the temperature increase in the middle of Lake Budgewoi is mostly within the surface waters with bottom water temperature generally showing no more than a 1 to 2°C increase. Temperature measurements in the shallow water fringing seagrass beds recorded at the same time as the January 2009 plume survey showed no temperature stratification other than in dense seagrass beds with limited water movement.

The shallow fringing seagrass areas are subject to daily heating and cooling cycles as a result of solar radiation and low flushing rate of 5 to 10 days (Roberts, 2001). High temperatures of 35°C to 37°C were measured in the dense *Zostera capricorni* beds in Lake Budgewoi, which is warmer than the power station cooling water outlet temperature (CSIRO, 1990). Temperature measurements in the seagrass beds on the southern side of Lake Budgewoi in 1986 and 1987 confirmed these observations (CSIRO, 1990). The elevated temperatures occur in seagrass areas sheltered from the mixing effects of wind and currents on the shoreward side of dense populations of seagrass (CSIRO, 1990).

Zostera capricorni occurs all along the eastern seaboard from NSW to QLD and in tropical waters of QLD is often recorded in water temperatures ranging from 19.8°C to 33.4°C (McKenzie, 1994). Short-term tolerance of this species to high summer temperatures was shown by Campbell *et al.* (2006), who found no effects on photosynthesis when subject to a temperature pulse of up to 35°C for four hours per day over three days with two days for recovery.

A similar study under laboratory conditions was undertaken by Ralph *et al.* (2008), on *Zostera capricorni* collected from Narrabeen Lagoon. Although they were unable to determine the thermal tolerance of the plant, growth rates were unaffected up to 35°C. Under the experimental conditions used, a reduction in photosynthetic rate was seen at temperatures above ambient summer temperatures. A reduction in the maximum photosynthetic rate was seen at the ambient summer temperature of 27°C and photosynthesis decreased for the winter test at 28°C. Further research was suggested.

The series of seagrass maps (Figures 8.13 to 8.16) show the consistent depletion of *Zostera* in the outlet

area which would indicate that the temperature difference directly adjacent to the outfall is above the tolerance limit of *Zostera*. However outside the immediate discharge zone it can be seen that the seagrass communities have continued.

Assessment of rehabilitation impacts

In order to gain an appreciation of the resulting distribution of seagrasses, the modelled plumes have been overlaid on existing imagery of the lakes using GIS Arcview and are shown in the following figures. The assessment was undertaken by modelling of the cooling water plume temperature and distribution for the 'as built' rehabilitated units.

Modelled temperatures in the seagrass beds for the untemperated rehabilitated two units show temperatures up to about 33°C at site 5 (Figure 8.9) near the cooling water outlet, reducing to <31°C at site 6 near Buff Point (Appendix F). As the discharge temperature was only 0.3°C cooler for the rehabilitated units, predicted temperatures at these sites were unchanged for the 'as built' units and there was a small decrease of 0.1°C at site 5 for the attemperated rehabilitated units. Likewise, no changes were predicted for the rehabilitated and 'as built' plumes in Lake Munmorah.

The seagrasses continue to grow in the warmer temperatures in the beds to the west and south-west of the lake where there is a natural daily cycle of heating during the day and cooling at night (Appendix F). The beds in the path of the cooling water plume (sites 5 and 6) are subject to more frequent, long-term, elevated temperatures and are depleted from the outlet to near Buff Point. As the temperatures in the seagrass beds, due to the cooling water plume, in this area are expected to be the same or slightly lower than the 'as built' plume, the rehabilitation is not expected to cause a change in effects on the seagrasses in the lakes.

The Proposal would result in a decrease in outfall temperature from those levels released during recent times. As such, no negative impact on the seagrass communities is expected. It is likely that the reduction of the outfall temperature may have a beneficial effect in that temperatures are likely to decrease. In addition, the rehabilitated power station plumes are significantly less extensive than the plume from the original 'as built' four unit station and marginally less extensive than the 'as built' two unit station.

8.6.2 Metal concentrations in lake sediments

Most of the nutrient inputs to the lakes are associated with silt input from the catchment with sedimentation rates estimated to be approx 11 mm/year in Lake Munmorah, 8.5 mm/year in Lake Budgewoi and 4 mm/year in Lake Tuggerah (CSIRO, 1990).

The nutrient input to the lakes from the catchment was calculated to be approximately 60,000 kg of phosphorus and 219,000 kg of nitrogen per year (Roberts, 2001). The inputs generated by the power station are likely to result in no more than 1-2% additional phosphorus and nitrogen to the system and as such are considered minor in significance. The sediment metal concentrations measured in 1989 by CSIRO (1990) represented the cumulative effects of

four and two unit power station operation added to catchment inputs. CSIRO (1990) surmised that the sediment metal concentrations in Lake Budgewoi and Munmorah were likely due to inputs from the power station cooling water system.

As part of the CSIRO work (as shown in Table 8.12), copper was found to be at, or slightly above, the ANZECC guidelines value in Lake Munmorah and below the guidelines in Lake Budgewoi and Tuggerah. Zinc and lead were below the guidelines in all three lakes. CSIRO (1990) also showed there was no evidence of excessive bioaccumulation in seagrass or sediment dwelling biota (benthic animals) in the lakes

Table 8.12 – Comparison of daily mass discharge of water quality and trace elements from the Munmorah Ash Dam

| Element | Discharge | | Adj. to 700 MW | | Sediments in 1997 | | | | ANZECC ⁽¹⁾ |
|-----------------------|-----------|-------|----------------|-------|-------------------|-------------------|-------------------|--------------------|-----------------------|
| | kg/day | | kg/day | | mg/kg dw | | | | mg/kg dw |
| | Avg | Max | Avg | Max | LM ⁽²⁾ | LB ⁽²⁾ | LT ⁽²⁾ | ALL ⁽²⁾ | |
| Water Quality | | | | | | | | | |
| Nitrate + Nitrite | 0.92 | 10.9 | 4.3 | 50.7 | | | | | |
| Total N | | | | | 2,500 | 2,200 | 1,850 | - | - |
| Total P | 0.40 | 2.38 | 1.86 | 11.1 | 270 | 260 | 340 | - | - |
| Reactive P | 0.14 | 1.36 | 0.65 | 6.3 | | | | | |
| TSS | 187 | 612 | - | - | | | | | |
| Trace elements | | | | | | | | | |
| Cadmium | 0.0025 | 0.017 | 0.012 | 0.079 | <0.16 | 0.12 | <0.09 | 0.09 | 1.5 |
| Copper | 0.041 | 0.221 | 0.191 | 1.028 | 42 | 46 | 15 | 23.1 | 65 |
| 1989 ⁽³⁾ | | | | | 60-70 | 25-40 | 40 | - | |
| Lead | 0.0034 | 0.024 | 0.016 | 0.112 | 27 | 30 | 24 | 26.4 | 50 |
| 1989 ⁽³⁾ | | | | | 35-40 | 25-40, | 40 | - | - |
| Manganese | 1.17 | 5.61 | 5.44 | 26.1 | - | - | - | - | - |
| Selenium | 0.013 | 0.043 | 0.060 | 0.20 | <3 | <3.5 | <3.5 | 2.79 | 4 ⁽⁴⁾ |
| Zinc | 0.119 | 0.272 | 0.553 | 1.26 | 91 | 90, | 72, | 72.2 | 200 |
| 1989 ⁽³⁾ | | | | | 140-150 | 100-140 | 110 | - | |

NOTE: ⁽¹⁾ ANZECC Sediment Quality Guidelines
⁽²⁾ LM – Lake Munmorah, LB - Lake Budgewoi, LT - Lake Tuggerah, LT, ALL - Average of all lakes
⁽³⁾ CSIRO (1990)
⁽⁴⁾ Interim guideline

Roberts (2001) also demonstrated that the sediment concentrations of metals in the lakes are lower than the ANZECC (2000) sediment quality guidelines for the protection of aquatic life. The concentrations of metals in Lakes Budgewoi and Munmorah were measured in 1997 as part of the Roberts Tuggerah Lakes Process study. Sediment concentrations for arsenic and nickel were reported as being above the ANZECC sediment guideline values at some sites in Lake Tuggerah in 1997. However, the concentrations of these metals (as well as silver, chromium, mercury and nickel) in Lakes Munmorah and Budgewoi were below the guidelines.

The ash dam discharge of nutrient, suspended solids and trace elements and cooling water discharge of trace elements with refurbished units operating would be the same as the 'as built' power station equivalent of two units at 700 MW because the amount of coal burnt and furnace ash produced would be equivalent or slightly lower due to the improved efficiencies.

As the mass emissions would remain the same or less than the 'as built' units, the sediment trace element concentrations are predicted to continue to be below the ANZECC (2000) guidelines for the Proposal.

In summary, the rehabilitation of units three and four would not generate any additional metal loading to the system and as such the sediment trace element concentrations are expected to continue to exist below the ANZECC (2000) guidelines following rehabilitation.

8.6.3 Bioaccumulation and biomagnification

Ecological risks from metal contaminants are difficult to assess as responses differ between species and for different contaminants. The rate that solutes move in and out of sediments (referred to as benthic flux) can be positive (into the water from bottom sediments) or negative (out of the water into bottom sediment).

Bioaccumulation occurs when an organism absorbs a substance that gradually accumulates within the organism. Marine animals, particularly filter feeders are able to accumulate most bioavailable forms of metals and organic contaminants from their food sources. Essential trace elements such as copper may also be actively accumulated by the organism as they are essential 'building blocks' (for example, copper is required by species with haemocyanin).

Biomagnification is the process whereby a chemical, as it is passed through a food chain or food web by trophic transfer, reaches increasingly higher

concentrations in the tissues of animals at each higher trophic level. Research has demonstrated that very few compounds (for example, methylmercury and PCB's) in freshwater and marine food webs biomagnify (Bargalagli et al. 1998; Evans et al 1991). An important distinction between bioaccumulation and biomagnification is that the former occurs within the organism and the latter occurs across trophic (food chain) levels.

Little information exists in relation to trace element behaviours in Australian aquatic systems, especially in relation to bioaccumulation. Several reports (Bowles *et al* 2001,; Cabana *et al* 1994) have reported bioaccumulation of metals such as selenium, zinc or mercury. However, many other studies (such as Shanmugam *et al* 2007; CSIRO 1990, Barwick and Maher 2003) have shown little evidence for bioaccumulation of these or other elements. Shanmugam *et al* (2007) who concluded that although there were elevated levels of metals (including Mg, Fe, Zn and Cu) within estuarine sediments tested in India, there was little evidence of elevated levels of trace element accumulation within marine gastropods tested from the area. Other research undertaken within the Lake Macquarie Estuary NSW (Barwick and Maher 2003) also concluded that there was little evidence of bioaccumulation (or magnification) within the food webs examined.

Roberts (2001) demonstrated that sediment concentrations of metals in the Tuggerah Lakes are lower than the ANZECC (2000) sediment quality guidelines for the protection of aquatic life. Sediment concentrations for arsenic and nickel were reported as being above the ANZECC sediment guideline values at some sites in Lake Tuggerah in 1997. However, the concentrations of these metals (as well as silver, chromium, mercury and nickel) in Lakes Munmorah and Budgewoi were below the guidelines.

As part of the CSIRO work (as shown in Table 8.12), copper was found to be at, or slightly above, the ANZECC guidelines value in Lake Munmorah and below the guidelines in Lake Budgewoi and Tuggerah. Zinc and lead concentrations were also reported as being below the guidelines in all three lakes.

CSIRO (1990) also tested species within the lakes system and concluded that there was no evidence of excessive bioaccumulation in seagrass or sediment dwelling biota (benthic animals) in the lakes.

The ash dam discharge of nutrients, suspended solids and trace elements and cooling water discharge of trace elements with the rehabilitated units operating would be the same as the 'as built' power station

equivalent of two units at 700 MW because the amount of coal burnt and furnace ash produced would be equivalent or slightly lower due to the improved efficiencies.

As the mass emissions would remain the same or less than the 'as built' units, the sediment trace element concentrations are predicted to continue to be below the ANZECC (2000) guidelines for the rehabilitated plant. In summary, the rehabilitation of units three and four would not generate any additional metal loading to the system and as such the sediment trace element concentrations are expected to continue to be below the ANZECC (2000) guidelines when the two units are rehabilitated to 700 MW. As demonstrated previously this is not likely to result in bioaccumulation issues.

8.6.4 Zooplankton

Zooplankton is an important source of food for fish larvae and benthic animals. Sampling in the Tuggerah Lakes was undertaken for the Roberts Estuary Process Study from May 1997 to November 1998. The average and range of densities for the three lakes are shown in Table 8.13.

The highest zooplankton densities in the three lakes occurred during spring and summer, with the lowest recorded during winter. Greater densities were often recorded in Lakes Munmorah and Budgewoi and they had higher average summer densities. It should be noted that the power station had a low level of generation during this study and CSIRO (1993) noted

significant reductions of zooplankton near the outlet during high summer discharge temperatures for the four unit power station operation.

The higher densities in Lakes Munmorah and Budgewoi in 1997/98 were suggested by Roberts (2001) as being due to lesser coastal mixing process (tidal exchange) than in Lake Tuggerah. The hydrodynamic study undertaken for the Process Study showed flushing times for the whole lake system was about 60 to 100 days, while flushing between the three lakes was estimated to take only 12 days.

The effects of entrainment of the power station for the four unit power station operation on fish larvae and eggs were reviewed by CSIRO (1993). Fish species that spawn in the near-shore areas, outside the Tuggerah Lakes (most of the recreationally and important species), leave the water column and settle in the seagrass beds as soon as they enter Lake Tuggerah. These species were identified as not at risk of entrainment in the cooling water system. Larvae that are entrained are from fish that spawn in the lakes, such as the Australian anchovy. It was found there was a loss of eggs due to damage on passing through the cooling water system but the effects on the anchovy population was not likely to be substantial due to the relatively small numbers involved (CSIRO, 1993).

Table 8.13 – Zooplankton densities (Roberts 2001)

| Density (individuals/L) | Lake Munmorah | Lake Budgewoi | Lake Tuggerah |
|-------------------------|---------------|---------------|---------------|
| Average | 102 | 97 | 93 |
| Range | 22 to 247 | 26 to 184 | 40 to 258 |
| Summer | 195 | 194 | 160 |
| Winter | 97 | 80 | 63 |

8.6.5 Effects of screening fish and prawns

Trash racks are located in the cooling water inlet canal to divert large pieces of debris such as driftwood, tree branches and large clumps of weed, and prevent large fish from entering the rotating drum screening system. The trash racks are immediately upstream of the main drum screens and are manually cleaned as required. Collected debris is removed for disposal in the ash dam.

Seven rotating drum screens are operated in the inlet canal with screening mesh of 10 mm to divert material that pass through the trash racks, such as fish, prawns and jellyfish, as well as floating weed, for the cooling water before it enters the condensers. Screened aquatic life is flushed, with additional water from the intake canal, to the lake system via a channel to the outlet canal.

The Ecology Lab (2006) reviewed the effects of fish and prawn collection on cooling water screens at coastal power stations in NSW, including Munmorah

Power Station (Ruello, 1978 and Henry and Virgona, 1981). They found the rate of impingement on the screens was not large and affected relatively few species of economic importance. Table 8.14 shows the combined average sampling each month for 12 months by Ruello (1978) and Henry and Virgona (1981)

Table 8.14 – Average monthly sampling for fish and crustaceans collected on cooling water screens

| Species | Screen Rate |
|-------------------------|-------------|
| Fish | |
| Anchovy | 0.21 |
| Arenigobus bifrenatus | 0.08 |
| Atherinids | 0.46 |
| Bream, yellowfin | 1.08 |
| Eel, shortfin | 0.33 |
| Fortesque | 0.13 |
| Garfish | 0.33 |
| Glassfish, Port Jackson | 19.0 |
| Glassfish, Ramsey's | 0.13 |
| Gudgeon, flathead | 0.17 |
| Hardyhead | 0.33 |
| Herring, southern | 1.71 |
| Leatherjacket | 0.08 |
| Longtom | 0.21 |
| Luderick | 0.17 |
| Mullet, flat-tail | 0.08 |
| Mullet, sea | 0.33 |
| Redigobius macrostomus | 0.08 |
| Silver batfish | 0.08 |
| Sole, narrowbanded | 0.08 |
| Sandy Sprat | 13.7 |
| Stinkfish, spotted | 0.33 |
| Tailor | 0.21 |
| Crustacea | |
| Acetes australis | 1.42 kg |
| Macrobrachium sp | 9.2 |
| Greasyback prawn | 9.8 |
| King prawn | 15.0 |
| School prawn | 7.4 |

NOTE: ⁽¹⁾ Screen rate is number of individuals/hour/screen

The conservation status of the fish and crustacea species listed in the table above was undertaken using the following sites:

- *Threatened Species Conservation Act 1995* (<http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/index.aspx>)
- *Environment Protection and Biodiversity and Conservation Act 1999* (<http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl>)
- *Fisheries Management Act 1994* (http://www.austlii.edu.au/au/legis/nsw/consol_act/fma1994193/)

None of the species listed found in the lakes are considered threatened under these acts of legislation.

Henry and Virgona (1981) concluded from their study that the number of commercially or recreationally important fish impinging on the screens was low. They also found the recreational fishery benefited at the cooling water inlet and outlet canals and there was no apparent detrimental effect of Munmorah Power Station on the commercial fishery or on the biology of the main commercial or recreational fish species.

The White's Seahorse (*Hippocampus whitei*) is not under significant threat but is a listed species under the NSW *Fisheries Management Act 1994* and the EPBC Act (Wyong Shire website – Environmental Care). This species is only found in Australian waters and lives in the seagrass beds of the Tuggerah Lakes Estuary.

It has not been recorded at the cooling water screens at Munmorah Power Station even when the power station was operating at 1,400 MW; it is therefore unlikely that it would be collected on the screens with the rehabilitated power station operating at 700 MW.

A review of the effects of power stations in Lake Macquarie and the four unit Munmorah Power Station in the Tuggerah Lakes on fish, including screening effects, was undertaken by CSIRO (1993). They found that although some species may suffer screening mortality, the numbers involved were not sufficient to affect the commercial fish catches in the lakes. No threatened species or turtles have been recorded as being entrained on the Munmorah cooling water screens.

Under the Proposal, it is expected that attemperation would occur for approximately 24 days per year. The volume of aquatic organisms, and hence screening impacts, would be reduced by nearly half compared to

the four unit operation effects considered in the CSIRO study. As such there would be a significant positive effect of the rehabilitation in reducing the entrapment of species upon the screens.

8.7 Summary of Rehabilitation Impacts

A summary of the likely impacts of the Proposal, after consideration of mitigation measures, to fresh water consumption, water quality, aquatic ecology and recreational values of the Tuggerah Lakes System is presented in the following sections:

8.7.1 Water demand

While consumption would vary from year to year due to a range of factors, the domestic water consumption at Munmorah Power Station was 321 ML in 2008/09. The estimated consumption for the rehabilitated units 3 and 4 is 380 ML per annum.

This represents an 18% increase compared to the 2008/09 consumption at Munmorah and, based on 2007 consumption in the total Gosford City and Wyong Shire Councils water supply system, a 0.1% increase in the consumption in the water supply system in 2007.

Delta Electricity has been an active participant in the implementation of the Wyong Integrated Water Cycle Management (IWCM) Sub-Plan (WSC 2007) and has developed a Water Management Action Plan.

Clean surface water within the power station catchment is diverted around operational areas, through a clean water drainage system. These flows eventually discharge to the lake system. Clean water runoff from the power station site passes to the inlet canal.

Delta Electricity has sought to reduce its use of drinking quality water for industrial purposes. Delta Electricity's drinking quality water saving initiatives has been estimated to save around 500 million litres per annum, compared with water consumption in 2005. This is discussed in detail in Section 8.3.

As discussed in Section 8.3 Munmorah's domestic water usage is dependent on generation levels and current estimated saving at Munmorah is around 145 ML per year.

When it is considered that Munmorah's domestic water consumption in 2008/09 was 321 ML, and the projected nominal increase in consumption of domestic water is 59 ML per year, Delta Electricity

would maintain a reduction in water consumption at the site of around 86 ML per year which is 22% of the projected consumption.

The power station uses lake water for cooling and does not put an additional demand on freshwater resources. Relative to two unit operation, the proposed refurbishment of the plant is not expected to increase the overall freshwater consumption compared to the 'as built' power station's water use in the 1960s.

The water management measures adopted by Delta Electricity are consistent with the Wyong (IWCM) Sub-Plan and Delta Electricity is committed to ongoing monitoring of water consumption and consideration of measures to save water.

8.7.2 Water quality

Ambient water quality characteristics are not expected to be affected by the Proposal and lake water temperatures are expected to be unchanged or slightly cooler.

The ash dam discharge of nutrient, suspended solids and trace elements and cooling water discharge of trace elements with refurbished units operating would be the same as the 'as built' power station equivalent of two units at 700 MW because the amount of coal burnt and furnace ash produced would be equivalent or slightly lower due to the improved efficiencies.

The concentration increases in the inlet canal would remain well below the ANZECC guidelines (Table 8.3). As the mass emissions would remain the same or less than the 'as built' units, the sediment trace element concentrations are predicted to continue to be below the ANZECC (2000) guidelines for the rehabilitated plant.

The rehabilitated power station would be more efficient and have less reject heat, so the maximum temperature increase at the cooling water outlet would be 8°C compared with the current 9.5°C with an average of about 6.4°C based on the operation at 80% capacity over a year.

Cooling water plume modelling was undertaken to allow assessment of the effects of changes in discharge temperature.

The results of the five modelled scenarios discussed in Section 8.5 are provided in Appendix F. Due to the expected increase in efficiency of the rehabilitated plant, two units operating at base-load are expected to be lower than the average of 7°C reported in

Roberts (2001) for four units. With the downgrade to two units, the modelling has demonstrated the significant reduction in plume size when compared to the original four unit station. The 'as built' four units and the refurbished, untemperated and temperated plumes were also smaller than the 'as built' two unit plumes (Figure 8.8 and Figure 8.11, Appendix F).

The model predicted that the 'worst case' outlet temperature of the two unit, untemperated refurbished plume (Figure 8.9) would be 36°C and recirculation would be >28°C. The refurbished plume was 0.3°C cooler than the 'as built' plume and the plume extent was reduced in the order of 50 m. Similar results were predicted for the temperated plume (discharge temperature of <34°C and recirculation >28°C), so additional areas of seagrass are not predicted to be impacted by the Proposal.

8.7.3 Aquatic ecology

The seagrass beds have been considered to be the key habitat indicator for the assessment of effects of the rehabilitation on aquatic ecology in the Tuggerah Lakes due to their importance as habitat in the lakes system.

Due to the sensitivity of seagrasses to prolonged exposure to high temperatures, the cooling water plume temperatures and distribution were assumed to be the main characteristic of the rehabilitation that may cause changes in effects on the seagrasses in the lakes. The criterion used to assess the impact of the Proposal on seagrasses was a change in temperature distributions from the modelled plume compared to the 'as built' two unit power station. As shown above, the rehabilitated power station plumes are predicted to be smaller than the equivalent 'as built' plume.

The predicted extent of rehabilitation plumes from the modelling indicates no significant change in the seagrass distribution from the outlet to Buff Point compared to the effect of the cooling water plume under current operations.

As there would be no increase in the volume of lake water used at Munmorah Power Station following the rehabilitation works, effects on zooplankton are expected to be the same as the 'as built' units. Downgrading the power station from four to two units has significantly reduced the volume of water passed through the power station, so effects on entrained zooplankton are reduced.

Fish species that spawn in the near-shore areas, outside the Tuggerah Lakes, were identified as not being at risk of entrainment in the cooling water system. The number of fish and prawns diverted by the screens would not be increased by the rehabilitation compared to the 'as built' two unit power station and the effects on species that spawn in the lake are not likely to be significant due to the relatively small numbers involved.

Compared to the four unit operation the cooling water flows would be reduced by 50% so the numbers collected would be much lower than considered in the CSIRO study.

8.8 Mitigation Measures and Safeguards

The operation of the cooling water system has the following features to mitigate the impacts of its operation:

- trash racks in the inlet canal to divert large pieces of debris such as driftwood, tree branches and large clumps of weed, and prevent large fish from entering the rotating drum screening system
- seven rotating drum screens to transfer material that passes through the trash racks, such as fish, prawns and jellyfish, as well as floating weed from the intake canal, to the lake system via a channel to the outlet canal
- a training wall to increase mixing with cooler lake water in the discharge area and to direct the plume away from the seagrass beds on the western side of Lake Budgewoi
- access to additional water to temperate the cooling water discharge during above average warm weather conditions to maintain discharge temperatures within the licence limits of the EPL.

Delta Electricity has an ongoing commitment to ensuring the appropriate use of water in its operations at Munmorah Power Station. A system has been established for the regular review of water usage that includes routine inspection, metering and reporting.

In addition the use of salt water cooling avoids the consumption of fresh water for condenser cooling. Estimates of cooling tower consumption of water in NSW coastal power stations indicate savings of up to 380 ML per annum fresh water consumption is avoided through the adoption of salt water cooling. Significantly more water would be consumed by the equivalent sized plant at an inland location.

As there is little opportunity to reduce the water consumption requirements of the power production process, further water savings would be expected to primarily occur through source substitution approaches developed in consultation with Wyong Council.

Significant measures to manage the ash dam and cooling water discharge temperatures of the rehabilitated Munmorah Power Station, which have already been installed for the operating plant or would be installed include:

- design of the ash dam discharge to limit suspended solids to the EPL limit
- design of the condenser to limit temperature rise to a maximum of 8°C
- attemperation of the discharge to maintain the temperature below 35°C with provision for limited exceedance for 'heat wave' conditions to a maximum temperature of 37.5°C
- installation of a training wall to direct the plume away from the seagrass beds on the western side of Lake Budgewoi.

Delta Electricity proposes to map the distribution of seagrasses in summer 2009/10. A programme for the ongoing monitoring of the seagrass distributions following rehabilitation would be developed in consultation with DECCW.

8.9 Conclusions

Munmorah Power Station is an integral component of the Tuggerah Lakes system. The water management systems developed for the operation of Munmorah Power Station are subject to ongoing monitoring and improvement where necessary and provide adequate safeguards for the protection of water quality in the lakes.

The water balance for the power station is expected to remain unchanged or to be reduced for the rehabilitated plant compared to the 'as built' plant because freshwater (domestic) use and lake water for ash slurry purposes and cooling water remain the same. The ongoing commitment to the efficient use of freshwater water would be expected to result in further reductions in domestic water consumption.

Delta Electricity has demonstrated a commitment to water saving through the development and adoption of a site Water Management Plan in consultation with Wyong Council. Further water savings would be expected to primarily occur through source

substitution approaches developed in consultation with Wyong Council.

The refurbishment would not cause the discharge temperatures to exceed the current EPL conditions because the attemperation pumps in combination with improved turbine efficiency and reduction in condenser temperature rise can accommodate above average ambient lake temperatures and recirculation into the inlet canal.

Seagrass beds are assumed to be the key habitat indicator for the assessment of effects of the rehabilitation on aquatic ecology in the Tuggerah Lakes due to their importance as habitat in the lakes system. The model results illustrate that the size and temperature of the rehabilitated cooling water plumes are predicted to be the same or slightly smaller and not add to the effects of the equivalent 'as built' two unit power station on seagrasses in the lakes.

In addition an analysis of the model results shows that the plume dispersion and temperatures within the seagrass beds are not significantly different for the two units 'as built' and the 'rehabilitated' scenarios, although there is a general decrease in the temperatures for the 'rehabilitated' scenarios. The frequency of temperatures exceeding investigated threshold temperatures did not differ significantly due to the natural diurnal heating processes of the lakes.

As cooling water flow rates would remain unchanged and the condenser temperature rise reduced, the rehabilitation is highly unlikely to add to effects on water quality, zooplankton, fish and prawn larvae in Lake Budgewoi, Lake Munmorah or Lake Tuggerah.

When compared with the effects of the previously operating four unit power station, the effects of the Proposal on the Tuggerah lakes system also is likely to be significantly less, given the reduction in reject heat and the reduced size of the cooling water plume.