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## Water Cycle Management

8

## 8. Water Cycle Management

### 8.1 Introduction

Munmorah Power Station is located within the catchment of Lake Munmorah and Lake Budgewoi which are part of the Tuggerah Lakes system.

The Director-General's requirements identified matters related to water cycle management as a key issue. The requirements are as follows:

- include a water balance for the project identifying the maximum water use, waste generation and disposal requirements for the operation of the project
- demonstrate the availability of viable water sources to sustainably meet the water requirements of the project for the life of the project, considering the security of supply and current and future water demand in the region
- provide an assessment of the likely risks to water quality (including temperature) associated with the project considering key ancillary components (such as ash disposal), including demonstration that the cooling water disposal requirements of the project would not significantly impact on the water quality, aquatic ecology or recreational values of the Tuggerah Lakes System (including Budgewoi and Munmorah Lakes).

This section of the EA addresses the water cycle management associated with the rehabilitation of the power station and examines the following:

- the integrated water management system for the power station, which includes:
  - potable and salt water supplies
  - water uses within the power station
  - treatment of process water and potentially contaminated water before discharge.
- availability of water supplies to sustainably meet the water requirements of the Proposal,
- outlines the role and significance of Munmorah Power Station with regard to regional water supply and water management issues
- provides a general description of the Tuggerah Lakes system and the context of the Munmorah operations
- examines the physical and chemical characteristics of the lake in relation to the current operating conditions of the Munmorah Power Station

- examines available information on the role of the Munmorah Power Station in the functioning of the Tuggerah Lakes ecosystems and any changes that may occur as a result of the rehabilitation works as compared to the 'as built' power station
- provides a detailed description of plume modelling studies to assess the effects on seagrass in the lakes
- mitigation measures and safeguards.

As Munmorah Power Station is an operating facility and the scale of operations would not be increased beyond the original design capability following rehabilitation, the water management infrastructure required to effectively manage the potential effects of the power station operations on the water cycle is already in place. The water management systems established at the power station have been routinely monitored and improved over the 40 year life of the facility.

#### 8.1.1 Power station operations

The chronology of power station generation and the resulting typical and maximum cooling water discharge temperature rises for the period 1968 to 2008 are shown in Figure 3.1 and Table 8.1

The table shows that at the time of commissioning (the 'as built' system) the power plant was generating over >1,200 MW of electricity and the condenser cooling water temperature rise was 8.3°C. Over the 40 years of operation to 2008, the turbines have lost efficiency such that the condenser rise has increased from 8.3°C to the current 9.5°C.

For this assessment it was assumed the temperature rise, from inlet to outlet, increased at a constant rate of about 0.03°C/year from 1968 to 2008. The typical condenser temperature rise for each five year period was estimated from the average generation, compared to the power station capacity at the time. It should be noted that the power station was not as efficient as designed and mostly did not exceed 1,200 MW in generation. The power station was officially down rated in 1984.

Another measure of power station operation is the annual average condenser cooling water temperature rise. This annual average reflects a combination of the efficiency of the plant and the total generation for that year.

Prior to down rating, the estimated annual average temperature rise reached a maximum of 7.9°C in the

period 1978/79 to 1982/83. Despite lower efficiencies in recent years, the estimated annual average condenser temperature rise reduced to a minimum of 2.3°C in the period 1998/99 to 2002/03. Following the increase in generation in 2003/04 to 2007/08, the estimated annual average condenser temperature rise increased to 3.6°C.

The average annual electricity generation following rehabilitation would be 560 MW, based on a capacity factor of 80%. With a maximum design condenser temperature rise of 8.0°C, the corresponding annual average condenser temperature rise would be 6.4°C.

The 'rehabilitated' system would be more efficient and reject heat would be less when compared with the 'as built' and 'current' systems. Based on annual electricity production, shown in Figure 3.2, the annual heat rejection to the lakes would be at levels comparable to historical operation in the period immediately prior to downgrading to two unit operation.

An assessment of the likely risks of the Proposal (after consideration of mitigation measures) to the water quality, aquatic ecology and recreational values of the Tuggerah Lakes System following rehabilitation are provided in the following sections.

**Table 8.1 – Average total generation and MWs for five year periods from 1968/69 to 2007/08 and estimated typical and maximum condenser cooling water temperature rise**

Year <sup>(1)</sup>	Average total generation over 5 Year period (GWh)	Maximum estimated MW generated in period*	Average MW for 5 year period	Maximum condenser cooling water temperature rise (°C)	Maximum daily cooling water flow (ML/day) <sup>(4)</sup>
1968/69-1972/73	5,899	~1,200	1,024	8.3	4,700
1973/74-1977/78	6,033	NA	1,047	8.47	4,700
1978/79-1982/83	6,346	NA	1,102	8.64	4,700
1983/84-1987/88	4,119	NA	715	8.81	4,700
1988/89-1992/93 <sup>(3)</sup>	3,336	NA	579	8.99	2,350 <sup>(2)</sup>
1993/94-1997/98	1,274	NA	221	9.16	2,350 <sup>(2)</sup>
1998/99-2002/03	871	600	151	9.33	2,350 <sup>(2)</sup>
2003/04-2007/08	1,305	605	242	9.5	2,350 <sup>(2)</sup>
<b>Operational statistics Based on 80% Capacity Factor</b>					
As built 4 units	9,811	1,400	1,120	8.3	4,700
As built 2 units	4,906	700	560	8.3	2,350 <sup>(2)</sup>
Rehabilitated 2 units	4,906	700	560	8.0	2,350 <sup>(2)</sup>

Notes: <sup>(1)</sup> 1968-1993 based on generation during CW plume measurements

1999-2008 based on hourly records

<sup>(2)</sup> Does not include attemperation flows (588 ML/day with one pump, 1,175 ML/day if two pumps operate) which only occur for small amount of time (~7% for typical summer)

<sup>(3)</sup> Max assumed output at full load operation 600 MW

<sup>(4)</sup> CW Flow four Units 4,700 ML/day, three Units 3,525 ML/day, two Units 2,350 ML/day, one Unit 1,175 ML/day

## 8.2 Munmorah Power Station and the Water Cycle

Munmorah Power Station utilises potable and salt water in its power generation activities. A simplified representation of the water cycle is provided in Figure 8.1. Under current operations a large proportion of the water, including potentially contaminated stormwater runoff, discharges to Munmorah Ash Dam. Prior to entry into the ash dam the water undergoes a number of chemical treatment processes and is passed through retention basins and oil and grit removal systems. In addition, solids are removed and sent off site. The remaining treated water is discharged to Munmorah Ash Dam.

Clean stormwater runoff from roofs, vegetated buffers and other areas isolated from potential dirty water sources from power station operations, discharge directly to the inlet canal. Salt water is used in the cooling water system. This is extracted and returned to the inlet/outlet canal system.

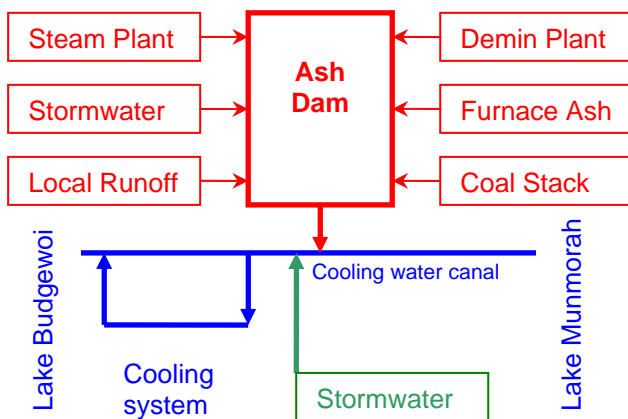


Figure 8.1 – Simplified water cycle

### 8.2.1 Water balance

The existing water systems at Munmorah Power Station consists of a series of inputs, outputs and losses.

The water system inputs include:

- potable water from Central Coast Water supply
- runoff/stormwater comprising input from: roofs/hardstand areas, coal storage areas, ash dams and green buffer areas
- salt water from Lake Munmorah.

The water system outputs from the site include:

- Munmorah Ash Dam
- steam plant release to the atmosphere
- Wyong Sewerage System
- Vales Point ash transport water management system
- salt water discharge to Lake Budgewoi.

The relatively small water system losses include:

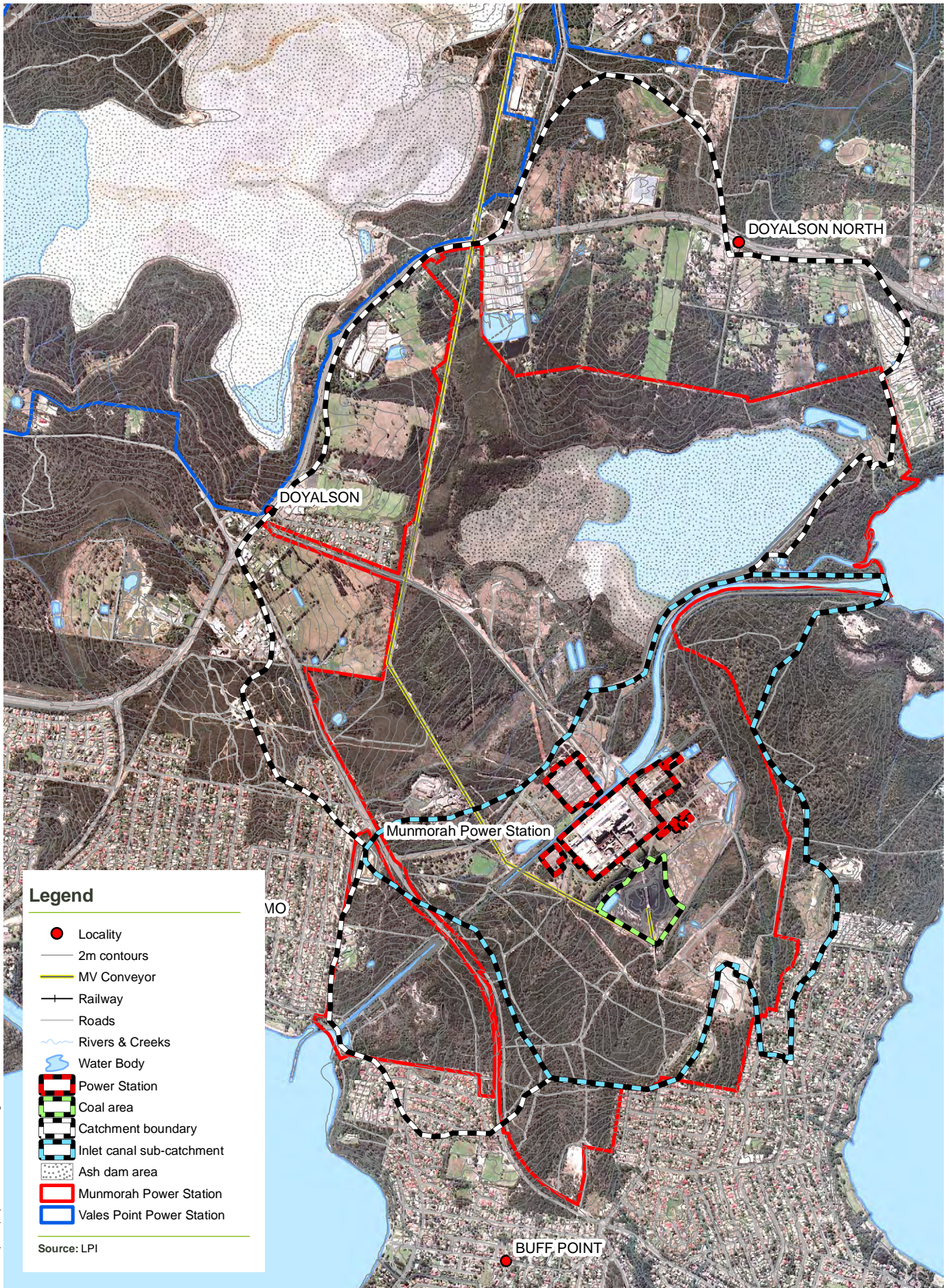
- on-site evaporation from ponds
- evaporation from vegetated buffer areas
- groundwater infiltration.

The immediate catchment surrounding Munmorah Power Station is shown in Figure 8.2. This figure also shows the extent of the ash dam sub-catchment with the remaining catchment either draining to the inlet/outlet canals or directly to Munmorah or Budgewoi Lakes.

The total catchment is approximately 1,050 hectares and has been estimated to comprise:

- hard surfaces 20 hectares
- coal storage area 9 hectares
- urban areas 48 hectares
- open water 79 hectares
- vegetated areas 894 hectares

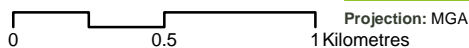
Areas that are not within the Delta electricity land holding largely occur within the upstream sections of the catchment. The catchment boundaries for each component of the water cycle are provided in Figure 8.2.



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Projection: MGA

Munmorah Power Station **Rehabilitation Environmental Assessment**

**FIGURE 8.2:** Munmorah Power Station Catchment Boundaries



## 8.2.2 Water cycle

The existing fresh water and salt water management system at Munmorah Power Station is shown diagrammatically in Figure 8.3. The schematic representation of water flows shows the clean and wastewater pathways and estimated quantities. The drainage systems on the site are clearly identified and segregated into clean water and potentially contaminated water.

### Potable water

Potable water for drinking, general power station use and steam plant make-up is currently obtained from the Central Coast Water Supply Authority (operated by Wyong and Gosford Councils). Water consumption varies from year to year depending on power station generation and other operational, local supply and climatic factors. Delta Electricity has advised that Munmorah Power Station consumed 321 ML of potable water in 2008/2009.

The estimated annual supply requirement following rehabilitation is 380 ML. This represents a 18% increase above the 2008/09 consumption for a 374% increase in expected power generation. The estimated rate of supply to Munmorah represents about 1% of the total water supply allocation within the Wyong distribution area.

#### *Demineralisation and steam plant*

Approximately 224 ML of the potable water supply is used for steam plant make-up. Prior to entering the steam plant the water is passed through the demineralisation plant. The demineralisation plant is used to convert potable water into boiler feed water for use in the steam process. This reduces the amount of fouling within the tubes from corrosion or the deposition of salts. Water from the potable water supply is passed through a series of resins (ion exchange process) to remove minerals. The resins are recharged with chemicals (dilute sodium hydroxide and sulphuric acid) and rinsed with heated water resulting in wastewater which is discharged to an effluent sump. The effluent is treated with either caustic or sulphuric acid to ensure the effluent is pH neutralised (Table 8.2) before being discharged via the dirty water pumping station to the eastern retention basin prior to discharging to the ash dam. Spent resin is removed off-site to a specialist waste disposal area.

Additional high purity water from the demineraliser plant is supplied to the Colongra Gas Turbine Power Station at a nominal rate of 7 ML/year.

Dissolved solids and particles entering a boiler through condenser cooling water leaks remain behind when steam is generated. During operation the concentration of solids builds up gradually affecting boiler operation efficiency. Boiler blowdown is a routine operation used to purge the system of the increased concentration of total dissolved solids. Boiler blowdown (Figure 8.1) is discharged via the dirty water pumping station and the eastern retention basin to the ash dam.

### Domestics water services

The remaining 156 ML of the potable water is used on the station for domestic purposes. Sewage is collected in several pumping stations located around the site and then pumped to the San Remo Sewage Treatment Plant.

Fire services waste water is directed into the 'potentially contaminated drains' and passes through a series of settling ponds and an oil separator before final discharge to the ash dam.

## 8.2.3 Stormwater runoff

Clean and potentially dirty stormwater runoff are managed through a series of clean and dirty drains.

### Operational areas

Potentially contaminated stormwater runoff from operational areas (29 Ha) including roads is directed to the various site wastewater management systems. Contamination of stormwater may occur from oils, solids or minor chemical waste.

### Clean water drains

Clean surface water from vegetated buffers, grassed areas and roofs within the power station catchment is diverted around operational areas, through a clean water drainage system.

These flows eventually discharge via the outlet canal to Lake Budgewoi and smaller areas discharge directly to Lake Budgewoi and Lake Munmorah. A small volume of the clean water runoff passes to the inlet canal contributing to the salt water cooling system.

## 8.2.4 Site run-off water

Site run-off water and process wastewater at Munmorah Power Station is passed through holding ponds, oil and grit removal systems before being transferred to the Munmorah Ash Dam.

Coal stockpile runoff comprising stormwater and run-off water used for coal dust suppression is treated in a separate pathway by passing through a settling basin before being discharged to Munmorah Ash Dam.

In addition, the auxiliary and salt water oil cooler systems are diverted to a holding pond and oil and grit trap facility before discharge to the cooling water canal. The oil and grit traps are designed to remove any oil and minimise suspended solids to an acceptable level so the ash dam discharge concentration does not exceed the EPL limit. Any oil collected is reclaimed while the solids are disposed off-site.

As the outlet canal also acts as a secondary oil containment facility to capture oil that could be spilled from the transformers or other electrical equipment in the event of a major equipment failure, an oil skimmer system is located in the outlet canal as a final protection measure to collect floating oil. An infrared oil detection beam is used to provide warning of any oil on the surface of the outlet canal water. Oil collected by skimmer pumps is retained in collection ponds for disposal off site. All wastewater on the site is either reused or treated prior to discharge.

The boiler blowdown water from the steam cycle is used within the plant with surplus water being discharged to the dirty water system. These losses are made up with demineralised water.

The boiler blowdown and demineralisation plant effluent are treated in a neutralising plant before discharge to the dirty water pumping station and then to Munmorah Ash Dam.

## 8.2.5 Ash dams

The combustion of coal produces around 24% ash of which about 10% is furnace ash and 90% is fly ash. While beneficial use of the ash product is preferred and promoted, the majority of the ash produced is currently stored in ash dams. The Central Coast Ash Management System (CCAMS) has been developed to manage ash from Munmorah and Vales Point facilities. The general location of the ash storages is shown in Figure 1.2.

Under the current operations, the fly ash produced at Munmorah Power Station is transferred to the Vales Point Ash Dam in a low-density slurry while the furnace ash is stored in the Munmorah Ash Dam.

Salt water extracted from the cooling water inlet canal is used to transport the ash. The coarser furnace ash collected from the bottom of the boilers, is piped as slurry to the Munmorah Ash Dam. Stormwater runoff from the Munmorah Ash Dam's catchment area, as well as treated water from various power station processes, and the dirty water management system also enters the dam.

The outflow from the Munmorah Ash Dam enters the inlet canal via siphons and settling ponds and flows to Lake Budgewoi. This system is designed to retain the ash in the ash dam and minimise total suspended solids (TSS) concentrations in the discharge from the dam. The ash dam discharge is diluted by the cooling water flow through the canal.

The finer fly ash, collected from the exhaust gases in fabric filters before they are discharged from the chimney, is transported to Vales Point Ash Dam for storage. This operation would continue while there is available storage capacity in the Vales Point Ash Dam. This water stream is incorporated in the Vales Point Ash Dam water management system. While the majority of this water is then beneficially used for ash transport at Vales Point, any surplus water from this system is discharged to Lake Macquarie via the Vales Point outlet canal.

Ash management plans for Delta Electricity's Central Coast Power Station operations are reviewed on a five yearly basis. The most recent management plan was prepared in 2009 and covers the period from 2009 to 2014. Further discussion of the beneficial use and management of surplus ash is provided in Chapter 9.

To maintain the salt water environment of the ash dam during times of low power production at the power station, lake water is pumped from the inlet canal to the ash dam through the ash transport system. A minimum flow of 17 ML per day lake water is provided to the ash dam at all times.

## 8.2.6 Groundwater

Groundwater in the power station area is protected from surface effects by paved working areas and the use of concrete lined drains to transport wastewater.

Site run-off water is directed to treatment plants, such as an oil/water separator and/or settling ponds to

remove particulates. The treated water is then sent to the ash dam, which acts as a final holding pond before the water is discharged to the inlet canal.

The Munmorah Ash Dam was constructed over wetlands that occurred around Colongra Creek and adjacent to Lake Munmorah and are within the property boundary, which extends to the lake edge (Figure 8.2). The catchment for the ash dam is estimated to be 8.8 km<sup>2</sup>. The dam embankment is homogeneous earth-fill approximately 1,800 m long with a maximum height of about 6.5 m.

Discharge of surplus water from the dam to the Munmorah inlet canal occurs via siphons installed through the dam wall. Seepage water is collected by a system of concrete lined toe drains that direct the water to the cooling water inlet canal.

### 8.2.7 Salt water cooling system

Munmorah Power Station draws cooling water for condenser cooling from Lake Munmorah via a 1.8 km canal that connects Lake Munmorah to Lake Budgewoi. Cooling water is drawn from the inlet canal and passes through the system absorbing waste heat from the steam cycle. This warmed water is discharged back into the outlet canal and flows to Lake Budgewoi.



Plate 8.1 – Cooling water screens and outlet canal

Trash racks are located in the cooling water inlet to prevent large debris entering the screening system. Collected debris is removed for disposal in the ash dam. The screening system diverts material (>10mm) that passes through the trash racks. Screened aquatic life is flushed back into the lake system (Section 8.7.3).

Elevated temperatures are experienced in the outlet canal when the power station is operating. The temperature rise is dependent on electricity generated, ambient temperature and use of attemperation flows when necessary.

The cooling waters are treated with antifouling products (Section 8.3.6). The condensers have been constructed with aluminium brass tubes and through mechanical cleaning to reduce fouling, trace amounts of elements such as copper, and any debris from the condenser tubes is released with the cooling waters.

The operation of the cooling water system relies on the water flow between Lake Budgewoi and Lake Munmorah. The channel between the two lakes at Budgewoi was deepened at the time of construction of the power station in order to provide sufficient capacity for the circulating water.

### 8.2.8 Chemical processes

Associated with the potential discharge pathways identified above, the chemicals identified in the following table are used to manage various water streams in the facility.

### 8.2.9 Key discharge pathways from Munmorah Power Station

There are a number of potential pathways from Munmorah Power Station as described above. There are three key discharge sources for the receiving waters:

- Munmorah Ash Dam discharge. The ash dam discharge is comprised of treated water from:
  - demineralisation plant
  - steam plant blowdown
  - domestic water services
  - stormwater runoff from potentially contaminated areas
  - coal stockpile runoff
  - ash dam disposal systems (furnace ash)
- clean stormwater runoff from roofs and vegetated areas which discharges directly to the inlet canal
- salt water cooling system discharge (temperature increase)

**Table 8.2 – Chemical processes**

Plant	Chemicals	Use	Mitigation measures
<b>Demineralisation plant</b>			
Water treatment and effluent sump	Sulphuric acid Sodium hydroxide (caustic)	Used for pH neutralisation	Stored in bulk tanks in bunded area
Resin	Amberjet™ 1500 H Resin	Removal of contaminants from potable water	Spent resin removed off-site to a specialist waste disposal site
<b>Boiler</b>			
Chemical injection	carbohydrazine Ammonia	Maintain concentrations of dissolved oxygen	Stored in bulk tanks in bunded area
	Hydrogen	used in generators	Hydrogen plants have been decommissioned delivered in cylinders
<b>Cooling water</b>			
Auxiliary cooling water	Antifouling biocide - N-trimethyldiamine acetate	Prevention of marine growth	Stored in bulk-bins in a stainless steel bund
Salt water cooling	Corostock B75 Bromide pellets	Corrosion inhibitor	Portable blue tanks
	hydrex 2470	Prevention of marine growth inside the condenser tube	Stored in plastic tanks in a bunded area
Antifoaming	No chemicals – salt water sprays only (CW, May 2008)	Management of excessive foam production	No chemicals used

### 8.3 Water Management Issues

In 2006 the Central Coast experienced severe water restrictions and while these have eased, Delta Electricity has sought to reduce its use of drinking quality water for industrial purposes.

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 equivalent 'as built' (four units) power station's water use in the 1960s. The fresh water utilisation will be much more efficient than with the present two unit operation.

#### 8.3.1 Water supply issues


The domestic water supplies that are consumed by Munmorah Power Station are regulated by the Water Sharing Plan for the Central Coast Unregulated Water Sources 2009 which is made under Section 50 of the *Water Management Act 2000*.

The Water Sharing Plan identifies that Munmorah Power station is within the Tuggerah Lakes Extraction Management Unit, which consists of the following water sources:

- Wyong River Water Source
- Tuggerah Lakes Water Source
- Ourimbah Creek Water Source (Water Sharing Plan for Ourimbah Creek Water Source 2003)
- Jiliby Jiliby Creek River Water Source (Water Sharing Plan for Jiliby Jiliby Creek Water Source 2003).

The operations within the Munmorah land holding are governed by the Basic Land Holder rights discussed in Part 5 of the Plan. Beyond these rights, Munmorah does not currently hold any special licences for water extraction. Domestic supplies are obtained through the domestic water supply.

Central Coast Water Supply Authority (operated by Wyong and Gosford Councils) controls the distribution of the allocated water resource. The availability of water to be taken from these water sources and the



management of the long-term average annual extraction of water limit in these water sources is provided through local water utility access licences held by Wyong Council. The Wyong local water utility has an allocation of 36,750 ML per year. Around 70% of the domestic water consumption comes from domestic users and the remaining 30% from non-domestic users.

Wyong Shire Council (WSC) has prepared an Integrated Water Cycle Management (IWCM) Sub-Plan (WSC 2007) to explore options for sustainably managing the provision of water supply, sewerage and stormwater services within the water supply catchment.

IWCM views urban water supply, sewerage and stormwater management in a single planning framework, in a whole of catchment context. An integrated approach to water management seeks to balance the competing demands on available resources within catchments to develop a strategy to ensure a sustainable water future.

The plan adopts an overall integrated strategy developed by the Gosford/Wyong Councils' Water Authority's (GWCWA), known as WaterPlan 2050 – An IWCM Strategy for the Central Coast.

### **WaterPlan 2050**

WaterPlan 2050 sets out the strategy to secure and sustain the Central Coast water supply system over the next 45 years. It contains a combination of actions to:

- further enhance the current water supply system
- continue to use water as efficiently as possible

- develop additional future sources of water.

Gosford City and Wyong Shire Councils formally adopted WaterPlan 2050 in July and August 2007.

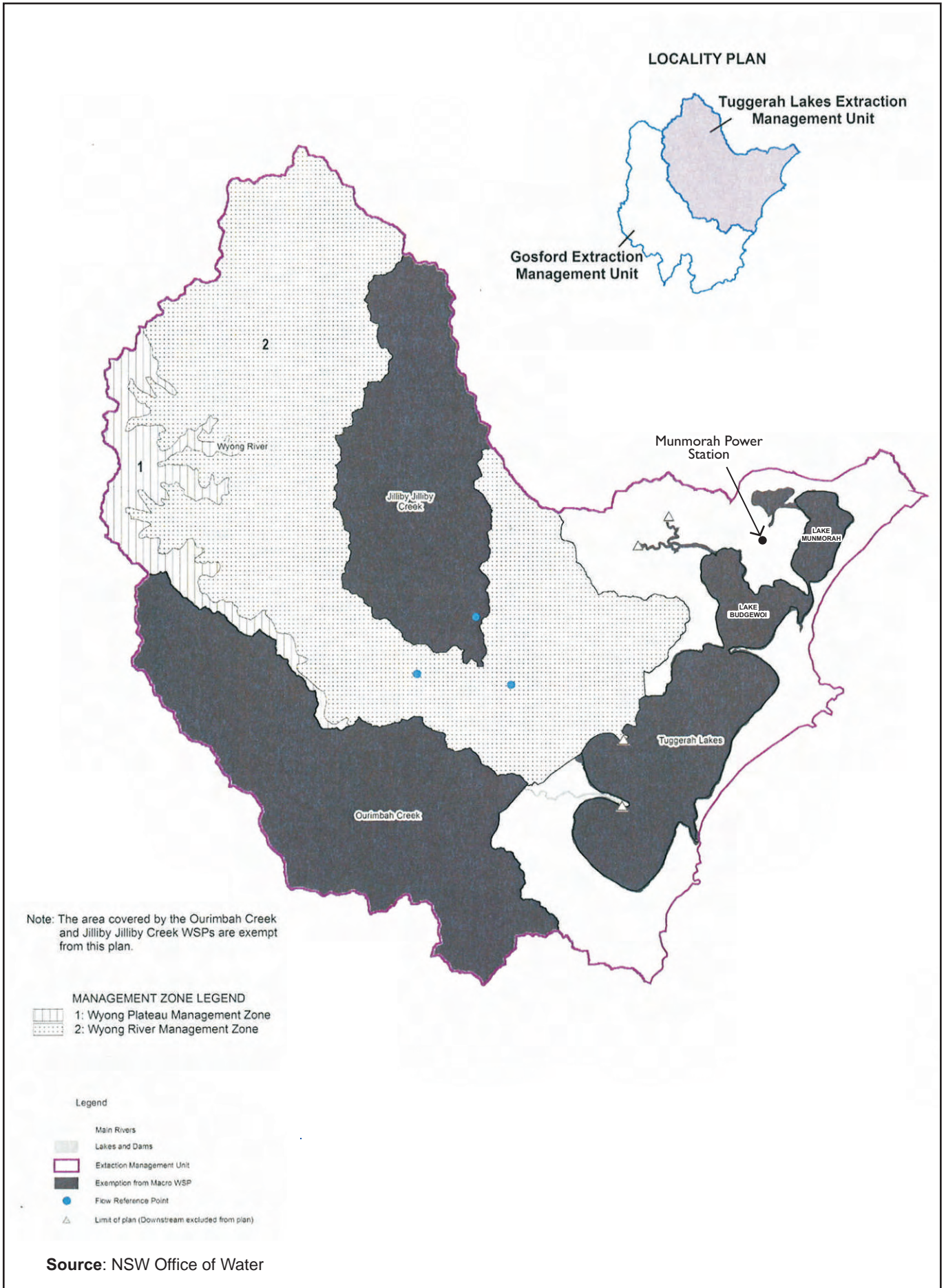
WaterPlan 2050 reported that while demand for town water on the Central Coast on a per capita basis has been steadily falling since the 1980s this has been offset by the Central Coast's growing population. The estimated population of the region is expected to increase from about 295,000 in 2001 to around 465,000 by 2051.

In response to the recent extended drought Gosford City and Wyong Shire Councils focused on the following key elements of our water supply system:

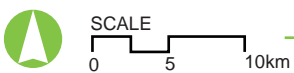
- system upgrades
- reducing demand
- accessing more water.

The Councils have also introduced additional sources of water to boost supplies including:


- construction of the \$37 million Hunter Connection which can deliver an annual daily average of 30 million litres of treated drinking water
- development of seven groundwater bore fields across the Central Coast to generate around nine million litres of drinking water a day
- a key part of WaterPlan 2050 is to encourage people to implement water conservation as a part of their everyday lives to achieve a sustainable reduction in demand compared to pre-restriction water usage.



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Munmorah Power Station **Refurbishment Environmental Assessment**  
**FIGURE 8.4:** Water Sharing Plan for the Central Coast Unregulated Water Sources



The Plan and Wyong Shire Council (WSC) through the Integrated Water Cycle Management (IWCM) Sub-Plan (WSC 2007) aims to achieve this through:

- mandatory water efficiency requirements
- increased uptake of water efficient appliances assisted by the provision of WSC rebates and industry water efficiency labelling schemes
- ongoing retrofitting of water efficient devices in homes and businesses
- continued community education to achieve permanent changes in how people use and value water
- continued use of mandatory Water Management Plans for businesses and organisations using more than 3.5 million litres of water a year
- continued active leak detection and repair programs to help further improve the overall efficiency of the water supply system
- continued water pressure reduction and management programs to help further reduce medium to long-term demand for town water
- further implementation of cost effective stormwater harvesting projects to generate additional water for non-drinking purposes such as irrigation of parks and sporting facilities
- additional recycled wastewater projects for non-drinking purposes such as irrigation, public toilet flushing and distribution to industrial users and businesses.

WaterPlan 2050 also includes a strategy to provide additional sources of water. Gosford and Wyong Councils plan to continue to transfer water between Hunter Water and the Central Coast via the pipeline connection until our total dam storages have recovered.

The plan notes that after the Central Coast recovers from the current drought the two-way link would remain a key measure to effectively manage the supply of water between the two regions. Other sources of additional water include groundwater and rainwater.

Other proposed supply enhancements include building the link between Mardi and Mangrove Creek Dams to provide access to more water and make the overall supply system more effective and sustainable, especially during years of above average rainfall.

Following this, the most feasible sources of additional water, should it be required would be highly treated recycled water and desalinated seawater.

Development consent was sought from the State Government for a 20 million litres a day plant so it could be constructed in an appropriate timeframe should it be needed over the next 45 years. The State Government granted conditional approval for the plant in July 2007.

WSC's current and planned urban water cycle management practices include large scale effluent recycling, water conservation education and rebate programs and investment in rainwater and stormwater harvesting opportunities. The adopted scenario in the Sub-Plan, fulfil Wyong's contribution to this requirement.

### **8.3.2 Delta Electricity's role in regional water management**

Munmorah Power Station is classed as an existing industrial consumer in the allocations made by Wyong Council.

A number of water saving measures have been implemented at Delta Electricity's Central Coast power stations. These have included:

- replacing drinking quality water used in cooling systems at Vales Point Power Station with seawater – a saving of up to 234 million litres a year
- implementing water efficiency measures, such as retrofitting showers and taps with water saving devices saving up to 10 million litres a year
- the construction of a \$7 million water reclamation plant which would save up to 230 million litres per year.

Delta Electricity's potable water saving initiatives at the Central Coast power stations has been estimated to have saved around 500 million litres per annum, compared to the potable water consumption in 2005.

While the power station's domestic water usage is dependent on generation levels, Delta Electricity, in consultation with Wyong Council, is continuing to review options for further water savings across the Central Coast. These are outlined in the current Water Management Plan for the site.

Recent initiatives at Munmorah have included:

- replacement of all shower heads with AAA type heads across its two sites in 2006/2007 (134 showers at Munmorah)
- dual flushed systems for new or defective toilets (ie 98 toilets and 32 urinals (manual) at Munmorah)
- replacement of water based cleaning with other forms of cleaning except where occupational health and safety concerns exist, such as cleaning of the dust extraction plant.

The estimated saving at Munmorah is approximately 145 ML per year.

### 8.3.3 EPL – receiving waters

Munmorah Power Station operates under Environment Protection Licence (EPL) No. 759 issued under the POEO Act (refer Section 4.3.2). The EPL sets emission and operational limits and monitoring requirements for the power station. In regards to water, the licence sets out the following concentration limits:

- cooling water discharge to Lake Budgewoi – temperature of 35°C, with an allowance for temperatures to reach 37.5°C for up to 1.5% of the time
- ash pond discharge to the inlet canal – pH in the range 6.5 to 9.5 and a total suspended solids limit of 50 mg/L. Delta Electricity is also required to report minimum and average data.

Under the EPL, the power station cooling water is licensed to discharge flows up to 4,750 ML/day. The ash pond discharge to the inlet canal can reach 50 ML/day.

### 8.3.4 Water quality guidelines

The ANZECC (2000) water quality guidelines are considered a relevant guide to assess the potential water quality impacts. The guidelines relevant to emission from Munmorah are listed in Table 8.3. These apply to areas outside of the mixing zone and.

The Guidelines suggest that the median temperature of the discharge, outside the mixing zone, be less than the 80<sup>th</sup> percentile of the background temperature. The dissolved oxygen guidelines are for percent saturation, which is suggested as not being less than 80% or above 110%. The Guidelines for temperature and dissolved oxygen do not apply to the

outlet monitoring site, which is located within the mixing zone in the immediate outlet area.

There are no ANZECC (2000) water quality guidelines for salinity, Secchi depth (water clarity) or zooplankton.

**Table 8.3 – ANZECC water quality guideline for protection of aquatic ecosystems**

Parameter	ANZECC Marine Guideline (2000)
	95% Level of protection
Temperature (°C)	(1)
Salinity (‰)	-
Dissolved Oxygen (sat. %)	80 – 110
Secchi Depth (m)	-
Zooplankton (# individuals/m <sup>3</sup> )	-
<b>Element (µgL<sup>-1</sup>)</b>	
Nitrate + Nitrite	15
Total Phosphorous.	30
Reactive Phosphorous.	5
TSS (1)	10.0
pH	7.0-8.5
<b>Metals &amp; Metalloids (µgL<sup>-1</sup>)</b>	
Cadmium	0.7
Chromium (CrIII)	27.4
Chromium (CrVI)	4.4
Copper	1.3
Lead	4.4
Manganese	-
Mercury (inorganic)	0.1
Nickel	7
Selenium (SeIV)	3 (2)
Silver	1.4
Zinc	15

NOTE: (1) Plume median outside mixing zone < background 80<sup>th</sup> percentile (2) Interim Guideline ANZECC (2000)

## 8.4 The Tuggerah Lakes System

The Tuggerah Lakes system has been described in a number of studies (Inter-Departmental Committee 1979, CSIRO 1990, CSIRO 1999, Roberts 2001). The lakes were formed by the establishment of a dune barrier between the lakes and the ocean, and comprise three interconnected coastal lagoons (Lake Munmorah, Lake Budgewoi and Tuggerah Lake), which connect to the sea by a narrow channel located near the southeast corner of Tuggerah Lake (Figure 8.5). The physical characteristics of the lakes are outlined in Table 8.4.

The catchment of the larger Tuggerah Lake accounts for around 90% of the system catchment area and receives the majority of the catchment runoff. The catchment of Lake Budgewoi accounts for some 6% of the total catchment area and is fed by Wallarah Creek while the smaller Lake Munmorah accounts for around 4% and is fed by small streams and local runoff. The mean depths of the lakes are similar

ranging between 1.6 and 1.8 m. The interchange of water between the lakes and the sea is small with about 1% tidal exchange reported (CSIRO, 1990).

Exchange between the lakes is dominated by wind driven mixing and exchange between Lakes Munmorah and Budgewoi is significantly enhanced by the power station cooling water.

West of the lakes, the catchment has a largely gentle to hilly topography draining into the three major rivers and low floodplains surrounding the lakes. The catchment has been subject to the effects of rapid development since the 1950s with the population growing from 13,079 in 1954 to an estimated residential population of 146,589 in 2008 (ABS 2007).

Mardi Dam, an off-stream storage within the Tuggerah Lakes catchment, is the principal water supply for the region. It is built on a tributary of Deep Creek, which flows into Wyong River and stores water pumped from both Wyong River and Ourimbah Creek.

**Table 8.4 – Physical characteristics of Tuggerah Lakes**

Lake	Surface Area	Volume	Mean depth	Shoreline Length	Catchment Area	Ratio of Lake to Catchment
	km <sup>2</sup>	10 <sup>6</sup> m <sup>3</sup>	m	km	km <sup>2</sup>	
Tuggerah	58.0	91.3	1.6	60	599.5	1:10.3
Budgewoi	11.2	17.9	1.6	30	42.0	1:3.7
Munmorah	7.8	14.0	1.8	15	28.5	1:3.7
<b>Total</b>	<b>77.0</b>	<b>123.2</b>		<b>105</b>	<b>670.0</b>	<b>1:8.7</b>

Source: CSIRO 1990

### 8.4.1 Tuggerah Lakes recreational values

#### Existing system

Tuggerah Lakes is used for numerous recreational activities including recreational fishing, sailing, power boating and jet-skiing. The shallow depth of the lake restricts the use of larger marine craft that prefer to use Lake Macquarie to the north. In addition, a number of business operations including caravan parks and hotels rely on the Tuggerah Lakes system.

Recreational fisheries are widely distributed around the lake waters. The Tuggerah lakes area is also regarded as one of the best regions in Australia for amateur prawn fishing. While prawning can occur anywhere on the three lakes the major commercial

and popular prawning areas are within Tuggerah Lakes and the Western Half of Lake Budgewoi.

Most of the lake foreshores are surrounded by grass, light timber or scrub. Sandy shores utilised by recreational users include areas around southern and eastern Budgewoi, Freemans Beach, northern Halekulani, Gorokan, south of Rocky Point, and around The Entrance. A large percentage of the surrounding shores are built up (although not necessarily waterfront properties), and this includes areas near Munmorah Power Station. Public access is available to most areas, where recreational activities such as fishing, boating and swimming occur.



The channel between the two lakes at Budgewoi was deepened at the time of construction of the power station to provide sufficient capacity for the circulating water.

The power station cooling water system and its effects on the lakes has created a focal point for commercial operations associated with recreational activities in the northern lakes (Tuggerah Lakes Estuary Management Study, 2006).

The recreation features of the Lakes are provided in Figure 8.5 (NSW Maritime 2007).

### Impact assessment

The main potential for impacts on recreational activities within the Tuggerah Lakes is related to exposure to contaminants or oil spills and through business losses in the event of a significant environmental incident from Munmorah Power Station.

As an operating power station, the site has well established environmental protection systems and emergency response procedures should an incident occur. This includes primary and secondary containment of potentially contaminated waste streams and measures to contain and remove contaminants in the event of an incident. These systems are subject to routine internal and external audits and continual improvement measures where risks are identified.

Safeguards, such as settlings ponds and oil containment booms, are in place to contain any discharges of oil and contaminants and prevent contaminants flowing to the lake. Impacts of the power station operations are therefore expected to be minimal.

Potential impacts to commercial or recreational fishing and have been discussed in Section 8.6.3.

## 8.4.2 Munmorah through-flow system

### Existing system

Munmorah Power Station was built between Lake Munmorah and Lake Budgewoi in the 1960s, commenced operating in 1967 and was fully operational by 1969.

A training wall was installed at the outlet during construction of the original plant in the 1960s to increase mixing with cooler lake water in the discharge area. The wall deflects the plume away

from the seagrass beds on the western side of the wall and generally away from the beds on the north western and western side of Lake Budgewoi.

### Discharge characteristics

The power station draws cooling water for condenser cooling from Lake Munmorah via a 1.8 km long inlet canal and discharges the warm water (up to 9.5°C warmer) via an outlet canal to Lake Budgewoi. This is referred to as a 'once-through' cooling system.

The discharge depends on the number of generating units operating. The flow through system typically discharges 1,175 ML/day (13.6 m<sup>3</sup>/s) for one unit and approximately 2,350 ML/day (27.2 m<sup>3</sup>/s) for two units. Other flows enter the system from catchment inputs and power station ash management operation.

The power station's cooling water system is currently licensed for discharge up to 4,750 ML per day.

### Plume characteristics

The waste heat energy from the power station is discharged to Lake Budgewoi and subsequently dissipates to the atmosphere and mixes with cooler ambient lake water. As the warm water discharges from the outlet it forms a 'heated surface water plume' entraining lake water at the undersides and sides of the discharge plume causing it to spread laterally. Due to mixing with the cooler lake water and heat loss through the water surface to the atmosphere, the warm water cools rapidly as it spreads from the outlet into Lake Budgewoi (CSIRO 1990).

Figure 8.6 shows a typical plume temperature section from the discharge point at the end of the outlet canal some 3 km to the middle of Lake Budgewoi and is representative of the 'current system'. The plume was measured in summer 2009. At the time of this survey two units were generating power (522 MW). The temperature increase was 10°C at a discharge of 2,350 ML/day. A plan view of the 2009 cooling water plume is provided in Appendix F.

The warmest part of the cooling water plume (up to +5°C above ambient water) is limited to an area extending to a distance of approximately 1 km from the outlet. Beyond this area, the 'mid-field' plume extends to Buff Point where temperatures approximately +2°C to +3°C above ambient temperature typically occur. The temperature rise at the outlet during two unit operation has been reported as being in the order of 7°C (Roberts 2001).

A typical cooling water plume temperature distribution for Munmorah representative of the 'as built' power station operating at levels similar to the rehabilitated station is shown in Figure 8.7. This plume was measured on 7 January 1987. At the time of the survey, three units were operating at between 573 MW to 653 MW, the wind was generally from the north east and the air temperature varied between 26°C and 30°C. Operation of the third unit is equivalent to having two units operating with attemperation. The heat rejection from the power station in 1987 is therefore similar to that expected to result from the rehabilitated two unit 700 MW plant (Aurecon, 2009).

Table 8.5 provides the characteristics of the plume measured in January 1987.

The cooling water plume was mapped in January 2009 when the turbines were less efficient and the cooling water temperature rise was about 10°C. Although the generation (522 MW) was lower than in 1987 (573 MW to 653 MW), the plume temperatures

were higher and the extent of the plume was larger in 2009.

The January 1987 plume was used by CSIRO (1990) as part of their estimation of reject heat to Lake Budgewoi for two unit operation. However, as this recorded plume does not represent the existing 'worst case' cooling water plume resulting from the operation of Munmorah Power Station, plume modelling (discussed below and in Appendix F) was undertaken in order to compare the proposed rehabilitation changes with the existing situation (discussed in Section 8.7).

The cycling flow between Lake Budgewoi and Lake Munmorah results in a small temperature rise at the cooling water inlet in Lake Munmorah. Typically the increase is less than 1°C but under certain conditions may be up to 2°C. The higher temperatures occur during unusually hot summer conditions when the power station is operating at high loads.

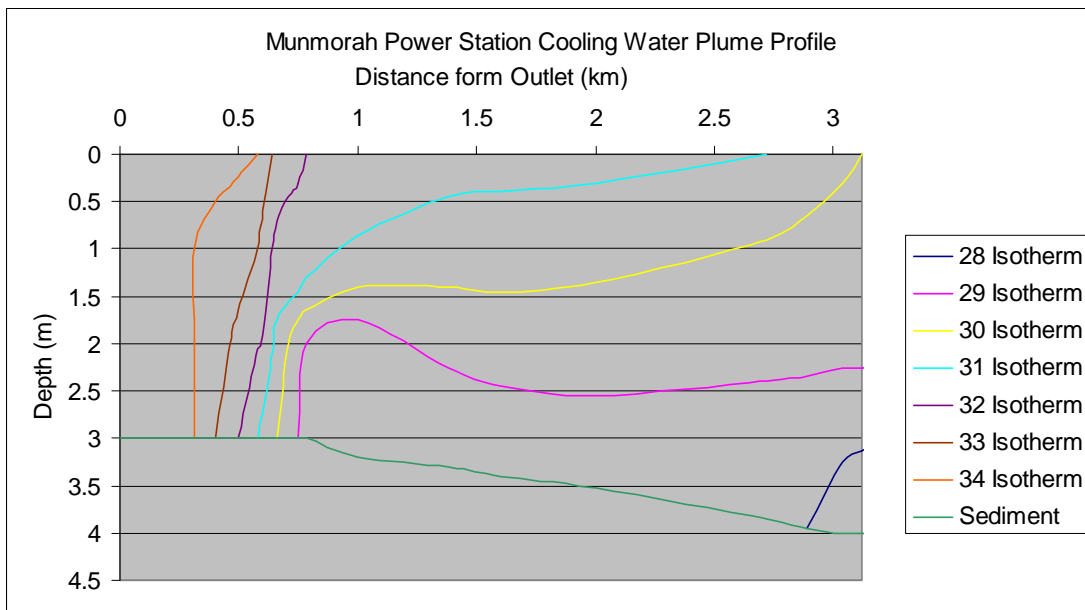
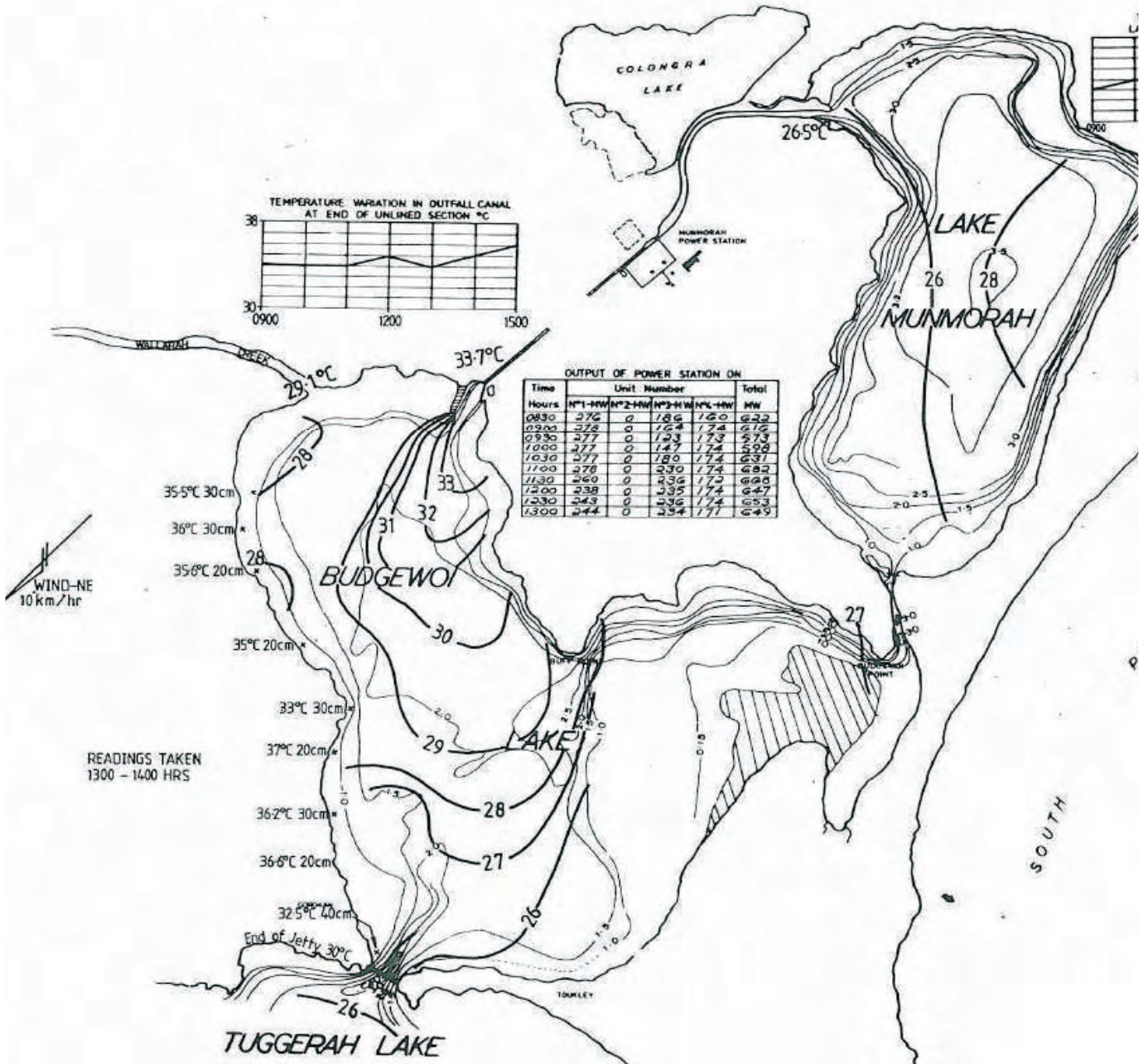


Figure 8.6 – Munmorah Power station Cooling Water Plume Profile (as measured by Aurecon in January 2009)



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**Table 8.5 – Plume Characteristics as measured in January 1987.**

Parameter	Min	Max	Mean
Time	09:30 hrs start	11:52 finish	
Generation (MW)	573	665	619
Ambient Temp (°C)	NA	NA	NA
Inlet Temperature (°C)	25	27	26.3
Outlet Temperature (°C)	34	36	34.6
Wind speed (m/s)	10	12.5	12
Wind Direction (deg)	90	135	128

### Dispersion modelling

The purpose of the modelling was to provide an indication of the likely plume temperature distributions that have occurred under ‘as built’ worst case conditions, for comparison with the predicted ‘worst case’ plume following the proposed rehabilitation works.

The modelling work was carried out by Cardno Lawson & Treloar (CLT) and is described in Appendix F. The Delft 3D model has been widely used to model similar heated discharge systems and was adapted to the Budgewoi and Munmorah Lakes water area to simulate the plume dispersion for a number of scenarios incorporating operational regimes and weather conditions.

The model horizontal resolution varies from the smallest cells of around 10 m near the outlet (where the largest temperature gradients occur) to larger 50 by 50 m cells in Lake Munmorah. It uses 10 vertical layers to resolve the vertical gradients in currents and temperature. The surface heat fluxes are controlled by meteorological data collected at the power station (wind, net solar radiation, air temperature, relative humidity, air pressure) and the water level and temperature are specified at the model open boundary, at Toukley Bridge between Lake Budgewoi and Tuggerah Lake.

Highest temperatures are known to occur in the warmer summer months during periods of clear hot days, low rainfall and light winds. These conditions have been assumed for the ‘worst-case’ scenario.

The following assumptions and characteristics were used in the model:

- the average maximum summer background lake temperature was taken as 28°C

- cooling water inlet and outlet temperatures at Munmorah and meteorological data at Munmorah Power Station during January/February 2001 were used as they had the worst case of prolonged air and water temperatures
- worst case wind speed and direction was set at north to easterly to mimic summer conditions that would direct the plume to the seagrass beds on the southern side of Lake Budgewoi. A continuous period of 23 hours of north to easterly wind at high air temperatures during the day time were used as the worst case
- condenser temperature rise for the ‘as built’ 1969 power station was 8.3°C
- the rehabilitated condenser temperature rise was assumed to be the same as the original design of 8.0°C
- cooling water flows used for four units was assumed as 4,700 ML/day, and for two units 2,350 L/day was used when the cooling water plume was not attemperated with an additional flow of 1,175 ML/day when two attemperation pumps operate during two units in operation. The four unit power station as built, operating at maximum output had no capacity to attemperate the cooling water plume.

The model was verified, as described in Appendix F, using:

- a two unit plume mapped on 15 January 2009 when the generation was 522 MW
- temperature profiles recorded at the cooling water inlet in Lake Munmorah, cooling water outlet and in the middle of Lake Budgewoi and at five sites in the seagrass beds on southern Lake Budgewoi

- Munmorah Power Station climatic data for the period 1 January to 15 January 2009.

*Model runs*

Modelling was undertaken to determine the extent of the Munmorah Power Station cooling water discharge plume under various scenarios as summarised in Table 8.6. Modelling was undertaken for the unattemperated 'as built' four unit 1,400 MW power

plant at full load (Scenario 1). The downgraded power station plumes for the 'as built' two unit 700 MW plant at full load, for attemperated and unattemperated conditions were generated (Scenarios 4 and 5 respectively). The rehabilitated power station plumes for the two unit 700 MW plant, for attemperated and unattemperated conditions were also modelled (Scenarios 2 and 3 respectively). The cooling water discharge rate and excess temperatures for each scenario are also provided in Table 8.6.

**Table 8.6 – Model scenarios runs**

Scenario Number	Power Station Output	Units / Pumps	Cooling water discharge (ML/day)	Cooling water excess temperature (°C)
1	As Built 1400MW - unattemperated	4/8	4700	8.3
2	Rehabilitated 700MW - unattemperated	2/4	2350	8.0
3	Rehabilitated 700MW - attemperated	2/6	3525	5.33
4	As Built 700 MW - unattemperated	2/4	2350	8.3
5	As Built 700 MW - attemperated	2/6	3525	5.53

*Plume dispersion*

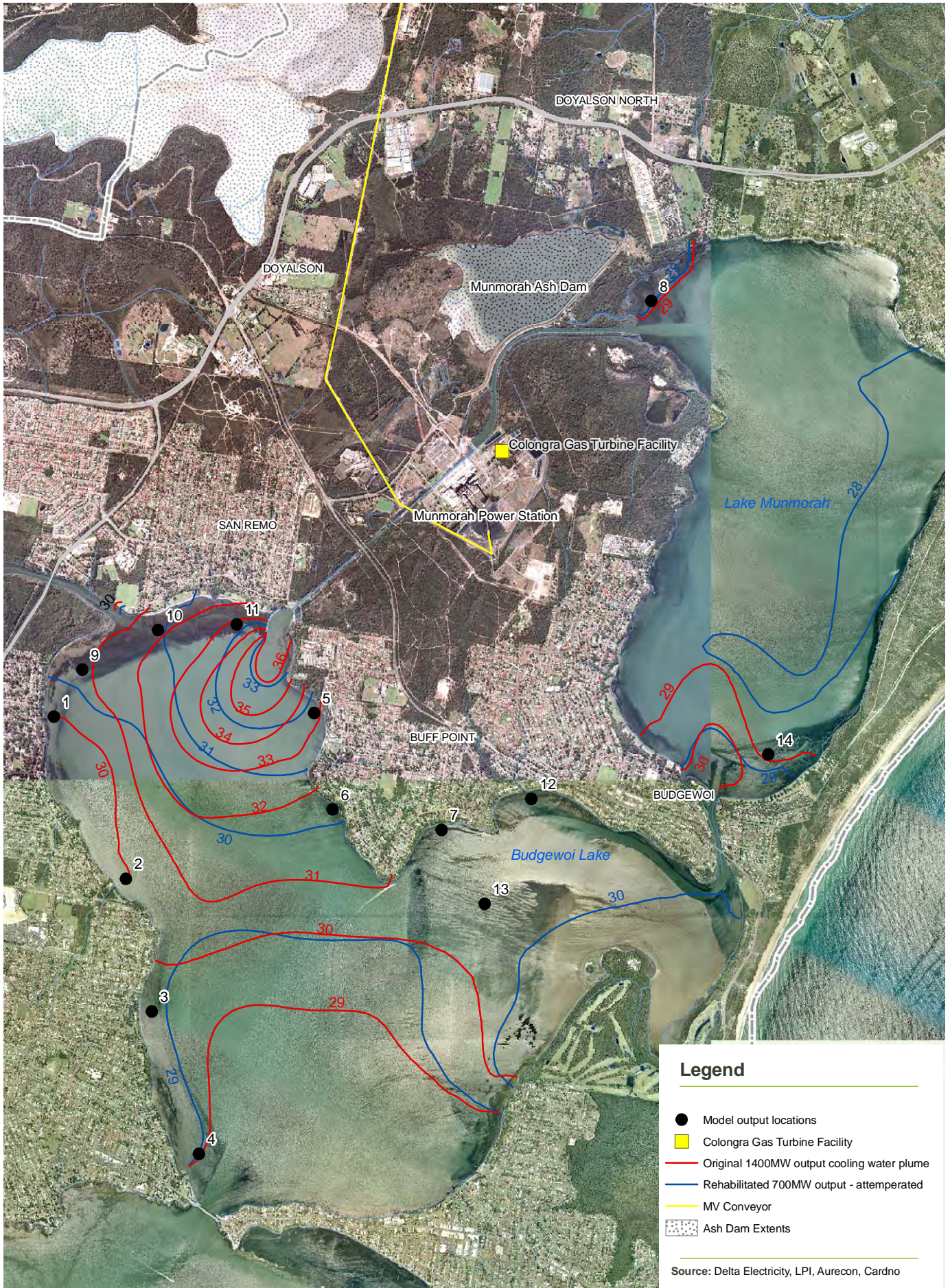
Dispersion of the heated discharge into the receiving waters of Lake Budgewoi, Tuggerah and Munmorah is controlled by the water currents (hydrodynamics) and the atmosphere – water heat transfer. The hydrodynamics control water transport and mixing between water parcels and the surface heat fluxes control the rate at which thermal energy is either gained or lost through the water surface.

The model results for the 'as built' and 'rehabilitated' scenarios were compared for the similar operating regimes. Scenario 2 and Scenario 4 were compared for the unattemperated 700 MW system, while Scenario 3 and Scenario 5 were compared for the attemperated 700 MW system. Scenario 1 was undertaken to establish the worst case conditions for the as built 1,400 MW power station.

The model predicted a much smaller cooling water plume for the downgraded two units compared to the original four unit operation (Figure 8.8).

It was also predicted that the worst case outlet temperature of the two unit, unattemperated refurbished power station plume 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. The difference was so small it made little difference to the plume temperature distribution or recirculation (Figure 8.9).

The attemperated, rehabilitated plume was about 3°C cooler at the outlet than the unattemperated plume but quickly cooled to have similar temperature rises in Lakes Budgewoi and Munmorah. As for the unattemperated plume, the refurbished attemperated plume had a slightly smaller extent than the 'as built' attemperated plume (Figure 8.10).


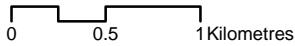


**Legend**

- Model output locations
- Colongra Gas Turbine Facility
- Original 1400MW output cooling water plume
- Rehabilitated 700MW output - attemperated
- MV Conveyor
- ▨ Ash Dam Extents

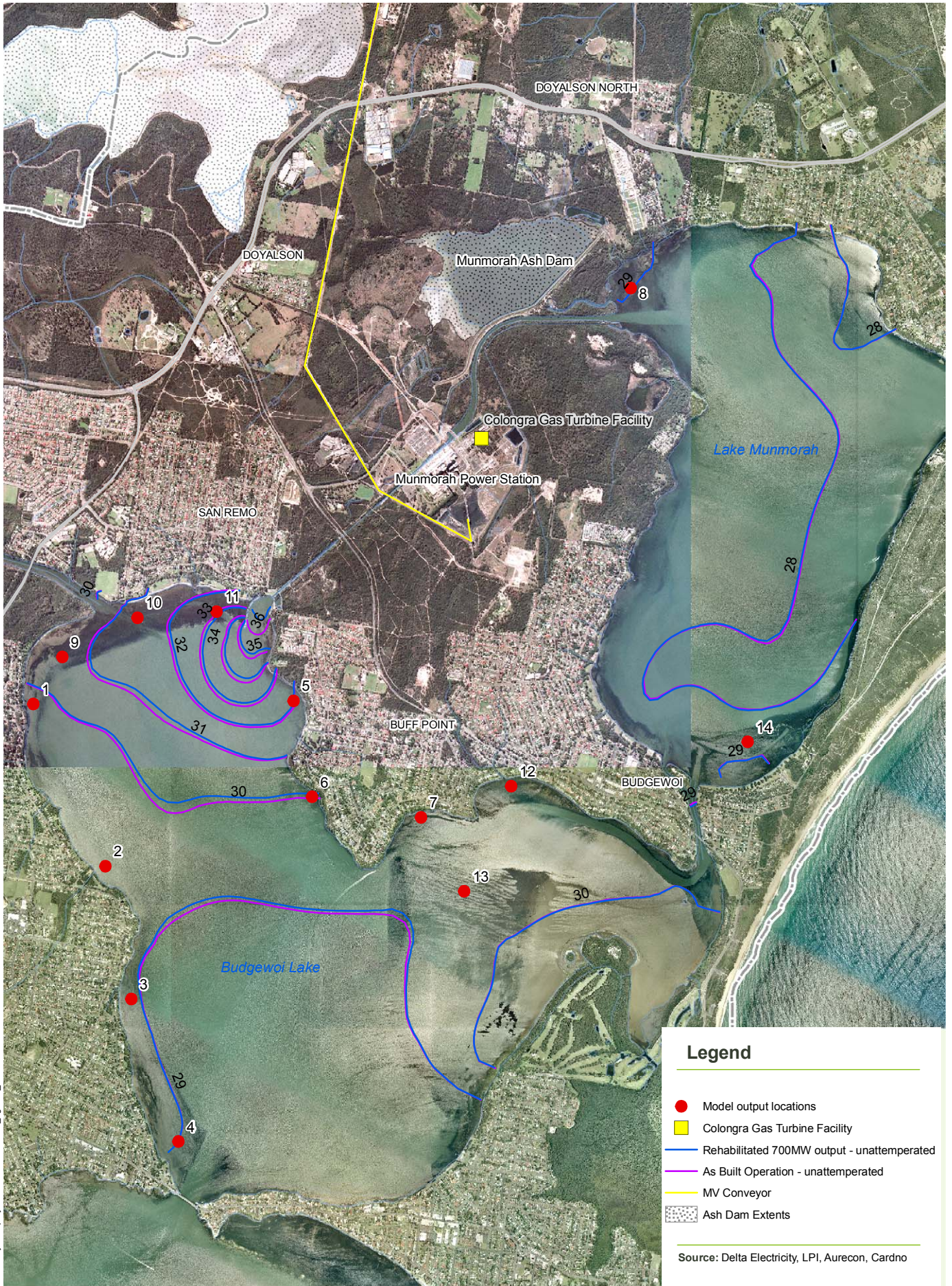
Source: Delta Electricity, LPI, Aurecon, Cardno

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 Projection: MGA

Munmorah Power Station **Rehabilitation Environmental Assessment**

**FIGURE 8.8:** Modelled Refurbishment 700MW Attemperated Cooling Water Plume compared to 1400MW output



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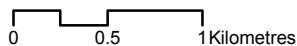
**Legend**

- Model output locations
- Colongra Gas Turbine Facility
- Rehabilitated 700MW output - unattenuated
- As Built Operation - unattenuated
- MV Conveyor
- Ash Dam Extents

Source: Delta Electricity, LPI, Aurecon, Cardno



SCALE 1:40,000 @ A4



Projection: MGA

Munmorah Power Station **Rehabilitation Environmental Assessment**

**FIGURE 8.9:** Modelled Refurbishment 700MW Unattenuated Cooling Water Plume