Appendix G

Water Quality Calculations

Contents

1. Calculation of Combined Temperature Changes

The combined discharge temperature was calculated according to the following formula:

Combined Discharge Temperature = (A/C x A_t) + (B/C x B_t)

The temperature difference from the lake input was calculated according to the following formula:

Temperature Difference from Lake Input = Combined Discharge Temperature - A_t

Where:

A is the flow rate in L/s of Stage A

B is the flow rate in L/s of Stage B

C is the combined flow rate of Stage A + B

A_t is the output temperature of Stage A

B_t is the output temperature of Stage B

	Stage A		Stage B		Combined (Stages A & B)		
	Flow (L/S)	**Outlet Temperature (deg C)**	**Flow (L/S)**	**Outlet Temperature (deg C)**	**Flow (L/S)**	**Combined Discharge Temperature (deg C)**	**Temperature Difference from Lake Input (deg C)**
Equation Reference	*A*	*At*	*B*	*Bt*	*C*		
Design	11550	25.1	217	29.4	11767	25.2	0.08
Hot Day	11550	33.1	271	29.9	11821	33.0	-0.07
Cold Day	11550	13.3	168	18.5	11718	13.4	0.07

2. Calculation of Concentration Factor

Most water quality parameters (aside from phosphorus and peracetic acid which are added as biocides and antiscalents) are concentrated due to evaporation rather than an added quantity during the cycling process a concentration factor was calculated to determine the combined discharge of various water quality parameters once Stage A and B were combined. The concentration factor of output parameters from Stage A and Stage B was calculated according to the following formula:

Concentration Factor = (A/C x CF1) + (B/C x CF2)

Where:

A is the flow rate in L/s of Stage A

B is the flow rate in L/s of Stage B

C is the combined flow rate of Stage A + B

Cf1is the concentration of Stage A

Cf2 is the concentration of Stage B

	Stage A		Stage B		Combined (Stages A & B)	
	Flow (L/S)	**Concentration Factor**	**Flow (L/S)**	**Concentration Factor**	**Flow (L/S)**	**Concentration Factor**
Equation Reference	*A*	*Cf1*	*B*	*Cf2*	*C*	
Design	11550	1	217	1.4	11767	1.007
Hot Day	11550	1	271	1.4	11821	1.009
Cold Day	11550	1	168	1.4	11718	1.006

Note:

Stage A is a once-through cooling system. Concentration of intake water is by a factor of 1.0 (per comm Angus McLennan 15/1/08)

Stage B concentration factor limited to 1.4 for control of system salinity and scaling (Section 2.6.1.1 of Tallawarra B Concept Design Draft Report, SKM Dec 2007)

3. Calculation of Combined Density & Salinity Changes for Low and High Lake Illawarra Salinity Scenarios

The combined discharge density was calculated under high salinity (32ppt) and low salinity scenarios (10ppt). As Stage A does not concentrate the salinity due to the once-through cooling system the discharge salinity of Stage A is the same as the input Lake Illawarra concentration. Combined discharge Salinity once Stage A and B are combined was calculated using the following formula:

Combined discharge Salinity = (Lake Salinity x Concentration Factor)

The concentration factor was calculated under each operating scenario in Step 2 above. Once the Combined Discharge Salinity was calculated density estimates for the combined discharge and input lake were obtained from Figure 4.8 of the Donker & Jirka (2007) Cormix User Manual (see below). Figure 4.8 uses the Salinity concentration and the associated temperature to determine the density as kg/m^3. The combined discharge temperature was calculated in Step 1 above.

The density change associated with Stage B from the Lake Illawarra input discharge was calculated according to the following formula:

Density Change = (Combined discharge density – Stage A density) ÷ Lake Illawarra density

	Lake Illawarra (Low Salinity)			Stage A Discharge			Combined Discharge			
	Temp (deg C)	Salinity (ppt)	Density (kg/m^3)	Discharge Salinity (ppt)	Temperature (deg C)	Density (kg/m^3)	Discharge Salinity (ppt)	Combined Discharge Temperature (deg C)	Combined Density (kg/m^3)	Density Change
Equation Reference			*	*Same as Lake (B)*	*From Step 1*	*		*Calculated in Step 1*	*	
Design	20	10	1006.7	10	25.1	1005.5	10.07	25.2	1005.5	**0.00%**
Hot Day	28	10	1004.2	10	33.1	1002.5	10.09	33.0	1002.5	**0.00%**
Cold Day	8	10	1009	10	13.3	1008.2	10.06	13.4	1008.2	**0.00%**

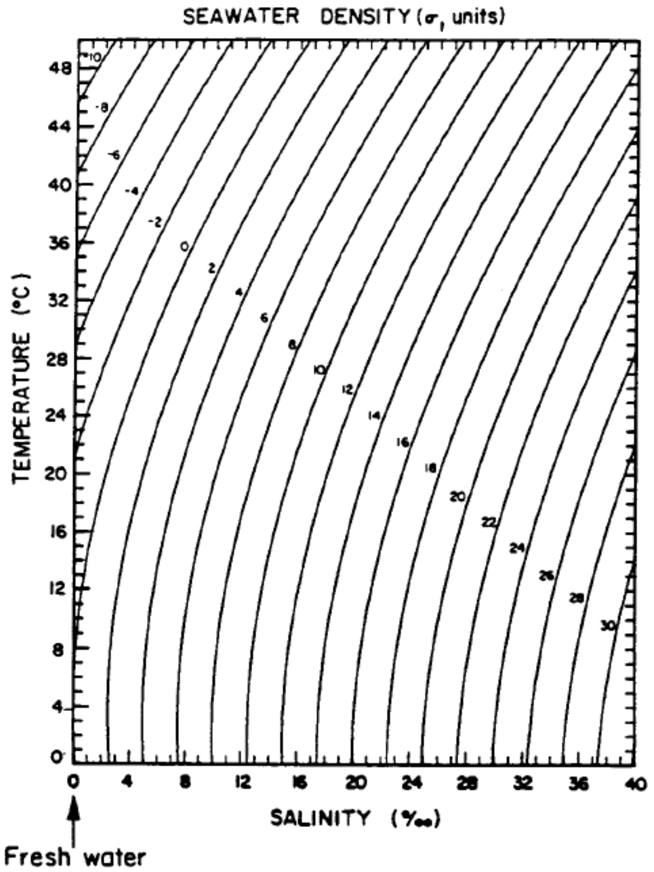
* Density calculated using the density calculation figure from Donker & Jirka (2007) using temperature and salinity.

Note: Stage A discharge and combined discharge Temp and Salinity virtually the same, hence Density will be virtually the same

	Lake Illawarra (High Salinity)			Stage A Discharge			Combined Discharge			
	Temperature (deg C)	Salinity (ppt)	Density (kg/m^3)	Discharge Salinity (ppt)	Temperature (deg C)	Density (kg/m^3)	Discharge Salinity (ppt)	Combined Discharge Temperature (deg C)	Density (kg/m^3)	Density Change
Equation Reference			*	*Same as Lake (B)*	*Calculated in Step 1*	*		*Calculated in Step 1*	*	
Design	20	32	1021.4	32	25.1	1019.8	32.24	25.2	1020	**0.02%**
Hot Day	28	32	1018.8	32	33.1	1017	32.29	33.0	1017.2	**0.02%**
Cold Day	8	32	1023.7	32	13.3	1023	32.18	13.4	1023.1	**0.01%**

* Density calculated using the density calculation figure from Donker & Jirka (2007) using temperature and salinity.

Density Calculation as a function of temperature and salinity (Donker & Jirka 2007)



Density [kg/m³] = 1000.0 + σ_t

Figure 4.3: Diagram for density of seawater as a function of temperature and salinity

Reference: Donker, R.L. and G.H. Jirka, "CORMIX User Manual: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters", EPA-823-K-07-001, Dec. 2007. Available for download at http://www.mixzon.com/downloads/

4. Calculation of Water Quality from the Combined Discharges of Stage A and Stage B

Mean water quality of Lake Illawarra (presented in the table below) was determined from the following available literature:

- Scanes, P., Coade, G., Doherty, M., & Hill, R., (2007) Evaluation of the utility of water quality based indicators of estuarine lagoon condition in NSW, Australia. *Estuarine, coastal and Shelf Science* **74:** 306:319;
- Monitoring, Evaluation and Reporting (MER) data (Mean 2007 – 2008);
- EPA Unpublished Report – South Coast Water Quality Report (Mean 1994 – 1996);
- EPA Unpublished Data (Summer 2003); and
- LIA (2006) Lake Illawarra Estuary Management Study and Strategic Plan. Prepared by WBM Oceanics Australia for Lake Illawarra Authority, Queensland

Parameter	Scanes et al. (2007) Mean Water Quality in Shallow Sub-Littoral Fringe 2002	Scanes et al. (2007) Mean WQ in Deep Mud Basin 2002	Scanes et al. (2007). Mean WQ between 1994 -1996	EPA Unpublished Data - Monitoring Evaluation and Reporting	EPA Unpublished Data -Scanes et al. (2007) Summer 2003	EPA Unpublished Data - EPA Unpublished South Coast Water Quality Monitoring Report	LIA (2006) Historic Mean Value
No_x (µg/L)	1.25	1	-	3	1	9	15
NH_3 Ammonia (µg/L)	6.88	-	-	13	7	9	
Total Nitrogen (µg/L)	470	420	340	302	470	340	300
FRP (Filterable Reactive Phosphorus) (µg/L)	2	-	-	32	2	-	5
Total Phosphorus (µg/L)	120	-	70	58	120	70	30
Salinity	34.7	-	26.1	-	-	-	25
Dissolved Oxygen (%sat)	98.85	97.35		-	-	-	-
Temperature (°C)	-	-	21.2	-	-	-	15-35
Turbidity (NTU)	7.05	7.6	5.1	-	-	-	5
Chlorophyll-a (µg/L)	6.96	15.24	6.3	-	-	-	5

Combined discharge water quality from Stage A and Stage B was calculated under the three alternative operating scenarios using the Concentration factor determined in Step 2 according to the following formula:

Combined Water Quality Parameter = (Concentration Factor x Mean Water Quality Parameter)

These concentrations were compared to the relevant ANZECC and LIA Management and Strategic Plan guidelines.

Parameter	Mean Water Quality	Combined Design Output	Combined Hot Day Output	Designed Cold Day Output	ANZECC (2000) Guidelines	LIA Estuary Management and Strategic Plan Guidelines (LIA 2006)
No_x (ug/L)	5.04	5.08	5.09	5.07	15	-
NH_3 Ammonia (ug/L)	8.97	9.04	9.05	9.02	-	-
Total Nitrogen (ug/L)	377.43	380.21	380.89	379.59	300	500
FRP (Filterable Reactive Phosphorus) (ug/L)	10.25	16.62	16.62	16.62	5	20
Total Phosphorus (ug/L)	78.00	86.15	86.15	86.15	30	50
Salinity	28.60	28.81	28.86	28.76	20-30	-
Dissolved Oxygen (%sat)	98.10	98.82	99.00	98.66	-	-
Temperature (°C)	21.20	21.36	21.39	21.32	-	-
Turbidity	6.19	6.23	6.24	6.22	1–20	-
Chlorophyll-a (ug/L)	8.38	8.44	8.45	8.42	15	4

*Mean water quality data obtained from Scanes *et al.* (2007); DECC Unpublished Data & LIA (2006).

5. Calculation of Worst Case Peracetic Acid Concentration

The mixing chamber is 892.9m^3, which enables it to contain 892900L when filled to capacity. Under all operating scenarios the flow rate of Tallawarra A is 1150L/sec. The flow rate from Tallawarra B depends upon the operating scenario, ranging from 168 L/sec to 271 L/sec. The time until the mixing chamber becomes full was calculated based on the combined flow rate per second at each operating scenario.

A total of 9mg/L of peracetic acid is to be dosed from Tallawarra B over a 15 minute interval, which equates to 0.01mg/L peracetic acid per second.

Operating Scenario	**Stage A Flow rate L/s**	**Stage B Flow rate L/s**	**Combined Flow L/s (Stages A & B)**	**Mixing Chamber (892900 L) Full Capacity Rate**	**Total Peracetic Acid (mg) Per 892900L**	**Total Peracetic Acid (ug/L)**
Design	11550	217	11767	75.8817 seconds	0.758817	0.000849
Hot Day	11550	271	11821	75.5351 seconds	0.755351	0.000845
Cold Day	11550	168	11718	76.1990 seconds	0.76199	0.000853

6. Calculation of Worst Case HEDP Concentration

The mixing chamber is 892.9m^3, which enables it to contain 892900L when full. Under all operating scenarios the flow rate of Tallawarra A is 1150L/sec. The flow rate from Tallawarra B depends upon the operating scenario, ranging from 168 L/sec to 271 L/sec. The time until the mixing chamber becomes full was calculated based on the combined flow rate per second at each operating scenario.

HEDP is to be dosed at 1mg/L based upon the blow down rate of Tallawarra B under different operating scenarios.

Blowdown rate = Flow rate ÷ cycles of concentration

	Flow Rate	Cycles of Concentration	Blow Down Rate	HEDP Concentration
	L/sec		L/sec	mg/sec
Design	217	1.4	155	155
Hot Day	271	1.4	193.5714	193
Cold Day	168	1.4	120	120

Operating Scenario	Stage A Flow rate L/s	Stage B Flow rate L/s	Combined Flow L/s (Stages A & B)	Mixing Chamber (892900L) Full Capacity Rate	Total HEDP (mg) Per 892900L	Total HEDP (mg/L)
Design	11550	217	11767	75.8817 seconds	11761.6635	0.013
Hot Day	11550	271	11821	75.5351 seconds	14578.2743	0.016
Cold Day	11550	168	11718	76.1990 seconds	9143.88	0.010