APPENDIX H10

LAGOON LEAKAGE ASSESSMENT 2006

ANGAS PROCESSING FACILITY

MISCELLANEOUS PURPOSES LICENSE APPLICATION 2019/0826

TERRAMIN

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Our Ref: 06009a

16 August 2006

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Mr Geoff Hodgson
Terramin Australia Ltd
28 Greenhill Road
Wayville SA 5034

Dear Geoff,

Re: Lagoon Leakage Assessment, DC Alexandrina Wastewater Treatment Lagoons

Introduction

AWE Projects Pty Ltd (AWEP) was commissioned by Terramin Australia Ltd (Terramin) to conduct an assessment of possible leakage from the DC Alexandrina wastewater treatment lagoons at Swamp Road, Strathalbyn, SA.

The aim of the investigation was to identify the potential for wastewater to leak from the ponds to the subsurface profile in the area targeted by Terramin for the underground mining of the Angas Deposit. Whilst the mine portal will be located on the Garwood Quarry property south of Callington Road, it is understood that the decline and stopes will be constructed under the lagoons at depths as shallow as 50m below ground level.

Background

The wastewater lagoons were constructed in the 1980's by the District Council of Strathalbyn, a precursor to DC Alexandrina (Council). Discussions were held with Council in July 2005 and information sought and provided regarding the construction of the lagoons, lagoon engineering and volumes of wastewater pumped to them. This included the provision of copies of design drawings of varying quality and completeness.

The lagoons hold about 120 megalitres of water and were constructed in about 1982. They consist of 1 large pond (area approx 5 ha) that was originally compartmentalised using fencing (this is largely broken or falling down), and another smaller lagoon termed the evaporation pond. Pond walls are about 2m in height, with wastewater impounded to within 1m from the top of the bund walls.

The lagoons were constructed by Heywood Earthmovers, and included the installation of a clay liner derived from locally won materials. We understand that the placement of the liner was coodinated by Council. Design drawings provided by Council indicate that excavation extended below the base of a clay layer identified, presumably by the logging of geotechnical investigation boreholes or test pits

drilled within the footprint of the lagoons. Council was not able to provide details of the geotechnical investigation (N Stynan, pers comm 11 Aug 2005). Design levels of the floors of the main lagoon and evaporation pond are shown on the drawings provided by Council to be 69.5m AHD and 70.4m AHD respectively. It was also stated that the lagoons store all town wastewater (except that used by the racecourse) without discharge to the watercourse (A Peachy, pers comm.). In addition, about 25kL/d of water is diverted to the racecourse in winter, with about 450 to 500 kL/d being discharged to the lagoons. In summer, both the racecourse and the lagoons receive about 250kL/d of wastewater. Wastewater from the lagoons is also used for olive grove irrigation and also for irrigation of the polo ground.

Scope of Work

Scope items formulated to assess possible leakage from the wastewater lagoons included:

- The installation of a groundwater investigation well into the uppermost water bearing unit
- The installation of a groundwater investigation well into the Cambrian age basement rocks
- The collection of core samples for laboratory vertical hydraulic conductivity analysis
- Test pumping and anlaysis
- The survey leveling of both wells
- The collection and analysis of water samples
- Seepage Modelling

Each scope item is described in more detail below.

Installation of Groundwater Investigation Wells

Two groundwater wells were installed in the swamp adjacent to the southern wastewater lagoon in the period 10 April to 12 April 2006. Both wells were drilled by a licensed water well driller (Geodrill). Well construction permits were obtained for each from the Department of Water Land and Biodiversity Conservation (DWLBC).

The shallowest well (permit number 116743) was drilled by solid flight auger to 4.3m below ground and intersected grey brown high plasticity clay, with minor sand and lithic pebbles to 2m and then dark grey weathered schist to total depth. Seepage flow was observed at about 1m. This well was backfilled with cuttings from 4.3m to 2.5m and then completed using 50mm screw threaded PVC casing from 2.5m to surface (slotted from 2.5m to 1m).

The deeper well (permit 116744) was drilled to 27m using a combination of auger and hammer (air circulation) and also encountered clays to 2m and then weathered schist to 11m, followed by moderately then slightly weathered mica schist to total depth. Push tube core samples were collected at depths of 0.5m, 1.0m, 1.5m and 2.0m.

Seepage flow was observed at 15m, but the air lift yield was low (rate too small to measure (RTSM)). Additional fracture derived inflow was not observed from 15m to total depth. This well was completed by backfilling with cuttings to 22.5m and then installing 100mm PVC screw threaded casing, machine slotted from 16.5m to 22.5m.

Solvents and adhesives were not used in the construction of these wells. Standpipes, end caps and standpipe protectors were fitted to both wells.

On completion, both wells were purged to remove cuttings, allowed to recover, and then depth to water measured.

Summary well completion logs are presented as attachments.

Survey Leveling

Both wells were surveyed to Australian Height Datum (AHD) by Allsurv Engineering Surveys Pty Ltd. Results are presented in Table 1 below.

Table 1. Survey Levelling Results

Well name	Well Permit number	Easting	Northing	Ground Elevation (m AHD)	Standpipe Elevation (m AHD)	Standpipe Height (m)
Lagoon shallow	116743	310525.691	6097328.334	69.61	70.312	0.702
Lagoon Deep	116744	310524.767	6097330.901	69.59	70.208	0.618

Depth to water was measured on 19 April 2006. Data are presented in Table 2.

Table 2: Depth to Water and Water Elevation Data

Well number	Well Name	Depth to water below top of standpipe	Standpipe Elevation (m AHD)	Water elevation (mAHD)
116743	Lagoon shallow	1.105	70.312	69.207
116744	Lagoon Deep	1.06	70.208	69.148

These elevation data indicate that at the time of measurement, the water elevation in the shallower completed well (116743) was higher than the water elevation in the deeper completed well (116744). This means that there is an hydraulic gradient from shallow to deep in the profile at this location, resulting in the potential for water to move in that direction.

The elevation of water in the lagoons is stated on the design drawings to be 70.7m AHD. If the water in the lagoons is at this elevation and groundwater elevations are approximately 69m AHD, there is the potential for lagoon water (if leakage is occurring) to move toward the groundwater system.

Core Sampling and Laboratory Permeability Analysis

As stated above, push tube core samples were also collected at 0.5m, 1.0m, 1.5m and 2.0m from well 116744 and sent to Coffey Geosciences for testing. The samples from 0.5 and 1.5m were analysed for triaxial permeability. The permeability of the 0.5m sample was 2.4×10^{-10} m/s and the 1.5m sample permeability was measured as 1.3×10^{-10} m/s. Both samples were described by Coffey as dark grey medium to high plasticity silty clay. This description and the permeability values obtained are consistent with field observations and the swampy lacustrine depositional environment adjacent to the wastewater lagoons.

Test Pumping and Analysis

A pumping trial was conducted in well 116744 on 2 May 2006.

This consisted of the installation of a submersible pump and the extraction of groundwater at a rate of 0.066 L/s for 82 minutes, produced a drawdown of 7.95m. The hydraulic conductivity calculated from these data is 0.006 m/d. According to Todd (1980), such an hydraulic conductivity value in consolidated rocks is considered to be low and typical of shales and mudstones.

Collection and Analysis of Water Samples

Water samples were collected from both wells on 19 to 20 April 2006 and 26 May 2006. A sample was also collected from 116744 on 2 May 2006.

All samples were collected by AWEP scientists in accordance with AWEP sampling protocols.

Samples were analysed by Australian Water Quality Centre (AWQC). Analytical results are presented in Table 2. ANZECC (2000) Aquatic Ecosystem Guideline values are also presented for comparison purposes.

Table 2. Laboratory Analytical Results

Analyte	Well					ANZECC (2000) Aquatic Ecosystem Guideline Value in mg/L 80% level of protection
	116744 lagoon deep 19/04/2006	116744 lagoon deep 2/05/2006	116744 lagoon deep 26/05/2006	116743 lagoon shallow 20/04/2006	116743 lagoon shallow 26/05/2006	
coliforms	>2400	>2400	>2400	>2400	1400	
E Coli	0	0	53	0	5	
aluminium tot	0.245	620.1	158	0.048	3.67	
antimony tot	0.0013	0.001	<0.0005	0.0022	0.0018	ID
arsenic tot	<0.001	<0.001	0.03	0.006	<0.001	0.036 (as As [111])
beryllium tot	<0.0005	0.0097	0.0126	<0.0005	<0.0005	ID
cadmium tot	0.0005	0.0005	0.0038	<0.0005	<0.0005	0.0008
calcium	180	161	188	542	573	
chromium tot	<0.03	0.199	0.338	<0.03	<0.03	0.04 (as Cr [V1])
cobalt tot	<0.02	0.079	0.096	0.035	0.038	ID
copper tot	<0.03	0.089	0.115	<0.03	<0.03	0.0025
iron tot	0.086	<0.03	232	0.652	3.91	ID
lead tot	0.0406	0.1142	0.1277	0.0424	0.0157	0.0094
magnesium	433	507	526	943	1010	
manganese tot	0.062	8.26	2.48	0.231	1	
mercury tot	<0.0003	not provided	0.0023	<0.0003	0.0043	
molybdenum tot	0.007	0.003	0.0027	0.0068	0.0054	
nickel tot	0.0117	0.045	0.1142	0.001	0.008	0.017
potassium	99.2	109	113	202	208	
selenium tot	<0.003	<0.003	<0.003	0.019	<0.003	0.034
sodium	3830	4780	5010	6940	7250	
sulphur (SO4)	1520	1820	1930	2590	2580	
tin tot	<0.0005	0.0054	0.0031	<0.0005	<0.0005	ID
vanadium tot	<0.003	0.867	0.264	0.004	0.016	ID
zinc tot	0.038	4.4	1.24	0.027	0.046	0.031
chloride	6420	8290	7890	13500	13200	
fluoride	3	not provided	3.4	1.5	1.4	
Nitrate as N	0.066	0.003	0	0.715	0.024	
Nitrite as N	0.022	<0.005	<0.005	0.037	<0.005	
NO2+NO3 as N	0.088		<0.005	0.752	0.029	
NO2+NO3 as NO3		0.008	<0.02		0.13	
TKN as N	0.57	6.46	1.49	2.26	3.15	
Phosphorus	0.044		1.42	0.08	0.056	
TOC	2.8	22	nr	5.7	nr	

alkalinity as CaCO3	355	464	458	448	438	
bicarbonate	433	565	540	547	534	
carbonate	0	0	9	0	0	
hydroxide	0	0	0	0	0	
EC	19800	23700	24500	36000	36700	
TDS by EC	11700	14200	14700	22500	23000	
pH	7.8	7.4	7.4	7.6	7.4	

These results indicate that, in general, groundwater in the shallow well (116743) is of higher salinity, with corresponding higher concentrations of calcium, magnesium, potassium, sodium, sulphate and chloride. Nutrient concentrations are low in all samples analysed, but the presence of TKN indicates that wastewater from the lagoons is leaking into the ground. Concentrations of metals including beryllium, cadmium, chromium, copper, lead, manganese, nickel, tin, vanadium and zinc are greater in the samples collected from the deep well (116744). Copper and zinc concentrations exceed ANZECC aquatic ecosystem guideline values. pH is alkaline in all samples analysed.

These results are interpreted to indicate that:

- Shallow groundwater is more saline than the deeper water, and could be due to the evaporative concentrating of salt near the land surface
- Water in the shallow well has lower metals concentrations possibly due to dilution by recharge from rainfall and possibly wastewater lagoon leakage.
- The presence of coliforms and TKN in samples from both wells indicates that wastewater lagoon leakage is occurring to depths of 15m (the depth of water intersection in well 116744).

Seepage Modelling

The modelling of seepage from the lagoons was also carried out as part of the assessment of possible mine dewatering rates and the extent of the influence of groundwater pumping for groundwater control. This model consisted of a single aquifer layer simulating the Cambrian rocks hosting the mineralization, the setting of dewatering for mining at -190 m AHD, the establishment of a regional groundwater flow field, the simulation of the Angas River through the use of 'river' cells, and the assigning of hydraulic conductivity and storage coefficients derived from test pumping. The lagoons were initially simulated through the use of general head cells, with a lagoon water elevation of 70.7 m AHD, and using the vertical hydraulic conductivity of swamp sediments (10^{-5} m/d) obtained from the triaxial laboratory tests as the vertical hydraulic conductivity of the lagoon liner materials (as they are the source materials).

As the lagoon has operated since the 1980's, the first simulation ran for twenty years. Using these input parameters, the model calculated a flux from the lagoon to the aquifer of about 0.8 m^3/d (800 L/d).

This was used for recharge from the lagoon in a subsequent model which included 7 years of mine dewatering and 20,000 years of recovery. It was found that, using the input parameters selected, the lagoon had negligible impact on drawdown around the mine.

A sensivity analysis was performed to assess the impact of the lagoon if it was unlined and the water level of the lagoon remained constant at the design level (70.7m) during the mining and recovery periods. This meant that, in this simulation, leakage was controlled by the hydraulic conductivity of the underlying rocks**.** The flux to the aquifer calculated by the model using these altered inputs was 100 m^3/d or about 1 L/s. The model also indicates that this leakage will result in a reduction in the extent of the cone of depression around the mine. For example, the maximum radius of the 0.1 m drawdown contour was 665 m, compared to 1016 m for the simulation where the lagoon had a liner.

Summary and Conclusions

The activities carried out as part of this investigation indicate the following:

- The design elevation of water in the lagoons is 70.7m AHD.
- Groundwater occurs at an elevation of about 69m AHD, resulting in the potential for wastewater from the lagoons to move into the aquifer due to the establishment of a downward hydraulic gradient.
- Discussions with Council indicate that the lagoons were lined with locally derived materials but the extent of compaction and engineering control during liner placement is unknown. We have considered that the liner permeability is the same as the in situ permeability of the locally derived materials, but cannot as yet verify this.
- Test pumping indicates that the hydraulic conductivity of the fractured Cambrian basement rocks is about 0.006 m/d.
- Laboratory permeability tests indicate that the vertical permeability of the shallow lacustrine sediments occurring adjacent to the lagoons is about 1.3×10^{-10} m/s (1.12×10^{-5} m/d).
- Groundwater sampling results indicate that the shallow groundwater is more saline than the deeper groundwater, possibly due to the effects of evaporation.
- Coliforms are present in samples from both wells, and ecoli was also identified in both. This is interpreted to indicate that wastewater has entered the aquifer. This is supported by the presence of TKN in the groundwater samples.
- Deeper groundwater contains greater concentrations of metals than groundwater in the shallower well. This may be due to the effects of infiltration recharge or greater proximity of the deeper well to the zone of mineralization.
- Groundwater elevations near the lagoons appears to be significantly higher than anticipated from the contouring of regional groundwater monitoring data. This indicates the presence of groundwater mounding and implies that the lagoons may be acting as recharge sources for the aquifer.
- Groundwater modelling indicates that, assuming that the lagoon liner vertical permeability is the same as the permeability of in situ swamp sediments, about 0.8 m^3/d of wastewater could currently be leaking from the lagoons into the aquifer system. This rate of leakage will change significantly if the liner material permeability differs appreciably from the value used in the model. If no liner remains, the model indicates that about 100 m^3/d of wastewater could enter the groundwater system.

Yours sincerely,

Rick Aldam
Principal Environmental Scientist
AWE Projects Pty Ltd

Australian WATER Environments

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Project:	Lagoon Leakage
Job No.	06009a

Bore data	
Permit No.	116743
Unit No.	
Obs. No.	
AWE Name	shallow hole (the most southerly)
Purpose	Lagoon leakage assessment

Location Data	Council wastewater lagoons
Hundred	Strathalbyn
Zone	54
Easting (m)	310526
Northing (m)	6097328
Datum	AHD

Elevation data	**(m)**
Ground Surface	69.610
Ref. Point above Ground	
Ref. Point	70.312
Top of open interval	
Bottom of open interval	

Drilling data	
Start date	10/04/2006
Finish date	10/04/2006
Driller	Geodrill
Drilling Method	hollow auger
Circulation	nil
Maximum drilled depth (m)	4.3
Completed bore depth (m)	2.5
Samples logged by	R Aldam

Post-development data	
Date	
Development duration (min)	
Depth to SWL below Ref. Pt. (m)	1.11
Depth to SWL below GL (m)	
RSWL (m AHD)	
EC Field (uS/cm)	17600
EC Lab (uS/cm)	
Yield (L/s)	
Method	

Completion data				
Hole Diameter	**mm**	**From**	**To**	**Bit**
	125	0.0	4.3	auger
Backfilled		**From**	**To**	**Material**
		4.3	2.5	cuttings
Casing Diameter	**mm**	**From**	**To**	**Material**
	50	0.0	1.0	PVC
Screen Diameter	**mm**	**From**	**To**	**Material**
	50	1.0	2.5	machine slotted PVC
		From	**To**	**Type**
Grout				
Bentonite Seal		0.4	0.0	
Gravel Pack		2.5	0.4	

Chemistry		**Units**
pH		
TDS by EC		mg/L
EC		uS/cm
TDS by calc.		mg/L
Ca		mg/L
Mg		mg/L
K		mg/L
Na		mg/L
HCO3		mg/L
F		mg/L
Cl		mg/L
SO4		mg/L
NO2/3 as N		mg/L
NO2/3 as NO3		mg/L
Boron		mg/L
Fe - Total		mg/L

Geophysics	
Job No.	

Geology					**Drilling Flow and Salinity Data**				
Depth (m)	**Stratigraphy**	**Bore Diagram**	**Material**	**Description / Notes**	Depth (m)	Volume (L)	Time (sec)	Yield (L/s)	Salinity (EC)
0 - 1	Quaternary		Clay	dark grey brown,high plasticity,carbonaceous, trace sand and lithic pebbles					
1 -2	Quaternary		Clay	red brown, grey, light yellow brown,high plasticity,wet, minor gravel and trace sand, possible weathered basement at 1.5m	2	seep			
2 - 4.3	Cambrian		Schist	dark grey, red brown,yellow brown, firm to moderately hard, blocky and crumbly texture, damp					

Australian WATER Environments

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Project:	Lagoon Leakage
Job No.	06009a

Bore data	
Permit No.	116744
Unit No.	
Obs. No.	
AWE Name	lagoon deep (most northerly)
Purpose	Lagoon leakage assessment

Location Data	Council wastewater lagoons
Hundred	Strathalbyn
Zone	54
Easting (m)	310525
Northing (m)	6097331
Datum	AHD

Elevation data	**(m)**
Ground Surface	69.590
Ref. Point above Ground	
Ref. Point	70.208
Top of open interval	
Bottom of open interval	

Drilling data	
Start date	10/04/2006
Finish date	10/04/2006
Driller	Geodrill
Drilling Method	auger, hammer
Circulation	nil, air
Maximum drilled depth (m)	27.0
Completed bore depth (m)	22.5
Samples logged by	R Aldam

Post-development data	
Date	
Development duration (min)	60
Depth to SWL below Ref. Pt. (m)	1.06
Depth to SWL below GL (m)	
RSWL (m AHD)	
EC Field (uS/cm)	12300
EC Lab (uS/cm)	
Yield (L/s)	<0.1
Method	air lift

Completion data				
Hole Diameter	**mm**	**From**	**To**	**Bit**
	150	0.0	4.0	auger
	150	4.0	27.0	hammer
Backfilled		**From**	**To**	**Material**
		27.0	22.5	cuttings
Casing Diameter	**mm**	**From**	**To**	**Material**
	100	0.0	16.5	class 18 screw threaded PVC
Screen Diameter	**mm**	**From**	**To**	**Material**
	100	16.5	22.5	class 18 screw threaded PVC
		From	**To**	**Type**
Bentonite Seal		0.5	0.0	
Cuttings		10.0	0.5	
Bentonite Seal		10.5	10.0	
Gravel Pack		22.5	10.5	

Chemistry		**Units**
pH		
TDS by EC		mg/L
EC		uS/cm
TDS by calc.		mg/L
Ca		mg/L
Mg		mg/L
K		mg/L
Na		mg/L
HCO3		mg/L
F		mg/L
Cl		mg/L
SO4		mg/L
NO2/3 as N		mg/L
NO2/3 as NO3		mg/L
Boron		mg/L
Fe - Total		mg/L

Geophysics	
Job No.	

Geology

Depth (m)	**Stratigraphy**	**Bore Diagram**	**Material**	**Description / Notes**
0 - 1	Quaternary		Clay	dark grey brown,high plasticity,carbonaceous, trace sand and lithic pebbles
1 -2	Quaternary		Clay	red brown, grey, light yellow brown,high plasticity,wet, minor gravel and trace sand, possible weathered basement at 1.5m
2 - 4.0	Cambrian		Schist	dark grey, red brown,yellow brown, firm to moderately hard, blocky and crumbly texture, damp
4 - 11	Cambrian		Schist	green grey, firm to moderately hard, highly weathered damp, micaceous
11 - 27	Cambrian		Schist	medium yellow brown, hard, micaceous, fractured at 15m, wet at 15m, seepage flow only

Drilling Flow and Salinity Data

Depth (m)	Volume (L)	Time (sec)	Yield (L/s)	Salinity (EC)
2	seep			