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Department of Water, Land and Biodiversity Conservation

GURRA GURRA WETLAND COMPLEX – GROUNDWATER DATA REVIEW

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INTRODUCTION

The Gurra Gurra wetland complex covers an area of 3000 ha that stretches along the eastern bank of the River Murray to the east of Berri (Fig. 1). At normal river pool levels, about 800 ha of floodplain are permanently inundated. As a result of river regulation and changed flow regimes, approximately 50% of the management area is affected by salinisation, with samphire and salt scalds widespread. The northern extremity of the wetland area is affected by irrigation drainage from the Lyrup Irrigation Area. Wetland Care Australia rates the complex a high priority land unit for changes in management.

Three reports have been prepared on investigations into the impact of saline groundwater discharge associated with drying the wetlands.

1. Gurra Gurra Wetland Management Plan - Hydrogeological Assessment & Salt and Water Balance Study ; by Australian Water Environments in 2001.
2. Gurra Gurra Wetland Complex – Suitability for Drying Trials Assessment ; by Australian Water Environments in 2003.
3. High Salinity Groundwater Investigations – Gurra Gurra Wetland Complex ; by Resource & Environmental Management in 2003.

The purpose of this Technical Note is to provide a summary of the above reports, identify data gaps and provide recommendations for upgrading the existing groundwater observation network.

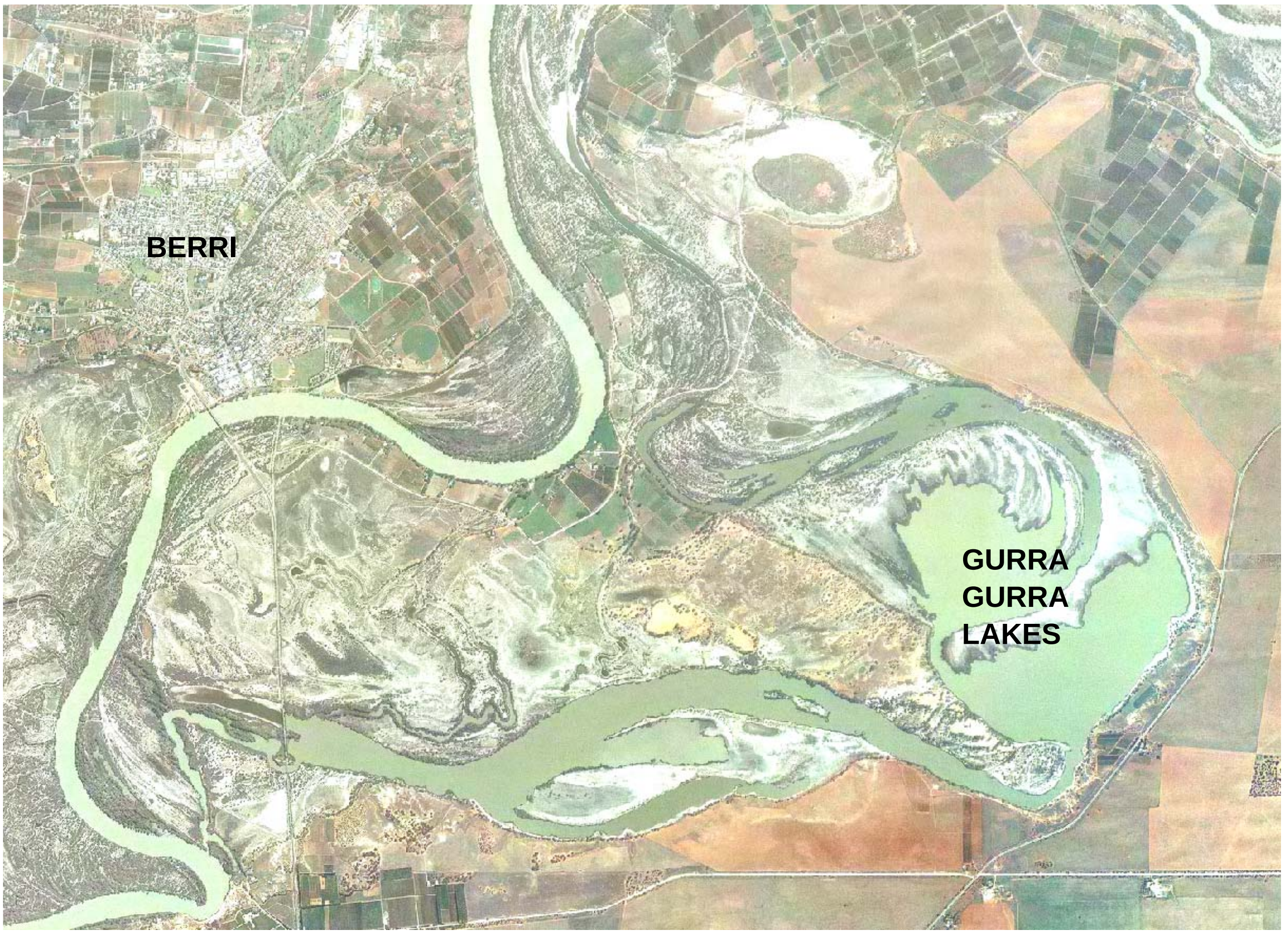

Figure 1. Gurra Gurra Lakes location plan

HYDROGEOLOGY

The regional hydrogeology of the Riverland region is well known after decades of investigations. Table 1 lists the important hydrostratigraphic units present in the Gurra Gurra Lakes (GGL) area.

Table 1. Hydrostratigraphic units in the Gurra Gurra Lakes area

Formation	Description	Aquifer characteristics
Coonambidgal Formation	Unconsolidated grey silts and clays	Surficial semi-confining layer
Monoman Sands	Unconsolidated grey-brown sands and gravels	Floodplain aquifer
Pliocene Sands	Unconsolidated yellow-brown and orange well sorted quartz sand, grading to grey fine clayey sand near the base of unit.	Regional watertable aquifer
Bookpurnong Beds	Green-grey fossiliferous silts and clays with minor sand layers	Regional confining layer
Murray Group Limestone	Consolidated pale grey to yellow fossiliferous limestone	Regional confined aquifer

Figure 2 presents a regional hydrogeological cross section across the floodplain in the vicinity of the area of interest.

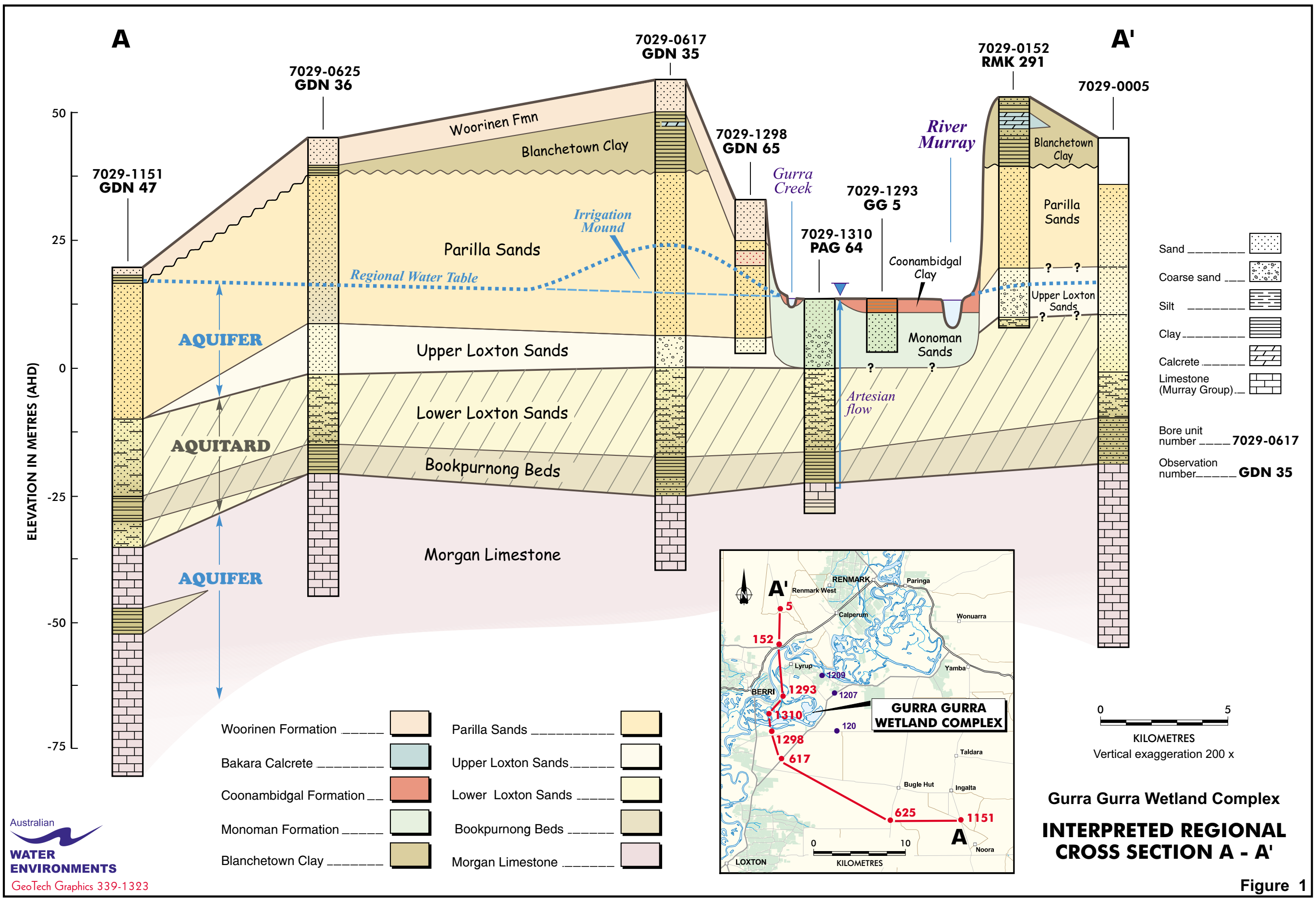

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Figure 2. Hydrogeological cross section (after AWE, 2001)

The River Murray floodplain is the natural discharge area for the regional aquifers of the Murray Basin. Within the Pliocene Sands watertable aquifer, groundwater flows toward the floodplain from the south and southeast, as shown in Figure 3. Irrigation development at Lyrup and Lyrup Heights has created a watertable mound to the northeast of GGL and exacerbated groundwater inflows to the floodplain from that direction. There is no evidence of increased groundwater inflows from the south due to irrigation. Regional groundwater salinities vary between 35 000 and 70 000 mg/L in this aquifer.

The head in the confined Murray Group Limestone is artesian across the floodplain ie it is a metre or so above ground level, and indicates discharge from the aquifer by upward leakage into the watertable aquifer. Salinities in the confined aquifer are of the order of 25 000 mg/L.

Within the floodplain itself, groundwater salinities are generally above 25 000 mg/L, with evaporative concentration raising salinities to over 70 000 mg/L in some areas where the watertable is within a metre or two of the land surface.

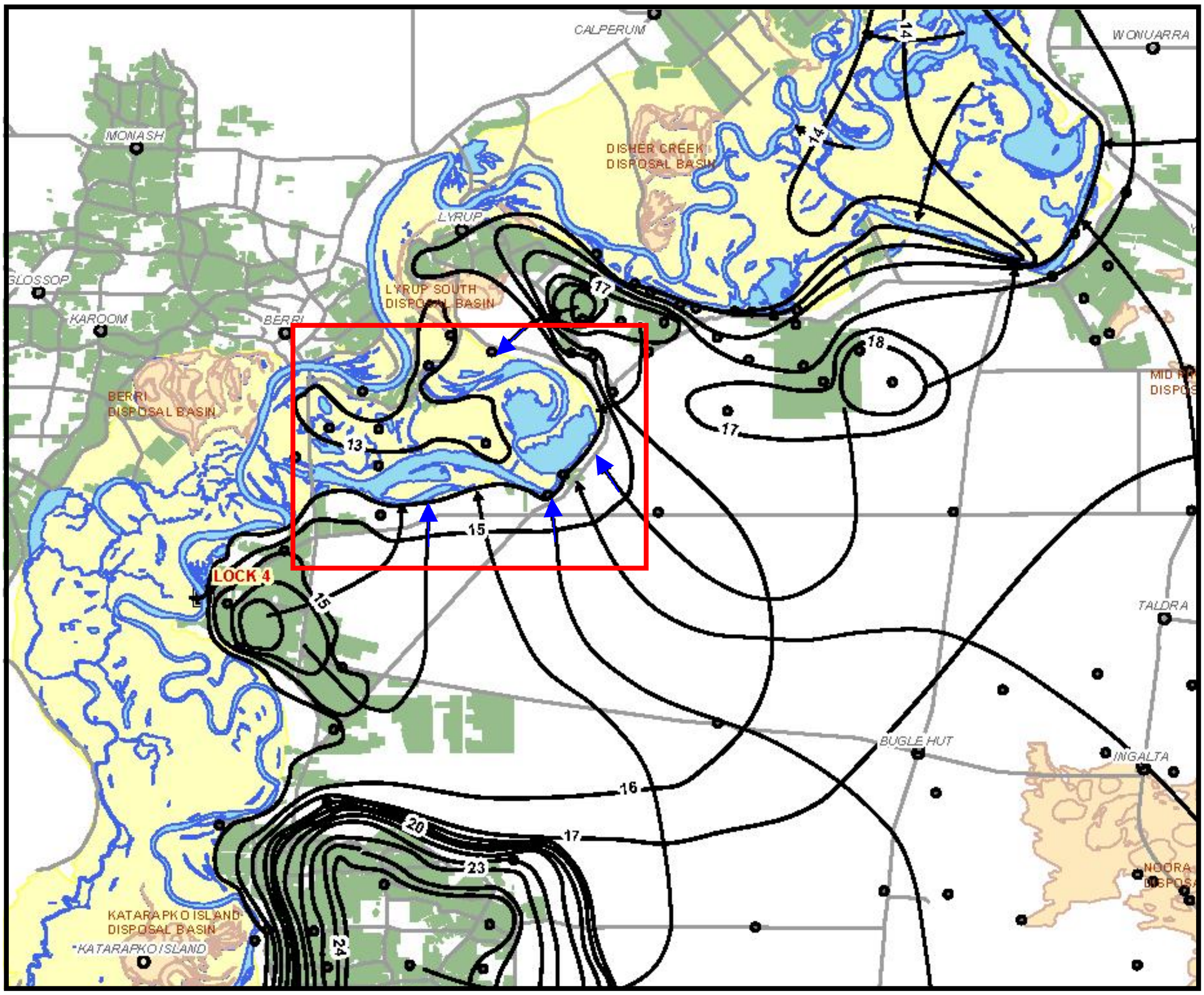

Figure 3. Groundwater flow directions (after REM, 2003)

INVESTIGATIONS BY CONSULTANTS

Both AWE and REM carried out field investigations to gain a better understanding of floodplain groundwater processes. The results will be discussed under broad categories.

Groundwater flow

REM recorded groundwater levels and salinity at 30 locations around the Wetland Complex during a field program (groundwater levels were corrected for density). From this data, estimated upward leakage rates from the confined Murray Group Limestone aquifer to the watertable aquifer ranged between around 0.02 and 2 mm/year (which is small compared to lateral flow). It was also noted that evaporative discharge from the main floodplain between the Wetland Complex and the River Murray had lowered the watertable up to one metre lower than the stage elevation of Gurra Gurra Creek near South Gurra Gurra Lake. This would induce discharge of wetland water into the floodplain aquifer, resulting in the Wetland Complex acting as a flow through system. A conceptual model is presented in Figure 4.

AWE did not collect any groundwater level data from existing wells for their analysis of groundwater inflows, and their interpretation of regional potentiometric surface contours is highly inaccurate (AWE, 2001 Fig.4).

Hydrochemistry

In order to assess the contribution of groundwater discharge to the surface water system, five surface and five groundwater samples were analysed for major ions (Ca, Mg, K, Na, Alkalinity, Cl and SO_4), dissolved radon gas (^{222}Rn), and the stable isotope of water, Oxygen-18 (^{18}O). The major ion data suggests that the majority of salt within the Gurra Gurra Creek is derived from groundwater (REM, 2003). The reported ^{18}O and chloride data indicated that around 75% of the salt carried in Gurra Gurra Creek is derived from groundwater, with the remaining 25% originating from the River Murray. The presence of ^{222}Rn data in surface water suggests active groundwater discharge to the Gurra Gurra Wetland Complex is taking place.

AWE took existing chemical analyses from four wells in the vicinity of the Wetland Complex completed in the Monoman and Pliocene Sands aquifers, and sampled one well completed in the confined MGL aquifer from within Complex. From a simplistic analysis of the results, it was concluded that the MGL aquifer does not make a great contribution to the Monoman sands aquifer, and that recharge from rainfall and the river dilutes the Monoman Sands aquifer, compared to the Pliocene Sands.

Aquifer Parameters

To determine groundwater flow volumes, it was necessary to determine representative hydraulic conductivity values for each of the aquifers that occur in the Wetland Complex. As there was no existing information on the hydraulic properties of the floodplain sediments, REM conducted a number of aquifer tests at several locations fill this data gap. Three types of aquifer tests were conducted during the field program: slug tests, constant rate pumping tests, and recovery tests (REM, 2003). Table 2 summarises estimates of aquifer parameters from data collected during this program of work, together with previous local investigations.

It can be seen that within the Gurra Gurra area, the hydraulic conductivity of the Pliocene Sands is fairly consistent with other areas in the Riverland region and any inconsistencies with other areas can be explained by the well construction of the observation wells which were not designed for aquifer testing.

AWE did not carry out aquifer testing to determine aquifer parameters in the Wetland Complex.

Table 2. Results of regional aquifer testing programs

Aquifer	Hydraulic Conductivity (m/day)
Monoman Sands	>15
Pliocene Sands	0.6 – 3
Bookpurnong Beds	0.0006
Murray Group Limestone	0.5 - 1

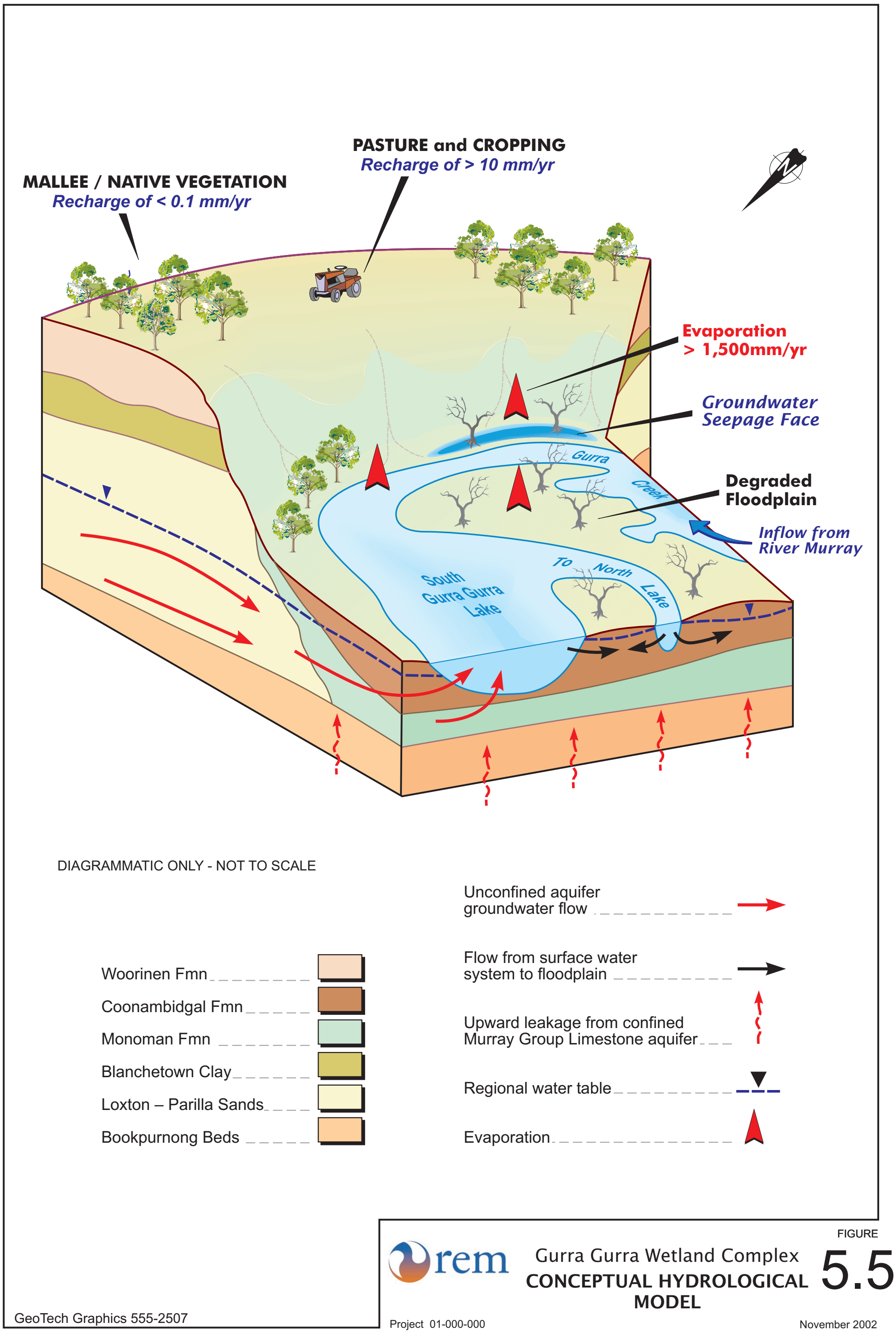

Figure 4. Conceptual model of Gurra Gurra Wetland Complex (after REM, 2003)

AWE Modelling

AWE (2003) set up a spreadsheet model to determine the salt and water balance, with the Wetland Complex sectioned into five zones, as shown in Figure 5. The zones were chosen based on surface water salinity and water level data collected in a boat run of Gurra Creek. The basic volumetric equation for the model is :

River inflow = Evaporation - Rainfall - Groundwater inflow - change in volume

However the volumetric change of water stored in the Wetland Complex was assumed to be zero, therefore the change in volume was zero.

Essentially, the model calculated the total amount of evaporation from the total surface area of the Wetland Complex, added rainfall and a specified groundwater inflow (per cell) and calculated river inflow volume required to maintain the creek's water level. The model was calibrated to the observed salinity time series data (at the causeway and at the north end of the Gurra Creek), and to the run-of-creek data collected during the study.

The average groundwater salinity for input into each of the five cells of the model was determined by a number of backhoe pits dug around the outer perimeter of the Wetland Complex at approximately one kilometre intervals. The volume of groundwater inflow to each cell was determined in the model calibration stage.

This approach highlights the "non-uniqueness" problem in modelling – a given groundwater salt flux can be generated by numerous combinations of groundwater flow and salinity. There is some uncertainty as to whether the spacing and depth of the back-hoe pits were sufficient to obtain representative salinities of the groundwater that is discharging to the Complex. Holland (CSIRO, written comm., 2003) also pointed out the model should be used with caution as it estimates the very small volume of groundwater fluxes from the difference between much the larger volumes of rainfall and evaporation. Nevertheless, the model accounted for salt and water movement temporally and spatially between the five reaches, and estimated the groundwater discharge flux actually entering the wetland, although it does not take into account discharge of wetland water into the floodplain aquifer. Table 3 shows the modelled groundwater inputs to the various zones.

Table 3. Groundwater inputs to the model (after AWE, 2001)

Zone	Salinity (mg/L)	Inflow (m^3/day)	Salt load (t/day)
1	27 000	5	0.13
2	45 000	25	1.13
3	30 000	25	0.75
4	12 000	0	0
5	48 000	5	0.24
	Total	60	2.25

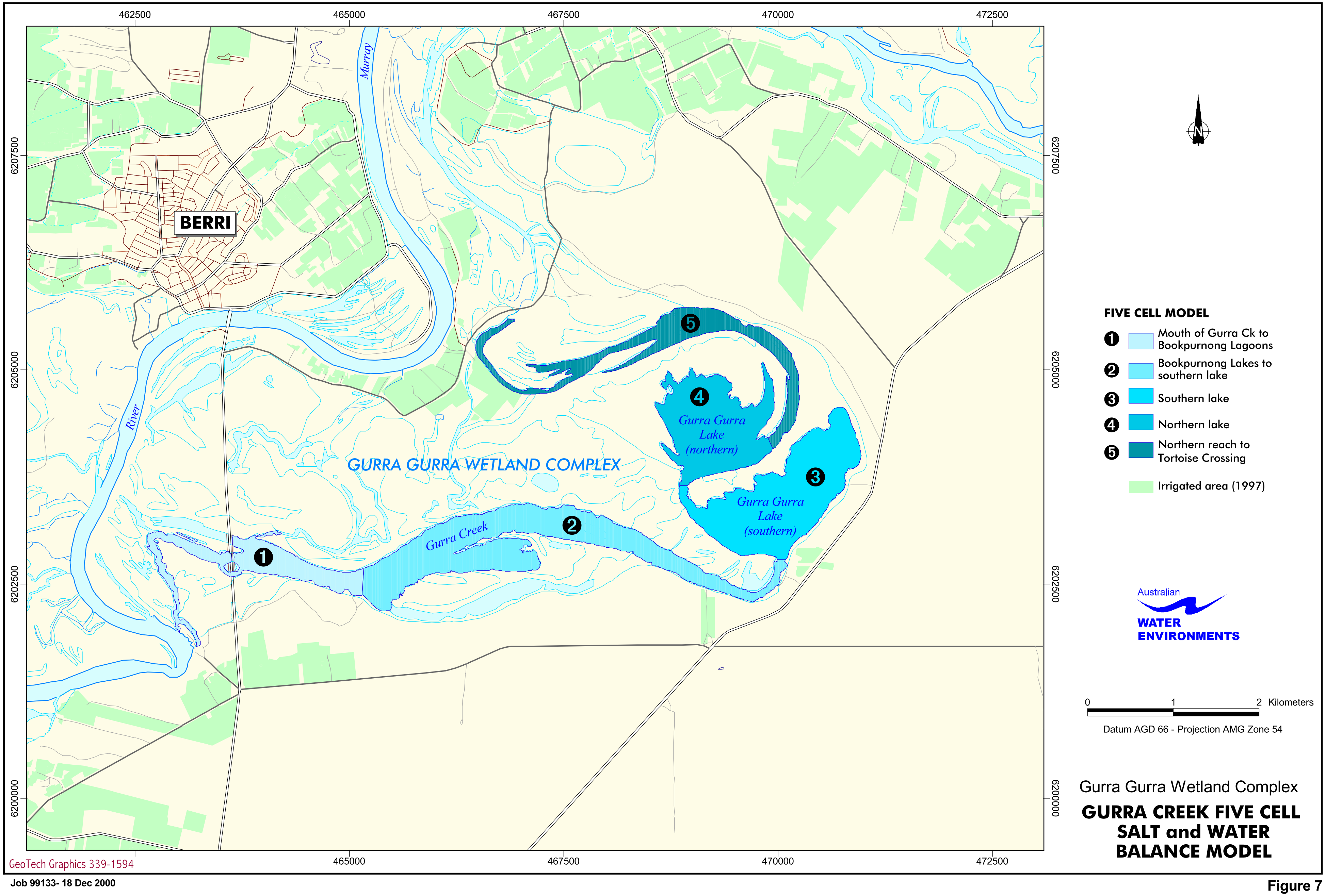

Figure 5. Zones used salt and water balance models (after AWE, 2003)

REM Modelling

REM used a range of methods to calculate groundwater discharge to the Wetland Complex.

Flow net modelling used the Darcy equation to calculate groundwater fluxes:

$Qh = L\ K\ D\ i$ $\qquad$ $Qv = A\ K\ i$

where Qh and Qv are the horizontal and vertical groundwater fluxes (m^3/day), K is the hydraulic conductivity (m/day), D is thickness of the aquifer (m), L is the length of the reach (m), A is the area of the surface water body (m^2), and i is the hydraulic gradient (m/m).

Flow net calculations were based on the zones (Fig. 5) defined by AWE (2001) to allow comparison with their results. An interesting assumption is that the surface water body is assumed to be fully penetrating into the aquifer and captures all groundwater flow directed towards it from the regional watertable aquifer. This assumption ignores throughflow and account discharge of wetland water into the floodplain aquifer, as well as evaporative discharge on the floodplain between the highland cliff and the wetlands.

The existing **Pike–Murtho groundwater flow model** (REM, 2002) was refined for use in the simulation of groundwater conditions, and a number of land and water management scenarios for the area around the Wetland Complex. Calibration was achieved with 2002 monitored water levels in 19 wells in the area, as well as those within the Bookpurnong and Loxton Irrigation Districts. The model was found to reasonably simulate observed water levels, with the largest errors on the floodplain. Assumptions made for the flow net modelling regarding floodplain processes also apply to the numerical modelling exercise.

Chemical tracers were also used to determine inflows. Experimental work has been undertaken recently regarding the qualification and sometimes the quantification of groundwater-surface water interactions using dissolved radon gas (^{222}Rn). The radon data can be used to estimate the rate of groundwater inflow on a point scale using an analytical mass balance equation relating the observed radon content in surface water to groundwater inflow (REM, 2002). Although experimental at this stage, the technique provides a check on other more traditional methodologies employed in estimating salt loads.

Table 4 shows that three methods of estimating Wetland Complex salt accessions described above, agree reasonably closely, particularly in the total salt load delivered to the Wetland Complex.

Table 4. Predicted Wetland Complex salt loads in tonnes/day (after REM, 2002)

Zone	^{222}Rn Analysis	Flow Net Model	Numerical model
1	3	3	3
2	12	5	3
3	5	3	7
4	-	0.02	0.02
5	-	9	3
Total	> 20	20	16

CSIRO Modelling

Outputs from the preliminary Floodplain Impacts Model (FIP) were used as an independent check of these two reports. This model does not include any surface water - groundwater interaction functions, but distributes groundwater entering the floodplain as seepage, evapotranspiration and baseflow to the river, assuming a flat floodplain. Table 5 shows that the model predicts that two thirds of inflows are discharged as evapotranspiration within the floodplain, with the remainder flowing to the river. Dividing the floodplain into either wetland or terrestrial floodplain on an areal basis, approximately 60 m^3/day of groundwater is discharged into the Wetland Complex (Table 5).

Table 5. FIP salt loads (after Holland, 2003)

	Inflow (m^3/day)	Salt load (t/day)
Floodplain ET		
Wetland	185	1.83
Floodplain	58	5.81
Baseflow to river	122	3.73
Total	365	10.37

This model is fairly simplistic in considering floodplain processes, and its assumption that groundwater eventually reaches the river is not supported by the floodplain groundwater levels, which are all lower than the normal river pool level of 13.2 m AHD. This implies that the river, as well as the Wetland Complex, is discharging water to the floodplain. The total inflow of 365 m^3/day would therefore be absorbed on the floodplain.

SALT AND WATER BALANCES

All three predictions indicate that evaporation is several times greater than the sum of groundwater discharge and rainfall inputs. If cut off from the river, between 2.5 and 16 tonnes/day will accumulate in the Wetland Complex, with the discrepancy in values relating to differences in the methods of estimation (the higher value represents the total flux at the edge of the river valley adjacent the Gurra Gurra Wetland Complex). Holland (2003) recommends a value of 4 tonnes/day, but this may be a slight underestimate based on unlikely assumption that there is groundwater discharge to the river.

Holland also estimates that the wetland would dry in ~300 days if River Murray inputs were removed, as evaporation exceeds total rainfall and groundwater inflows. Drying by evaporation would result in salt accumulation in the low-lying parts of the wetland.

MONITORING

Only four observation wells in the Wetland Complex have been regularly monitored as part of the Pike SIS investigation. Those wells located on the eastern margins of the Complex are showing a slow decline in groundwater level (as shown in Figure 6), probably in response to falling lake levels due to a lack of flow down the river since 2005.

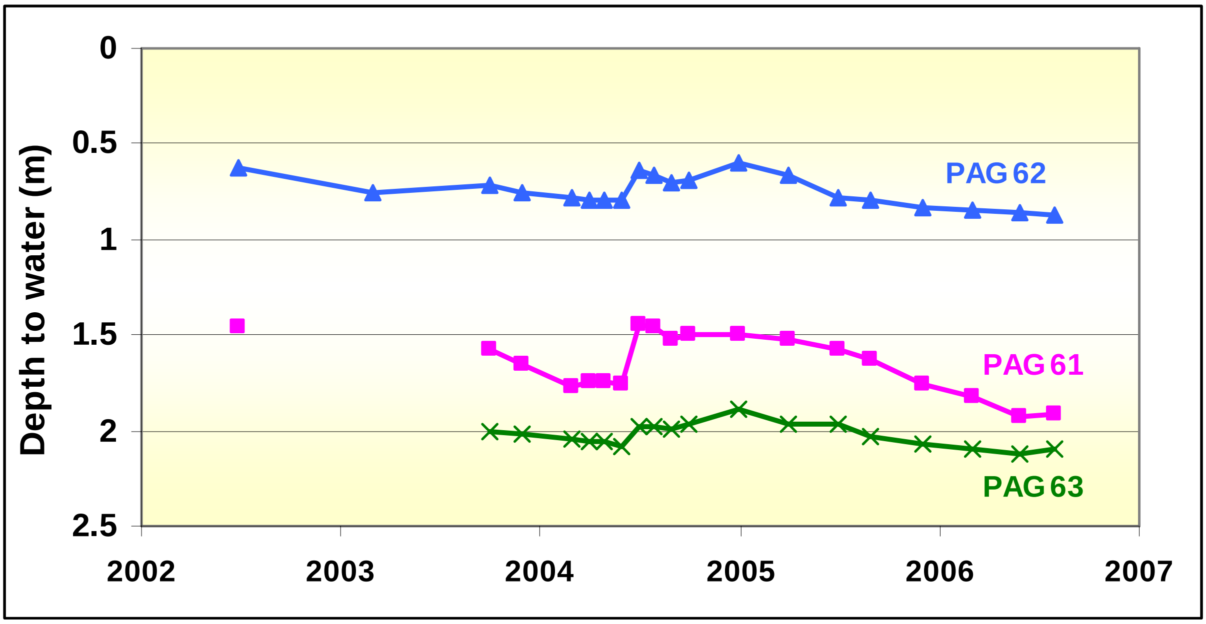

Figure 6. Observation well hydrographs

The remaining observation wells (AWE, 1998) should be included in the Gurra Gurra network, together with the nested piezometers drilled in 1983. This network (identified as "GURAGURA" in Obswell) should be monitored at six monthly intervals, and is located in Figure 7 as red dots. There are also three shallow holes drilled for the CSIRO vegetation health project (LOX 1510, 1513 and 1518) that could be incorporated if found to be in suitable condition (shown in yellow). These wells will have to surveyed if they can be included in the network.

If drying of the Complex is considered (either as a drought water conservation measure, or as part of wetland management), several piezometers should drilled in the bed of the dry lagoons into the Monoman Sands where access permits, to monitor groundwater levels and salinity beneath the lake floor. This will also provide information on the degree of connection between the lakes and the Monoman Sand aquifer (which is considered strongly connected to the regional watertable aquifer). An additional well is suggested adjacent to the lagoons to confirm the throughflow process. Suggested locations are shown in Figure 7 as blue dots.

If such management interventions are considered, the whole network should be monitored at two monthly intervals.

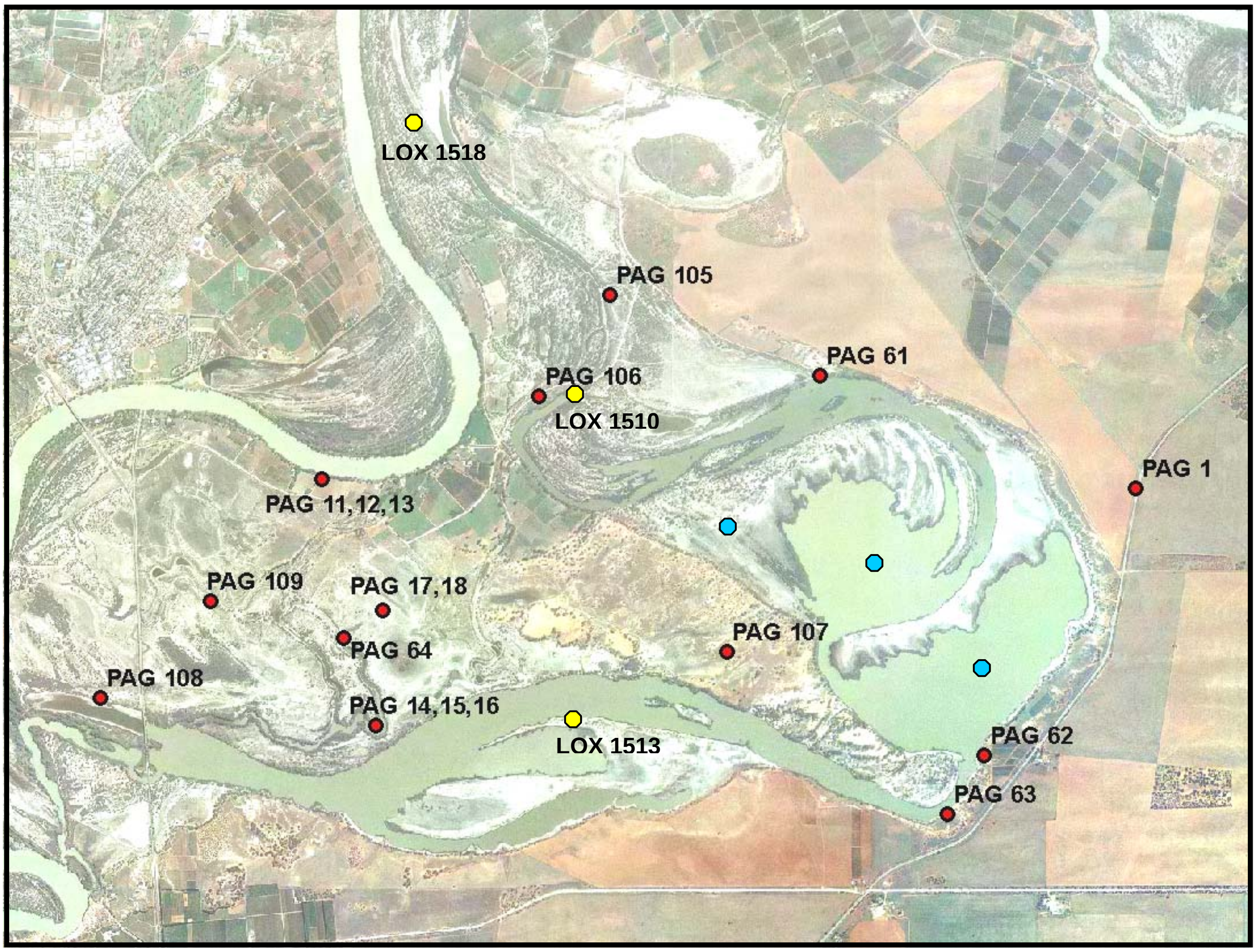

Figure 7. Observation well location plan

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