Gurra Gurra wetland modelling –
Phase 2 scenario modelling

DEWNR Technical note 2017/29



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1 Introduction

1.1 Background

The Gurra Gurra wetland (the wetland) covers an area of 3000 ha that stretches along the eastern bank of the River Murray to the east of Berri. As a result of river regulation and changing flow regimes the wetland has experienced salinisation due to saline groundwater discharge and evaporation. A locality plan is shown in Figure 1.

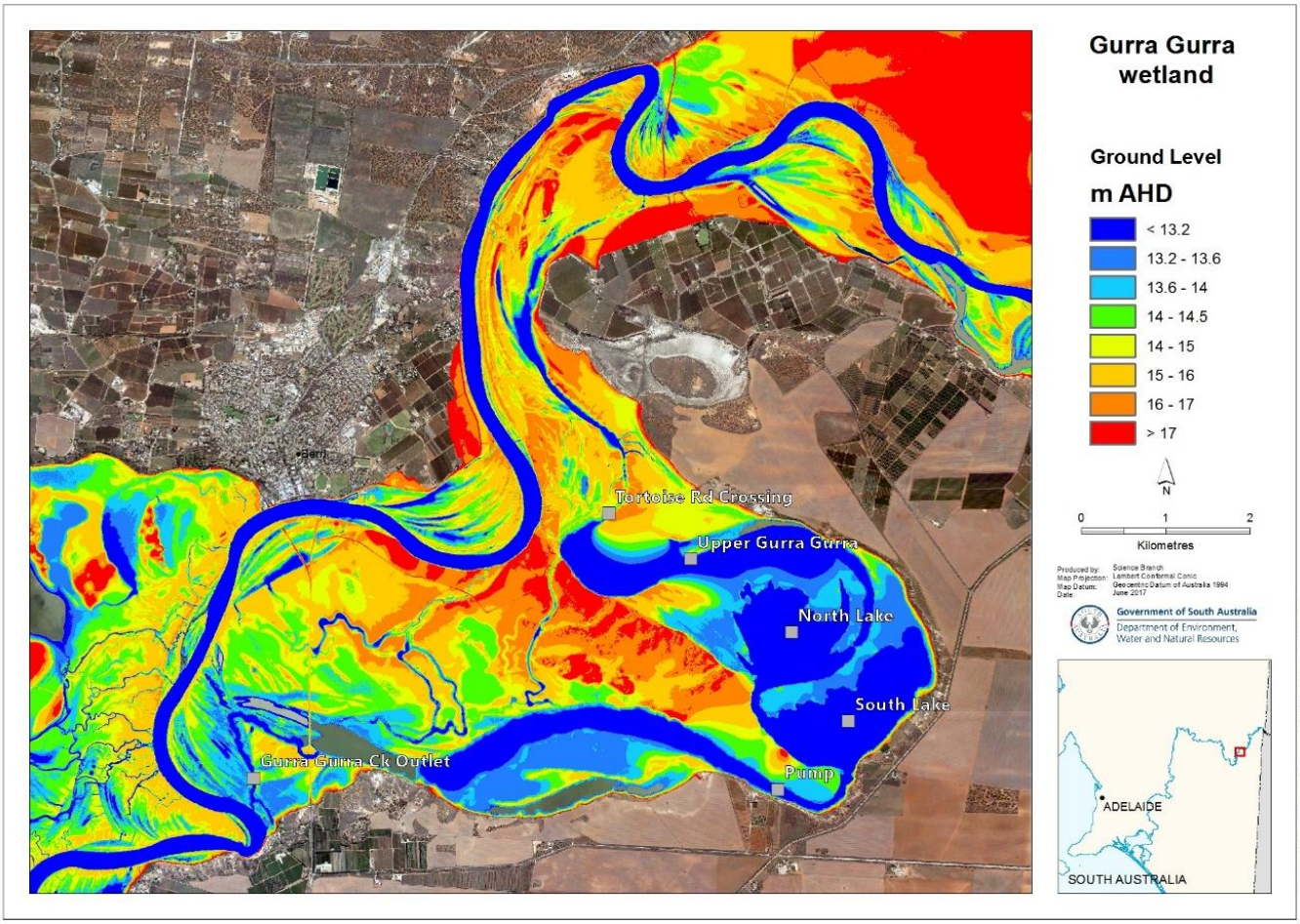


Figure 1. Locality Map for Gurra Gurra wetland also showing location of monitoring and modelling points referred to in this report

As part of the South Australian Riverland Floodplains Integrated Infrastructure Program (SARFIIP), salinity management strategies have been initiated to improve the wetland condition. DHI Water and Environment were commissioned to perform hydrodynamic and advection dispersion numerical modelling within two phases to assist with assessment of salinity management strategies and measures.

Phase 1 involved the development of numerical models of the wetland, and the River Murray channel and associated floodplain creek and channels. The models incorporate hydrodynamics (water levels, flows and current velocities) and advection dispersion (the transport of salinity due to the hydrodynamics and dispersive processes) and were applied to assess the impacts of weir pool manipulation on the wetland and associated salinity impacts. Details of the model configuration are presented in DHI (2016).

Additional flow, water level and run of the river salinity data were collected after completion of Phase 1, including the 2016 high flow event which could be used for model validation purposes. Therefore, Phase 2 of the modelling was initiated in order to validate models based on recently collected salinity transects and also to identify commence to flow thresholds through Lyrup Creek for different weir pool levels, River Murray flows and also different sill lowering conditions within the Lyrup Creek.

The first part of Phase 2 (Validation) complemented and supported the findings of the Phase 1 investigation. The observed, and subsequently modelled flushing characteristics that occurred during the high flow event in the Phase 2 validation exercise were consistent with that described in Phase 1 investigation. Furthermore, the Phase 2 validation exercise addressed a number of uncertainties raised in Phase 1, including the conveyance (flow of water) through Lyrup Creek, response to high flow events and flushing characteristics of the wetland. Details of the findings are presented in DHI (2017).

This report presents the scenario modelling undertaken as second part of Phase 2 to provide technical information to support planning and management of weir pool manipulation at Lock 4 to minimise any adverse impact on water quality within the wetland and subsequent uses of water.

1.2 Scope

The 2016 high flow event freshened the wetland and reduced the salinity concentrations. A weir pool level raising event at Lock 4 is being considered for the benefit of Katarapko floodplain and the riverine environment in 2017. The department's Water Science Unit was requested to undertake modelling using the existing model of the wetland to investigate the impact of this weir pool raising event on the water quality conditions in the wetland.

Modelling was also requested to identify flow through Lyrup Creek under different Lock 4 weir pool levels, River Murray flows and also different sill levels within Lyrup Creek and to inform of conditions required to improve and maintain the water quality in the wetland.

2 Model validation

Upon the completion of the validation exercises undertaken by DHI as part of Phase 2, more salinity data was gathered during the run of the river survey on 7 March 2017 shown in Figure 2. The model was validated against recent data without any further adjustment to model parameters. The results can be seen in Figure 3.

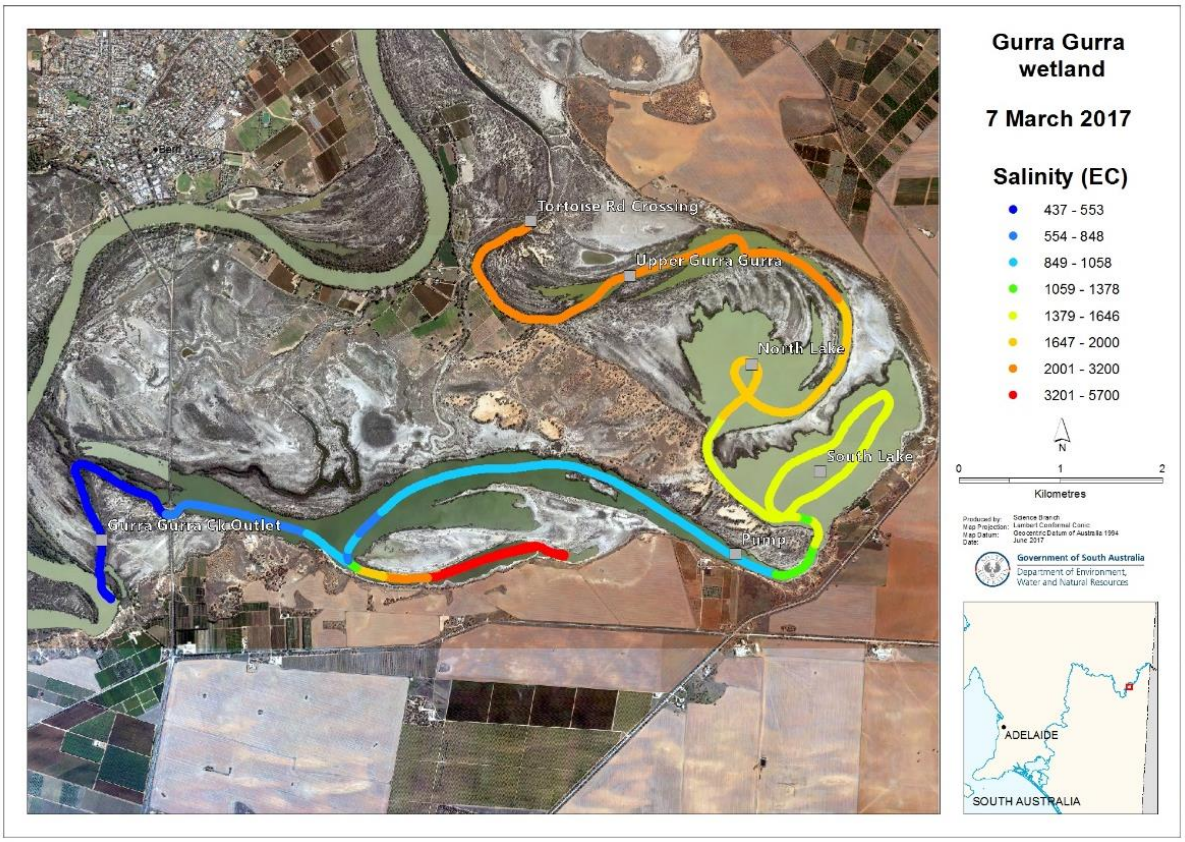


Figure 2. Salinity spatial survey on 7 March 2017

It can be seen that the model in general tends to under-predict salinity concentrations across the wetland. This may be due to limitation of the model to assess the impact of saline discharge from groundwater on salinity concentrations as acknowledged in Phase 1 of the modelling. DHI (2016) stated that quantifying saline intrusion particularly for the long term simulations is challenging and additional information is required to improve the model accuracy. The information included in this modelling is based on a previous water balance analysis (REM, 2003) that was undertaken over a period of nine months. This was a relatively short period for analysis and representative of only a small range of conditions. Given the underestimation of modelled salinity, particularly compared to the observed increases in salinity post the flood event in December 2016, this saline discharge could undergo further sensitivity testing in order to more accurately represent the observations. Further on ground investigations of the discharge to the wetland would further increase confidence in the assumptions used in the modelling.

Despite these limitations, the model is considered a useful tool for the purpose of comparative analysis of different operational and structural changes, as these are effects largely driven by changes in the water balance.

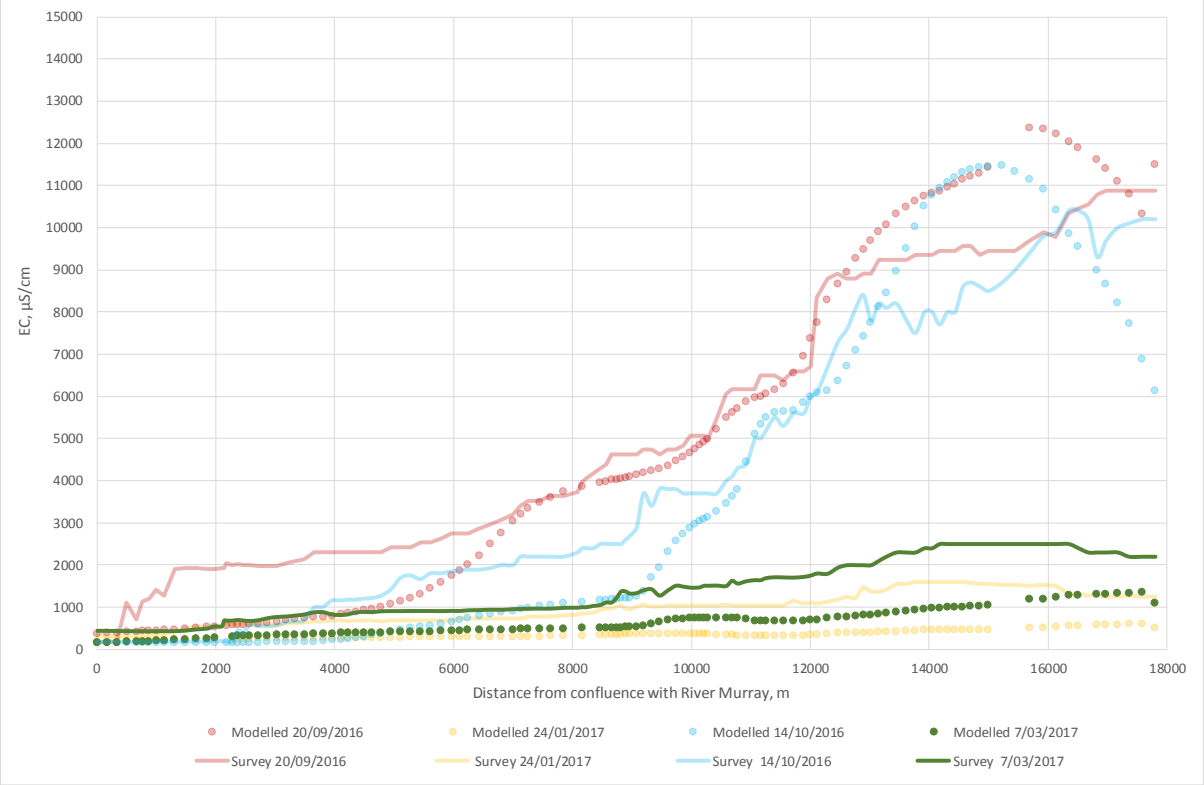


Figure 3. Comparisons to salinity spatial surveys

3 Scenario modelling

This section presents sets of scenarios that have been considered in this study:

- 2017 proposed weir pool raising event at Lock 4 (3 month period). This scenario simulated an event originally considered for implementation during spring 2017
- 2017 proposed weir pool raising event at Lock 4 (12 month period)
- Series of scenarios to address the conditions required to flush the wetlands
- Series of scenarios to address the long term impact of weir pool raising events and sill lowering.

All scenarios and the subsequent results are outlined in detail below.

3.1 2017 proposed weir pool raise event at Lock 4 (3 month period)

A River Murray weir pool level raising trial at Lock 4 was considered for a spring 2017 implementation: a raise in water level by up to 60 cm above the normal pool level in order to mimic natural

(pre-regulation) variations in water level. The water level was planned to be manipulated by 2 cm per day, starting on 1 September 2017 and lasting approximately 90 days until 1 December 2017.

The 1D/2D model of the wetland calibrated within previous phases of modelling was used to simulate this scenario, and investigated the changes in salinity concentrations due to this raising event. Details of the model configuration are presented in DHI (2016).

Since this scenario modelling started in August, the salinity data gathered through run of the river on 12 July 2016 was processed and used as the initial salinity condition. River Murray flow was assumed to be 20,000 ML/day and mean monthly climate data was applied for the modelling period. Time series of salinity concentrations were extracted at five points within the wetlands (shown in Figure 1) to understand the impacts of the proposed raising event on water quality within the wetland.

As can be seen in Figure 4, salinity concentration declined in the first stage of the weir pool raising event since River Murray water with lower salinity flows into the wetland through the Gurra Gurra outlet, due to hydraulic head difference created by weir pool raising. However, salinity increased dramatically at the pump location by the end of the raising event as salt was exported from upper parts of the wetland by relatively small inflows of 20 ML/day through Lyrup Creek during the holding phase.

As can be seen in Figure 4, the "outlet" of the wetland acts as inlet and outlet. Positive flow represents flow from the wetland to the river and conversely negative flow represents flow from the river to the wetland.

As a result of this proposed raising event, salinity concentration at "Upper Gurra Gurra" was simulated to reduce from approximately 12,000 EC to 9000 EC. However, salinity concentration at the pump location was modelled to increase from initial value of 2500 EC on 1 September 2017 to 7000 EC on 1 December 2017 as salt is exported through the wetland.

A normal weir pool level (no raising) scenario with the same initial salinity condition and constant flow of 20,000 ML/day was simulated to provide a base case for comparison to the weir pool raising scenario. Time series of salinity concentrations can be seen in Figure 5.

The results indicated that under constant conditions where the Lock 4 weir can control the water level, evaporation from the wetland results in a regular inflow of river water past the pump location to maintain the water level in the wetland. As a consequence of the continued evapoconcentration, the salinity in the North and South Lakes and Upper Gurra Gurra continued to increase. It should be noted that the modelling does not consider wind effects, which in practice would result in some bi-directional flow through the wetland, and at the connection between the wetland and the river. This will result in some higher salinity flow out of the wetland past the pump location at times, but is not expected to change the overall results for the comparison between the with-and-without weir pool raising scenarios. Snapshots of salinity concentration at key stages of raising event can be seen in Appendix A.

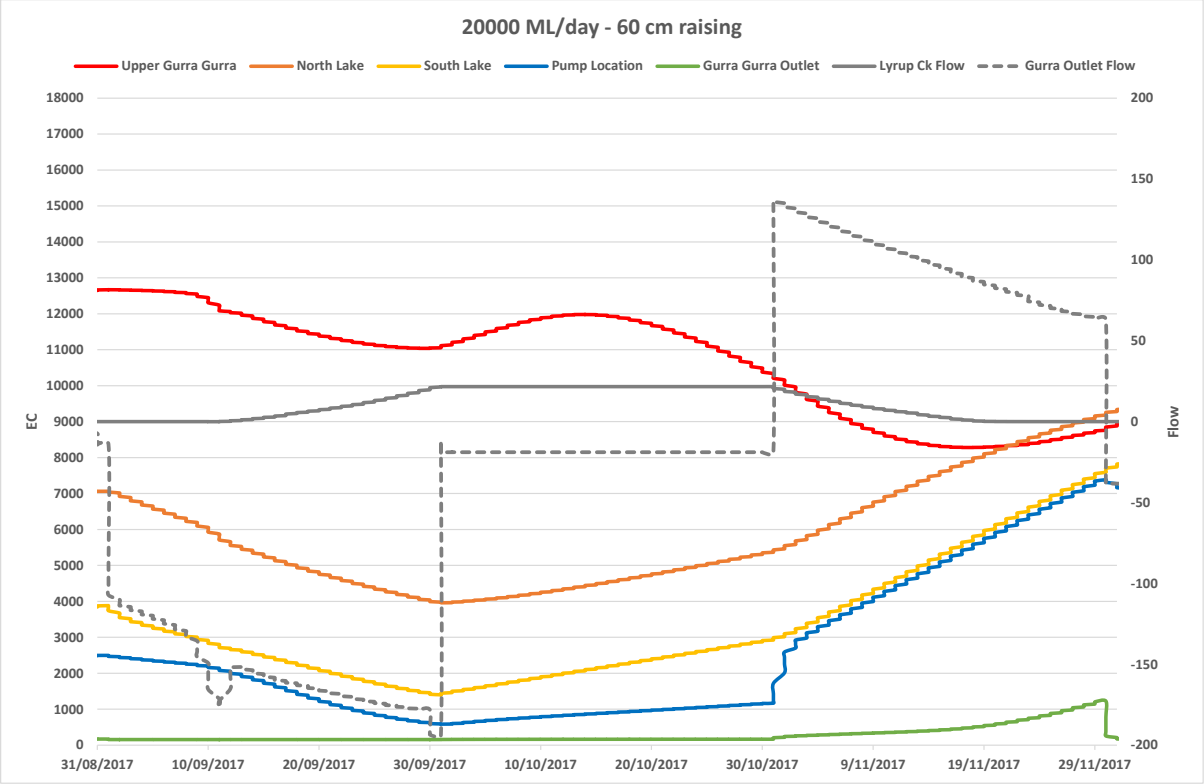


Figure 4. Time series of salinity (EC) and flow (ML/day) at outputs locations in the wetland – 20,000 ML/day and 60 cm raising

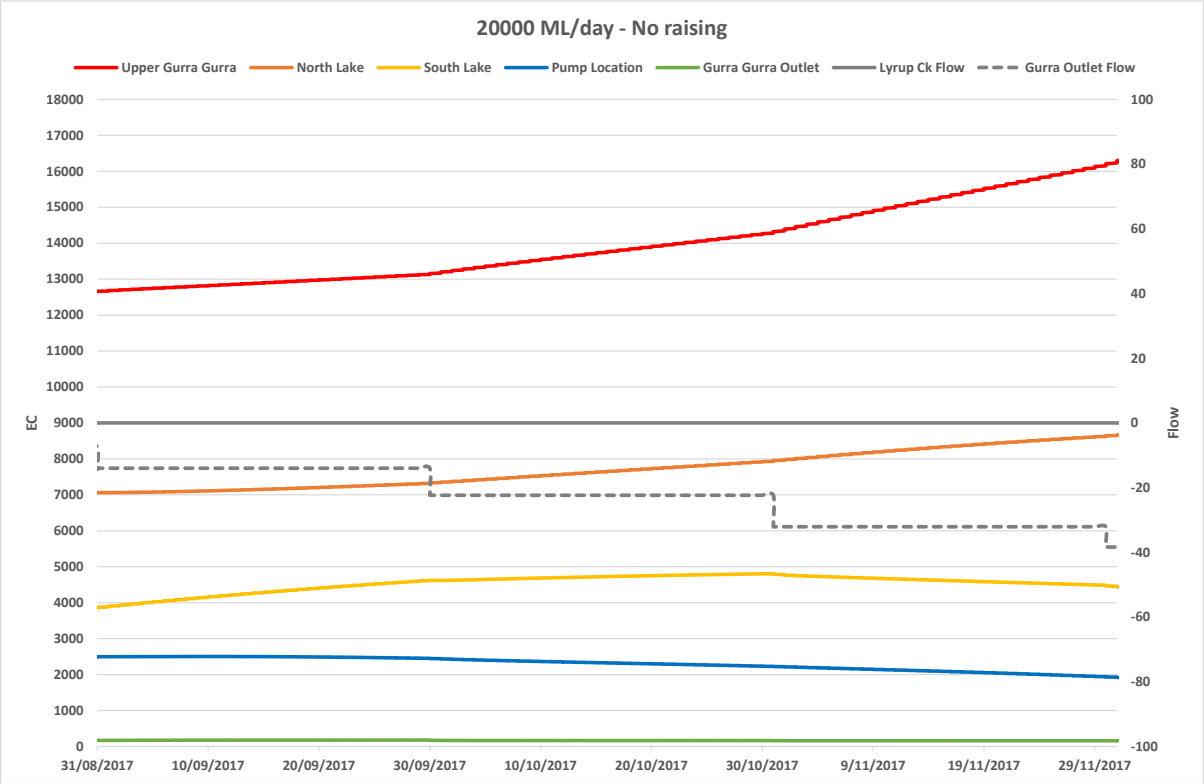


Figure 5. Time series of salinity (EC) and flow (ML/day) at outputs locations in the wetland – 20,000 ML/day and no raising

3.2 2017 proposed weir pool raise event at Lock 4 (12 month period)

This scenario extended the similar weir pool level raising trial at Lock 4 discussed in Section 3.1 to be simulated over a 12 month period to understand how salinity changes over time due to both longer-term evapoconcentration and weir pool raising events. The latest available salinity data gathered through run of the river on 7 March 2017 was processed and used as the initial salinity condition. Similarly, River Murray flow was assumed to be 20,000 ML/day, and mean monthly climate data was applied for the modelling period.

As can be seen in Figure 6, salinity concentrations in North and South Lakes increased by 100% over the first 6 months, mostly due to evapoconcentration. The rise in salinity concentration at the pump location is less (approximately 50%), which is attributed to small, fresher water inflows (~20 ML/day) from the River Murray through Gurra Gurra outlet. During the 3 months of the weir pool raising event, the salinity level at the pump location is modelled to reach nearly 3500 EC, since saline water flows from Lyrup Creek into the wetland. However, the results showed a decline in salinity concentrations at the pump over the next 3 months after the weir pool raising event.

A normal weir pool level (no raising) scenario with similar flow of 20,000 ML/day was also simulated (Figure 7) as a baseline comparison for the changes due to the raising scenario over 12 months. The results generally indicated similar behaviour to the 3 month scenario, where the evaporation demand from the wetland resulted in a continued fresh inflow to the wetland, with continued evapoconcentration within the northern end of the wetland. However, for the conditions assumed, the weir pool raising scenario increased the salinity in the South Lake, indicating that a longer raising event would be required for this flow to flush the wetland effectively. Spatial distribution of salinity for both scenarios can be seen in Figure 8 and Figure 9. The spatial results highlight the large reductions in salinity that occur, particularly in Upper Gurra Gurra wetland, following weir pool raising.

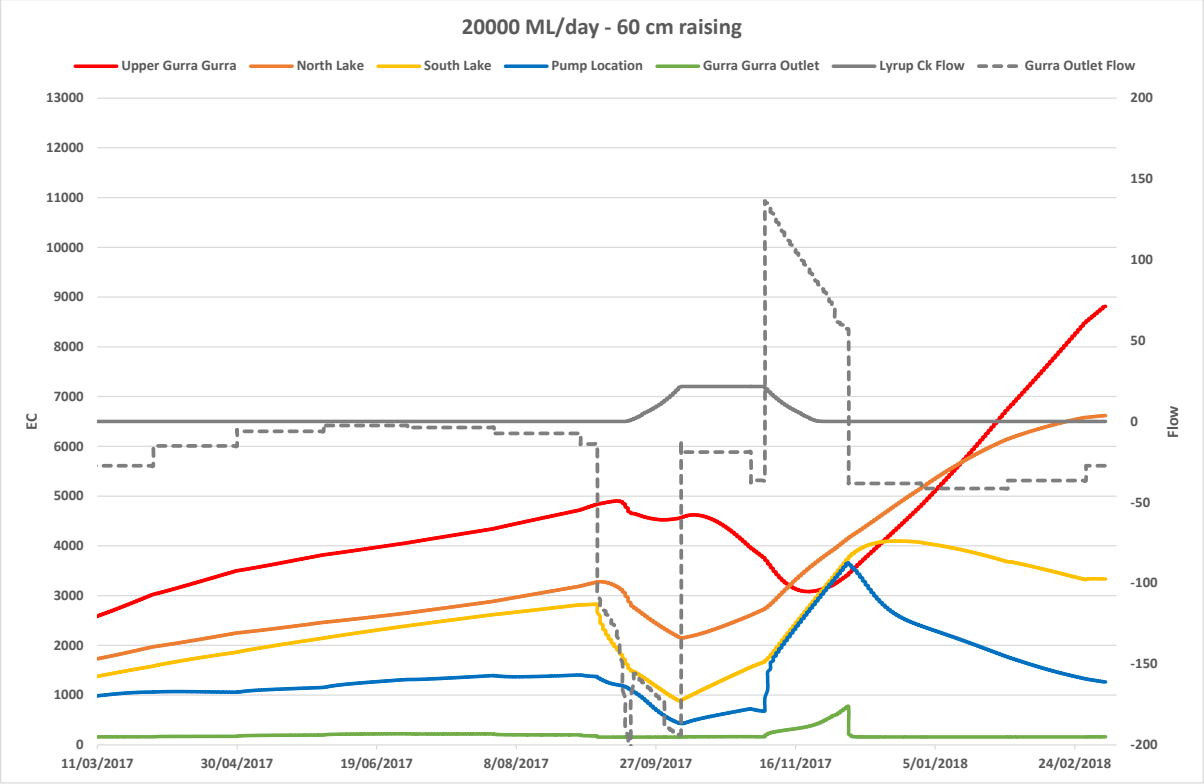


Figure 6. Time series of salinity (EC) and flow (ML/day) at outputs locations in the wetland – 20,000 ML/day and 60 cm raising over 1 year

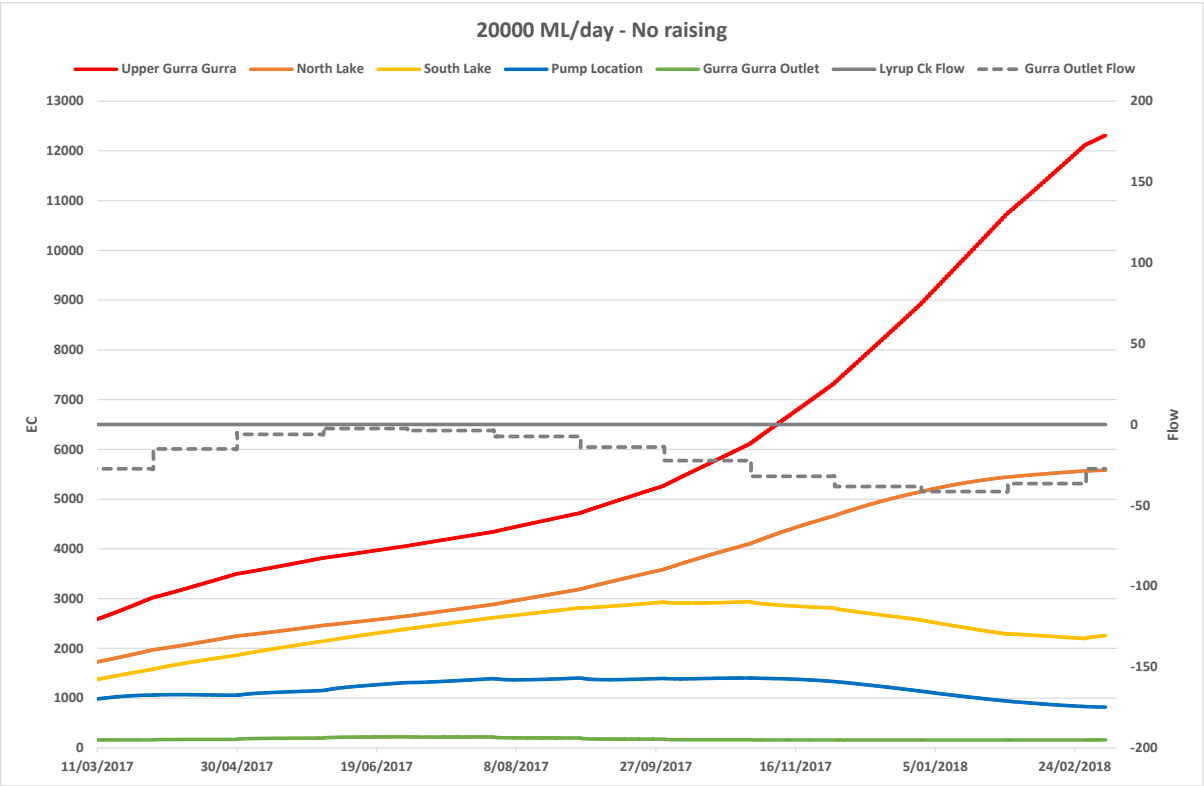


Figure 7. Time series of salinity (EC) and flow (ML/day) at outputs locations in the wetland – 20,000 ML/day and no raising over 1 year

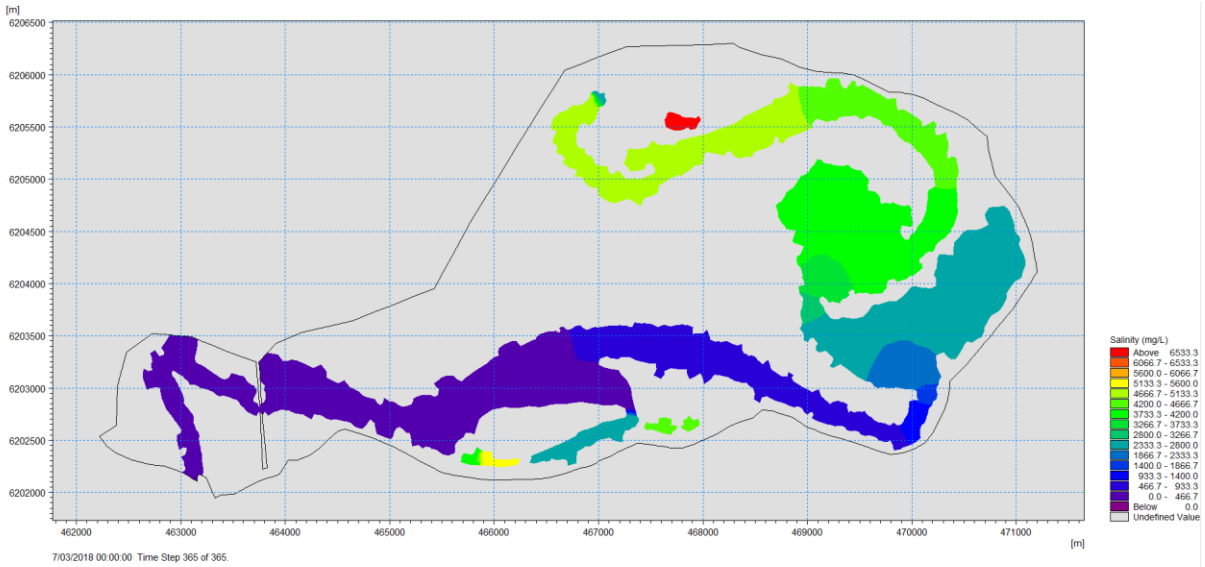


Figure 8. Salinity concentration (mg/L) at the end of the 12 month period – 60 cm raising

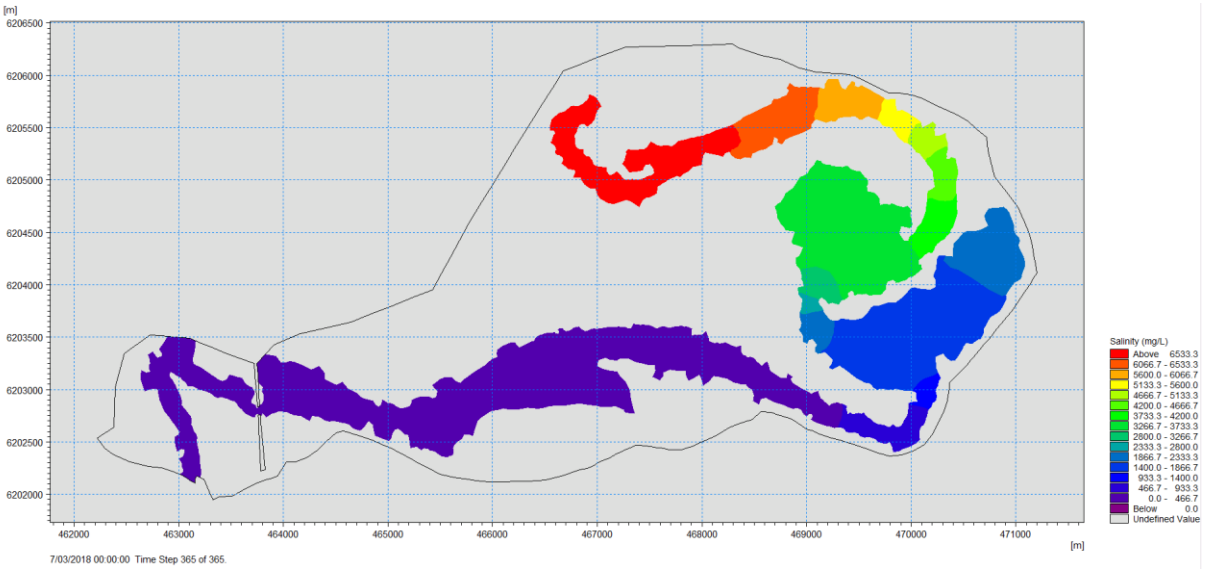


Figure 9. Salinity concentration (mg/L) at the end of the 12 month period – no raising

3.3 Required conditions to flush the wetland

Given that the previous scenario did not result in complete flushing of the wetland, this scenario is designed to investigate the conditions required to flush the wetland and improve the water quality conditions.

In order to get an indication of the required condition to reset/flush the wetland, a simplified water balance model of the lakes was developed. It should be noted that for the purpose of water balance calculation, the volumetric requirement for flushing the wetland is defined as filling the wetland from an empty condition, since the proper reset/flush of the wetland potentially requires several cycles.

Bathymetry data for the permanently inundated sections of the wetland were derived from the latest 2016 River Murray DEM which includes both LIDAR and photogrammetric data. Figure 10 shows the bathymetry relationships for the wetland.

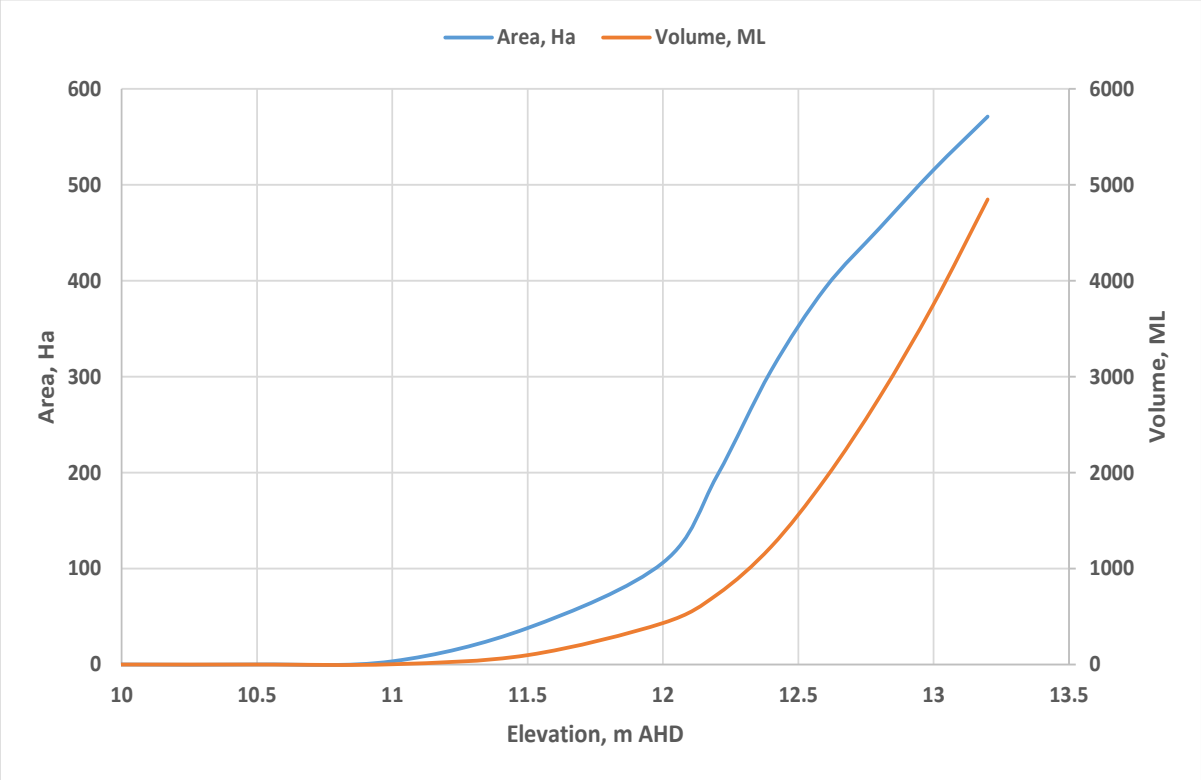


Figure 10. Bathymetry relationships for the wetland

Water balance analysis was undertaken to estimate the duration of series of particular inflows that is required to fill the wetland to the maximum volume of 4950 ML. Table 1 shows flow and duration of flow though Lyrup Creek that is required to flush the wetland.

Since weir pool raising event has been proposed for a duration of 30 days, it is estimated that flow through Lyrup Creek in the order of 200 ML/day is required to flush the wetland during a 30-day raising event. It should be noted that this approach provides a first pass assessment of flow rates required as a number of aspects are not considered, for example groundwater discharge, evapoconcentration and increases in volume due to weir pool raising. The approach also assumes

plug flow through the wetland, where river water pushes out the higher salinity water in the wetland, with no short circuiting (or preferential flow characteristics).

Table 1. Condition required to fill the wetland

Inflow (ML/day)	Duration (days)
60	203
70	134
80	95
90	77
100	65
120	51
150	38
200	28

Furthermore, a range of scenarios were simulated using the hydrodynamic model to estimate flow through Lyrup Creek under different flows, weir pool levels and also different sill levels. Table 2 shows modelled flow through Lyrup Creek under various conditions. Scenarios that are expected to flush the wetland in a 30-day period are highlighted in yellow. Black shading indicates scenarios that are not expected to be feasible from a weir pool raising perspective, confirmation of the ability to undertake weir pool raisings at higher flows is required.

Table 2. Flow through Lyrup Creek (ML/day) under different river flow and WP raising conditions

River flow (ML/day)	No raising	No raising	No raising	60 cm raising	75 cm raising	114 cm raising
	Lyrup Ck Not deepened	Lyrup Ck Deepened 13.3 m AHD	Lyrup Ck Deepened 12.5 m AHD	Lyrup Ck Not deepened	Lyrup Not deepened	Lyrup Not deepened
20000	0	1	2	22	39	102
25000	0	6	49	30	49	131
30000	1	19	106	42	64	155
35000	8	47	170	59	84	182
40000	17	93	246	81	109	215
45000	51	230	407	153	193	332
50000	116	443	625	268	323	
55000	226	748	922	544		
60000	362	1112	1274			
65000	857	1484	1637			
70000	995	1897	2048			

From this analysis, for a 60 cm weir pool raising event over 30 days and assuming the current Lyrup Creek sill level condition, is it calculated that a minimum QSA flow of 50,000 ML/day is required.

To test this first-pass assessment, this scenario was simulated using the hydrodynamic model. The salinity data gathered through run of the river on 12 July 2016 was processed and used as the initial salinity condition. River Murray flow at the border was assumed to be 50,000 ML/day and mean monthly climate data was applied for the modelling period. Time series of modelled salinity concentrations are shown in Figure 11.

It can be seen that salinity concentrations are expected to reduce to less than 2000 EC at all five reporting points in the wetland. However, as a result of flowing saline water from Lyrup Creek into the wetland, the salinity concentration at the pump location increased to approximately 6000 EC during the holding phase as salt was exported through the wetland.

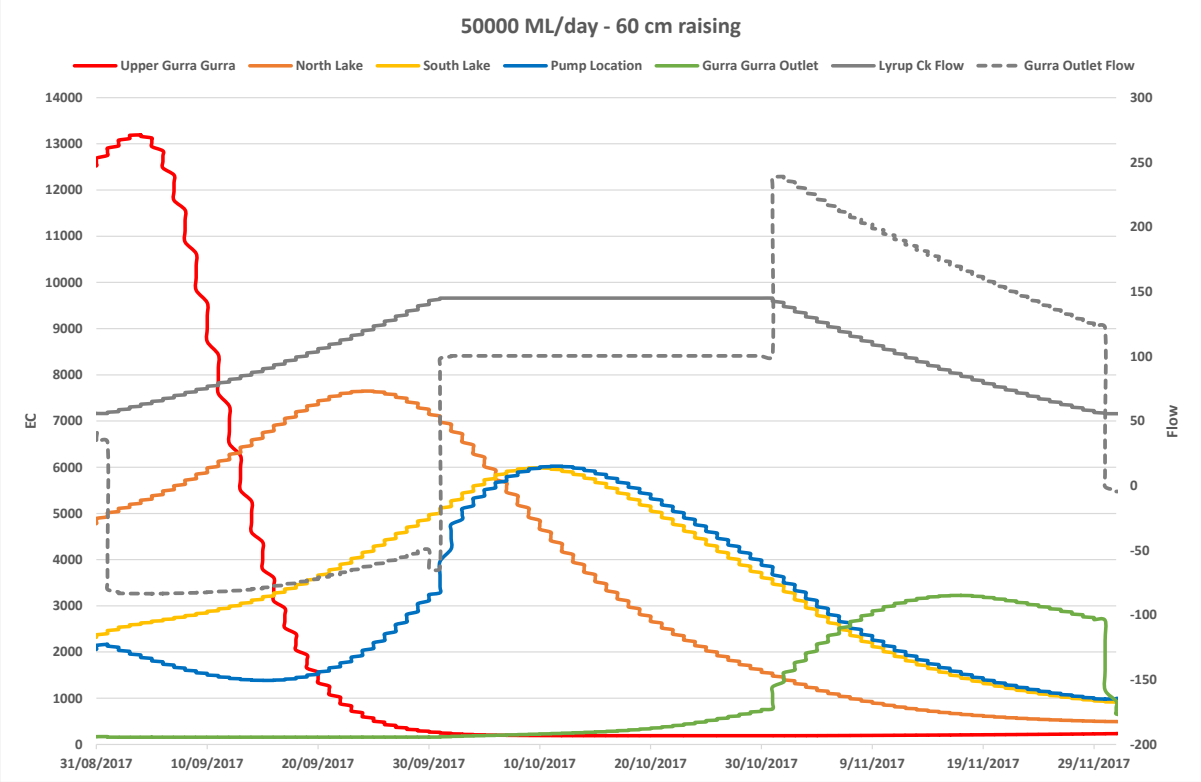


Figure 11. Time series of salinity (EC) and Flow (ML/day) at outputs locations in the wetland – 50,000 ML/day and 60 cm raising

3.4 Longer term weir pool raising and sill lowering scenarios

The previous results indicate that over the short term, when under a weir pool raising condition there is always a negative salinity impact at the pump location, as any salt exported from the wetland on the recession from a weir pool raising event will result in increased salinity, compared to an inflow of river water driven by the evaporative demand in the wetland. However the constant water level case also results in continued evapoconcentration within the wetland.

Therefore, a range of scenarios were designed to investigate if longer-term regular flushing of the wetland through weir pool raising is able to improve the water quality, and mitigate the high salinities that may temporarily occur when overbank flows do flush higher-salinity water from the wetland.

Scenarios that deepened the Lyrup Creek to a minimum 12.5 m AHD where necessary were also considered to increase the flow rate into the wetland.

The scenarios considered were:

- No raising and Lyrup flow path not deepened
- Raising (114 cm for 30 days every year) and Lyrup flow path not deepened
- No raising and Lyrup deepened
- Raising (114 cm for 30 days every year) and Lyrup deepened

To simulate the deepening of the Lyrup Creek a low flow channel through the creek was enforced in the model, having a 2 m base width and 12.5 m AHD invert.

A 5-year period was considered from March 1961 to March 1966 from a Murray–Darling Basin Plan water recovery scenario (BP2750), with maximum QSA flow less than 40,000 ML/day (a flow that cannot flush the wetland naturally) for three consecutive years, followed by a high flow of around 80,000 ML/day which flushes the wetland. Time series of river flow at the border and corresponding water level upstream of Lock 4 is shown in Figure 12. The latest salinity data gathered on March 2017 was used as the initial salinity condition.

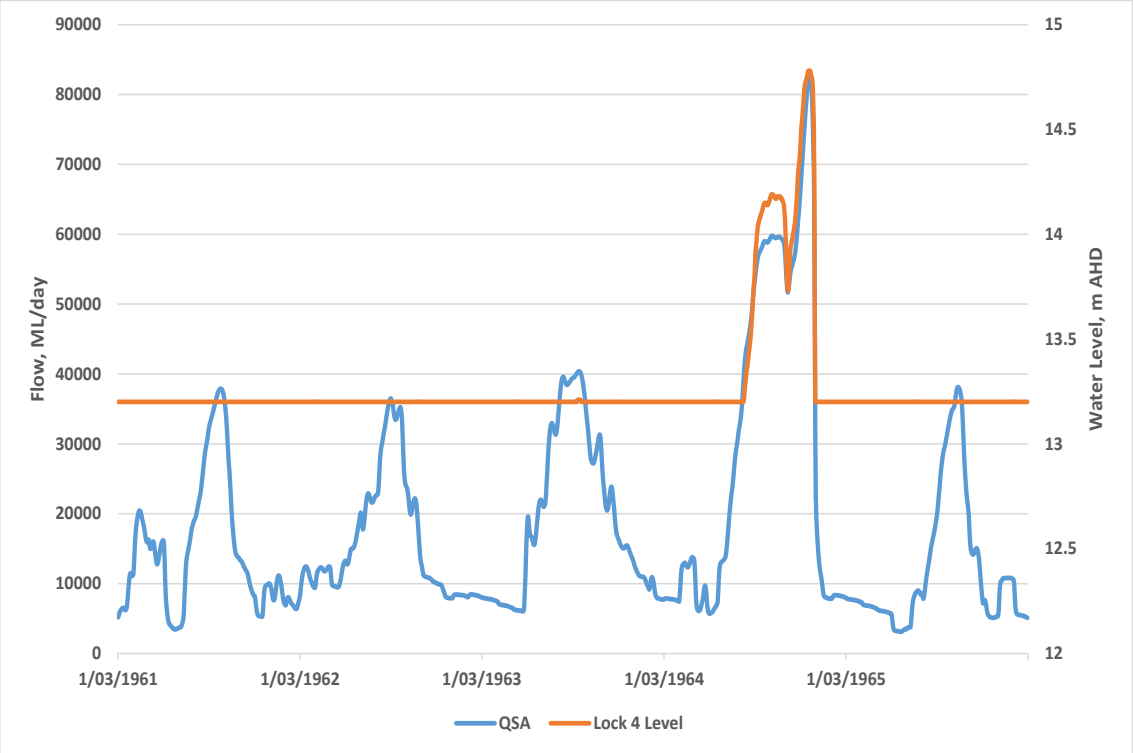


Figure 12. Time series of river flow (ML/day) and Lock 4 level from 1961 to 1966

3.4.1 Long term impact of Weir pool raising events

As shown in Figure 13, under the "no raising" condition, salinity concentrations in North and South Lakes increased during the first three years, as peak flow rates were less than 40,000 ML/day and inflows through Lyrup Creek was very small during these flows, limiting the amount of flushing through the wetland. However, these very small flows through Lyrup Creek during peak flow rates resulted in some spikes of salinity at the pump location. After three years the salinity reached up to 16,000 EC in North Lake, which resulted in salinity at the pump location peaking to approximately 7000 EC in response to the high flow event in the fourth year, an event that reset the simulated wetland salinities below 2000 EC.

Under weir pool raising condition "114 cm raising", the increase in salinity concentrations in North and South Lakes was almost halved compared to the "no raising" condition (shown in Figure 14). Salinity concentrations only reached 8000 EC in North Lake as a result of higher inflows through Lyrup Creek during the raising events, and consequently the high flow event in the fourth year did not increase the salinity as much at the pump location. However, longer periods of higher salinity concentrations at the pump location are observed during the first three years when compared to the "no raising" condition.

The results indicate that upper parts of the wetland are most benefited from weir pool raising events and the water quality in upper parts is improved due to higher inflows through Lyrup Creek. However, the changes at the lower parts of the wetland including the pump location are mixed, with reduced peak salinities due to the fresher wetland, but longer periods of elevated salinities due to more regular export of salt from the wetland.

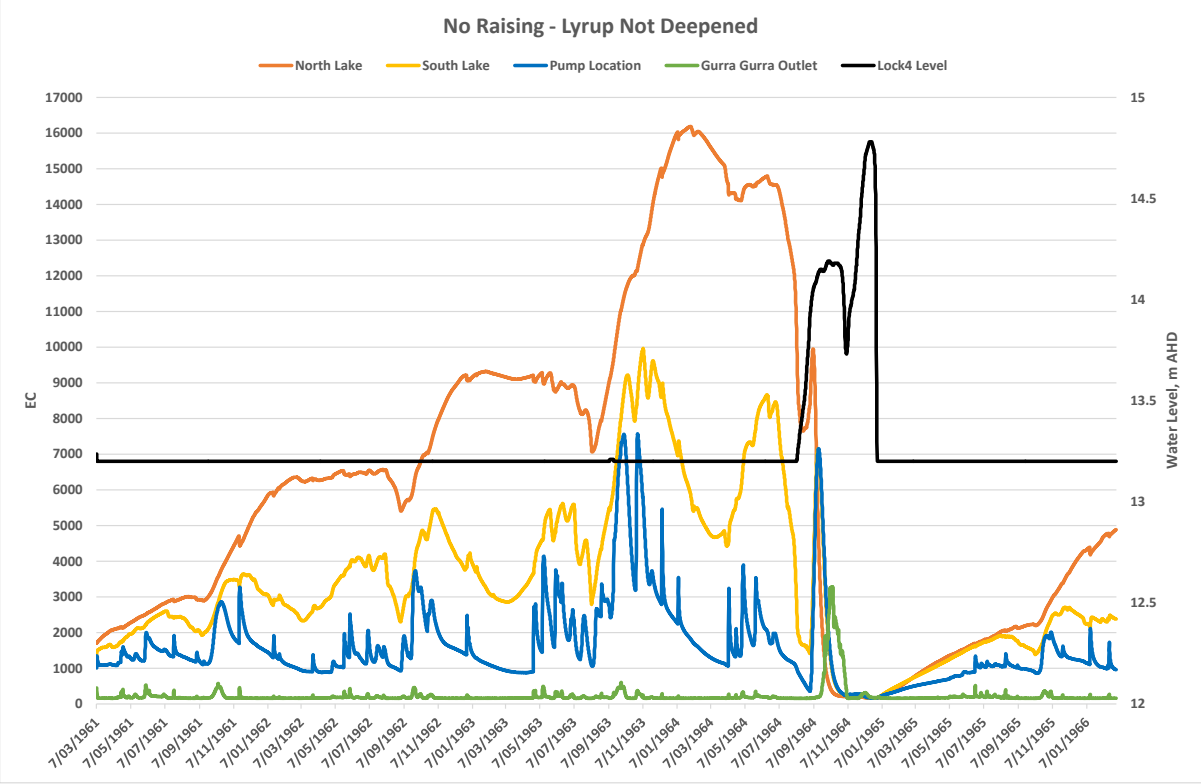


Figure 13. Time series of salinity (EC) at outputs locations and Lock 4 level (m AHD) – natural condition

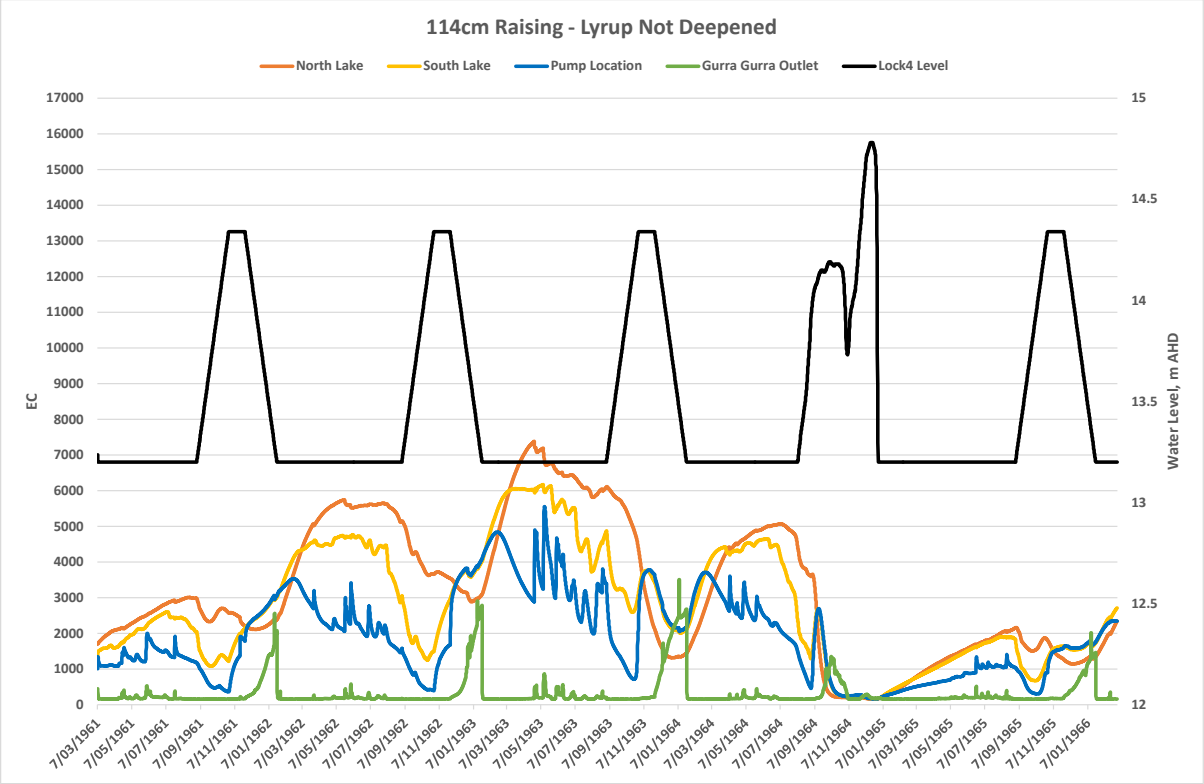


Figure 14. Time series of salinity (EC) at outputs locations and Lock 4 level (m AHD) – 114 cm raising and Lyrup not deepened

3.4.2 Long term impact of deepening Lyrup Creek

The impact of deepening Lyrup Creek to 12.5 m AHD on salinity concentrations in the wetland was assessed for comparison with the impact of weir pool raising events.

To deepen the Lyrup Creek it was assumed that a low flow channel is being enforced through the creek that has a 2 m base width and 12.5 m AHD invert. The long section of Lyrup Creek and an example of a deepened cross-section is provided in Appendix B.

In Phase 1, it was estimated that approximately 20,000 m^3 of material are required to be removed based on available cross-section information to deepen Lyrup Creek sills to 12.5 m AHD (DHI, 2016).

As can be seen in Figure 15, a sill lowering by almost one metre without weir pool raising events significantly reduced the salinity concentrations in North and South Lakes. Maximum salinity in North Lake reached approximately 4000 EC and salinity at the pump location was substantially lower, with salinity peaked up to 3500 EC during the peak flow periods.

However, the most effective management scenario is a combination of weir pool raising events and the deepening of Lyrup Creek, which resulted in a substantial reduction in salinity concentrations across all parts of the wetland. In this case, the maximum salinity at the pump location reached approximately 2000 EC during the peak flow periods (shown in Figure 16).

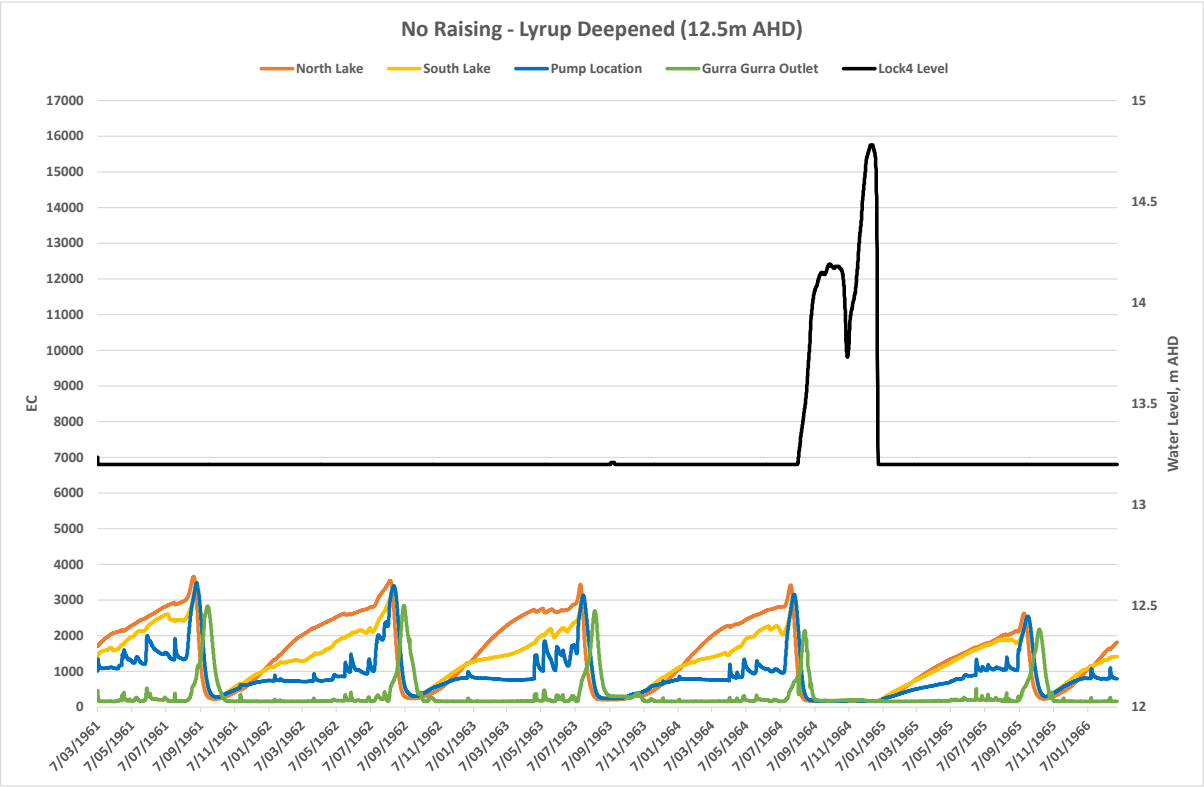


Figure 15. Time series of salinity (EC) at outputs locations and Lock 4 Level (m AHD) – no raising and Lyrup deepened to 12.5 m AHD

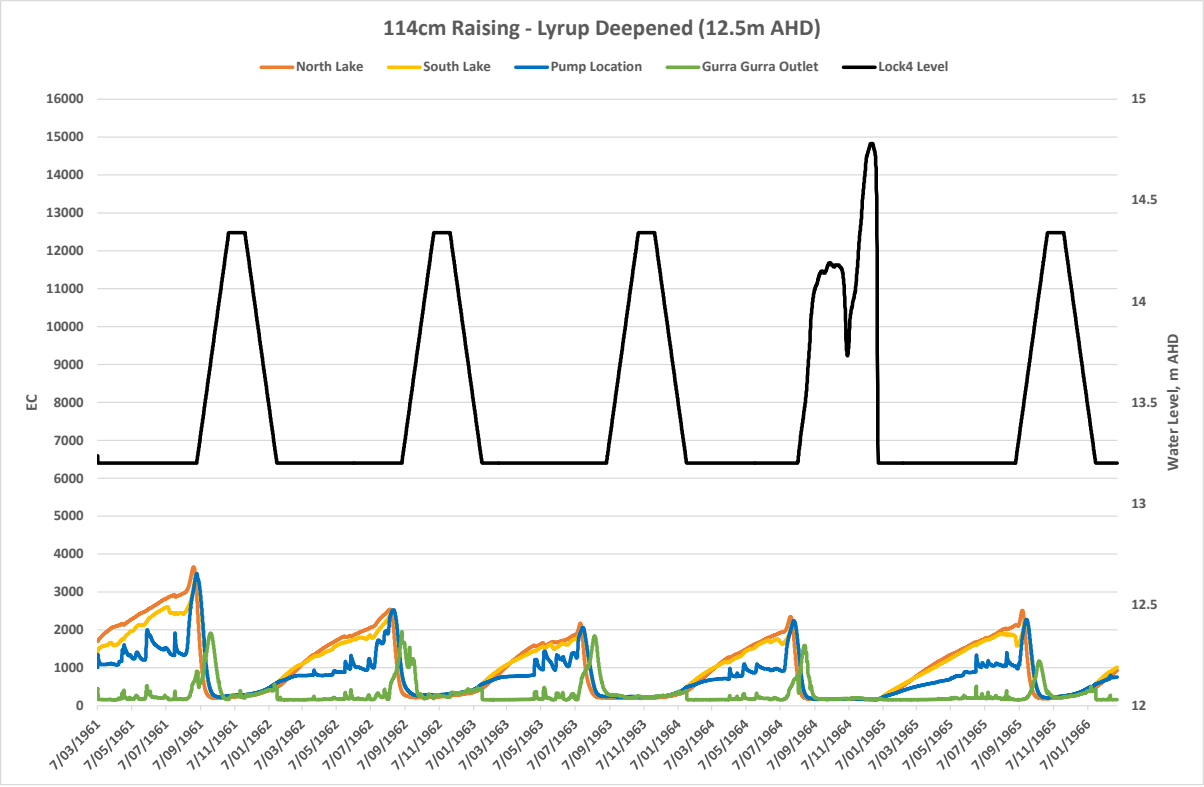


Figure 16. Time series of salinity (EC) at outputs locations and Lock 4 Level (m AHD) – 114 cm raising and Lyrup deepened to 12.5 m AHD

The scenarios above represent extreme cases, that is, for full weir pool raisings every year to 114 cm (top of piers) and a substantial deepening of Lyrup Creek to 12.5 m AHD, 0.7 m below normal pool level. This following additional scenario considered a more refined option from the extreme extents above:

- 60 cm weir pool raising and Lyrup Creek deepened to 13.3 m AHD

The level of 13.3 m AHD was selected as it represents a minor excavation activity compared to deepening to 12.5 m AHD and it matches with the level of invert of the culverts at Tortoise Crossing that act as a flow constraint just upstream of the wetland.

This level is above the normal pool level of 13.2 m AHD, which means water is not expected to flow into Lyrup Creek under normal conditions. However, during weir pool raising events inflows through Lyrup Creek are expected to be higher when compared inflows with current sill level.

As can be seen in Figure 17, the maximum salinity in North Lake is expected to reach approximately 4500 EC, and salinity at the pump location remained under 2000 EC for the majority of the time with peak salinity up to 4000 EC.

It should be noted that only one configuration of each of the sill-lowering levels have been considered. Different combinations of depth and width will influence the flow through Lyrup Creek, up to the point where flow constraints shifts from Lyrup Creek to the culverts at Tortoise Crossing. For example, Lyrup Creek deepened to 13.3 m AHD with additional widened would be expected to increase the flushing capability.

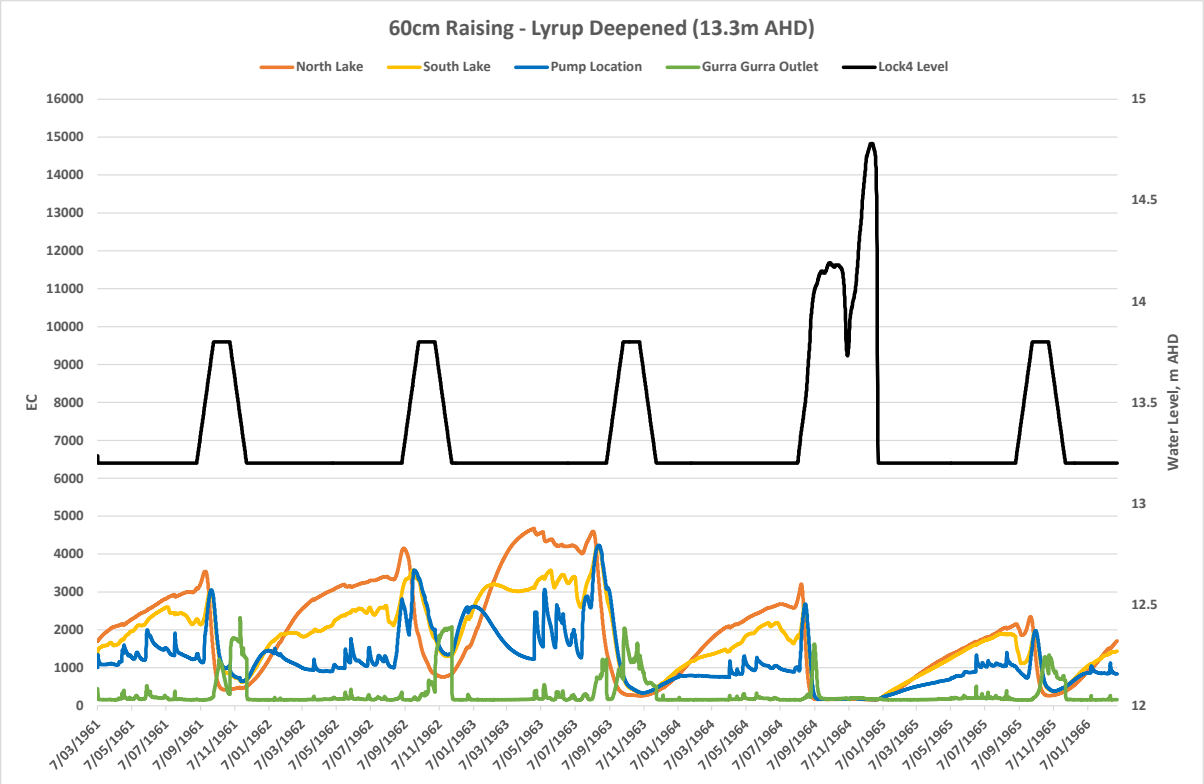


Figure 17. Time series of salinity (EC) at outputs locations and Lock 4 Level (m AHD) – 60 cm raising and Lyrup deepened to 13.3 m AHD

4 Summary

A weir pool raising event at Lock 4 was simulated over a three month period to understand the impact of weir pool raising on the distribution of salinities within the wetland. The results indicated that under a weir pool raising event, salinity increased at the pump location by the end of the weir pool raising event as salt was exported from the upper parts of the wetland by relatively small inflows through Lyrup Creek during the holding phase. Under current conditions, evaporation from the wetland resulted in a regular fresh inflow to the wetland and contributes to the water quality at the pump location. However as a consequence of the continued evapoconcentration, the salinity in the upper parts of the wetland continued to increase.

An extended weir pool level raising trial at Lock 4 was simulated over a 12-month period to understand how salinity changes over time due to both evapoconcentration and weir pool raising event. The results did not reveal any significant changes in salinity or flow behaviour compared to the three month scenario.

Water balance analysis was undertaken to investigate the conditions required to flush the wetland. It was estimated that flow through Lyrup Creek in the order of 200 ML/day is required in order to flush the wetland during a 30-day raising event. Consequently, a range of scenarios were simulated to estimate flow through Lyrup Creek under different flow, weir pool levels and also different sill levels to identify conditions that result in inflow of >200 ML/day through Lyrup Creek.

Longer term 5-year scenarios were designed to investigate if regular flushing of the wetland through annual weir pool raising could improve the salinity within the wetland, and mitigate the high salinities that may occur when overbank flows do flush higher salinity water through the wetland. The results indicated that upper parts of the wetland most benefited from regular weir pool raising events, as the water quality in the upper parts of the system improved due to higher inflows through Lyrup Creek. However, the changes at the lower parts of the wetland, including at the pump location, were mixed, with reduced peak salinities (5500 EC compared to 7500 EC under no raising condition) due to the fresher wetland, but longer periods of elevated salinities due to increased regularity of salt export through the wetland.

Impact of deepening Lyrup Creek to 12.5 m AHD on salinity concentrations was also assessed and compared with the impact of weir pool raising events. The results indicated that sill lowering by almost one metre without weir pool raising events significantly reduced the salinity concentrations across all parts of the wetland. Salinity at the pump location was substantially lower, with salinity peaks up to 3500 EC, compared to 5500 EC under natural conditions (i.e. without sill lowering or weir pool manipulation).

However, the most effective management scenario was a combination of regular weir pool raising events and a deepening of the Lyrup Creek that resulted in a substantial reduction in salinity concentrations across all parts of the wetland. In this case, the maximum salinity at the pump location reached approximately 2000 EC during the peak flow periods.

Further investigations should include:

1. Increase in the discharge of saline groundwater along the reach between the River Murray and the wetlands, to better represent the observed increases in salinity post the 2016 flood event.
2. On ground investigation to further understand saline discharge from groundwater on salinity concentrations in the wetland.
3. Refinement of the benefits from lowering and/or widening modifications to Lyrup Creek to freshen the wetland relative to excavation required.
4. Interaction between Lyrup Creek modifications with the frequency and size of Lock 4 weir pool raising and lowering.

5 References

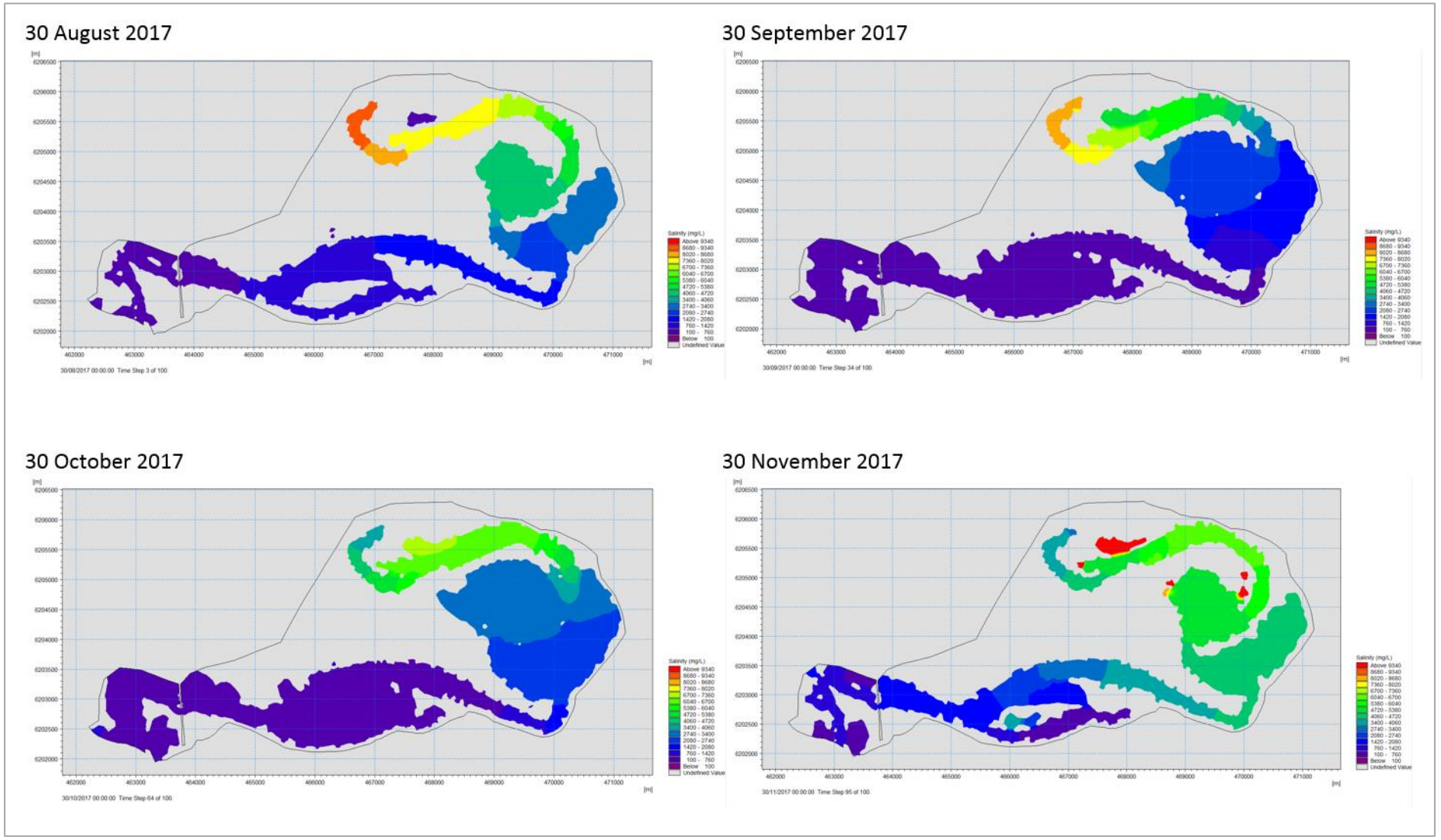
DHI 2016, DEWNR Gurra Gurra Lyrup Forest Modelling, Final Report, September 2016

DHI 2017, DEWNR Gurra Gurra Lyrup Forest Modelling, Phase 2 Model Validation, February 2017

REM 2003, High Salinity Groundwater Investigations – Gurra Gurra lakes

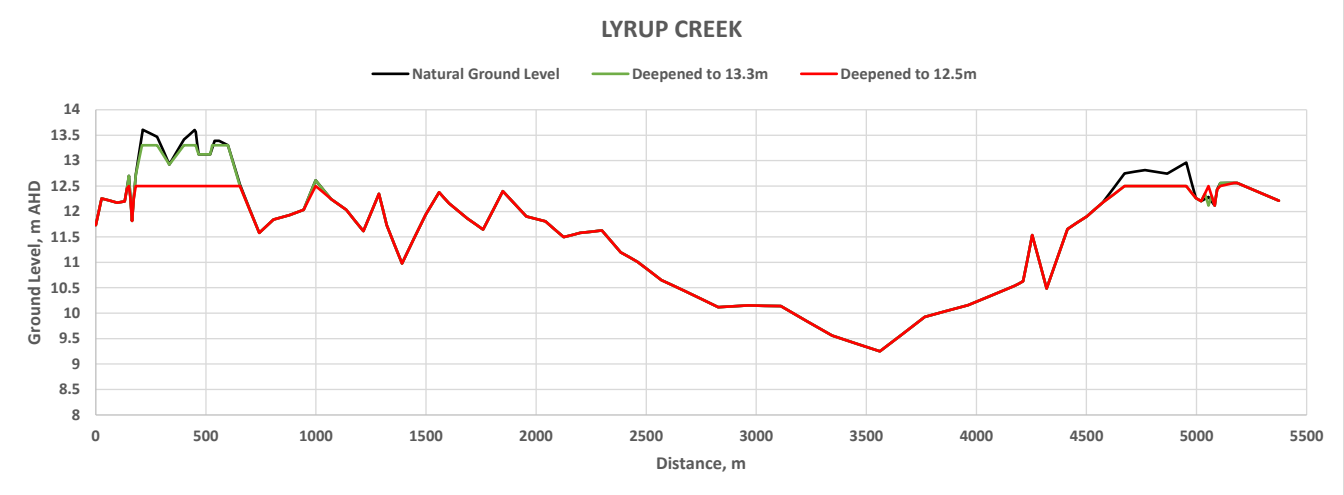
Appendix A

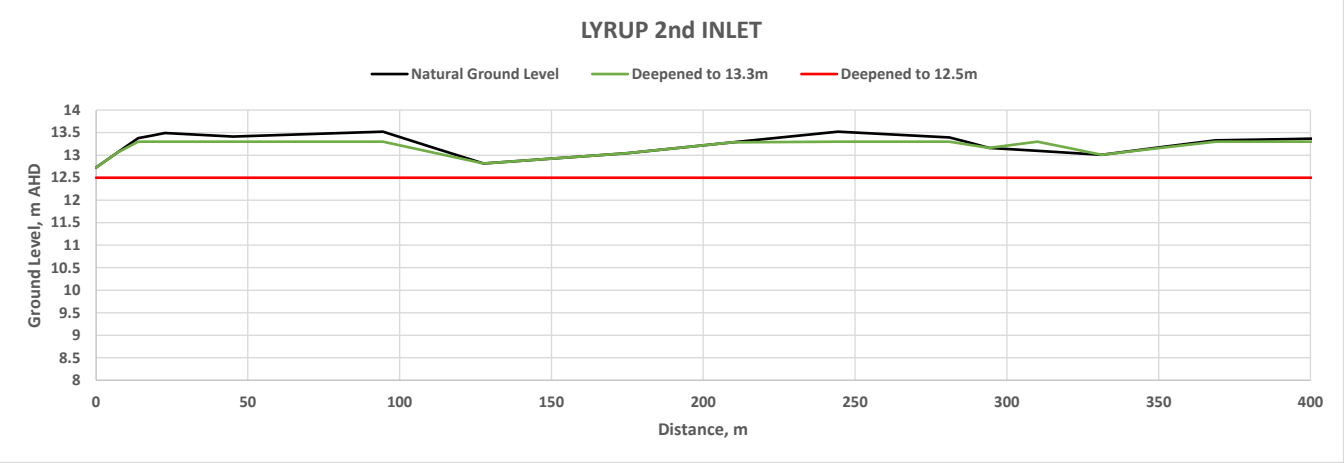
Snapshot of salinity concentration (mg/L) at key stages of 2017 proposed raising event



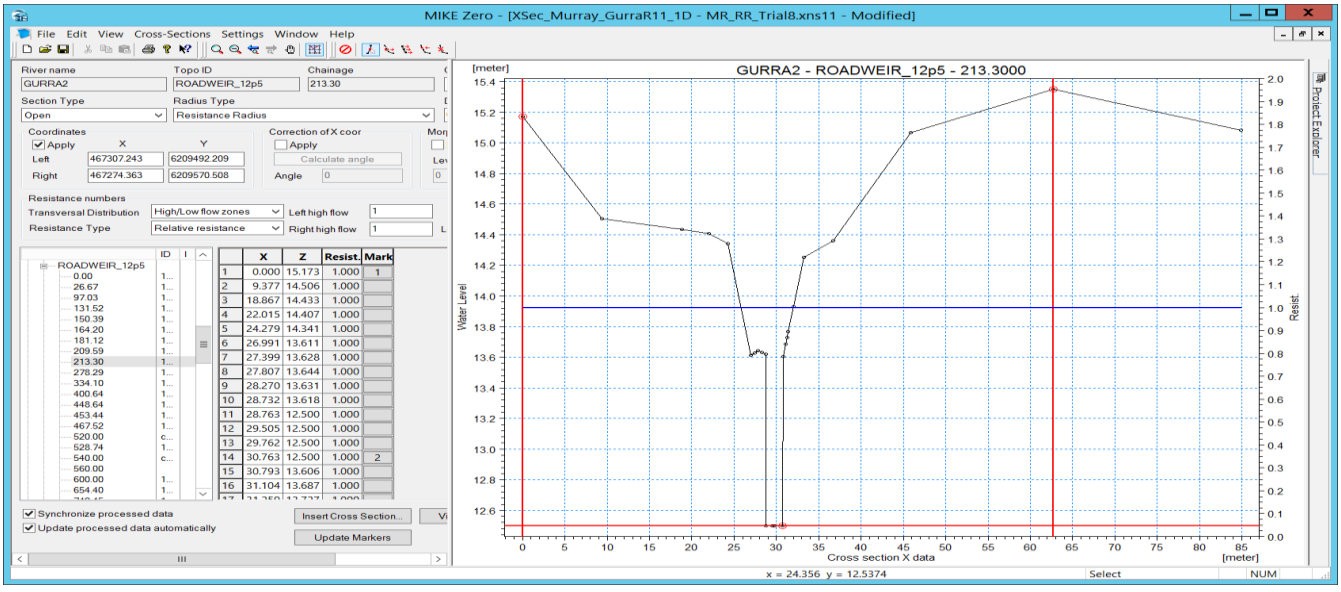
Appendix B

Lyrup Creek long sections





Example of a deepened cross-section





Government of South Australia
Department of Environment,
Water and Natural Resources