Estimation of potential water savings at Yatco Lagoon through hydrological manipulation

for

Yatco Wetlands Landcare Group

by

Dr Christopher Gippel

Fluvial Systems Pty Ltd

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1 Introduction

1.1 Objective

Yatco Lagoon is a large permanent wetland located on the west bank of the River Murray in South Australia (Figure 1 and Figure 2), approximately 454 km from the mouth and immediately upstream of the township of Moorook (SKM, 2006). The Lagoon comprises two main water bodies with a total surface area of approximately 346 ha (SKM, 2006). The two sections are separated by a man-made causeway (Figure 3). Pipes have been placed in the causeway to promote flow between the two water bodies (SKM, 2006).

The northern inlet of the wetland is the deepest part of the wetland, with the southern half of the North Lagoon being the deepest part, at around 2 m deep when the wetland is full (Figure 3). The South lagoon is less than 1 m deep.

SKM (2006) recommended a number of works for Yatco Lagoon that would achieve water savings and ecological rehabilitation. The main structure was a bank with regulator across the northern (downstream) river-wetland connecting channel approximately one kilometre from the entry to the main river (Figure 3). This location was selected to eliminate any impact of the regulating infrastructure on dwellings located on the northwestern bank of the wetland.

As part of the current water savings and wetlands management initiative of the Yatco Wetlands Landcare Group professional advice has been sought in relation to the potential water savings that can be achieved through the re-introduction of various wetting and drying regimes to Yatco Lagoon. The wetting and drying regimes will be achieved by construction of the northern bank (described above).

Two main water saving scenarios are envisaged. The first scenario is drought contingency measure drying, which involves immediate closure of the North Lagoon with the proposed bank, and allowing the wetland to naturally draw down by evaporation. The North Lagoon will initially be isolated from the South lagoon, which will remain connected with the River Murray for irrigation supply. There remains a possibility that the South Lagoon could also be drawn down should the government decide to support provision to irrigators of a piped supply from the river. The second scenario involves phased, incremental drying over three years.

The objective of this report is to estimate the potential for water savings under the proposed wetting and drying scenarios. Savings are expressed as water that would otherwise have been lost from the River Murray in supplying water to Yatco Lagoon had the structure not been in operation. The savings were calculated using the SWET (Savings at Wetlands from Evapotranspiration daily Time-series) daily time-step water balance model (Gippel, 2005a; 2005b; 2005c). The model has been endorsed as a procedure for listings on The Living Murray Developmental Register.

The SWET model attempts to estimate all the components of the hydrological cycle that influence water level in the wetland or lake. Net evaporation (or evapotranspiration) is the component of the budget that is targeted for reduction by water recovery interventions. Net evaporation is the balance of evaporation plus rainfall, plus inflows, minus pumping and minus seepage. When the wetland or lake water budget is balanced for current hydrological and operating conditions, the volume of water that is currently lost from the river to the wetland can be estimated. The estimate can be described by the annual average, or some other relevant statistic(s), calculated over the standard time period (i.e. the 109-year Cap Benchmark period from May 1891 to April 2000). The components of the balanced water budget model can be modified to fit the conditions that will apply under proposed future operating scenarios (with water recovery interventions in place), and the revised estimate of losses can then be compared with that for current conditions. The difference in these two modelled values is the water 'savings'.

This report describes the input data sources, provides summaries of input data, documents model parameters, describes model sensitivity, provides estimates of potential water savings under the defined future operating conditions, and characterizes wetland water level regimes under the defined future operating conditions.

It is stressed that the SWET estimates of savings are presented as a statistical result, not as a firm prediction of the savings that might be realized into the future. The future savings cannot

be known because the future climate and river flows cannot be known. Thus, the estimates are based on a statistical analysis of the savings that would have been achieved over the period 1891 – 2000 had the proposed works been in place over that period.

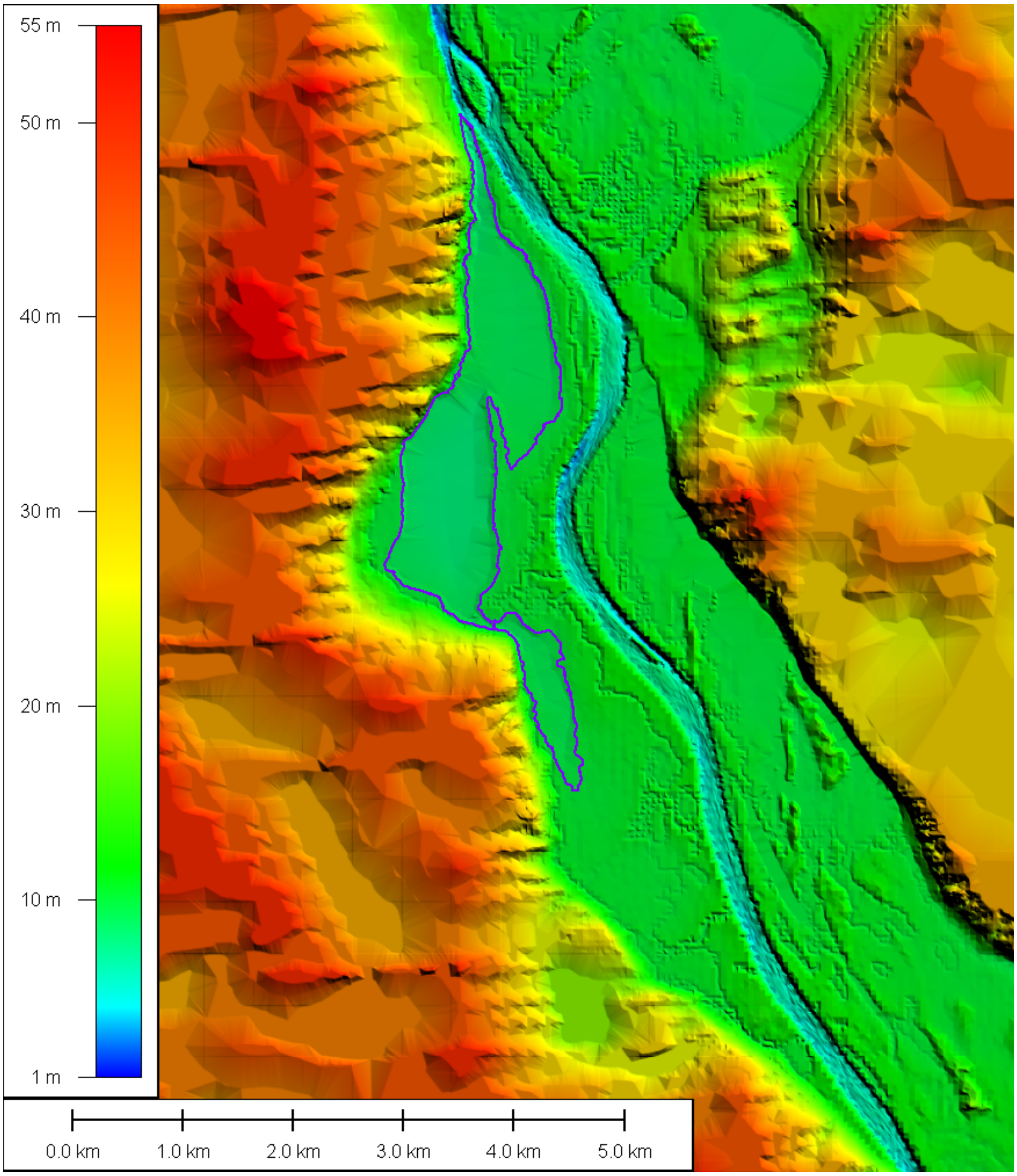

Figure 1. Plan view topography of River Murray in the vicinity of Yatco Lagoon. River flow is south (bottom) to north (top). Yatco Lagoon outline is shown at 9.9 m AHD, which corresponds to bankfull level (upper regulated river flow level). Based on 50 m grid DTM dataset 514 (DEH) merged with 5 m grid DTM generated from hydrographic data surveyed by SKM (2006).

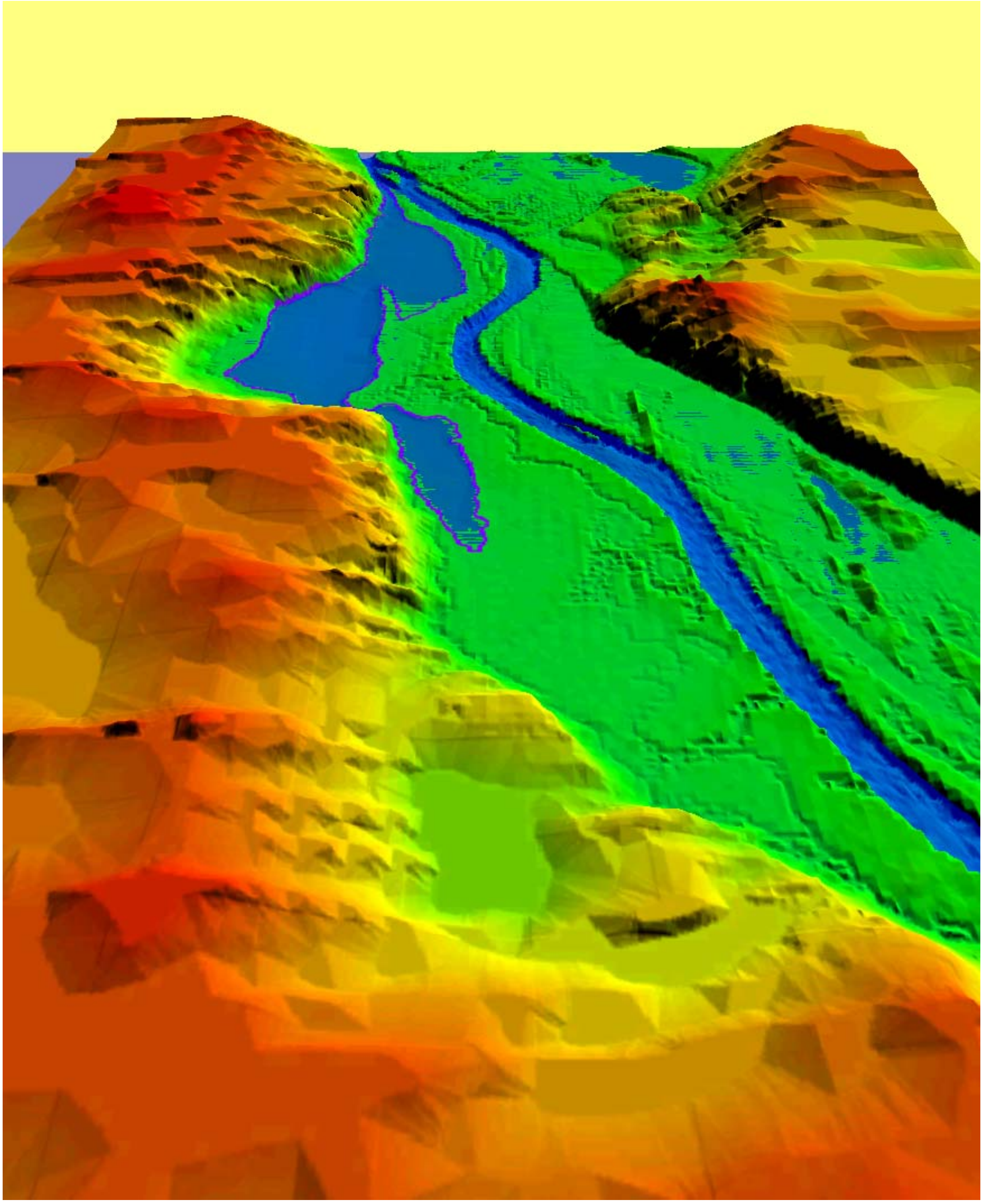

Figure 2. 3-D view topography of River Murray in the vicinity of Yatco Lagoon, shown with 10x vertical exaggeration. River flow is south (bottom) to north (top). Water level is shown at 9.9 m AHD, which corresponds to bankfull level (upper regulated river flow level). Based on 50 m grid DTM dataset 514 (DEH) merged with 5 m grid DTM generated from hydrographic data surveyed by SKM (2006).

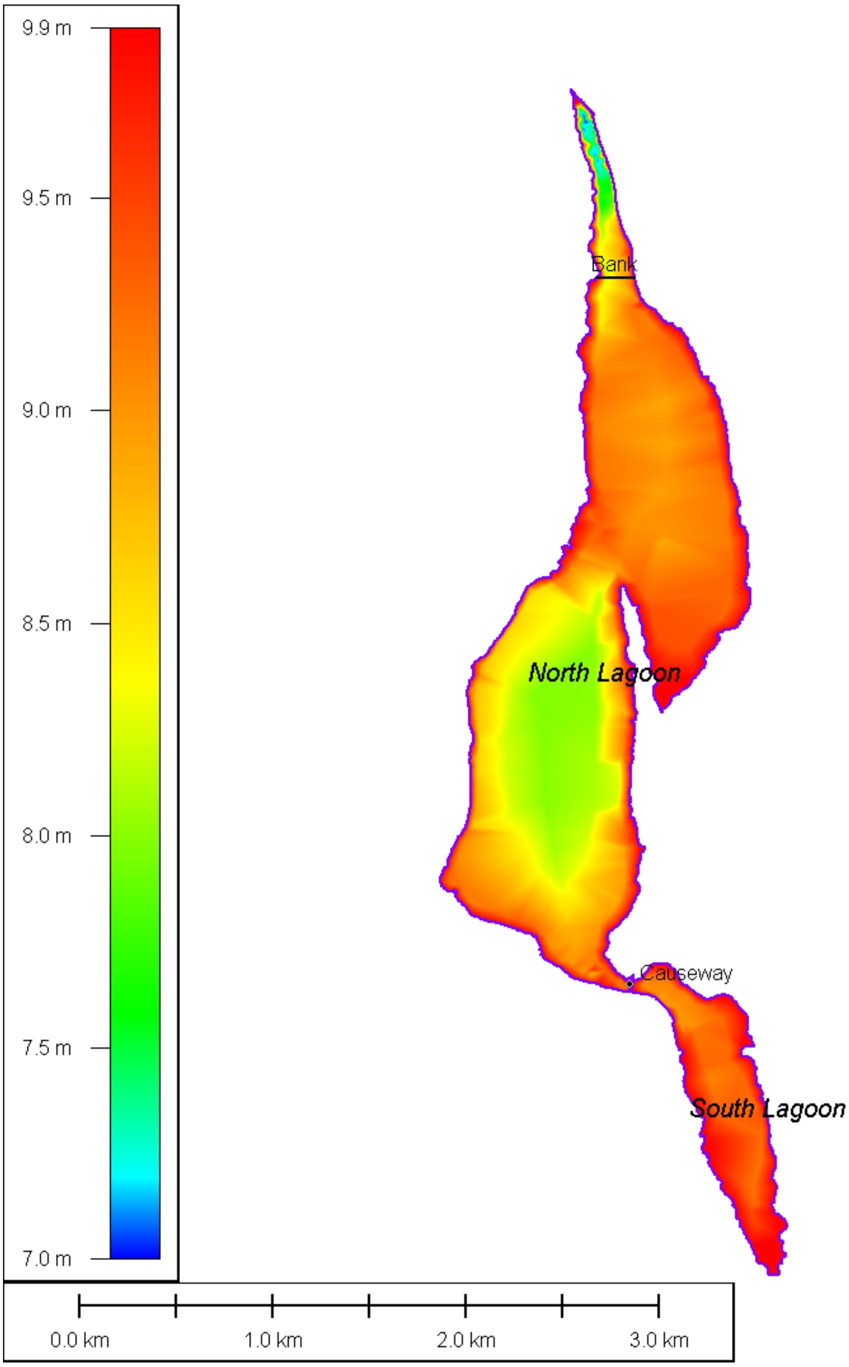

Figure 3. Bathymetry of Yatco Lagoon. Outline is shown at 9.9 m AHD, which corresponds to bankfull level (upper regulated river flow level). Based on 5 m grid DTM generated from hydrographic data surveyed by SKM (2006).

1.2 Previous investigation

Yatco Lagoon was one of 11 wetlands modelled using SWET as part of the Water Recovery from SA River Murray Wetlands – Stage 2 (SKM, 2006). In that study Yatco Lagoon was considered a single unit, with North and South Lagoons combined and the northern boundary extending to the River Murray. The 5-year regulator operating cycles proposed in SKM (2006) were based on information obtained from the River Murray Baseline Survey. These cycles were not reflective of management objectives for any site as in many cases these have yet to be determined. The management cycles were considered representative of typical hydrological management scenarios used in other River Murray wetlands. The scenario modelled for Yatco Lagoon realized a long-term average annual water saving of 331 ML.

The basic Yatco Lagoon SWET model developed for SKM (2006) was retained for this study, with considerable improvements and modifications made to suit the objectives of this study. The main differences relate to:

- splitting the wetland into two separate units (North and South Lagoons);
- setting the northern boundary of the North Lagoon at the proposed bank, rather than at the River Murray junction;
- recalculating the bathymetric relationships for the wetland;
- using improved seasonal adjustment factors for evapotranspiration; and
- using completely new operating scenarios

The model description and discussion of model error and sensitivity found in SKM (2006) also apply to the modified model presented here. SWET estimates of savings are subject to uncertainty because of uncertainty in specifying some model parameters and likely error in input data (Gippel, 2005b). This problem is common with every hydrological modelling exercise and is no more pronounced in SWET than in any other model. The SWET model attempts to account for all physical water balance processes, and is the best available model for this purpose. Every effort was made to minimize the errors in input data, and the most appropriate model parameters were selected for use in this application.

2 Data Inputs

2.1 Introduction

This section details how the model input data were collected or derived. For most parameters, a description is provided of the main characteristics of the input data.

2.2 Bathymetric relationships

SWET requires two bathymetric relationships: wetland water level versus wetland surface area and wetland water level versus wetland volume. The relationships cover the full range of possible wetland water levels, from the invert (deepest point) to the maximum height of the river. As the model is run over the 109-year MSM-Bigmod Benchmark period, this means that the range of the elevation data must cover the range from very low flows to the maximum flow on record.

Bathymetry data for elevations over the range from the invert to the normal summer regulated flow level were derived from detailed survey data. Yatco Lagoon was surveyed from an elevation of 9.9 mAHD and below as part of Water Recovery from SA River Murray Wetlands – Stage 2 (SKM, 2006). The raw hydrographic data were supplied to this project. The spot height data were gridded to a 5-metre grid digital elevation model (DEM). The areal extent of the DEM was expanded by merging it with the 50-metre grid DTM dataset 514 for the River Murray in South Australia (DEH). Bathymetry for the wetland basins was calculated up to an elevation of 10 mAHD at a number of elevation increments (35 increments for South Lagoon and 44 for North Lagoon). The bathymetry of the section of North Lagoon north of the proposed bank was also estimated. Data for the three units were then combined, and the areas and volumes checked against the original Yatco Lagoon bathymetric relationships used in SKM (2006). The values were virtually identical, which confirmed that the derived DEM was the same as the original version, and the bathymetric estimates were correct.

A linear interpolation algorithm was used to calculate volumes and surface areas at 0.01 m intervals. Note that this resolution exceeds the survey accuracy but the daily water level responses are sometimes sensitive to hydrological processes (evaporation, inflows etc.) of this order. Thus, the model elevation resolution of 0.01 m is justified on the basis that this is required in order to represent the physical processes. However, model water level outputs should be interpreted to an accuracy of probably ±0.1 - 0.3 m for any particular elevation (includes survey and other input data error and modelling error).

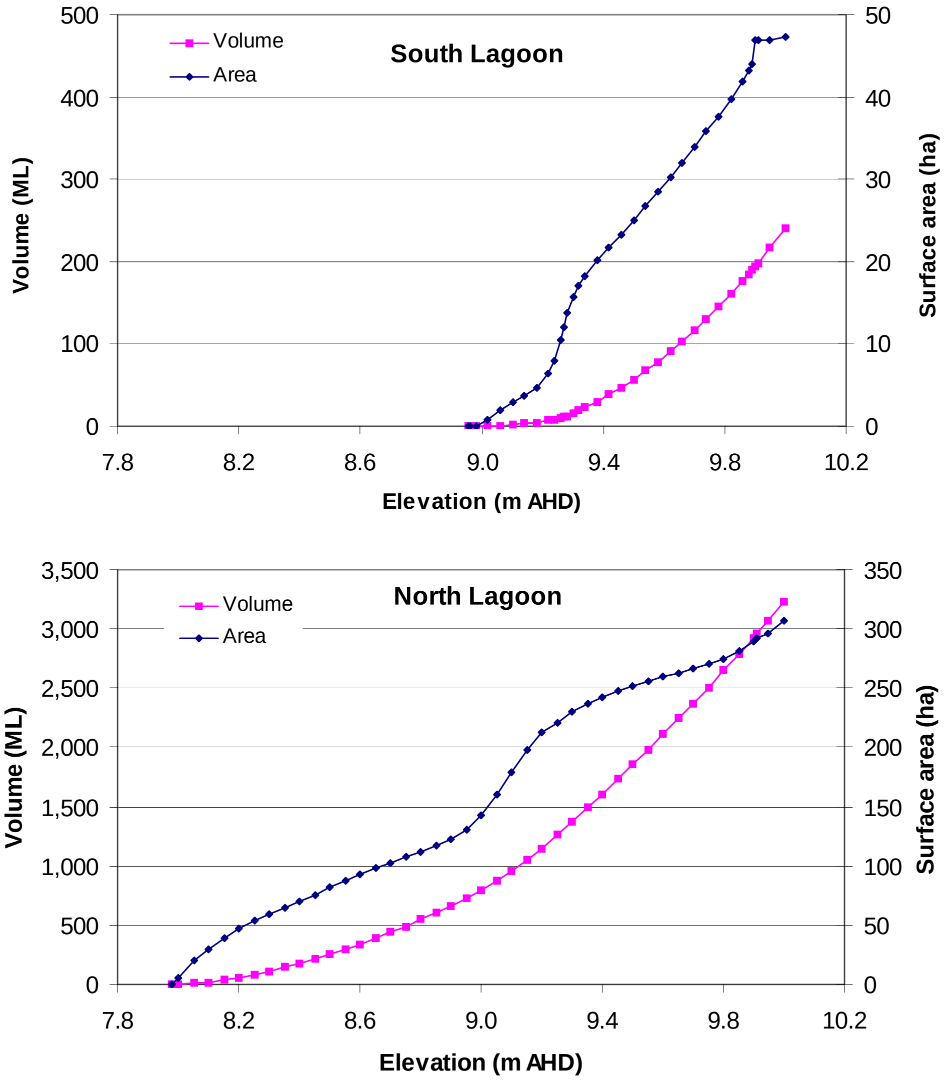

Figure 4. Bathymetric relationships for Yatco Lagoon, shown for South (top) and North (bottom) Lagoons. Note variable axis scales. Marked points are measured values.

Beyond 10 mAHD elevation lies the main floodplain surface, up to 15.38 m AHD, which corresponds to the maximum flood on record (1956). In the original Yatco Lagoon SWET model, the River Murray Flood Inundation Model II (FIM) (Overton, 2001) was used to estimate surface areas above 9.9 m up to 15.38 m AHD. Local hillslope sources of runoff were ignored, largely because of lack of local information, and also because of an assumption that this would be a small contribution.

As explained in SKM (2006), inclusion of above-bankfull (i.e. floodplain) surface areas and volumes in the bathymetry models does not greatly influence overall losses and savings. During overbank events, most of the water in excess of that required to fill the wetland returns to the river during the recession. The only losses incurred are a few days of elevated evaporation during the flood peak. For these few days the estimate of losses may be in error (due to uncertainty of the surface area), but the error would not be large. In any case, the current and future model runs produce exactly the same estimate of loss for these conditions (as the river is well above the structure), so any error is cancelled in the calculation of savings. However, the other way that inaccuracy in above-bankfull surface areas affects the water balance is during local rainfall events, when runoff to the wetland is dependent on the local catchment surface area. In SWET, this local runoff is predicted using a very simple rainfall-runoff model. The runoff coefficients are rainfall intensity-dependent values selected as appropriate for the local land use, but only one relationship applies to all runoff sources. In the

reconfigured Yatco Lagoon SWET model the local runoff generated within the wetland was estimated separately from that of the surrounding hillslope and floodplain land (see later).

2.3 Sill levels and dimensions of points of connection with the river

Yatco Lagoon was assumed to have an open connection to the River Murray under current conditions. The northern connection is wide and deep and offers no restriction to inflows and outflows. For future scenarios, it was assumed that a bank would be constructed at the point indicated in SKM (2006). Also according with SKM (2006), it was assumed that the bank would be 10.65 mAHD high, and would have a regulator consisting of twelve 1.5 m wide bays.

In modelling the North Lagoon only, the existence of the South lagoon was ignored. The South Lagoon was not modelled in isolation from the North Lagoon. Rather, the scenarios modelled the North and South Lagoons combined as one unit (assuming perfect connection between the two) and savings for the South Lagoon were reported as the difference between those modelled for the combined wetland and the North Lagoon.

2.4 Wetland bed physical properties

No data were available regarding the thickness of the bed sediment, its material composition, or its porosity. Values for these parameters were estimated on the basis of professional experience. The bed material was assumed to be clay rich with a porosity of 0.33 and a wetting depth to 0.3 m.

2.5 Local direct rainfall and runoff

Local runoff to the wetland was partitioned into:

- direct rainfall on the wet wetland surface (up to 10 mAHD)
- runoff from direct rainfall on the dry wetland surface (up to 10 mAHD)
- runoff from the surrounding hillslopes to the west of the wetland
- runoff from the surrounding floodplain land (10 mAHD to 15.38 mAHD)

Rainfall on the wet surface was converted directly to wetland water. For rainfall on the dry portions of the wetland bed, the runoff was estimated using a rainfall intensity-dependent relationship. The area of wet and dry wetland surface are dynamically calculated in SWET on a daily time-step. The areas of contributing hillslope (Table 1) were measured from the DEM (Figure 1 and Figure 2) by following local ridge crests. The areas of contributing floodplain (Table 1) were also measured from the DEM. The amount of runoff from the hillslopes and floodplain surfaces were factored relative to that produced from the dry wetland bed. The dry wetland bed, being directly adjacent, and well connected, to the wet part of the wetland, was assumed to make the highest relative contribution. The hillslopes (less well connected but relatively steep) were assumed to contribute at a rate 0.6 of the dry wetland bed and the floodplain (poorly connected and flat) was assumed to contribute at a rate 0.3 of the dry wetland bed.

Table 1.
Contributing areas for local runoff to Yatco Lagoon.

Component	Contributing area (ha)	
	Hillslope	Floodplain
North Lagoon	523	179
South Lagoon	263	449

2.6 Rainfall and evapotranspiration

Rainfall and evaporation data for the period May 1891 to April 2000 were obtained from the Bureau of Meteorology SILO DataDrill service. The DataDrill

(http://www.nrm.qld.gov.au/silo/datadrill/datadrill_frameset.html) accesses grids of data derived from interpolation of point station records from the Bureau of Meteorology. Interpolations are calculated by splining and kriging techniques. The surfaces are interpolated to 0.05 degrees (i.e. 3 minutes, around 5 km). It is NOT actual recorded data; it is derived from actual recorded data as provided by the Bureau of Meteorology.

DataDrill provides a synthetic data set covering popular meteorological data including rainfall, pan evaporation, FAO56 Reference Crop Potential Evapotranspiration (ET_O) and Morton shallow lake evaporation.

Pan evaporation based on daily measured values is only available in DataDrill from 1970 onwards; prior to that the data series is based on long-term averages, so it has a muted daily variation, and no yearly variation, compared to the post-1970 data. FAO56 ET_O is calculated using the FAO Penman-Monteith formula as described in FAO Irrigation and Drainage paper 56, http://www.fao.org/docrep/X0490E/X0490E00.htm. The FAO56 method requires average daily temperature and sunshine hours, and estimates of long-term average relative humidity and daytime wind run. Where actual wind data are not available, reasonable estimates of mean daytime windspeed and relative humidity may be used without compromising the results (Grayson et al., 1996).

Pan evaporation is subject to considerable day-to-day variation. This is partly due to real variations in evaporation, but it is widely recognized that the variation is partly due to measurement difficulties. In some respects an estimate of ET_O based on the FAO Penman-Monteith formula could be considered superior, especially as it is available from DataDrill for the entire period from 1891 to 2000. Morton's shallow lake evaporation has not been evaluated for use on Australian lakes and wetlands.

Whether using pan evaporation or FAO56 ET_O, these data have to be factored to suit the wetland situation. Recommendations for pan to open water factors are provided in Gippel (2005a), but there is always uncertainty because the empirically derived factors were measured on wetlands and lakes that may be quite different in characteristics and location compared to the site of interest (Hoy and Stephens, 1979).

When the pan evaporation data and FAO56 ET_O were compared, it was found that FAO56 ET_O could be factored by monthly variable coefficients ranging from 1.22 (growing season) to 0.87 (winter) (Table 2) so as to closely match average monthly pan evaporation data factored according to Lake Wyangan monthly coefficients (Table 2) (from Hoy and Stephens, 1979) (which is an alternative approach to using the factored FAO56 ET_O data). It was decided to represent wetland evapotranspiration by the factored FAO56 ET_O daily time series, because it approximated the best alternative (factored pan data), and it had the advantage of being available for the entire 109-year modelling period.

Mean Net ET was strongly seasonal, with an annual total of 1,296 mm. This means that on average, if there are no inflows, the maximum annual net loss of water from the wetland is 1.3 m, or a reduction from the bankfull level of 9.9 mAHD to 8.6 mAHD. In other words, the wetland cannot dry out in a single average year. If it did not rain at all over a single year, the evapotranspiration would be 1,552 mm, on average. Even in this case of a no-rainfall year, the most the wetland level could be reduced would be from 9.9 mAHD to 8.3 mAHD, which is still short of complete drying, which occurs at 7.98 m in the North Lagoon.

Table 2
Monthly Pan to open water coefficients for Lake Wyangan, Griffith (Hoy and Stephens, 1979) and open water factors used to convert FAO56 ET_O to open water ET.

Month	Lake Wyangan	FAO56 ET_O
January	0.86	1.19
February	0.86	1.19
March	0.87	1.17
April	0.92	1.15
May	0.78	0.92
June	0.69	0.87
July	0.66	0.87
August	0.68	0.87
September	0.82	1.02
October	0.97	1.22
November	0.85	1.17
December	0.83	1.17

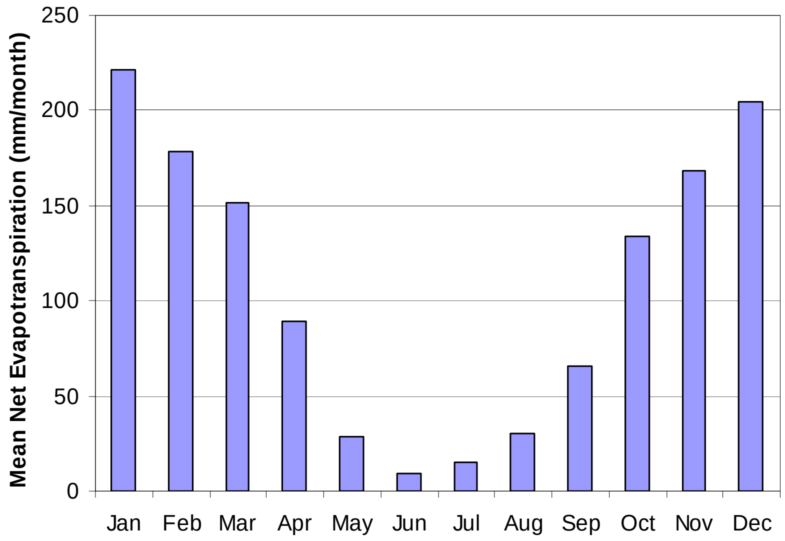

Figure 5. Mean monthly Net Evapotranspiration for Yatco Lagoon, calculated from DataDrill data over the period 1891 to 2000.

2.7 River discharge and level time series

Modelled River Murray flow data were obtained from the Murray-Darling Basin Commission. The data were from MSM-Bigmod Benchmark Run 0505 31/05/2005. The files consisted of modelled River Murray mean daily discharge, assuming "current" conditions, from May 1891 to April 2000.

SWET determines whether water is flowing into the wetland, out of the wetland, or if the river is disconnected from the wetland, on the basis of the relative heights of water in the river, the wetland, and the sill (or regulator). Thus, the river flow time series must be specified as a water level time series specific for the location adjacent to the main wetland connection point. MSM-Bigmod uses rating curves for various sites, and most of these rating curves are also available from other sources. A rating curve was interpolated for the location of Yatco Lagoon inlet using upstream and downstream rating curves.

2.8 Groundwater flux

The groundwater component in SWET models only the daily flux between river and wetland. Regional groundwater fluxes are not modelled as there are no time series data available for the water table. The basis of the groundwater component in SWET is Darcy's Law. The hydraulic conductivity (*k*) value is user selected on the basis of available information. It is likely that most wetlands have a natural clay lining that acts to limit the rate of groundwater exchange, so the default case is set to $k = 10^{-4}$. The daily time series of hydraulic head is determined from the relative levels of the river (input data) and the wetland (model predicted). In SWET there is a feedback between the predicted wetland level on a particular day and the groundwater exchange, as the wetland level at the end of the previous day will partially determine the rate of groundwater exchange, while the wetland level is also an outcome of the water balance (which includes the groundwater exchange component). The distance between the river and wetland was a single average value measured from the DEM. The cross-sectional area to flow was interpreted as the longitudinal cross-sectional area of the wetland parallel to the river. This area reduces as the wetland level falls. Wetland longitudinal cross-sectional area is not a data input or output of SWET, so it had to be approximated. This was done by assuming a constant wetland length (measured from the DEM) and determining mean wetland depth by dividing wetland volume by wetland surface area (both predicted by SWET as a continuous time series). Cross-sectional area for each day was then determined as length multiplied by mean depth. Although this is only a rough approximation of the actual cross-sectional area, it was not considered to be the major weakness of the model because of the high level of uncertainty in allocating a value for hydraulic conductivity.

2.9 Regulator operating scenarios

The regulator management scenarios modelled were:

A. Drought contingency measure drying scenario

B. Phased, incremental drying over three years scenario

2.9.1 Scenario A: Drought contingency measure drying scenario

The drought contingency measure drying scenario (A) involves construction of a bank across the inlet to isolate the wetland from the river. The objective is to immediately obtain savings to the river by preventing the evaporative loss from the wetland being replaced by river inflows. Obviously, the longer the wetland is closed to the river, the greater is the total savings. Periods of steady regulated river levels generate greater savings, as periods of high river levels (>10.65 mAHD) overtop the bank and inundate the wetland regardless of the presence of the bank (if conditions are the same for current and future scenarios there are no savings). Also, the drier the period, the greater the savings, as net evapotranspiration losses are higher in dry periods. Under this scenario the models were run for current conditions, and three future runs, assuming the wetland was closed by the bank for periods of 6 months, 12 months and 18 months, with each closure beginning on 1st October.

2.9.2 Scenario B: Phased, incremental drying over three years scenario

Under this scenario the proposal is to undertake a series of three sequential, incremental reductions in water level over three successive years. The idea is to achieve a greater drawdown in each successive year by extending the length of the drying phase from, for North Lagoon, December to April (Year 1), to November to April (Year 2), to October to April (Year 3) (Table 3). For South Lagoon the start months are the same, but the drying phase ends in March each year (Table 4).

The refilling rate for these scenarios is to be limited to less than 2 cm per day for the first 30 days of refilling, and then raised to 4 cm per day until the target level is achieved. Drawdown rates were assumed to correspond to the natural rate of evapotranspiration.

The target water levels were calculated on the basis of the bathymetric relationships each lagoon. Targets were expressed as a usual range of elevation and percentage of the bed exposed (Table 3 and Table 4), as the water levels and surface areas achieved vary depending on seasonal climate variations throughout the 109-year modelling period.

Table 3
Scenario B: Phased, incremental drying over three years scenario for North Lagoon. Expected levels and percentage of bed exposed cover the usual range, but wetland occasionally goes beyond this range. Area exposed is relative to area at 9.9 m AHD (normal summer regulated pool level).

Year/details	Start	Finish	Expected water level (mAHD)	Expected % of wetland bed exposed
Year 1				
Drying phase	1 December	30 April	9.2-9.0 m	26-51%
Refilling phase 1 (30 days @ 2 cm/day)				
Refilling phase 2 (4 cm/day) - until back to prevailing pool level, then follow pool level				
Year 2				
Drying phase	1 November	30 April	9.15-8.8 m	31-61%
Refilling phase 1 (30 days @ 2 cm/day)				
Refilling phase 2 (4 cm/day) - until back to prevailing pool level, then follow pool level				
Year 3				
Drying phase	1 October	30 April	9.1-8.6 m	38-68%
Refilling phase 1 (30 days @ 2 cm/day)				
Refilling phase 2 (4 cm/day) - until back to prevailing pool level, then follow pool level				

Table 4
Scenario B: Phased, incremental drying over three years scenario for South Lagoon. Expected levels and percentage of bed exposed cover the usual range, but wetland occasionally goes beyond this range. Area exposed is relative to area at 9.9 m AHD (normal summer regulated pool level).

Year/details	Start	Finish	Expected water level (mAHD)	Expected % of wetland bed exposed
Year 1				
Drying phase	1 December	31 March	9.34*-9.2 m	47-60%
Refilling phase 1 (30 days @ 2 cm/day)				
Refilling phase 2 (4 cm/day) - until back to prevailing pool level, then follow pool level				
Year 2				
Drying phase	1 November	31 March	9.45-9.15 m	51-91%
Refilling phase 1 (30 days @ 2 cm/day)				
Refilling phase 2 (4 cm/day) - until back to prevailing pool level, then follow pool level				
Year 3				
Drying phase	1 October	31 March	9.4-9.1 m	55-94%
Refilling phase 1 (30 days @ 2 cm/day)				
Refilling phase 2 (4 cm/day) - until back to prevailing pool level, then follow pool level				

* A lowest target level of 9.34 m is set to prevent drying more than 60% of the bed in this phase. The wetland is maintained at this level as required through regulated in-flows.

3 Model sensitivity and error

Every effort was made to minimize the errors in input data, and the most appropriate model parameters were selected for use in this application. Despite the care taken in model

preparation, there are unavoidable problems. Specification of local wetland evapotranspiration rates is notoriously difficult (Gippel, 2005a). Here, every effort was made to derive a realistic ET time series, but the actual ET rates could be systematically different (either tending to be higher or lower) or more or less variable than those specified.

The hydraulic parameters for inflow and outflow channels were selected on the basis of survey data These parameters were unimportant, because when wetlands are connected the rate of inflow usually exceeded the rate of evaporative loss, and wetland level only slightly lagged river level during flood events.

Although groundwater interaction was an active model component, the low head difference between the river and the wetland combined with the assumed low hydraulic conductivity of the soil meant that the groundwater component of the water balance was insignificantly small in every model run. The model results were highly insensitive to the selection of groundwater model parameter values.

The results presented here reflect the particular scenarios tested. It may be that other scenarios could be devised that would produce higher savings, but it was not an objective of this project to seek to optimize savings. It was noticed that the running of the management cycles was sensitive to the start year of the cycle. This arises by chance alignment of managed flood and drawdown events with natural variations in river level that impact the wetland's hydrology. All of the management cycles were run starting with the drawdown phase, as this maximized the long-term average savings.

4 Modelling results

4.1 A note on reporting conventions

The losses and savings for Yatco Lagoon were modelled over the 109-year MSM-Bigmod Benchmark period. In discussing modelling results, the past tense is used to describe losses, savings, patterns of water levels etc. This is not to imply that such events actually occurred in the wetland, but rather that they occurred in the modelled time series (which ran over the period 1891 to 2000). There are two main differences between the modelled hydrology and the actual hydrology. The first and main difference is that the river level time series used in the modelling describes "Current" conditions (which would have occurred if the current level of water resources development applied for the entire period), not "Historical" conditions (which actually prevailed, with the level of development increasing through time). The second difference is that the model approximates reality, and is subject to error.

Savings can be calculated by summing the value of saving for each day of the 109-year time series, and then dividing by 109 to get mean annual saving. The alternative is to sum savings for each year and then take the mean of the 109 annual values. For a 109 year time series these two methods produce almost identical results. However, in this report the second method was used, for two reasons:

1. Mean savings over 3-year and 2-year management cycles was of greater interest than mean annual savings, and
2. The distribution of savings over 3-year and 2-year periods for the 109 year time series was of interest.

Water savings can be expressed as an annual average, but in the case of Yatco Lagoon, for Scenarios B and C it makes more sense to report savings as the volume saved per 3-year and 2-year period. This is because the wetland management scenarios are based on recurring 3-year and 2-year management cycles.

When statistics are generated for hydrological data, it is normal to calculate them over a "hydrological" year, rather than a calendar year. There is no convention for the beginning of the hydrological year – a month is selected that suits the objectives of the study or which fits the seasonal hydrological pattern. For example, in a highly seasonal river, the beginning of the hydrological year might be set on the month that coincides with the beginning of the high flow period, rather than being within the high flow or low flow period. In other systems the start of the hydrological year might coincide with the beginning of the irrigation period. In this study, the hydrological year began on 1st May, which corresponds with the beginning of the

MSM_Bigmod time series, and approximately corresponds with the end of the irrigation season and end of the high regulated flow period in the River Murray.

By convention, losses are reported using a positive sign, so that a negative loss represents a gain. Similarly, by convention a water savings is reported with a positive sign, so that a negative savings represents a cost in water.

4.2 Losses for current conditions

Under the current regime, the water level at Yatco Lagoon is generally held by Weir and Lock 3 at 9.8 – 9.9 mAHD, only exceeding this level during flood events. Calculated over the full 109-year MSM_Bigmod time series, the mean annual volume of water drawn from the River Murray to maintain the North Lagoon water regime was 3,699 ML (3.70 GL), the South Lagoon was 513 ML (0.51 GL), and the North and South Lagoons combined was 4,212 ML (4.21 GL), although the annual losses varied over a fairly wide range for North Lagoon (Figure 6). This value of loss is the volume required to replace evapotranspirative loss.

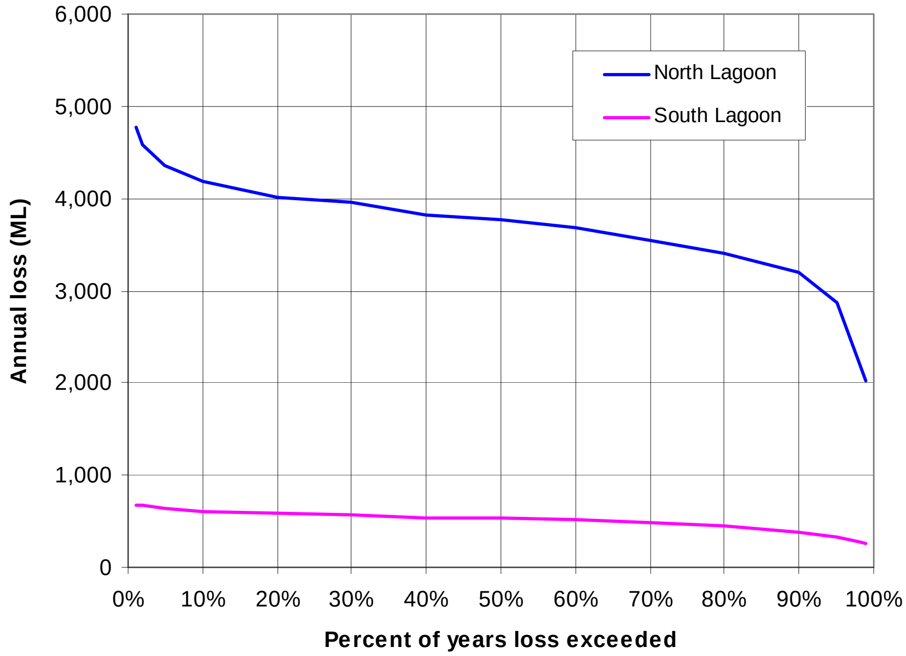

Figure 6. Distribution of annual loss from Yatco North and South lagoons under current conditions.

4.3 Savings for drought contingency measure drying Scenario A

Under this scenario the North Lagoon and South Lagoon models were run for current conditions, and three future runs, assuming the wetland was closed by the bank for periods of 6 months, 12 months and 18 months, with each closure beginning on 1st October. For the current run, the loss was calculated for the same periods as for the future runs (i.e. in sequential periods of 6 months, 12 months and 18 months, starting on 1st October). For the 6 month run, a value of loss and savings could be calculated for each year in the series (i.e. it was opened and closed once per year). For the 12 month and 18 month runs the loss and savings could only be calculated for 54 instances (i.e. it was opened and closed once per two-year period).

While closure of the wetland for periods of time achieved savings in every year considered, only a small number of cases are relevant to the drought contingency scenario. These relevant cases correspond to the years of maximum savings, when conditions were dry and there was no significant overtopping (similar to what would be expected in the near future of the current drought continues). Thus, only the results for the top 10 percentile and 1 percentile

are reported here, and this is meant to represent the range of savings expected for future drought years (i.e. years equivalent to the driest 10% of years on record).

The savings are reported in two ways (Table 5). The first is the absolute water saved during the period when the wetland was closed from the river. This is the difference between the net water lost from the river had the wetland been connected to the river, compared to the net water lost from the river had the bank been in place (loss is reduced to zero only if there is no overtopping of the bank, which is not common). The second way of reporting savings is net savings, which is the absolute savings achieved over the period when the bank was closed minus the volume of water required to re-fill the wetland when the bank is opened.

If the North Lagoon is closed for the 6 warmest months, under drought conditions a saving of 3.2 – 3.5 GL can be expected over that 6 month period (Table 5). This reduces to 0.8 – 0.9 GL if the volume required to re-fill the wetland is discounted from the total. Closing the wetland for 12 months generates savings of 4.5 – 5.2 GL, reduced to 1.3 – 1.4 GL for net savings. Savings are substantially higher over an 18 month drying period (7.0 – 7.4 GL), because this includes two summer periods, and net savings are also relatively high (3.9 – 4.3 GL), because there is only one re-filling required for two summer savings periods. Absolute savings achieved for the South Lagoon are in proportion to its area, but the net savings are relatively higher (Table 5) because it is a shallow wetland that requires less water per hectare to fill than the North Lagoon.

Table 5.
Savings achieved for drought contingency measure drying scenarios for the driest periods in the record (i.e. periods with highest savings potential).

Scenario	Absolute savings over closed period, compared to permanently open (ML)		Net Savings – includes water required to re-fill when re-opened (ML)	
	Percent of years savings exceeded		Percent of years savings exceeded	
	10%	1%	10%	1%
North Lagoon				
6 months closed	3,175	3,476	775	934
12 months closed	4,498	5,235	1,258	1,407
18 months closed	7,022	7,422	3,905	4,300
South Lagoon				
6 months closed	466	518	249	296
12 months closed	640	763	352	382
18 months closed	1,019	1,071	803	846
North and South Lagoons added				
6 months closed	3,641	3,994	1,024	1,230
12 months closed	5,138	5,998	1,610	1,789
18 months closed	8,041	8,493	4,708	5,146

4.4 Savings for phased, incremental drying over three years Scenario B

Under Scenario B, the North Lagoon and South Lagoon models were run for current conditions, and the future run. Losses were calculated over the 3-year management period for both current and future runs, and then compared.

Under Scenario B, the maximum drying for North Lagoon was generally less than 60% of the bed exposed (Figure 7). Under this Scenario, South Lagoon drying was limited to 60% bed exposure in the first year of the cycle, and this limit was realised in most cycles (Figure 8). The second and third years in the cycles achieved variable degrees of drying, but it was often 90% of bed exposed or greater (Figure 8).

For North Lagoon, the average savings per 3-year cycle was 1.51 GL and for South Lagoon the savings was 0.51 GL (Table 6). There was considerable variation in the savings achieved in each 3-year cycle throughout the modelled period (Figure 9).

For around 9% of the 3-year managed cycles in North Lagoon there was a cost in water to the river compared to the current scenario (Figure 9). This comes about from the wetland, when closed, not being permitted to contribute water to the river during rainfall events. In some period the loss of this input to the river outweighs the savings made, and there is a net loss, or cost in water.

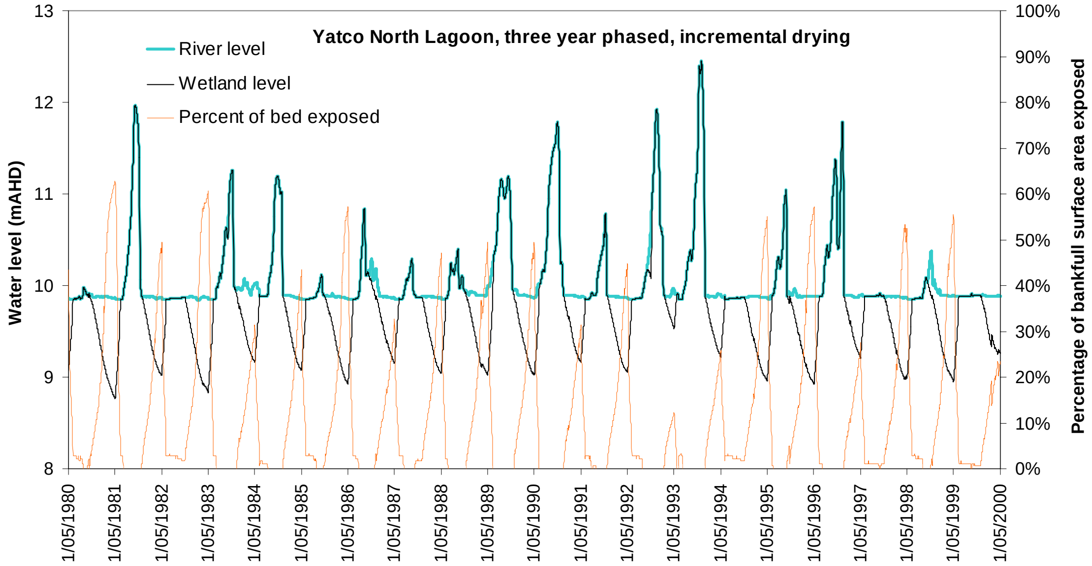

Figure 7. Scenario B, 3-year phased, incremental drying for Yatco North Lagoon, for example period 1980 to 2000.

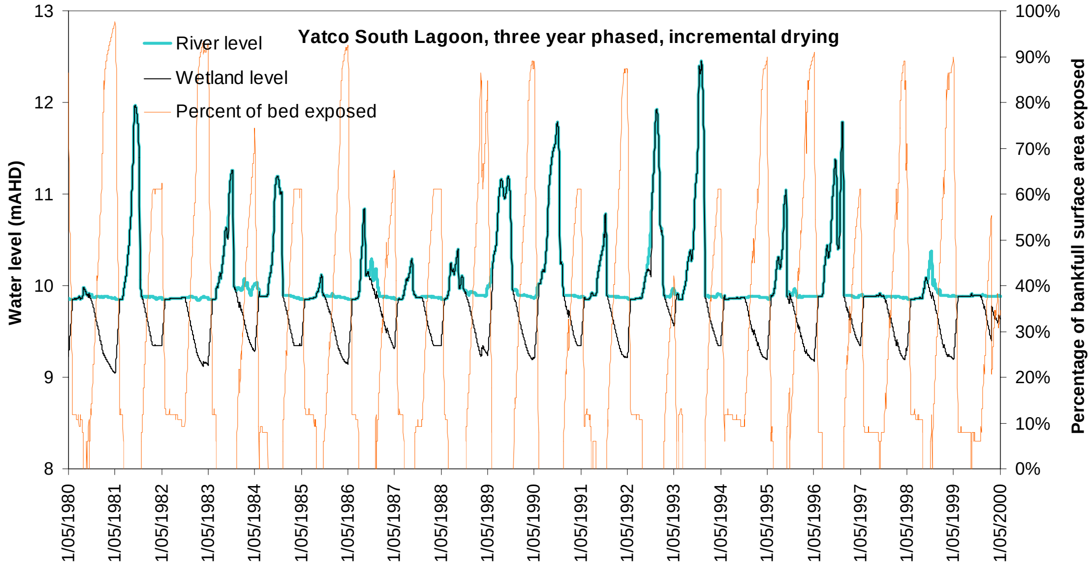

Figure 8. Scenario B, 3-year phased, incremental drying for Yatco South Lagoon, for example period 1980 to 2000.

Table 6.
Savings achieved for 3-year phased, incremental drying Scenario B. Negative value indicates water cost.

Statistic	3-year cycle savings (ML)	
	North Lagoon	South Lagoon
Mean	1,512	511
Minimum	-1,418	31
Maximum	3,189	752
Median	1,644	558

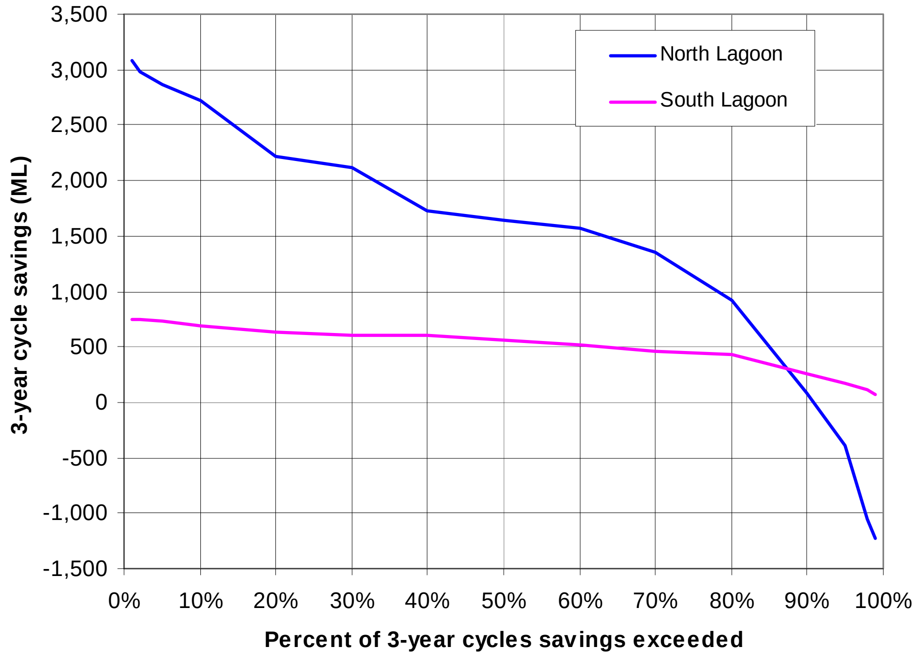

Figure 9. Distribution of three-year cycle savings for Scenario B, phased, incremental drying for Yatco Lagoon. Represents distribution of 36 three-year cycles over 109-year modelling period.

4.5 Volume of water required for re-filling (Scenario B)

At the end of the drying cycle the regulator would be opened to allow water to re-fill the wetland. It is of interest to know the volume of water required, because this would be supplied under an allocation, and allocations require a numerical definition. It is important to recognize that the volumes of savings calculated here include the volume required for re-filling.

The volume required for re-filling was defined as the volume of water required to be released from the river to the wetland to raise it back to normal pool level following the drying phase. Normal pool level was defined here as median pool level (9.89 m AHD). Once the wetland reached normal pool level any further contributions to the wetland were not included in the calculation. Such contributions were usually in the form of flood events overtopping the structure. Also not included were spills to the wetland during the drying cycle. The annual volumes required for re-filling were summed to volumes required over the 3-year management cycles (Table 7).

The average volume required per 3-year cycle was 6.8 GL for North Lagoon and 0.6 GL for South Lagoon (Table 7). However, the volume of water required to re-fill the wetlands after the drying phase was variable between years, especially for North Lagoon (Figure 10).

Table 7.
Re-filling volume required for 3-year phased, incremental drying Scenario B.

Statistic	3-year cycle volume (ML)	
	North Lagoon	South Lagoon
Mean	6,801	597
Minimum	3,223	337
Maximum	8,543	693
Median	6,795	614

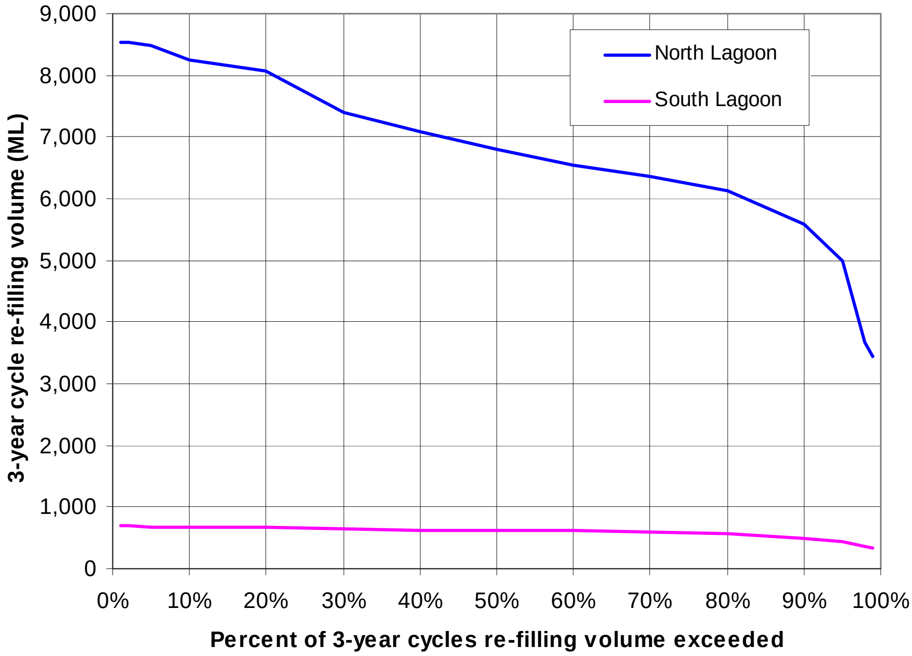

Figure 10. Distribution of three-year cycle re-filling volumes for Scenario B, phased, incremental drying for Yatco Lagoon. Represents distribution of 36 three-year cycles over 109-year modelling period.

4.6 Summary of mean losses and savings for wetting-drying scenario

The wetting-drying scenario B achieved variable savings over the 109-year modelling period. The long term annual average savings for Scenario B for North and South lagoons combined is around 674 ML/year, which is around double that of the mean savings of 331 ML/year calculated for the scenario modelled by SKM (2006). Compared to Scenario B, the SKM (2006) scenario was wet more often and not dried to the same extent, explaining the lower savings achieved.

The sum of savings and end of drying period re-filling volume does not equal total current loss (Table 8). The difference is accounted for by uncontrolled spills. The full cost in river water under Scenario B is the total losses.

Table 8.
Mean savings achieved for 3-year cycle scenario B. Savings are long-term mean for total for cycle length. Savings are compared with mean total losses from the wetlands and mean volume required to re-fill the wetland.

Scenario		North Lagoon (ML/cycle)	South Lagoon (ML/cycle)	Total (ML/cycle)
3-year cycles	Current loss from river	11,111	1,542	12,653
	Scenario B loss from river	9,599	1,031	10,630
	Saving	1,512	511	2,023
	End of dry phase re-filling volume required	6,801	597	7,398

5 Conclusion

The results of the SWET hydrological modelling work detailed in this report suggest that significant water recovery can be made at Yatco Lagoon wetland. The drought contingency drying scenario generates immediate savings, with greater savings achieved the longer the wetland is closed.

The regulator management scenario modelled here also achieved savings. In general, higher water savings are promoted by starting the drying phase earlier in the season, extending the length of the drying phase, and eliminating, or shortening the length of, the period of raised wetland levels (the wetting phase). Complete drying of North Lagoon cannot be achieved in a single season, while South Lagoon achieves almost complete drying in a single season.

The 3-year cycle Scenario B will achieve a long term average annual saving of 674 ML/yr for North and South Lagoons combined; or 504 ML/yr for North Lagoon and 170 ML/yr for South Lagoon. It is important to note that savings are highly variable from year to ear, and from cycle to cycle. Also, a volume of water will need to be allocated for re-filling the wetlands following the drying phase. The mean of these volumes are: 6.8 GL per 3 years for North Lagoon and 0.6 GL per year for South Lagoon.

Every effort was made to minimize errors in input data and values selected for model parameters. However, it must be realized that there is considerable potential for error in an exercise such as this. The results are relatively insensitive to most model parameters. However, the evapotranspiration data strongly condition the rate of losses from wetlands, and there are several choices of data available. The data chosen for this study are believed to be the most appropriate for this application. The river hydraulics and hydrology are also critical variables in determining losses and savings. Here the river level time series was modelled on the basis of available data, but because the site is within a controlled weir pool, the error in this variable would be minor.

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