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Darling River Water Savings Project

Hydrology Evaluation

of

Key Options

FINAL REPORT - MAY, 2007

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EXECUTIVE SUMMARY

This report evaluates the potential water saving volumes and associated impacts for a range of core options in the Darling Basin, focussing primarily on those at Menindee Lakes. The Menindee Lakes Scheme has a full supply capacity of 2,050 Gigalitres and provides water for New South Wales, South Australian, and Victorian purposes. The shallow expansive nature of the lakes scheme results in considerable losses through evaporation. The full extent of this is manifested in streamflows, which are 23% less below the lakes than the flows immediately upstream.

The results from this report will be used as input into the development of water saving strategies for the basin as part of the Darling River Water Savings Project. As such the options in this report should not be viewed as water saving strategies, but rather as components to strategies.

The magnitude of all water savings in this report has been determined at the source. However, the consequences of savings in terms of changes to river flows and consumptive reliability have been assessed wherever possible over a wider area including both the Lower Darling and Murray Rivers.

Water savings have been quantified using a mix of observed data, together with results from sophisticated computer models. Hydrologic modelling for this project has been carried out using the Murray Monthly Simulation Model (MSM), (Close, A.F. 1986). This model is the principle water planning tool for the Murray and Lower Darling River systems.

Options that were assessed using modelling are:

- Base Case - The base case (current operation and development)
- M0 - Rapid emptying of the Scheme in the range of 480GL to 200GL
- M1 - Rapid emptying of the Scheme in the range of 480GL to 300GL
- M2 - Rapid emptying of the Scheme in the range of 680GL to 100GL
- M3 - Rapid emptying of the Scheme in the range of 300GL to 100GL
- NoMC - More natural wetting and drying of Lake Menindee and Lake Cawndilla
- NoCExMO - More natural wetting and drying of Lake Cawndilla
- NoCEnMO - More natural wetting and drying of Lake Cawndilla
- NoMExCO - More natural wetting and drying of Lake Menindee
- NoMEnCO - More natural wetting and drying of Lake Menindee
- MCell - Construction of two Menindee Lake cells
- 0.5M - Construction of a two Menindee Lake cells (One Filled)
- PInc - Increasing the capacity of Lake Pamamaroo
- Potential water savings from privately owned storages.

Options that were assessed using observed data on flows, losses and infrastructure performance are:

- Improved extraction from residual pools in the Menindee Scheme.
- Improved use of existing smaller deeper lakes in the Menindee Scheme.
- Utilisation of existing and new storages upstream of the Menindee Scheme.

- Utilisation of existing and new storages downstream of the Menindee Scheme.

Menindee Scheme Saving Options

Evaporative savings and diversion changes from modelled scheme options are presented in Tables E1 and E2.

All but one of the modelled options produces evaporative water savings. The exception is the option for increasing the capacity of Lake Pamamaroo. For this option the savings created by increased storage in Lake Pamamaroo is exceeded by the additional evaporative losses incurred in Lake Wetherell.

All but two options produce reductions in Lower Darling diversions of greater than 5%. For all options, diversion changes for New South Wales, Victorian and South Australian Murray users is small.

Out of all restoration options, restoration of both Menindee and Cawndilla Lakes to more natural wetting and drying cycles achieves the biggest evaporative saving of 211 Gigalitres per annum. However, this option also has the largest reduction in irrigation diversions (75% in the Lower Darling).

Out of all rapid emptying options, emptying in the range of 680GL to 100GL gives the biggest evaporative saving of 91 Gigalitres per annum. Lower Darling diversions are reduced by 13%. Murray diversions are largely unchanged.

Table E1 – Key Modelled Options - Evaporative Savings (GL/Yr)

Option	Wetherell Net Evap	Pamamaroo Net Evap	Menindee Net Evap	Cawndilla Net Evap	Total Net Evap (GL/Yr)	Decrease From Base Case (GL/Yr)
Base case	50	82	168	126	426	0
M0	62	77	128	105	372	-54
M1	64	81	133	108	387	-39
M2	55	69	117	95	335	-91
M3	69	81	143	113	406	-20
NoMC	117	94	5	0	215	-211
NoCExMO	80	91	183	0	353	-73
NoCEnMO	82	92	176	0	351	-76
0.5M	56	84	87	130	357	-70
NoMExCO	75	83	0	134	291	-136
NoMEnCO	83	92	0	118	292	-134
PInc	65	86	162	123	435	+9
MCell	50	82	130	123	388	-38

Table E2 – Longterm Average Diversion Change (GL/Yr)

Year	Total NSW Lower Darling Div (GL/Yr)	Decrease from Base Case (GL/Yr)	Total NSW Div (GL/Yr)	Decrease from Base Case (GL/Yr)	Total Vic Div (GL/Yr)	Decrease from Base Case (GL/Yr)	Total SA Div (GL/Yr)	Decrease from Base Case (GL/Yr)
Base case	129		1966	0	1675		1139	
M0	119	-10	1979	13	1671	-4	1143	4
M1	121	-8	1986	20	1674	-1	1143	4
M2	112	-17	1969	3	1665	-10	1145	6
M3	124	-5	1979	13	1673	-2	1144	5
NoMC	32	-97	1922	-44	1636	-39	1141	2
NoCExMO	55	-74	1968	3	1670	-5	1142	3
NoCEnMO	55	-74	1969	3	1671	-4	1142	3
0.5M	116	-13	1968	2	1675	0	1142	3
NoMExCO	116	-13	1963	-2	1673	-2	1142	3
NoMEnCO	112	-17	1964	-2	1672	-3	1143	4
PInc	122	-7	1966	0	1675	0	1140	1
MCell	129	0	1966	0	1675	0	1139	0

Flow changes resulting from key modelled options are presented in Tables 11 and 12 within the report. With the exception of the option for increasing the capacity of Lake Pamamaroo, all options produce increased flows in the Lower Darling. Most options also reduce the volume of flow released and spilt from Lake Cawndilla.

Flows in the Murray upstream of Wentworth are largely unchanged by water saving options at the Menindee Scheme. The largest change of 80 Gigalitres per annum occurs with restoring Lakes Menindee and Cawndilla to natural wetting and drying cycles.

Flows downstream of Wentworth generally increase in most options. This results in increased spills from Lake Victoria and a corresponding reduction in Lake Victoria regulated releases. Flows across the South Australian border also increase for most options.

Modelled options produce changes in salinity concentrations both within and downstream of the lakes scheme. Restoration of Lakes Menindee and Cawndilla to more natural wetting and drying cycles result in an increase in average salinity in the other lakes. However, restoration of Lake Menindee alone results in a reduction in average salinity in Lakes Cawndilla and Wetherell. The average salinity in Lake Pamamaroo is also improved if the Cawndilla outlet capacity is increased.

Restoration of Lake Cawndilla to a more natural wetting and drying cycle results in a reduction in salinity in Lake Pamamaroo, an increase in salinity in Lake Menindee and negligible change in Lake Wetherell. Options that involve rapid emptying of the lakes appear to result in increased lake salinity levels.

Downstream of the scheme, average salinity levels generally increase in the Lower Darling and the Murray for options that involve restoration of the lakes to more natural and wetting and drying cycles. However, for options that involve more rapid emptying of the lakes, average salinity levels decrease both in the Lower Darling and in the Murray.

Off River Storage Saving Options

Three potential water savings options with respect to reducing evaporation from off river storages were evaluated for a Namoi Valley case study. These consisted of

1. Purchasing of all supplementary licenses.
2. Decommissioning off river storages and enlarging Keepit and Split Rock Dams.
3. Reducing evaporation by covering off river storage surface area.

Reduced access to supplementary water was found to be offset by increased general security and floodplain harvesting usage. As a result, reduction in evaporation from off-river storages was negligible. Reduced access to supplementary water does however increase the Namoi end of system flows by 13 Gigalitres per annum.

Removal of off river storage capacity and a corresponding increase in the capacity of Keepit and Split Rock Dams results in increased evaporative losses from Keepit and Split Rock. However, this is more than offset by the reduction in evaporation from off-river storages. The total saving in evaporation from this option is 55 Gigalitres per annum. The major impact from this saving strategy is the large decrease in valley diversions. Therefore enlargement of Keepit and Split Rock cannot offset the impacts of removal of off-river storage.

Covering off river storages results in extra water in the storages and evaporative savings of 79 Gigalitres per annum. This extra water allows users to divert less water and plant a greater area. An additional benefit is that the average volume in Keepit and Split Rock Dam also increases with little change in major storage evaporation.

More Efficient Instream and Floodplain Storage Saving Options

Creation of Instream and floodplain storage upstream and downstream of the Menindee Scheme has been assessed as potentially being more efficient than storing water in the Menindee Scheme.

Instream and floodplain storage immediately upstream of the Menindee Scheme will result in reduced evaporative volumes when compared to the equivalent volume being stored at the Menindee Lakes Scheme. However, additional instream and floodplain storage has to approach in excess of 140 Gigalitres for a surface area of 5,200Ha before any appreciable evaporative savings can be made.

The small volume of instream storage in the Lower Darling below the Menindee Scheme means that it usefulness in terms of storage and reduction in evaporative losses is severely limited. Consequently, no further assessment of this option has taken place.

The viability of storage of water in existing tributary major dams has also been assessed. Possible locations for storage and supply of Lower Darling volumes are:

- Keepit Dam on the Namoi River,
- Chaffey Dam on the Peel River,
- Pindari Dam on the Macintyre River.

A preliminary assessment of delivery losses associated with differing storage and delivery volumes from Keepit Dam to the Lower Darling in critical supply years was undertaken using historic information. Losses of 50% in the Namoi and an initial loss of 30 Gigalitres (for Weir filling) and a continuing loss of 15% were assumed in the Barwon Darling.

Losses associated with delivery of water from Keepit Dam and evaporation from the Menindee Scheme are similar in magnitude. However, there may be an environmental and riparian benefit to the losses associated with delivering water from upstream. Evaporative losses have no such benefit.

In conclusion, hydrologic analysis of key options has indicated that that significant water savings have been found to be possible both at the Menindee Scheme and elsewhere in the Darling Basin. However the consequences of this with respect to alterations in diversion volumes, increased salt concentrations and flow changes appears to be high.

1 INTRODUCTION

1.1 Purpose and Content of the Report

The opportunity for water savings in the Darling Basin lies primarily through reduction of evaporative losses from the many storages that are used to enhance supply reliability for the annual cropping regimes that predominate. The long-term net evaporative losses for the various types of storages that exist within the Darling Basin are presented in Table 1.

Table 1- Net Evaporative Losses for Water Impoundments [1]

Valley	*Major Dams*	*Hillside Dams* [a].	*Ring Tanks*	*Total*
Border Rivers	29	55 [a]	125	209
Moonie	0	78 [a]	0	78
Gwydir	31	49 [a]	109	189
Namoi/Peel	52	187 [a]	52	291
Macquarie	56	128 [a]	56	240
Condamine Balonne	57	214 [a]	194	465
Nebine	0	0	0	0
Warrego	0	16 [a]	0	16
Paroo	0	0	0	0
Barwon Darling	0	0	94	94
Total Upper Darling Basin	***225***	***727*** [a]	***630***	***1582***
Lower Darling	393	0	20	413
Total Darling Basin	***618***	***727*** [a]	***650***	***1995***

Note

[a] There is some doubt concerning hillside dam sizes. This also means there is doubt about the accuracy of these evaporation estimates. Whether these figures are net or gross evaporation has not been clarified.

[b] This figure includes all the small weirs. Annual Losses from Beardmore Dam, Leslie Dam, Jack Taylor Weir, Moolabah Weir and Buckinbah Weir combined are approximately 40 GL.

In almost all cases the majority of these storages reside on farm and in private ownership. The exceptions to this are the government owned storages. These are typically constructed in the incised valleys that characterise the headwaters of the Darling tributaries. The low evaporative and high rainfall regimes in these regions, together with large storage depths and small surface areas give rise to small net evaporative losses. As a consequence, the opportunity for savings from these storages is small. This can be seen in Table 1, where the major dams in the Upper Darling basin only account for a combined evaporative loss of 225 Gigalitres per annum, compared to 727 Gigalitres per annum for hillside dams and 630 Gigalitres per annum for ring tanks.

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[1] Source; MDBC - State of the Darling Interim Hydrology Overview Report- 2006

One exception to this major dam trend is the government owned Menindee Lakes Scheme. The scheme has a full supply capacity of 2,050 Gigalitres and provides water for both New South Wales, South Australian, and Victorian purposes. Utilising existing natural lakes for storage, the shallow expansive nature of the lakes scheme results in considerable losses through evaporation. The full extent of this is manifested in streamflows, which are 23% less below the lakes than the flows immediately upstream. A further example of the scale of evaporative losses can be seen in Figure 1, which shows the resource distribution required to meet Broken Hill and High Security and Riparian requirements for New South Wales when dry times exist. As can be seen the evaporative loss component of the available resource is considerable.

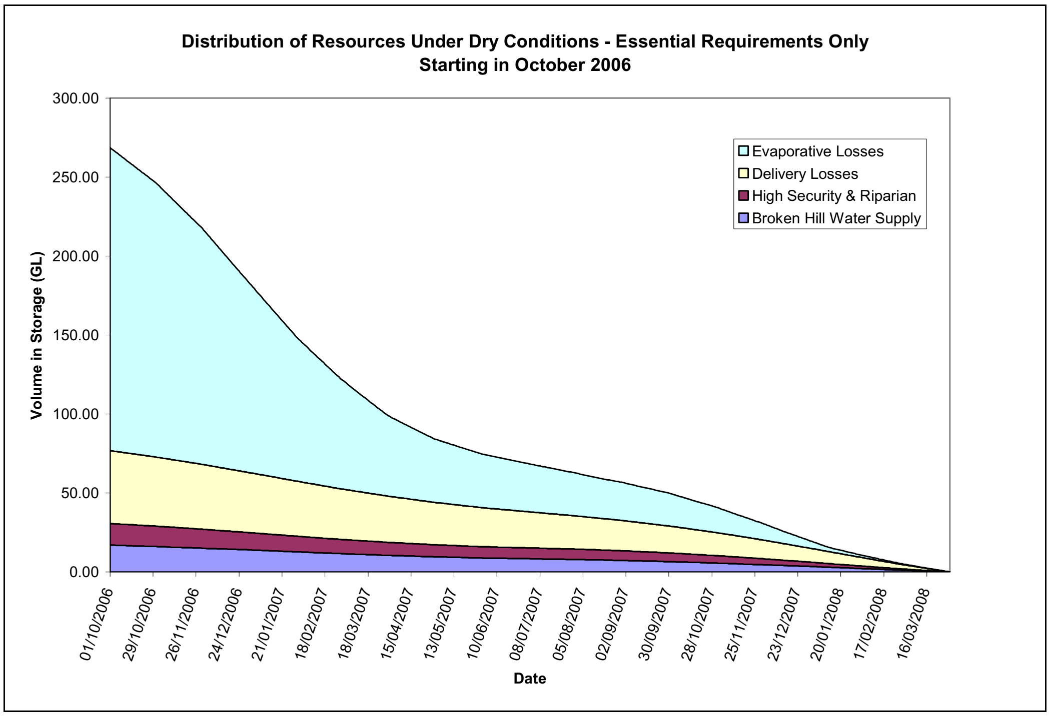

Figure 1 – Distribution of Resources under Dry Conditions

Demands on the Menindee Scheme include providing water for Broken Hill and for adjacent and downstream water users in the Lower Darling. The scheme is also used by both New South Wales and Victoria to provide entitlement and dilution flows to South Australia in accordance with the Murray Darling Basin Agreement. Some flood mitigation benefit from the scheme is also possible. However, this is heavily dependent upon storage volumes and operational practices.

Historically, lake management has aimed to maximise the potential supply reliability, ensure ecological sustainability and to maximise water quality of water within the lakes and the Lower Darling River. Operational objectives can be summarised as:

- minimise lake evaporation,
- maximise lake storage volumes,

- maximise water quality in terms of salinity, and blue green algae (cyanobacterial) blooms,
- maximising ecological benefits, including fish and wildlife habitat,
- control of foreshore erosion.

This report provides a hydrologic assessment of the potential significant water saving volumes that can be made from structural and operational strategies at both Menindee Lakes and the greater Darling Basin. Information from this report will be used as input into the option and strategy evaluation process for realising significant water savings in the Darling River.

The significance of a water saving volume is dependant upon both its size and when it occurs. A small saving volume in a time of resource shortage is likely to be just as important as a large volume when resources are plentiful. This has been borne in mind when selecting key saving options and throughout the hydrologic assessment process.

In conducting the hydrologic analysis the magnitude of water savings has been determined at the source. However, the consequences of savings in terms of changes to river flows and consumptive reliability have been assessed wherever possible over a wider area.

Due to the short study timeframes the methodology for assessing water savings for each option has varied. Wherever possible, a quantitative analysis using existing hydrologic models and data has been undertaken. However, in some instances a qualitative assessment of the likely magnitude of water savings and consequences has had to be made.

2 MENINDEE LAKES OPERATION

2.1 Target Storage Operation

Operation of the lakes scheme mainly consists of movement of water between the interconnected lakes, and supply of water to meet downstream demands whilst minimising evaporative losses. Evaporation in the area is approximately 2.5 metres (426 Gigalitres per annum) a year.

Based on discussions with staff from the Department of Natural Resources and State Water, the preferred lake filling strategy is to:

1. Fill Lake Wetherell to 59.8 metres AHD.
2. Fill Lake Pamamaroo to full supply level (60.45 metres) (filling Lakes Pamamaroo and Wetherell simultaneously above 59.8 m).
3. Fill Lake Menindee/Cawndilla to full supply level (59.84 metres).
4. Fill Lake Wetherell to full supply level (61.67 metres).
5. Surcharge Lake Pamamaroo (61.5 metres) and Lake Wetherell (62.3 metres), and then Lakes Menindee and Cawndilla (60.45 metres).

In most instances the procedures for releasing water from the lakes are generally the reverse of this, with all immediate consumptive demands being firstly met from Lake Menindee and Lake Cawndilla and Lake Wetherell above 59.8 m.

2.2 Releases to the Great Darling Anabranch and Lake Tandou

Lake Cawndilla discharges into the Darling Anabranch via Tandou Creek with the water level being maintained by a regulator at Packers Crossing. The lake is primarily used to supply demands along this system. The main user of water from the lake is Tandou Pty Ltd. Tandou Pty Ltd syphons water to its irrigation development at Lake Tandou. Generally, rates of release from Lake Cawndilla range from 200 to 500 Megalitres a day depending upon seasonal conditions. The Cawndilla outlet regulator has a capacity of 2,000 Megalitres per day but seldom operates at this due to head limitations.

The Pennelco pumps on the Lower Darling River are used to supply Tandou Pty Ltd when insufficient resources are available from Lake Cawndilla. These pumps are not operated to supply other water users or the Anabranch.

A pipeline to supply stock and domestic uses and environmental watering along the anabranch is currently being constructed. When finalised, this pipeline will see a change to the operation of the Menindee Lakes system.

2.3 Interstate Commitments

When the combined volumes of the Lakes exceed 480 Gigalitres during a draw down phase and 640 Gigalitres during a filling phase, water may be released to the Lower Darling River as requested by the Murray-Darling Basin Commission (MDBC). When MDBC resources are available in Menindee Lakes, releases from the Hume Reservoir are made only to the extent to meet minimum flow requirements at Euston on the River Murray.

The MDBC will generally specify releases from Menindee Lakes when:

- total storage in the lakes is greater than 480 Gigalitres, and
- there is insufficient flow in the River Murray and storage in Lake Victoria to meet South Australia's flow requirement to maintain storage in Lake Victoria at or above specified target volumes.

Throughout these periods of MDBC control, operation of the Lakes is still optimised in order to minimise evaporative losses and maximise water available to supplement River Murray flows by transferring water from the Menindee Lakes to Lake Victoria.

Demands on the Lake system when in MDBC control can be up to 7,000 Megalitres per day, although higher releases may be required under certain circumstances such as a very dry season with high Murray River irrigation demand, or if storage in Lake Victoria is below target prior to the start of the irrigation season. The maximum regulated flow rate in the Lower Darling is between 9,000 and 9,500 Megalitres per day. Release rates of 7,000 Megalitres or more exceed the outlet capacity of any of the individual regulators, other than the main weir, leading to demand being usually supplied from two or more lakes.

2.4 Drought Management

The Menindee Lakes Scheme was constructed to provide for water conservation. Consequently, management for drought conditions forms an important aspect of operation of the lakes.

When the total storage volume within the scheme falls to 480 Gigalitres, all rights to the water remaining in storage reverts to New South Wales, and supply is primarily for Lower Darling water users only.

The 480 Gigalitres can potentially provide security of supply to all adjacent and downstream users for one year under a zero inflow scenario. This assumes that all entitlements are fully utilised. In most cases, entitlements are not fully utilised and this under usage extends supply potential beyond one year.

More often than not when the scheme falls to 480 Gigalitres, the upstream catchments can be in extended drought. This is not uncommon in the Darling with the scheme dropping below 480 Gigalitres in 50% of **years** and as shown in Figure 2 for 20% of the time.

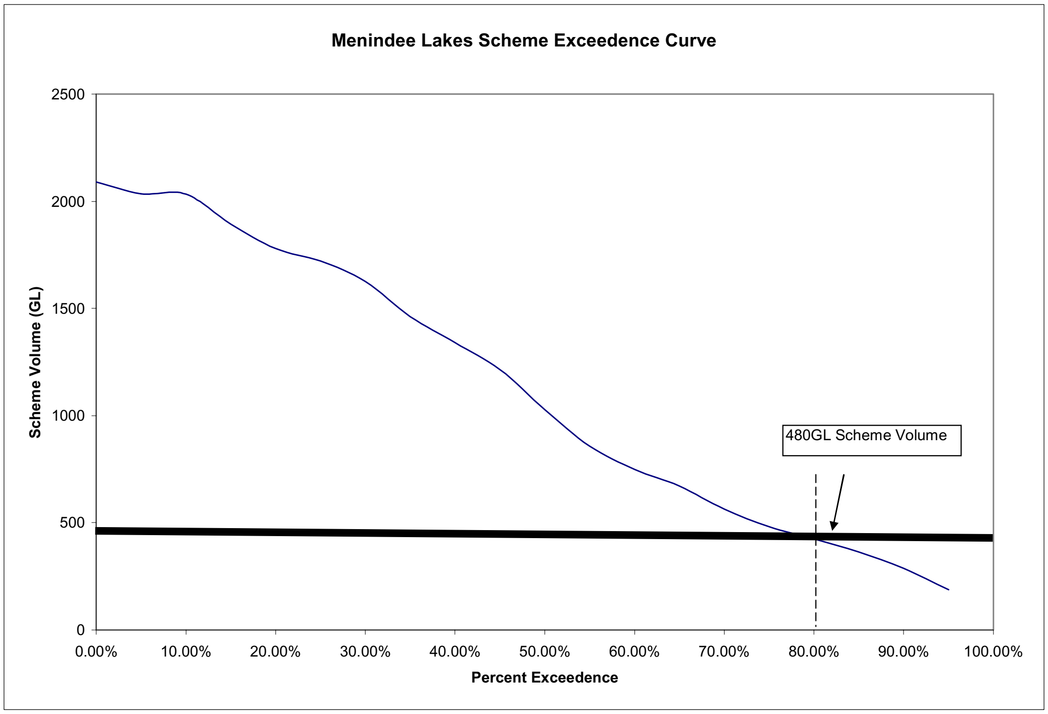

Figure 2 – Menindee Scheme Volume Exceedence Curve

Although the scheme can supply all users for one year when at 480 Gigalitres, a continuing drought results in the availability of water for licensed consumptive use on the Lower Darling being reduced, and restrictions being imposed. The priority for maintaining supply for different purposes is prescribed in the Water Management Act 2000. Under the Act, priority for security of supply aims to ensure adequate supplies in the following order:

- town water supply and riparian entitlement for domestic supply,
- riparian entitlement for stock supply,
- high security for permanent plantings (horticulture and vines),
- general security for non-permanent plantings (pasture and cereal crops).

A typical lake volume distribution with respect to demands when the lakes are within New South Wales control and under prolonged drought is shown in Figure 3. At the commencement of drought management (typically at volumes of 275 GL), resources in the scheme are sufficient to supply Broken Hill and High Security and Riparian users for 18 months.

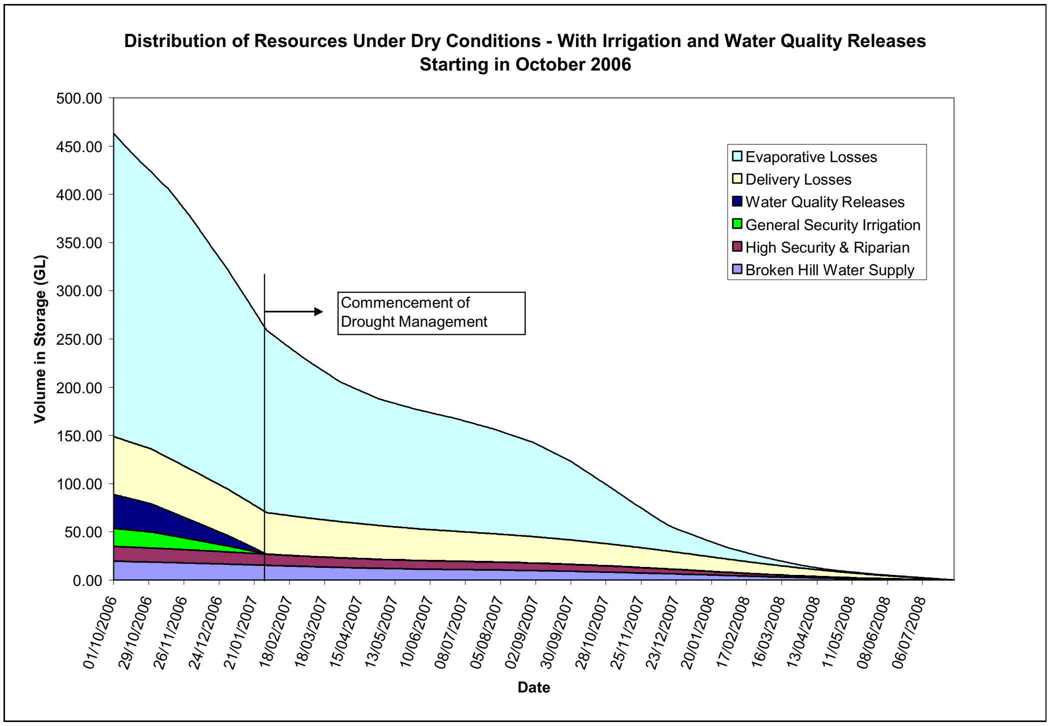

Figure 3 – Distribution of Scheme Resources When In NSW Control

2.5 Flood Management

The severity of floods in the Menindee Lakes and the Lower Darling River is dependent on:

- the volume, peak and duration of floods upstream,
- the volume currently stored in the Lakes,
- the level of lake surcharge adopted during a flood event.

The primary objective of flood operations is to ensure the safety of the structures and to minimise damage to downstream property. The lakes scheme was primarily not built to provide flood mitigation. In most instances the benefit of the lakes for the purposes of flood mitigation is small, due to the limited lake storage capacity relative to the cumulative volume of floodwaters.

Floods in the Darling River (which commences at the confluence of the Culgoa and Barwon rivers) are dependent upon rainfall events generating floods in the catchments of the major upstream tributaries. The relative distribution of flows to the Darling River from Queensland and New South Wales tributaries is shown in Figure 4. The travel time of floodwaters from these upper catchments to the lakes can be up to three months and accurately predicting the volume, duration and peak of a flood is difficult, particularly when Darling River tributaries closer to Menindee, including the Paroo and Warrego Rivers, contribute inflow. The long flood travel times in the Darling River mean that some additional capacity can be realised by pre-releasing stored volumes before the flood arrives at the scheme.

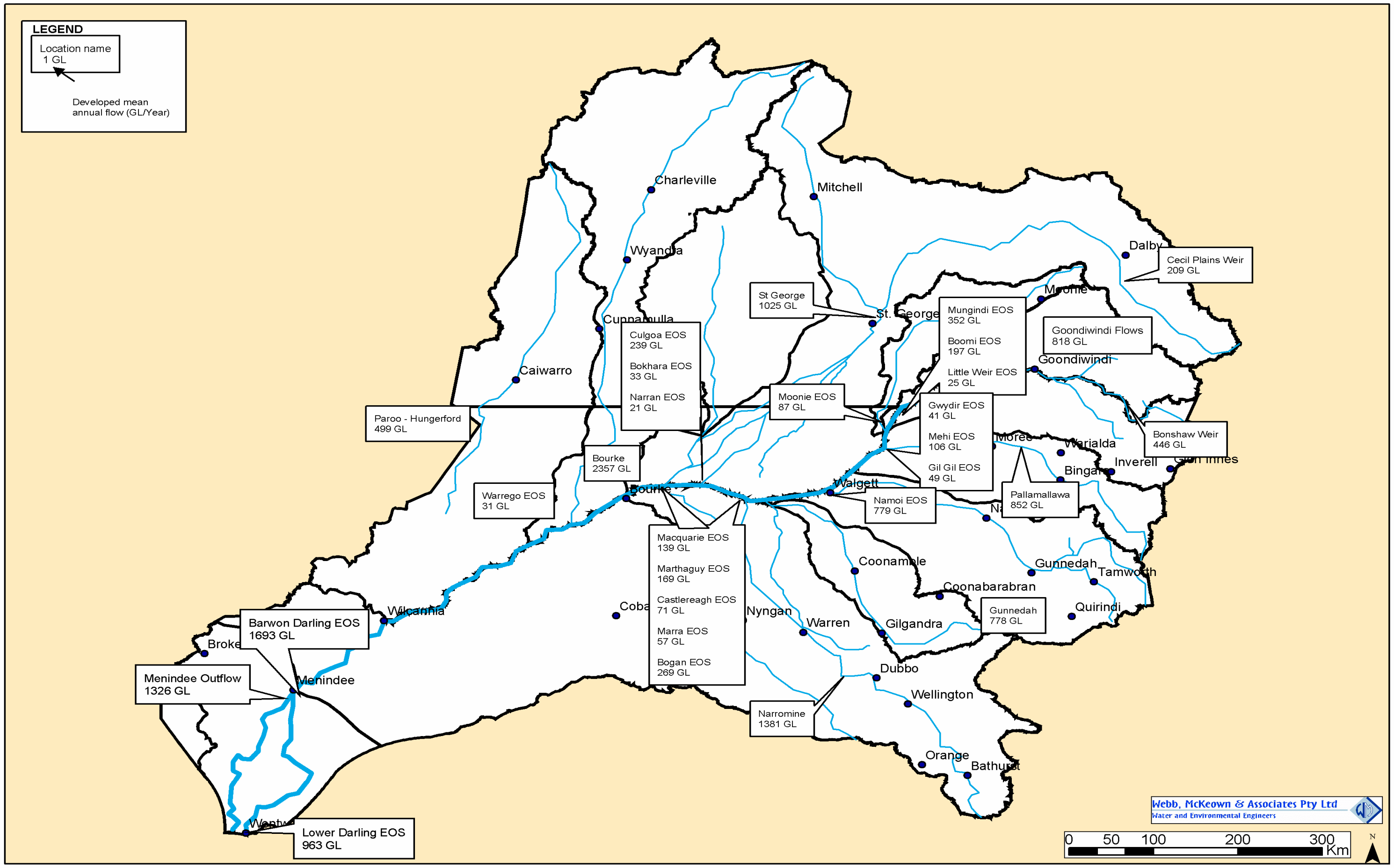

Figure 4 – Darling Tributary Relative Flow Contribution (EOS = End of System)

3 DARLING RIVER WATER SAVINGS OPTIONS

3.1 Tools for Determination of Water Savings

Water savings have been quantified using a mix of observed data, together with results from sophisticated computer models.

Numerous options for potential significant water savings within the lakes have been identified in this study. Some options lend themselves to computer modelling whilst others require an assessment using observed information for river flow, losses and infrastructure volumes.

The computer models allow the long-term hydrologic effects of development, water use and structural and operational changes in river management to be assessed in a consistent and detailed way. Computer models of river systems are, necessarily, simplified representations of the many complicated interactions between the many factors that affect river flows. The complex and variable nature of the basin's hydrology, and the changing scale and effect of water use development, mean modelling is the most reliable way to assess the impact current development and management arrangements on long-term water savings and flow outcomes.

Hydrologic modelling for this project has been carried out using the Murray Monthly Simulation Model (MSM), (Close, A.F. 1986). This model is the principle water planning tool for the Murray and Lower Darling River systems.

3.2 Description of Modelled Water Saving Options

3.2.1 General

For those options that can be modelled, detailed modelling of every option in the short study timeframe is not possible. This is further complicated by the true extent of water savings usually only being realised through the integration of individual "saving options".

Fortunately, as all options seek to produce significant savings through combinations of reduction in demand, reduction in lake storage time, and reduction in lake storage area, it is possible to assess key options that can then be used to infer savings for the larger option suite. Key options for which water savings were assessed using the detailed model are:

Key Modelled Options

- The Base Case (Current Operation and Development).
- Increasing the release rate from the Lakes when in NSW control.
- Variation to dilution flow release patterns.
- Restoration of more natural wetting and drying cycles for Lake Menindee and Lake Cawndilla.
- Restoration of more natural wetting and drying cycles for Lake Menindee.
- Restoration of more natural wetting and drying cycles for Lake Cawndilla.
- Construction of a two cells in Lake Menindee (Both Filled).
- Construction of two cells in Lake Menindee (One Filled).
- Increasing the Capacity of Lake Pamamaroo.
- Potential water savings from privately owned storages.

Restoration options entail utilising the lakes for flood mitigation purposes only.

3.2.2 The Base Case (Current Operation and Recent Development)

The base case is used as a benchmark comparison with respect to all water savings options. The base case ideally represents current management, and operational practices as well as current infrastructure volumes and resource demands.

This base case is the same as that used for the Menindee EIS Project, and includes the anabranch pipeline with an environmental release of 60GL every two years on average. It also assumes use of the Penelco pumps to supply Tandou Pty Ltd when resources are unavailable from Lake Cawndilla.

The current scheme inflow data in the base case reflects varying levels of development upstream of the Lakes. Around the mid 1990's the MDBC updated their estimate of the Menindee Scheme monthly inflows by adjusting the pre-development flow dataset for upstream New South Wales development at that time based on New South Wales model results. Therefore, the model inflow data reflects mainly mid 1990's New South Wales development levels. The inflow set does not incorporate the reduced flows caused by growth in Queensland in the Late 1990's. Whilst reduced inflows will reduce Lake Evaporation, changes in Lake Evaporation from the benchmark are likely to be unaffected.

The filling strategy adopted in the model base case is:

1. Fill Lake Wetherell to 59.8 metres AHD.
2. Fill Lake Pamamaroo to full supply level (60.45 metres).
3. Fill Lake Menindee/Cawndilla to full supply level (59.84 metres).
4. Fill Lake Wetherell to full supply level (61.67 metres).
5. Surcharge Lake Pamamaroo (61.5 metres) and Lake Wetherell (62.3 metres), and then Lakes Menindee and Cawndilla (60.45 metres).

The maximum storage volumes adopted in the model are presented in Table 2.

Table 2 – Modelled and Current Lake Maximum Volumes

Lake	Base Case Maximum Volume (GL)	Current Operational Maximum Volume (GL)
Wetherell	262	262
Pamamaroo Copi Hollow	350	350
Menindee	719	631
Cawndilla	705	631
Total Scheme Volume	2049	1874

The assumed residual storages in the base case for each of the lakes are presented in Table 3 [2]. As can be seen, the modelled base case residual storage volumes differ

[2] At the time of preparing this report the with the exception of Lake Cawndilla, the accuracy of the Menindee Scheme capacity table at low levels is thought to be good, with bathometric surveys of Wetherell and Pamamaroo, and aerial mapping of Lake Menindee having taken place. A more accurate survey of the lower parts of Lake Cawndilla may be warranted given the importance of the residual pool volume.

somewhat from the advised Department of Natural Resources (DNR) residual storage volumes. The greatest difference is in the assumed residual pool volume for Lake Cawndilla.

Table 3 – Modelled Residual Storage

Lake	Base Case Residual Volume (ML)	Advised Residual Volume (ML)
Lake Cawndilla	9,620	100,970
Lake Menindee	88,000	71,190
Lake Pamamaroo	10,063	31,730
Lake Wetherell	390	12,376
Total Residual Storage	108,640	216,266

Differences between base case and actual residual pool volumes will affect the volumes of savings identified in this report. In the case of Lake Cawndilla, the modelled base case assumes that stored volumes in the range of 100 Gigalitres to 9.6 Gigalitres can be released through the existing outlet works. In practice, lowering of the storage from 100 Gigalitres to 9.6 Gigalitres will require pumping. It is likely that if the base case were adjusted to reflect an appropriate residual pool volume of 100 Gigalitres then savings identified in this report will be increased for any option that incorporates works capable of accessing the residual pools. The magnitude of increase will be commensurate with the frequency at which these residual pool volumes are accessed over the period of model simulation and the amount of difference between the base case and advised residual pool volume.

It should also be noted that the Lake Wetherell capacity table in the modelled base case does not include an adjustment for dead storage in Lakes Tandure, Balaka, Malta, or Bijijie. The Lake Menindee capacity table does not include Lake Speculation. The Lake Cawndilla capacity table includes Lakes Spectacle, Morton Boolka, Cawndilla Ck, and Lake Eurobilli, and the Lake Pamamaroo capacity table includes Copi Hollow with an adjustment for Copi Hollow dead storage of 2,800 Megalitres.

When the volume of water in Lakes Menindee and Lake Cawndilla reaches (55.46), Lake Cawndilla becomes isolated from Lake Menindee. Water can then only be released from Lake Cawndilla through the Cawndilla outlet regulator. At the time of isolation, the stored volume for the base case in Lake Cawndilla is 164 Gigalitres. State Water has advised that a more appropriate estimate is 212 Gigalitres. The effect of this on modelled options is that the evaporative savings as a result of improved works at Lake Cawndilla are likely to be slightly underestimated.

The modelled base case does not incorporate the current drought security arrangements of Figure 1. Consequently, the impact of some options on general security users may be sightly overstated. Despite not incorporating current drought security measures, the lakes scheme does not run out of water under the benchmark scenario. As a consequence, from a quantity perspective sufficient resources are available to meet Broken Hill and High Security requirements over the simulation period.

3.2.3 Increasing the Release Rate from the Lakes when in NSW Control

When the lakes are in New South Wales control and being drawn down for New South Wales requirements, a volume of water sufficient to allow Broken Hill town water supply, high security and riparian demands to be met over an 18 month window assuming no lake inflows is set aside. A significant portion of this volume is for evaporative losses, with volumes increasing if the 18 month window includes two summer periods. This was shown previously in Figure 1.

A number of scenarios whereby the release rates from the lakes is increased when in New South Wales control (below 480 and 680 Gigalitres) have been modelled. Without any clear guidelines on how this water might be released or used, the model was setup to just achieve a monthly target volume of 200 Gigalitres per month at Burtundy (bottom of Lower Darling River) that would simulate the extra water being transferred through to South Australia. The following options were simulated with the model.

- Rapid emptying of the Scheme in the range of 300GL to 100GL.
- Rapid emptying of the Scheme in the range of 480GL to 200GL.
- Rapid emptying of the Scheme in the range of 480GL to 300GL.
- Rapid emptying of the Scheme in the range of 680GL to 100GL.

3.2.4 Variation in Dilution Flow Release Patterns

Under the Murray Darling Basin Agreement, additional releases of 58 Gigalitres per month are made from the Menindee Lakes Scheme to provide dilution flows for South Australia. Variation of this pattern to allow delivery of dilution flows over a shorter time period may have the potential to produce water savings whilst still reducing salinity at Morgan. The viability of this water saving option will be heavily dependent upon channel capacity constraints and the changed dilution pattern resulting in substantial reduction in average surface area.

3.2.5 Restoration of Lakes to more Natural Wetting and Drying Cycles

Reducing the frequency of lake filling will produce water savings, with greater reductions in filling leading to greater savings. The lake exceedence volumes for the scheme and individual lakes are shown in Figure 5. A number of options that aim to restore one or more lakes to natural drying cycles were evaluated. These are discussed in the following sections.

<u>More Natural Wetting and Drying of Lake Menindee and Lake Cawndilla</u>

In this option both Lake Menindee and Lake Cawndilla are restored to a more natural cycle of wetting and drying. In modelling this option, the volumes into Lake Menindee and Lake Cawndilla was reduced to zero by constraining the Lake Menindee inlet regulator capacity. In reality, implementation of this scenario would see the lakes still being utilised during flood times. Unfortunately, this flood mitigation behaviour cannot be represented in the model. As a consequence, any calculated water saving amounts will have to be reduced to account for the short durations of times that the lakes are used for flood mitigation purposes.

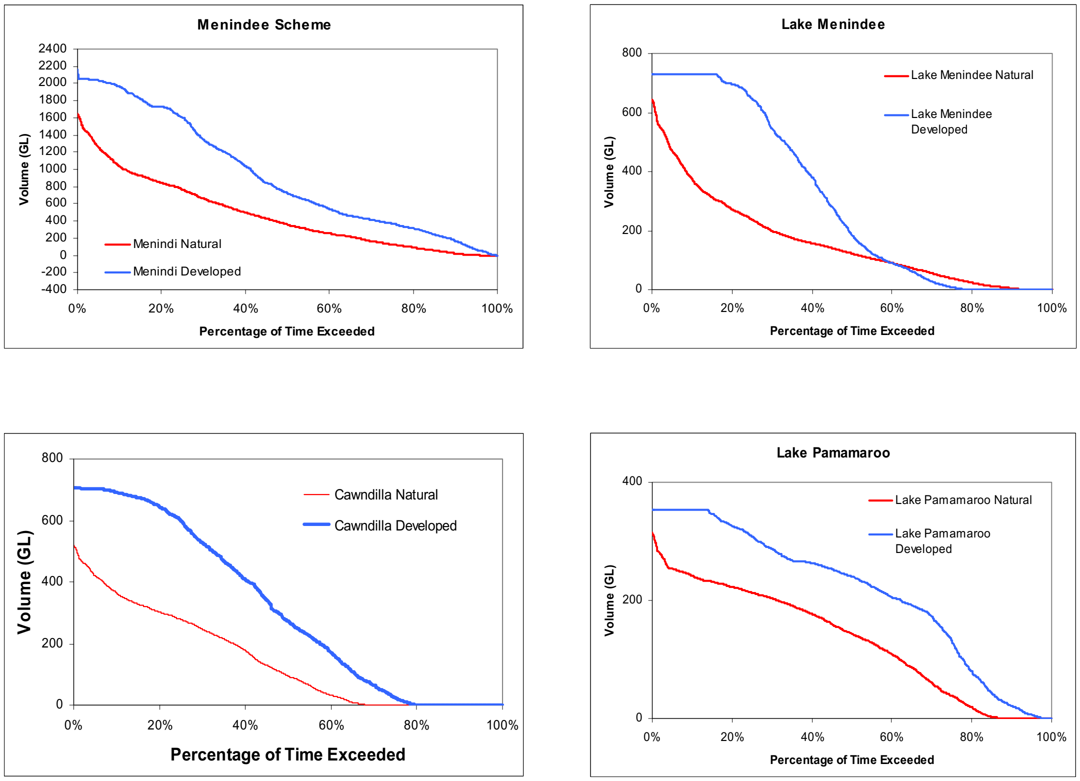

Figure 5 – Natural and Benchmark Lake Exceedence Volumes

<u>More Natural Wetting and Drying of Lake Menindee</u>

An alternate option involves restoration of only Lake Menindee to a more natural regime of wetting and drying. Implementation of this scenario, assumes that water will enter Lake Cawndilla from Lake Pamamaroo via an alternate means. This could be either by construction of a supply channel through or around the outer edge of Lake Menindee. In modelling this option it was assumed that the storage volume versus area relationship for Lake Cawndilla is identical to that which currently exists. This assumption is reliant on the construction of a block bank between the two lakes.

Two variations of this saving option were modelled:

i) The first with the existing outlet regulator for Lake Cawndilla.
ii) The second with an increased Cawndilla regulator outlet capacity of 6,000 Megalitres per day to the Lower Darling river.

The second run tries to compensate for the reduction in available outlet capacity as a result of the more natural wetting and drying of Lake Menindee.

<u>More Natural Wetting and Drying of Lake Cawndilla</u>

This option is similar to the proceeding Lake Menindee option in that Lake Cawndilla is restored to a more natural cycle of wetting and drying. Implementation of this option will involve the construction of a block bank and regulator across Morton

Boolka in order to fill Lake Menindee to its current capacity and allow volumes into Lake Cawndilla during times of floods.

Two variations of this saving option were modelled:

i) The first with the existing outlet regulator for Lake Menindee.
ii) The second with an increased Menindee regulator outlet capacity of 10,000 Megalitres per day.

The second run tries to compensate for the reduction in available outlet capacity as a result of the more natural wetting and drying of Lake Cawndilla.

3.2.6 Construction of a Two Menindee Lake Cells (Both Filled)

Splitting of Lake Menindee into two cells with appropriate regulators or pumps to allow efficient filling and emptying of each cell potentially allows for increased operational flexibility. For the purposes of modelling, it has been assumed that each cell can hold fifty percent of the existing lake storage volume for fifty percent of the existing lake storage area. This means that the storage volume area relationship for each cell is effectively half that of the total lake relationship. Target storage operation of the scheme and draw down of Lake Cawndilla via the existing Menindee outlet regulator remains unchanged when the lakes are connected.

Modelling has also assumed that draw down of each Menindee Lake cell is able to be achieved using the existing Menindee outlet regulator. However, construction of the two cells will result in the outlet being able to deliver the same discharge for half the existing volume. Consequently, the existing Menindee outlet regulator storage volume versus discharge relationship was adjusted to cater for this as shown in Figure 6.

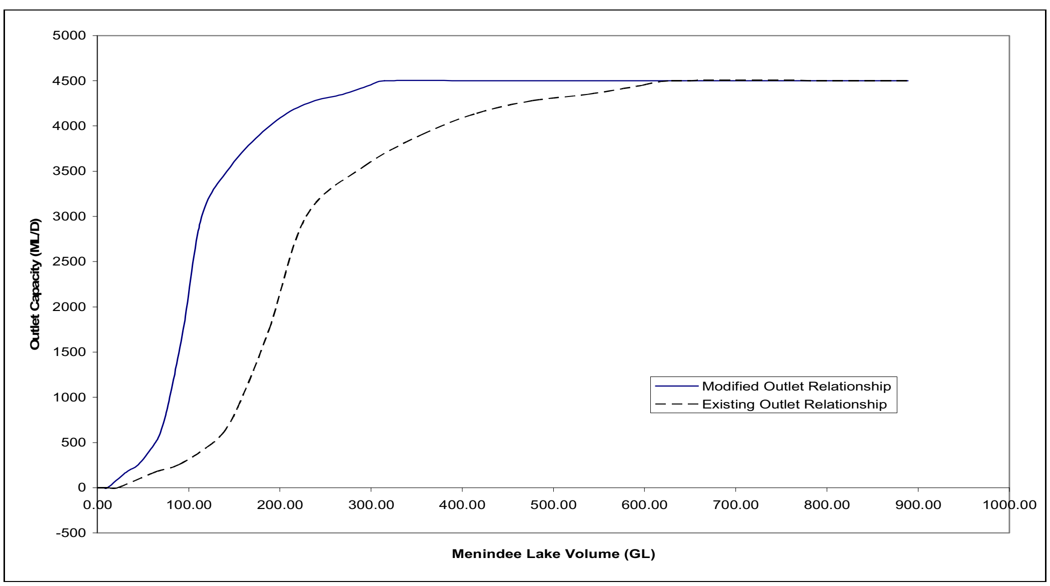

Figure 6 – Existing and Adjusted Menindee Outlet Capacity Relationship

3.2.7 Construction of a Two Menindee Lake Cells (One Filled)

Under this option only the half of Lake Menindee is used to store water, whilst the other half is restored to a more natural cycle of wetting and drying. The option still involves the construction of two cells, with the cell that is connected to Lake Cawndilla via Morton Boolka being filled.

3.2.8 Increasing the Capacity of Lake Pamamaroo

With appropriate target storage operation, creation of additional storage capacity in Lake Pamamaroo has the potential to reduce storage volume and storage durations in the more inefficient lakes. In modelling this option it was assumed that filling of Lake Pamamaroo to its new full supply level utilised the existing lakes filling sequence.

In increasing the lake capacity, the surcharge level of Lake Pamamaroo was raised by 0.8 meter to give a total capacity at an RL of 62.3 metres of 390 Gigalitres. This represents an increase in Lake Pamamaroo capacity of approximately 40 Gigalitres. Filling of this additional storage was achieved in the model through surcharging of Lake Wetherell. This surcharging increases the capacity of Lake Wetherell from 195 to 262 Gigalitres. In increasing the capacity of Lake Pamamaroo, the surface area was assumed to remain unchanged from the existing full supply level.

In modelling this option, the Pamamaroo regulator outlet capacity was increased in recognition of the additional available head created through increased lake capacity.

3.2.9 Potential Water Savings from Privately Owned Storages

As indicated in Table 1, the evaporative losses associated with off river dams such as ring tanks are quite large in comparison to major dams. A number of preliminary modelled case studies in the Namoi Valley were undertaken to assess potential water saving strategies from reduced evaporation from off-river storages. These consisted of:

i) Purchasing all supplementary water licenses. Supplementary water is unregulated water in excess of releases from Keepit and Split Rock Dams.

ii) Removal of all off-river storages and increasing storage capacity in Keepit and Split Rock Dams. Capacities for Split Rock and Keepit Dams were increased to 1,000 Gigalitres each.

iii) Stopping of evaporation from on farm storage through surface covering.

3.3 Description of Non-Modelled Water Saving Options

3.3.1 General

As stated in Section 3.1, some options cannot be modelled, but still require assessment with respect to potential water savings. Key non modelled options for which potential water savings have been assessed using observed data on flows, losses and infrastructure performance are:

Key Non Modelled Options

- Improved extraction from residual pools in the Menindee Lakes Scheme.
- Improved use of existing smaller deeper lakes in the Menindee Lakes Scheme.
- Utilisation of existing and new storages upstream of the Menindee Lakes Scheme.
- Utilisation of existing and new storages downstream of the Menindee Lakes Scheme.

3.3.2 Improved Extraction from Residual Pools

The current distribution of residual storage in the Menindee Scheme is presented in Table 4.

Table 4 – Advised Residual Storage Volumes

Dead Storages	RL (m)	Residual Volume (ML)
Lake Balaka	61.50	1,200
Lake Malta	61.75	350
Lake Bijijie	61.00	900
Lake Tandure	57.80	9,448
Lake Wetherell	52.50	478
Lake Wetherell Total		**12,376**
Lake Pamamaroo	56.50	28,930
Lake Copi Hollow	58.35	2,800
Lake Pamamaroo Total		**31,730**
Lake Menindee	56.00	60,860
Lake Speculation	59.50	10,330
Lake Cawndilla	54.50	100,970
Total Residual Storage		216,266

As discussed in section 3.2.2 differences exist between the residual storage volume assumed in the modelled base case and the volume provided by DNR. In addition, the modelled frequency of access to residual pools is also likely to be different to that which is observed in practice. Any calculation of saving volumes and strategies will need to recognise these two issues.

An indication of the frequency of time that each lake spends in the residual pool zone based on the advised pool volumes and model results is shown in Figures 7. As can be seen, all lakes are above the residual pool zone for the majority of time.

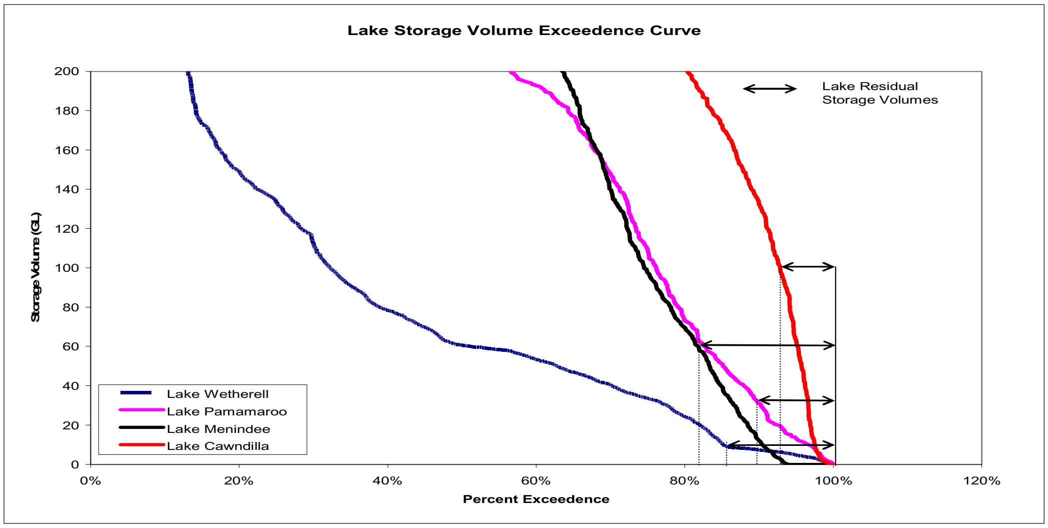

Figure 7 – Frequency of Lake Residual Storage Volume Exceedence

Improved access to residual storage volumes is likely to deliver only small long-term water savings. However, the years in which access takes place are drought years therefore the importance of these volumes cannot be understated. An approximate indication of when these opportunities arise can be seen from the variation in total scheme volume over the long-term. This is shown in Figure 8.

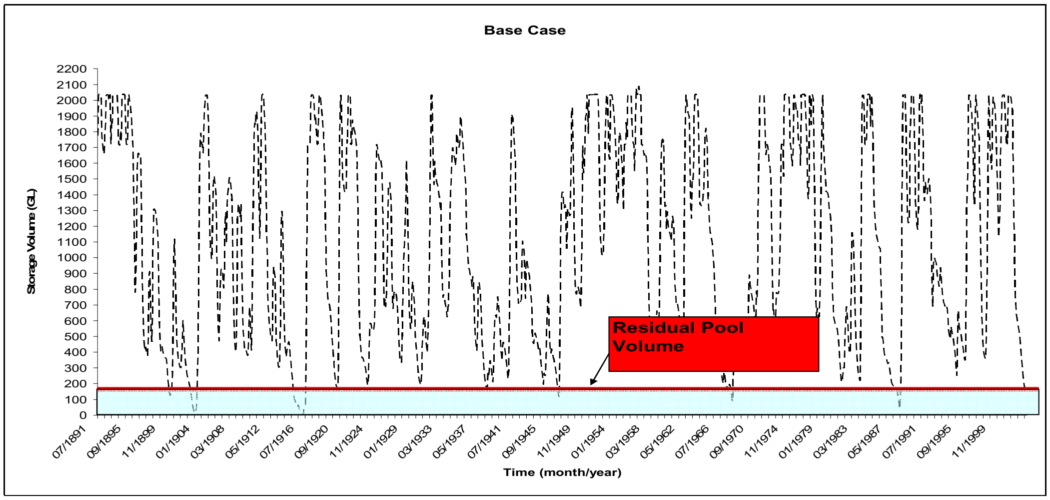

Figure 8 – Approximate Opportunities for Residual Pumping Over Time

3.3.3 Improved Use of Existing Smaller Deeper Lakes

There are a number of smaller lakes with the Menindee scheme that may be utilised more efficiently, through surcharging or increasing capacity. Use of these smaller deeper lakes as opposed to the wide shallow main lakes in times of low volumes and high demands may result in small water savings.

3.3.4 Use or Creation of Upstream Storage Capacity

<u>Instream in The Upper Darling and Floodplain Storage at Menindee</u>

An evaluation of the potential instream storage capacity in the Darling River above Menindee was undertaken using channel capacity and longitudinal survey section information for the Darling River.

An assessment of the volume of available storage resulting from the raising of Bourke Weir was made. Bourke was selected as information on channel cross section and longitudinal profile was available. In reality implementation of an instream storage option may need to occur closer to the Menindee Scheme to ensure that water can be moved from the inefficient lakes into the instream storage in times of drought operation. It is likely that the instream storage characteristics will remain unchanged.

The variation of storage volume with weir crest height is presented in Table 5. Construction of an impoundment with a crest level approaching the top of bank with a suitable regulator will lead to creation of 46 Gigalitres of storage occupying a surface area of 2,676 Ha. The weir pool will extend 200 kilometres upstream to Brewarrina.

Table 5 – Bourke Instream Storage

Comment	Crest Level (m)	Channel Area (Sqm)	Volume (GL)	Weir Pool Length (Km)	Surface Area (Ha)
Current Weir Hgt	4.9	168	4.8	86	443
	5	173	5.1	88	459
	6	227	8	105.6	591
	9	411	22	158.4	1077
Top Of Bank	12	652	46	211.2	2677

From a water saving perspective the small surface area of this additional storage offers advantages over the storing of an equivalent volume in the shallower more expansive Menindee Lakes.

Given that instream storage only offers small additional volumes, creation of additional floodplain storage in the immediate vicinity of the scheme to complement this instream storage was also assessed. In order for floodplain storage to be efficient, storages have to be deep. Typical ring tank depths are in the order of 3 metres, with depths to 6 metres also possible. The equivalent ring tank surface area for 150 Gigalitres of instream storage is presented in Table 6 for ring tank storages of 3 metres to 6 metres depth.

Table 6 – Bourke Ring Tank Storage

Storage Depth (m)	Surface Area (Ha)
3m	5,000
4m	3,750
5m	3,000
6m	2,500

<u>Use of Existing Tributary Storages</u>

The storage of water in dry times in existing or enlarged upstream storages in the New South Wales tributaries of the Darling as opposed to Menindee Lakes potentially offers water savings through reductions in evaporative losses. As discussed in Section 1.1 and shown in Table 1 upstream major dams have considerably less evaporation than that of the Menindee Scheme.

However, only a limited number of upstream storages can be used to supply Lower Darling water users. Limitations are primarily due to channel capacity constraints or the large flow reductions caused by flows passing through terminal wetlands. On the basis of this and discussions with NSW State Water staff, possible locations for storage and supply of Lower Darling volumes are :

- Keepit Dam on the Namoi River,
- Chaffey Dam on the Peel River,
- Pindari Dam on the Macintyre River.

Based on Table 1, it is likely the losses associated with evaporation will be considerably less than those at Menindee. However, this saving in volume may be potentially offset by the losses associated with delivering volumes to the Lower Darling. This is especially the case if delivery takes place during the summer months after a prolonged period of low to no flows.

It is important to note that delivery "losses" may have some environmental benefit. This should be borne when evaluating the relative merits of water savings strategies at the Menindee Scheme and upstream.

In order to gain an appreciation of the size of the losses associated with delivery of water from tributary storages to the Lower Darling, an analysis of the losses associated with small flow event releases Keepit Dam along the Namoi and Barwon Darling river systems has been undertaken.

Small flow events, at times when there is negligible irrigation extraction and ungauged tributary inflow are rare. Consequently, only a limited number of events were available for the analysis.

3.3.5 Use or Creation of Downstream Storage Capacity

Instream Storage in the Lower Darling

An evaluation of the potential instream storage capacity in the Darling River below Menindee was undertaken using channel capacity and longitudinal survey section information for the Darling River.

An assessment of the volume of available storage resulting from the raising of Burtundy weir was made. The variation of storage volume with weir crest height is presented in Table 7. Construction of an impoundment with a crest level approaching the top of bank with a suitable regulator will lead to creation of only 5 Gigalitres of storage with a surface area of 400Ha. The weir pool extends approximately 80 kilometres upstream.

Table 7– Burtundy In-stream Storage

Comment	Crest Level (m)	Channel Area (sqm)	Volume (GL)	Weir Pool Length (Km)	Surface Area (Ha)
Current Weir Hgt	1	6.5	0.0	17.6	37.4
	2	37	0.4	35.2	122.1
	3	74	1.3	52.8	209.9
	4	116	2.7	70.4	309.1
Top Of Bank	5	162	4.7	88	414.4

Instream Storage in the Murray

There is potential to store a volume of water through utilisation and enhancement of the existing Locks on the Murray River downstream of Wentworth. Use of this storage may mitigate the impacts of reduced storage volumes at the Menindee Lakes Scheme.

The locks are currently operated in non flood times to maintain a fixed river level irrespective of flow. There is the potential to vary the operation of the locks to increase the instream storage downstream of Menindee. A one metre increase in water level at each lock equates to approximately 100GL. Varying the water levels in each of the locks is likely to have environmental benefits if the variation mimics some aspects of the natural behaviour. There is also potential for storage at Chowilla or surcharging the existing lakes

4 DISCUSSION OF MODELLED RESULTS

4.1 General

Detailed results for each key modelled option are included in the Appendices to this report. In the following sections, summaries of evaporative savings, together with diversion, flow and salinity changes are presented. The following nomenclature has been adopted for describing modelled water savings options that have their genesis at the Menindee Lakes Scheme.

Base Case	The base case (current operation and development)
M0	Rapid emptying of the Scheme in the range of 480GL to 200GL
M1	Rapid emptying of the Scheme in the range of 480GL to 300GL
M2	Rapid emptying of the Scheme in the range of 680GL to 100GL
M3	Rapid emptying of the Scheme in the range of 300GL to 100GL
NoMC	More natural wetting and drying of Lake Menindee and Lake Cawndilla
NoCExMO	More natural wetting and drying of Lake Cawndilla
NoCEnMO	More natural wetting and drying of Lake Cawndilla
NoMExCO	More natural wetting and drying of Lake Menindee
NoMEnCO	More natural wetting and drying of Lake Menindee
MCell	Construction of two Menindee Lake cells
0.5M	Construction of a two Menindee Lake cells (One Filled)
PInc	Increasing the capacity of Lake Pamamaroo

4.2 Menindee Scheme - Potential Evaporative Savings

Evaporative savings for each of the key modelled options are presented in Table 8. The time series variation of evaporation for each option with respect to the base case is presented in Appendix 1. In recognition that the importance of evaporative losses is a function of the volume available in storage, the variation of evaporation volume as a proportion of the average annual storage volume is presented in Appendix 2 for each option.

Table 8 – Key Modelled Options - Evaporative Savings (GL/Yr)

Option	Wetherell Net Evap	Pamamaroo Net Evap	Menindee Net Evap	Cawndilla Net Evap	Total Net Evap (GL/Yr)	Decrease From Base Case (GL/Yr)
Base case	50	82	168	126	426	0
M0	62	77	128	105	372	-54
M1	64	81	133	108	387	-39
M2	55	69	117	95	335	-91
M3	69	81	143	113	406	-20
NoMC	117	94	5	0	215	-211
NoCExMO	80	91	183	0	353	-73
NoCEnMO	82	92	176	0	351	-76
0.5M	56	84	87	130	357	-70
NoMExCO	75	83	0	134	291	-136
NoMEnCO	83	92	0	118	292	-134
PInc	65	86	162	123	435	+9
MCell	50	82	130	123	388	-38

All but one of the key modelled options produces evaporative water savings. The exception is the Pamamaroo increased capacity option in which the savings created by increased storage in Lake Pamamaroo is more than offset by the additional evaporative losses incurred in Lake Wetherell. This is a consequence of Lake Wetherell storage volumes and inundated areas having to be increased in order to fill Lake Pamamaroo.

Restoration of Lake Menindee and Cawndilla to more natural cycles of wetting and drying result in the largest evaporative saving of any option. This is followed by restoration of Lake Menindee only. As discussed previously use of these Lakes for flood mitigation purposes would reduce these saving volumes.

Options which seek to increase the release rate from the lakes when in New South Wales control, and thereby reduce the time that water spends within the scheme also produce substantial savings. In general approximately 100 to 200 Megalitres per annum is saved for every Gigalitre of water that remains in New South Wales control below 680 Gigalitres.

A number of savings options have been assessed with differing regulator outlet capacity configurations. This was undertaken in an effort to ensure that downstream demand could still be met on a daily basis. These options produced almost negligible change in the evaporative savings volumes. This is thought to be due to the modelled target storage operation remaining unchanged from the base case, and the times when demands avail of this additional capacity being infrequent.

There is potentially some scope to for further efficiency gains through optimising scheme operation for each of the modelled options. However, changing the assumed target storage operation within the model in order to better utilise the lakes for each water saving option requires modification to the source code within MSM. This was not possible as a consequence of the short study timeframes. However, this should be addressed during the more detailed second phase of the project.

4.3 Consequences of Menindee Scheme Savings

4.3.1 Longterm Average Diversion Change and Reliability

Any option that seeks to reduce the storage time or storage volume within the lake scheme is going to result in changes to average downstream diversions and reliability. Impacts on average diversions for each option are presented in Table 9. Changes in both the magnitude of peak shortfalls and their frequency are presented in Appendix 3 as part of the summary outputs for each option. Exceedence curves of changes in the Lower Darling, and New South Wales, Victorian and South Australian Murray Diversions are presented in Appendix 4. Time series of annual diversions are presented in Appendix 5.

Modelled options produce substantially larger average and inter year impacts upon Lower Darling Diversions than for Murray River Diversions. In general, average and inter year diversions for New South Wales, Victorian and South Australian Murray users are only altered by small amounts. The largest impact on Lower Darling average diversions is for the restoration of both Menindee and Cawndilla to more natural cycles of wetting and drying. This option result in average diversion reductions in the New South Wales Lower Darling of 74%. The restoration of Lake Cawndilla to more natural wetting and drying also results in a substantial decrease in

Lower Darling average diversions (53%) and increased spells of diversion shortfall years. This can be seen in the time series plots of annual diversions in Appendix 5. The option with the least impact on diversions and reliability is the construction of two cells in Lake Menindee.

Table 9 – Longterm Average Diversion Change (GL/Yr)

Year	Total NSW Lower Darling Div (GL/Yr)	Decrease from Base Case (GL/Yr)	Total NSW Murray Div (GL/Yr)	Decrease from Base Case (GL/Yr)	Total Vic Murray Div (GL/Yr)	Decrease from Base Case (GL/Yr)	Total SA Murray Div (GL/Yr)	Decrease from Base Case (GL/Yr)
Base case	129		1966	0	1675		1139	
M0	119	-10	1979	13	1671	-4	1143	4
M1	121	-8	1986	20	1674	-1	1143	4
M2	112	-17	1969	3	1665	-10	1145	6
M3	124	-5	1979	13	1673	-2	1144	5
NoMC	32	-97	1922	-44	1636	-39	1141	2
NoCExMO	55	-74	1968	3	1670	-5	1142	3
NoCEnMO	55	-74	1969	3	1671	-4	1142	3
0.5M	116	-13	1968	2	1675	0	1142	3
NoMExCO	116	-13	1963	-2	1673	-2	1142	3
NoMEnCO	112	-17	1964	-2	1672	-3	1143	4
PInc	122	-7	1966	0	1675	0	1140	1
MCell	129	0	1966	0	1675	0	1139	0

4.3.2 Flow Change

Flow changes resulting from key modelled options are presented in Tables 10 and 11. Specific examples of flow regime changes in the Darling at Wentworth and the Murray at Lock 7 are presented in the form of flow duration curves in Figures 9 and 10.

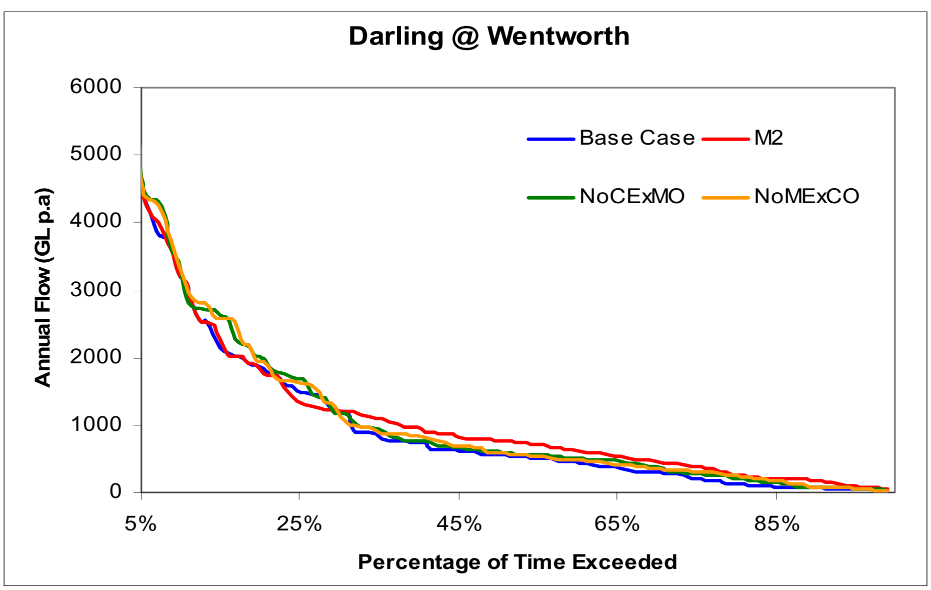

Figure 9 – Annual Flow Exceedence Curve (Darling River @ Wentworth)

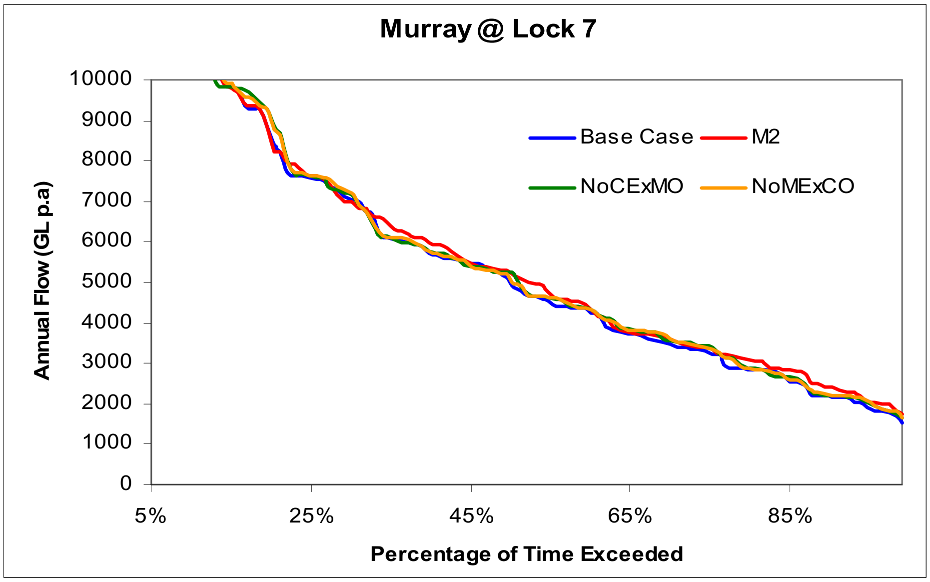

Figure 10 - Annual Flow Exceedence Curve (Murray River @ Lock 7)

With the exception of the option of increased capacity of Pamamaroo, all options produce increased flows in the Lower Darling. Most options also reduce the volume of flow released and spilt from Lake Cawndilla. The exception is the option in which the Cawndilla outlet is enlarged. Under this option Cawndilla releases increase by 98 Gigalitres per annum.

Flows in the Murray upstream of Wentworth are largely unchanged by water saving options at Menindee. Although restoring Lakes Menindee and Cawndilla to natural wetting and drying cycles results in increases in Murray flows upstream of Wentworth of approximately 80 Gigalitres per annum.

Flows downstream of Wentworth generally increase in most options. This results in increased spills from Lake Victoria and a corresponding reduction in regulated releases. Flow across the South Australian border also increases.

An example of the variability of flows with respect to time for both the base case and the restoration of Lake Menindee too a more natural regime is shown in Figures 11 to 13. Further examples of the alteration to flow regimes for additional options are presented in Appendix 6. Options generally increase the frequency of over bank events in the Lower Darling but result in only minor changes in the Murray River flow regime.

It should be noted that the distribution of flows within the Anabranch or outflows from the Anabranch are not simulated in the version of MSM used for the first stage of this project. Refinement of options in further stages of this project should incorporate a more detailed analysis of Anabranch flows.

Table 10 – Average Annual Flows (GL/Yr)

	Base Case	NoMC	PCI	0.5M	NoCExMO	NoCEnMO	NoMExCO	NoMEnCO	MO	M1	M2	M3
Lake Cawndilla Release (GL/Yr)	139	0	134	132	0	0	104	237	110	113	103	118
Lake Cawndilla Spill (GL/Yr)	11	0	0	18	0	0	0	0	11	11	10	11
Weir 32 Flow (GL/Yr)	1671	1968	1670	1751	1815	1817	1812	1817	1735	1718	1780	1697
Burtundy Flow (GL/Yr)	1158	1333	1144	1209	1235	1237	1241	1246	1223	1206	1268	1186
Darling U/S Wentworth (GL/Yr)	1140	1315	1126	1191	1217	1219	1223	1228	1205	1188	1250	1168
Murray U/S Wentworth (GL/Yr)	6062	6144	6062	6061	6066	6065	6068	6068	6055	6047	6070	6053
Lake Victoria Spill (GL/Yr)	4218	4867	4209	4324	4494	4495	4700	4705	4317	4287	4390	4253
Lake Victoria Release (GL/Yr)	248	232	244	230	207	206	195	188	242	250	238	251
Lock 7 (GL/Yr)	6460	6704	6447	6505	6533	6534	6541	6545	6516	6492	6576	6479

Table 11 – Increases in Average Annual Flows from Base Case

	NoMC	PCI	0.5M	NoCExMO	NoCEnMO	NoMExCO	NoMEnCO	MO	M1	M2	M3
Lake Cawndilla Release (GL/Yr)	-139	-5	-7	-139	-139	-35	98	-29	-26	-36	-21
Cawndilla Spill (GL/Yr)	-11	-11	7	-11	-11	-11	-11	0	0	-1	0
Weir 32 Flow (GL/Yr)	297	-1	80	144	146	141	146	64	47	109	26
Burtundy Flow (GL/Yr)	175	-14	51	77	79	83	88	65	48	110	28
Darling U/S Wentworth	175	-14	51	77	79	83	88	65	48	110	28
Murray U/S Wentworth	82	0	-1	4	3	6	6	-7	-15	8	-9
Lake Victoria Spill	649	-9	106	276	277	482	487	99	69	172	35
Lake Victoria Release	-16	-4	-18	-41	-42	-53	-60	-6	2	-10	3
Lock 7 Flow (GL/Yr)	244	-13	45	73	74	81	85	56	32	116	19
Evaporative Saving At Menindee (GL/Yr)	211	-9	70	73	76	136	134	54	39	91	

Base Case

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1891/92	16700	19000	20367	27433	30900	25733	17367	9167	1867	167	233	367
1892/93	533	5300	5800	6100	11900	16367	17600	15833	10667	12767	18167	19367
1893/94	20100	21133	27967	34500	31167	20967	11767	4233	767	2767	11933	19033
1894/95	20100	24133	22733	18533	14433	13500	5667	833	1200	2833	1800	467
1895/96	467	433	400	200	4367	7667	7467	3000	233	233	200	200
1896/97	167	167	133	5100	8233	6867	4967	3200	1167	200	200	167
1897/98	200	267	267	167	5067	7033	3400	1200	467	233	200	167
1898/99	167	167	133	100	4600	5667	2767	800	233	267	200	167
1899/00	167	167	100	100	133	67	167	167	33	167	200	200
1900/01	167	200	133	100	2867	5700	3933	1100	233	167	33	-33
1901/02	0	133	167	100	67	67	133	233	233	200	200	133
1902/03	167	167	133	100	67	67	-33	-67	-67	-67	100	167
1903/04	167	167	133	133	9167	15567	13233	4500	300	200	367	467
1904/05	1500	2267	2200	1067	1833	6167	7500	2900	233	300	233	233
1905/06	167	300	233	100	4467	6900	5000	2233	667	233	233	200
1906/07	167	300	300	133	167	133	3467	2300	1033	800	200	200
1907/08	167	333	267	5100	7100	4933	2267	633	233	233	233	200
1908/09	167	333	267	133	5000	6867	4733	1700	267	267	233	233
1909/10	167	167	133	100	633	2267	1400	200	333	233	233	200
1910/11	367	467	433	367	367	5167	7867	3167	1933	10333	10833	3067
1911/12	500	600	500	4667	7733	5600	5967	2933	233	233	200	167
1912/13	167	200	133	100	233	3767	3733	1067	333	167	100	133
1913/14	167	233	267	533	4433	6267	4100	1300	300	267	200	167
1914/15	167	200	200	167	167	167	133	233	233	200	133	33
1915/16	0	0	67	100	-67	-67	-100	-67	-67	67	200	200
1916/17	200	200	200	267	5100	7067	9167	12833	10533	12100	9333	2100
1917/18	500	633	533	400	8100	11633	13067	15333	9167	2533	867	500
1918/19	433	467	400	200	100	5067	8000	3200	233	233	267	200
1919/20	167	267	233	300	233	133	33	-67	-67	-33	-33	-33
1920/21	67	267	9333	16000	16400	13900	7900	2333	300	300	233	233
1921/22	2000	11467	19767	25133	33833	22500	14767	10800	3733	267	200	200
1922/23	167	167	100	1067	5700	7933	6033	3433	1067	200	200	200
1923/24	167	67	0	67	133	100	-100	33	233	267	200	167
1924/25	167	167	133	100	167	167	200	767	600	233	233	200
1925/26	200	333	233	100	3100	6867	6800	2467	267	300	267	200
1926/27	167	300	233	100	100	5067	6733	2433	233	233	200	167
1927/28	167	267	267	1833	1200	133	167	267	267	233	200	167
1928/29	200	133	100	2967	2833	5600	6467	2267	233	267	200	133
1929/30	167	267	267	2667	1800	200	167	233	100	100	67	67
1930/31	133	200	133	167	133	200	167	200	300	333	233	233
1931/32	167	8967	15200	11267	5300	5867	7800	3400	267	300	233	200
1932/33	167	167	167	100	167	4800	5000	1433	233	267	200	167
1933/34	167	267	267	133	1300	1167	5267	3333	233	267	200	133
1934/35	167	167	133	300	1767	2867	1333	3200	2167	300	367	433
1935/36	467	433	233	133	133	4233	2867	200	233	233	233	200
1936/37	200	167	100	100	1367	3233	1800	300	233	233	200	200
1937/38	167	267	267	2800	1767	133	133	167	167	133	0	67
1938/39	200	167	100	167	67	100	100	300	300	267	233	200
1939/40	167	167	133	133	200	133	867	667	200	300	200	167
1940/41	167	167	100	67	133	100	267	1433	1067	233	367	467
1941/42	467	600	500	200	3667	6400	5667	2167	233	267	267	233
1942/43	200	267	267	167	333	5233	8200	3367	200	267	200	167
1943/44	167	300	267	133	3167	3133	867	233	233	267	200	200
1944/45	167	167	100	100	100	133	167	233	233	233	200	200
1945/46	167	167	133	100	533	2800	1800	267	267	267	200	200
1946/47	167	167	100	67	167	100	-100	-67	167	267	200	133
1947/48	200	333	267	133	200	1767	5633	3033	233	300	200	167
1948/49	167	500	500	5233	8233	7267	5167	1867	333	267	267	200
1949/50	167	267	267	167	167	200	5133	3433	367	333	9333	15933
1950/51	16167	16733	20600	30500	37700	26067	28867	33433	20333	14867	12500	7500
1951/52	4300	6067	9233	8633	4767	5333	7700	3333	267	300	267	233
1952/53	167	367	9433	16967	18100	16100	14267	5233	267	1133	9500	9500
1953/54	2500	467	433	400	367	167	2467	1733	900	767	200	167
1954/55	167	3300	7133	8267	7000	2700	9000	8233	1533	9267	16000	15333
1955/56	12333	10333	7833	5733	8500	13133	8400	3200	10467	16733	23167	44867
1956/57	43867	43733	46333	46067	29100	17067	14600	5833	833	267	200	167
1957/58	167	167	1433	5967	7833	5900	3500	1167	267	233	200	200
1958/59	167	200	167	133	233	167	1600	1133	233	233	233	167
1959/60	167	300	1067	5700	4333	1000	4367	2833	233	267	267	200
1960/61	200	200	133	100	200	133	4100	2733	233	333	200	167
1961/62	167	267	233	133	233	167	233	200	267	233	833	767
1962/63	467	633	533	367	5167	8267	5733	1767	233	300	400	2100
1963/64	9633	7700	2700	5467	4167	5900	8233	7333	2767	300	200	167
1964/65	167	167	333	400	4300	3300	4600	2800	200	267	200	200
1965/66	167	333	300	100	1933	4033	1933	233	267	233	200	200
1966/67	167	200	133	100	200	167	167	233	233	233	200	167
1967/68	167	167	133	100	100	133	233	200	233	267	233	200
1968/69	167	200	133	100	167	167	167	233	400	267	233	200
1969/70	200	167	133	100	133	4067	4600	1433	233	300	200	167
1970/71	133	267	300	133	200	133	2300	1633	10267	19433	19767	13267
1971/72	9233	5767	5067	4100	4067	2800	833	1367	1000	267	667	467
1972/73	167	333	5233	7900	5800	6833	7167	2733	267	300	200	200
1973/74	200	300	300	233	2333	10333	12967	14400	20500	27533	21333	11633
1974/75	5767	3100	2567	4500	6000	3967	1200	667	533	967	2467	1500
1975/76	467	633	533	433	1000	8200	5067	8933	16100	22267	39467	31933
1976/77	9600	7367	3633	3300	3200	5867	8100	3367	233	300	7167	13433
1977/78	15300	10533	2800	5200	8267	8200	6800	2900	567	233	233	200
1978/79	200	200	333	5233	12333	14967	7400	1800	867	1033	667	233
1979/80	167	333	267	133	133	100	4600	3433	467	333	233	200
1980/81	200	167	100	100	100	100	0	-67	100	233	233	200
1981/82	200	200	133	100	167	1267	900	200	267	233	200	167
1982/83	133	233	3533	5367	2833	600	33	-67	-33	-33	-33	67
1983/84	2700	11100	16400	14333	11667	12067	12133	8500	8967	13167	9733	4033
1984/85	1600	8100	14467	16933	13767	7833	7967	3400	300	233	233	200
1985/86	167	200	133	133	3267	4433	5400	2600	200	233	233	200
1986/87	200	200	167	133	133	200	200	233	267	233	200	200
1987/88	167	200	167	67	100	167	133	200	267	267	267	533
1988/89	6067	9833	4933	3367	3967	5333	6700	2833	367	300	433	7500
1989/90	13800	15333	13567	5500	1800	5467	7900	3333	200	267	8300	15633
1990/91	19133	18467	16767	17933	17533	7833	6267	3300	1433	1833	1033	400
1991/92	200	167	100	67	133	5100	6400	2200	200	267	267	200
1992/93	167	300	300	167	233	267	367	233	267	233	233	167
1993/94	200	167	133	167	167	233	133	300	233	233	167	167
1994/95	167	167	100	100	167	67	233	733	567	1233	867	200
1995/96	167	133	133	133	167	167	200	1100	833	267	200	3100
1996/97	10300	6000	533	400	3300	2167	4733	3067	233	8267	5733	467
1997/98	433	467	367	5167	8233	7333	5367	3200	1100	267	200	133
1998/99	200	233	5933	13833	20033	22967	8700	1633	267	233	367	467
1999/00	467	467	400	2533	4400	6867	8200	3400	233	333	400	467
2000/01	1333	1667	1300	700	2033	9067	14167	8500	4567	3000	1067	600
2001/02	467	433	400	5233	7500	6000	6167	2733	233	267	200	167
2002/03	133	167	100	67	100	-67	-100	-67	-67	100	233	167

NoMExCO

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1891/92	16300	18667	21533	27400	31100	26200	15000	6567	1767	167	667	2533
1892/93	5133	7500	6067	6367	11967	16633	18300	12433	11200	15233	18767	20067
1893/94	20000	21167	28067	34733	31533	20900	8300	2467	833	6933	14500	19433
1894/95	21233	24133	22700	18633	12633	9800	4067	1233	7567	6867	1733	167
1895/96	167	167	133	67	1167	4767	4733	4467	2033	2533	2633	800
1896/97	167	167	133	4867	5900	3367	2467	2267	1000	200	200	167
1897/98	167	300	267	133	5033	7333	4800	4067	2000	2567	1633	167
1898/99	167	167	133	100	4533	4433	2067	1033	367	267	200	167
1899/00	167	267	233	133	133	67	167	133	0	167	200	200
1900/01	167	200	867	567	2833	6033	4200	1900	767	233	100	0
1901/02	0	233	300	133	2467	1633	133	233	233	200	200	133
1902/03	133	167	133	67	-67	-67	-100	-67	-67	-67	100	167
1903/04	167	167	1067	8133	14533	17167	12767	4200	467	1167	4300	3267
1904/05	2800	3533	3067	1167	100	5067	5767	1833	233	300	233	333
1905/06	233	300	233	100	3500	4833	2767	1067	467	233	233	200
1906/07	167	200	167	100	3433	2433	3267	3633	3200	2200	1533	800
1907/08	167	333	233	4633	5000	2700	1667	700	233	1400	3500	2300
1908/09	467	200	133	133	4633	6167	3800	1900	633	267	233	200
1909/10	167	300	267	133	633	3567	2200	833	3867	5067	7467	3800
1910/11	767	3000	2167	367	167	4733	4167	967	8367	15200	11567	2700
1911/12	267	167	133	1367	5133	4367	2633	1733	533	67	0	0
1912/13	0	100	133	100	233	3767	3767	1100	333	167	100	100
1913/14	133	3533	2733	467	4400	5400	2967	1467	567	233	200	167
1914/15	167	133	100	100	167	167	133	233	233	233	133	67
1915/16	0	33	167	167	0	-67	-100	-67	-67	33	167	200
1916/17	200	200	2033	10200	10833	7033	8967	12667	14833	15433	9600	1967
1917/18	200	200	167	133	6367	9467	12600	16267	14167	4867	767	200
1918/19	167	167	133	100	100	4233	4200	2067	800	233	267	133
1919/20	0	0	-67	-67	-67	-100	-100	-67	-67	0	0	0
1920/21	67	8900	16167	18567	17500	8433	4967	2667	300	300	233	200
1921/22	5767	13800	20100	26867	33967	22933	10033	7800	6967	2200	200	200
1922/23	167	167	100	100	4500	4433	2033	967	167	-67	0	0
1923/24	0	67	33	33	133	100	-100	33	233	267	200	167
1924/25	133	167	133	100	167	167	8233	8267	1967	233	233	200
1925/26	200	200	133	100	167	4633	4933	4500	2233	300	267	333
1926/27	2067	1633	333	100	100	4833	4967	2267	800	233	200	167
1927/28	167	267	233	1967	1300	133	167	267	267	233	200	167
1928/29	200	3833	6400	2600	200	4967	4867	2267	867	267	200	133
1929/30	167	267	233	2800	1867	200	167	233	233	233	200	200
1930/31	167	200	133	167	133	200	2600	1800	300	333	233	233
1931/32	5933	13567	18200	13500	3100	2700	6733	3400	267	300	233	200
1932/33	167	167	167	100	167	4133	4300	1233	233	267	200	167
1933/34	167	267	267	133	1300	1300	6967	5200	3233	2633	700	133
1934/35	167	167	100	2800	3900	3533	1500	3733	5933	2500	200	167
1935/36	167	300	233	133	133	2867	2033	200	233	233	233	200
1936/37	200	167	100	100	1367	1033	267	233	233	233	200	200
1937/38	167	267	267	3267	2067	133	133	233	200	233	167	133
1938/39	200	167	100	167	67	67	100	300	300	267	233	200
1939/40	167	267	267	167	200	133	2267	1567	200	300	200	167
1940/41	167	167	100	67	133	100	267	3067	7400	6767	7033	3233
1941/42	633	600	233	567	4333	4533	2433	1333	400	200	233	233
1942/43	200	167	133	133	600	5400	8200	3367	200	267	200	167
1943/44	167	333	267	133	3433	4033	1333	233	233	267	200	200
1944/45	167	167	100	100	67	133	167	233	233	233	200	200
1945/46	167	167	133	100	900	3933	2333	267	267	267	200	200
1946/47	167	233	233	133	167	167	133	267	300	2000	3900	2433
1947/48	600	333	267	100	200	1533	5567	3133	267	300	200	167
1948/49	4133	9667	6300	2467	2533	3900	4200	1767	333	267	267	200
1949/50	167	267	233	167	167	8133	6800	1367	2633	6033	12267	16800
1950/51	17067	16533	20700	31133	37967	26467	29367	34067	20767	15167	12567	7300
1951/52	4167	6133	9400	9233	3367	2133	5667	2867	267	300	267	233
1952/53	167	5067	12767	18200	19333	16300	9433	1967	200	7300	13533	9633
1953/54	2333	200	167	133	167	100	167	233	233	3500	3467	967
1954/55	167	167	4167	4367	2300	9067	14533	8700	4200	10900	16600	16600
1955/56	12367	10333	7967	6400	6533	11233	7733	3267	10533	16900	23900	47033
1956/57	43933	43533	46233	46200	29733	17533	10267	3167	1067	267	200	167
1957/58	167	167	100	4133	4633	2967	2000	900	200	133	200	167
1958/59	167	200	167	133	233	167	2067	1467	233	2367	8700	6667
1959/60	1500	367	1133	733	67	667	3800	2333	233	267	267	200
1960/61	200	200	133	100	200	133	4100	2733	233	333	200	167
1961/62	167	300	233	100	233	633	533	200	7633	11167	8667	3100
1962/63	200	333	233	133	3000	5600	4400	1467	233	300	6733	8267
1963/64	10967	7700	3033	6267	3333	5100	7467	2867	200	300	200	167
1964/65	167	2667	4200	2833	4767	2800	1367	933	200	233	200	200
1965/66	167	333	267	100	1900	2267	800	233	267	233	200	200
1966/67	167	167	0	33	167	167	167	233	233	233	200	167
1967/68	167	167	133	100	100	133	233	200	233	267	233	200
1968/69	167	200	133	100	167	167	167	233	400	267	233	200
1969/70	200	167	133	100	133	4067	4600	1433	233	300	200	133
1970/71	133	300	300	133	167	133	2300	10667	17200	21033	22933	13000
1971/72	8767	5567	5333	4933	1967	300	233	733	800	433	200	167
1972/73	167	333	233	4900	4900	6233	6900	2567	267	300	200	200
1973/74	200	300	367	3767	10933	14800	12633	14133	21067	30667	20967	11567
1974/75	5700	3000	2600	4667	3267	700	200	233	233	1300	8967	5767
1975/76	300	367	267	300	200	5333	3467	9267	16633	22767	42200	32233
1976/77	9667	7633	3800	1300	700	3733	6400	2800	233	8500	13167	12867
1977/78	14767	11700	2833	4467	5167	3633	2600	1367	567	233	233	200
1978/79	200	2400	8333	12700	15000	11033	4333	1300	233	267	267	233
1979/80	167	167	133	133	133	100	4133	3800	900	333	233	167
1980/81	167	167	100	100	0	0	-100	-67	100	233	233	200
1981/82	200	200	133	67	167	2800	1900	200	267	233	1733	1167
1982/83	133	267	233	4633	4500	1967	667	0	0	0	0	67
1983/84	9867	18500	19200	14867	9567	7933	10167	8967	12367	16233	9867	4200
1984/85	1467	6833	13700	17500	12133	4500	6667	3300	233	233	233	200
1985/86	167	200	133	133	2600	2867	2433	1233	200	200	200	200
1986/87	200	300	300	200	133	200	200	233	267	233	200	200
1987/88	167	200	167	67	100	167	133	200	267	267	267	9933
1988/89	15833	11533	5367	4333	2300	2067	3433	1533	367	300	4533	11367
1989/90	15333	16167	13867	6400	900	2167	5967	3033	200	267	9300	17033
1990/91	20233	20433	16500	17833	17167	5167	3267	2133	233	267	200	167
1991/92	200	433	267	67	133	4733	5267	1633	200	267	267	200
1992/93	133	200	167	133	233	267	367	233	267	233	233	167
1993/94	200	267	267	200	167	233	133	267	233	233	167	167
1994/95	167	167	100	2167	1500	67	233	2667	1800	267	233	200
1995/96	167	133	133	133	167	167	200	3400	6833	4033	3100	10600
1996/97	14600	5800	233	133	1233	867	1600	1133	6067	13067	7000	167
1997/98	167	333	267	1633	4033	3533	2000	900	167	0	33	133
1998/99	200	167	9967	19000	22733	24033	5367	233	267	2667	5233	2400
1999/00	200	167	133	133	1500	4900	5600	2167	233	4033	6967	5900
2000/01	3433	2500	1867	633	200	5767	12967	8733	9567	7100	1433	500
2001/02	167	167	133	933	2933	5133	3833	2133	867	267	200	167
2002/03	133	167	33	0	-67	-67	-100	-67	-67	100	233	167

15000 - 25000 ML/Day | 25000-35000 ML/Day | > 35000 ML/Day

Figure 11 – Base Case and NoMExCO Lower Darling Upstream Wentworth Weir

	Base Case												NoMExCO											
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1891/92	41133	60367	71267	64033	44800	29133	17567	10067	9300	7500	6200	6000	41133	60067	72167	64100	44967	29600	15367	7500	6200	4500	3100	7067
1892/93	13733	23467	30833	25967	24800	21533	17833	16067	11000	15867	26767	39700	26367	27967	31233	26233	24867	21767	18500	12900	11333	18233	27467	40233
1893/94	48400	55967	64600	71200	64233	36500	14500	9267	9300	7500	28000	44100	48400	55967	64700	71400	64500	36467	11200	6467	6200	14633	31400	44533
1894/95	53933	69833	82500	101833	109867	74900	19233	9267	9300	7500	6200	6000	54800	69967	82500	101900	108467	71933	17533	6467	7233	11300	10033	8267
1895/96	8167	18900	25833	17567	9000	8067	7233	6467	6200	7100	6200	6000	13167	18633	25533	17467	6000	7233	7233	6467	6200	4500	5900	9100
1896/97	6700	7333	7500	8800	6433	7233	7233	6467	6200	4500	3100	3000	9900	7500	4900	5700	6000	7233	7233	6467	6200	4500	3100	3000
1897/98	3633	4300	14500	6100	6000	7233	7233	6467	6200	4667	3100	3000	3633	4133	13133	6067	6000	7233	7233	6467	6200	4500	3100	5367
1898/99	3633	13033	14133	6167	6000	7233	7233	6467	6200	4500	3100	8000	9800	14100	14133	6167	6000	7233	7233	6467	6200	4500	3100	6667
1899/00	18700	14967	8533	5700	6000	7233	7233	6467	6200	4500	3900	13967	18700	15067	8633	5700	6000	7233	7233	6467	6200	4500	4033	13967
1900/01	23600	33033	34800	18767	6000	7233	7233	6467	6200	4500	3100	2967	23600	33033	35300	19300	6000	7233	7233	6467	6200	4500	3100	2967
1901/02	3567	6767	17433	11867	5800	7233	7233	6467	6200	4500	3100	2867	3567	6767	17633	11967	6000	7233	7233	6467	6200	4500	3100	2900
1902/03	3300	2567	2633	2933	3300	3900	4267	4067	4333	4000	3100	3167	3400	2833	2933	3400	3800	4533	4900	4600	4733	4233	3100	2733
1903/04	18800	18600	16900	12333	13233	17000	16100	8133	6200	4500	3100	3000	17233	18600	17767	20067	18900	18833	15700	7833	6200	4500	3100	7633
1904/05	13000	26533	22867	15100	7833	9667	7233	6467	6200	4500	3867	8333	18633	27833	22667	14167	5767	7233	7233	6467	6200	4500	3100	8000
1905/06	25200	31967	20100	8267	6467	7233	7233	6467	6200	4500	3100	14267	25367	31967	20100	8233	5300	7233	7233	6467	6200	4500	3100	8000
1906/07	30433	38200	42700	51933	59533	33367	7233	6900	9300	7500	6200	3000	30467	38133	42733	52300	63067	35900	7233	6467	6200	4500	3100	7467
1907/08	3633	4133	7500	6400	6000	7233	7233	6467	6200	4500	3100	3000	7867	10333	6867	5700	6000	7233	7233	6467	6200	4500	3100	3000
1908/09	3633	5367	12100	8167	6333	7233	7233	6467	6200	4500	6167	23367	5300	8967	12000	8167	6000	7233	7233	6467	6200	4500	5333	23367
1909/10	30400	38733	47867	34133	6000	7233	7233	6467	6200	6567	6200	6000	30400	38800	47967	34167	6000	7233	7233	6467	6200	4500	10100	11267
1910/11	6733	8600	26300	27233	11000	10333	8067	10800	9300	10733	16933	24867	13733	18600	28100	27300	10600	7233	7233	8500	12667	18300	17900	24567
1911/12	29300	29000	14867	8800	7900	7233	7233	6467	6200	4500	3100	3000	29067	28567	14467	5700	6000	7233	7233	6467	6200	4500	3100	3000
1912/13	6767	10933	20700	11433	6167	7233	7233	6467	6200	4500	3367	7500	3633	6867	20667	11433	6133	7233	7233	6467	6200	4500	3400	7500
1913/14	7700	5400	5800	5700	6000	7233	7233	6467	6200	4500	3100	3000	7700	8500	8333	5800	6000	7233	7233	6467	6200	4500	3100	3000
1914/15	3633	3733	4033	5000	5333	6500	6667	6133	6100	4500	3100	2833	3633	3700	4000	4967	5300	6467	6633	6067	6033	4500	3100	2867
1915/16	19233	29133	32433	29833	10733	6800	7233	6467	6200	4500	3100	2833	19233	29167	32500	29900	10767	6833	7233	6467	6200	4500	3100	2867
1916/17	14433	32733	41400	49400	59567	57467	37233	22333	14067	15233	19733	35333	14967	32733	42733	56867	65400	57967	37267	22200	18100	18633	20200	35233
1917/18	55833	90400	128867	166267	185133	144900	57033	24300	14233	7933	25433	36000	55600	90033	128567	165933	183333	142433	56100	25067	19000	10400	25467	35767
1918/19	46933	59167	64933	53167	15933	9967	7233	6467	6200	4500	3100	3000	46700	58900	64700	53067	15933	7233	7233	6467	6200	4500	3100	3000
1919/20	7000	5200	4500	5700	6000	7233	7233	6467	6200	4500	3100	3000	5800	5467	4500	5700	6000	7233	7233	6467	6200	4500	3100	3000
1920/21	9867	28967	44300	52433	38533	20700	10333	9267	9300	7500	6200	3000	9900	35900	50033	55100	39633	15667	7233	6467	6200	4500	3100	10633
1921/22	15633	37933	52267	62000	56533	30100	15300	11900	9300	7500	6200	6000	23633	39833	52767	63400	56367	30167	10733	8767	7067	4500	5633	6833
1922/23	6733	7233	15267	8800	8367	7233	7233	6467	6200	4500	3100	6367	7900	13200	18000	7900	6000	7233	7233	6467	6200	4500	3100	6533
1923/24	29333	39867	40333	33367	20000	7767	7233	6467	6200	4500	3100	5667	26767	39867	40333	33367	19533	7500	7233	6467	6200	4500	3100	5567
1924/25	8800	17867	31167	36067	37133	34367	14433	9267	9300	7500	6200	5000	8800	17533	30933	35733	36333	32900	20600	13233	6200	4500	3100	11100
1925/26	20033	30133	32467	23033	8767	7233	7233	6467	6200	4500	12533	19733	28167	30000	32367	23000	6000	7233	7233	6467	6200	4500	12300	19833
1926/27	25067	33233	36633	31267	12633	7633	7233	6467	6200	4500	3100	3000	26867	34300	36867	31267	12633	7233	7233	6467	6200	4500	3100	3000
1927/28	3633	4200	6600	5700	6000	7233	7233	6467	6200	4500	5133	18733	3633	4133	5567	5700	6000	7233	7233	6467	6200	4500	5033	18733
1928/29	20133	12167	7500	8800	8500	7267	7233	6467	6200	4500	3100	6267	20133	15633	10633	11833	6000	7233	7233	6467	6200	4500	3100	4567
1929/30	7900	6733	6300	5700	6000	7233	7233	6467	6200	4500	3100	3000	7900	6767	6300	5700	6000	7233	7233	6467	6200	4500	3100	3000
1930/31	3633	7233	10100	8967	6100	8467	7233	6467	6200	4500	24000	41233	3633	7433	10100	9067	6333	8433	7233	6467	6200	4500	25367	41233
1931/32	61633	97500	104900	74467	34300	10333	10333	9267	9300	7500	7467	22133	66233	102067	108067	76633	32400	7233	7233	6467	6200	7467	15233	22133
1932/33	30733	36667	40300	38867	15967	7667	7233	6467	6200	4500	3100	3000	30733	36667	40333	38900	16000	7233	7233	6467	6200	4500	3100	3000
1933/34	7233	18833	24533	12333	6000	7233	10067	9267	9300	7500	6200	5700	6500	18833	24533	12333	6000	7367	10167	8833	6600	7100	8033	5733
1934/35	3633	9900	24567	33800	41233	44400	26033	9267	9300	7500	6200	18000	7967	16400	24567	35600	43000	45033	26233	8500	7467	8067	14033	18267
1935/36	27800	36933	45767	46333	26233	8533	9000	6467	6200	4500	3100	3000	27500	36833	45767	46333	26233	7233	8133	6467	6200	4500	3100	3000
1936/37	17667	32667	39600	24433	6000	7233	7233	6467	6200	4500	3100	3000	17633	32667	39600	24433	6000	7233	7233	6467	6200	4500	3100	3000
1937/38	3633	4133	4500	5700	6000	7233	7233	6467	6200	4500	3100	3000	3633	4133	4500	5700	6000	7233	7233	6467	6200	4500	3100	3000
1938/39	3633	3733	4133	5400	5800	7100	7133	6233	6200	11167	21200	26933	3633	3733	4100	5367	5767	7100	7100	6167	6200	11000	21233	26933
1939/40	34867	42967	51433	51900	41433	16800	7233	6467	6200	4500	3100	3000	34867	43200	51967	52300	41533	16800	7233	6467	6200	4500	3100	3000
1940/41	3633	3900	4267	5533	6000	7233	7233	6467	6200	4500	3100	3000	3633	3900	4300	5567	6000	7233	7233	6467	6200	6700	11667	9900
1941/42	3633	6933	7000	4833	5133	6600	6933	6467	6200	4500	9067	21267	9100	8700	6633	4800	5533	7133	7233	6467	6200	4500	3200	21200
1942/43	32667	36633	36267	23267	6000	7233	7233	6467	6200	4500	3100	3000	32667	36567	36167	23100	6000	7233	7233	6467	6200	4500	3100	3000
1943/44	6067	7967	9833	5967	6000	7233	7233	6467	6200	4500	3100	3000	5967	8000	9833	5933	6000	7233	7233	6467	6200	4500	3100	3000
1944/45	5633	4400	3867	4733	5200	6500	6700	6167	6200	4500	3100	2700	5267	4400	4067	5067	5533	6933	7100	6467	6200	4500	3100	2800
1945/46	3733	8500	7933	4833	2900	3867	4133	5400	4633	5167	5767	6767	3767	8500	7933	4800	3067	4133	4533	6467	4633	5233	5800	6767
1946/47	14900	23900	12867	4767	5500	7233	7233	6467	6200	4500	3100	2967	14933	23967	13000	4700	5433	7233	7233	6467	6200	4500	3100	3000
1947/48	5867	23133	26167	22700	12500	7467	7233	6600	8900	4500	3100	5833	13833	23200	26167	22667	12433	7233	7233	6467	6200	4500	3100	8833
1948/49	11167	7233	7500	8800	9000	7700	7233	6467	6200	4500	3633	7233	14933	15567	9200	5700	6000	7233	7233	6467	6200	4500	3100	6367
1949/50	7367	7200	7800	16567	23367	10100	10333	9267	9300	21200	40833	42200	7367	7233	7733	16533	23300	17533	8267	8567	13733	27133	43267	43167
1950/51	38033	39800	46100	48600	53900	45000	33800	35567	23200	18100	21300	30733	38767	39767	46133	49100	54167	45333	34200	36067	23700	18400	21367	30533
1951/52	35233	44433	50933	45200	28600	10333	9433	6467	6200	4500	7567	33233	35167	44567	51400	46000	27467	7233	7233	6467	6200	4500	7200	33133
1952/53	53200	75900	86967	87467	86733	75000	46200	13033	9300	7500	6200	13700	53200	79567	89867	88600	87767	75233	42700	9400	6200	4500	17233	18767
1953/54	21333	33500	44233	55000	58933	38200	10333	9267	9300	7500	6200	6000	21200	33300	44000	54800	58733	38133	7500	6467	6200	4500	4300	8133
1954/55	6733	7233	7500	8800	8967	14867	13933	13167	9300	8867	22600	32300	7133	6267	8900	8133	8033	20567	19533	13933	8333	14067	23233	33367
1955/56	39400	58700	99200	129000	111300	62100	19500	9267	24167	47733	77233	137233	39533	58700	99333	129500	109800	60633	18633	6467	27033	47867	77833	138867
1956/57	189600	237067	251467	213333	153300	96200	34433	9667	9300	7500	6200	3667	189867	236933	251400	213433	153800	96667	30367	6900	6200	4500	3100	3000
1957/58	6733	7233	7500	7700	6000	7233	7233	6467	6200	4500	3100	3000	8633	9633	5833	5700	6000	7233	7233	6467	6200	4500	3100	3000
1958/59	9167	33067	43200	45067	38933	21533	7233	6467	6200	4500	5200	4667	7667	33067	43267	45133	38867	21267	7233	6467	6200	4500	12067	13433
1959/60	6733	7233	7500	8800	9000	7800	7767	6467	6200	4500	9300	26300	7833	5600	5633	7533	7267	7233	7233	6467	6200	4500	8767	26300
1960/61	30833	37933	51800	61100	53233	19533	7233	6467	6200	4500	5167	7067	30833	37933	51800	61100	53233	19533	7233	6467	6200	4500	5167	7067
1961/62	10433	17567	18300	12733	6000	7233	8733	6467	6533	7500	6200	6000	10433	17600	18300	12733	6000	7233	9300	6467	6667	13000	15500	14133
1962/63	9600	16800	15100	11933	9000	10300	7233	8667	9300	7500	6200	7533	14700	16533	14833	11700	6000	7233	7233	6467	6200	4500	7500	22133
1963/64	23833	32967	25800	20500	10233	10333	10333	9267	9300	7500	6200	3000	29533	33033	26100	21533	9667	7233	7233	6467	6200	4500	3100	9333
1964/65	22267	37200	43667	51567	62133	42033	10333	8533	6267	4500	3100	3000	25567	39067	46767	53800	62767	41733	7233	6467	6200	4500	3100	3000
1965/66	3633	8233	20800	10200	6000	7233	7233	6467	6200	4500	3100	3000	3633	8300	20800	10200	6000	7233	7233	6467	6200	4500	3100	3000
1966/67	7467	11467	22200	19000	8167	9933	7233	6467	6200	4500	3100	3000	5100	11433	22067	18933	8133	9933	7233	6467	6200	4500	3100	3000
1967/68	3633	4133	4500	5700	6000	7233	7233	6467	6200	4500	4300	24700	3633	4133	4500	5700	6000	7233	7233	6467	6200	4500	4300	24767
1968/69	30233	31467	31500	15133	6000	7233	7233	6467	6200	5167	10633	10400	30233	31467	31500	15133	6000	7233	7233	6467	6200	5200	10633	10400
1969/70	18567	24167	30600	23767	8700	7233	7233	6467	6200	4500	9067	11933	18567	24167	30567	23667	8667	7233	7233	6467	6200	4500	9067	11933
1970/71	18067	28000	43200	56100	51867	23233	7233	7667	16867	26867	32133	27000	18067	28033	43200	56100	51867	23233	7233	13500	26567	28767	34600	27100
1971/72	23133	19833	27100	27533	31800	29600	10333	9267	9300	7500	6200	3000	22700	19633	27333	28333	30033	27267	9267	6467	6200	4500	3100	3000
1972/73	3633	5800	6267	5700	6000	7233	7233	10233	7367	9667	17500	23633	3633	6067	4500	5700	6000	7233	7233	8667	7333	9667	17500	23633
1973/74	29233	38633	55033	78567	83800	45833	31467	27167	26733	41300	56200	66833	29233	39133	56133	83567	92500	49800	31700	26867	27267	43600	56267	66733
1974/75	67567	73333	112167	146267	155400	115900	29467	9267	9300	7500	6200	6000	67533	73233	112200	146367	153433	113033	28333	6467	6200	4500	5933	12667
1975/76	8667	32067	56467	94167	135433	132567	51367	15567	16500	23733	41133	38767	16967	36100	56233	94000	134867	130400	49900	15733	17000	24200	43133	39300
1976/77	16800	10333	7500	8800	15033	10333	10333	9267	9300	7500	6200	13333	16933	10600	6700	7933	12567	8200	7233	6467	6200	5100	19433	21333
1977/78	28000	19733	8133	8800	9000	7667	7233	6467	6200	4500	3100	7533	28733	20833	8267	5700	6000	7233	7233	6467	6200	4500	3100	3000
1978/79	23233	32200	35100	37600	35033	22700	10333	9267	9300	7500	6200	3000	23033	33767	41100	43967	38200	19467	7233	6467	6200	4500	3100	4433
1979/80	3633	4133	15633	30633	30033	7333	7233	6467	6200	4500	3100	3000	5500	4933	20700	30600	29967	7300	7233	6467	6200	4500	3100	3000
1980/81	9500	14400	11467	6100	6000	7233	7233	6467	6200	4500	3100	3633	9767	14400	11467	6100	6000	7233	7233	6467	6200	4500	3100	3667
1981/82	31867	58600	91700	83167	28133	7233	7233	6467	6200	4500	3100	3000	31900	58600	91700	83167	28133	7233	7233	6467	6200	4500	3100	3000
1982/83	3633	4133	4500	5700	6000	7233	7233	6467	6200	4500	3100	4567	3633	4133	4500	5700	6000	7233	7233	6467	6200	4500	3100	4333
1983/84	20200	37767	50667	53333	29900	16167	18433	17233	14267	16933	18333	11267	26967	43533	53533	54100	27933	12233	16433	17467	17433	20000	18633	11400
1984/85	8067	31500	48567	58367	47967	16333	10333	7467	6200	4500	3100	3000	7967	30333	48000	58833	47000	13067	7233	6467	6200	4500	3100	3000
1985/86	3633	16700	24867	11100	6000	7233	7233	6467	6200	4500	3100	3000	3633	19533	24867	11067	6000	7233	7233	6467	6200	4500	3100	3000
1986/87	21500	37133	38833	37467	30967	16067	7233	6467	6200	4500	3100	3467	18300	37200	38933	37500	30933	16033	7233	6467	6200	4500	3100	3467
1987/88	24533	31100	21733	6667	6000	7233	7233	6467	6200	4500	3100	9033	24533	31100	21733	6667	6000	7233	7233	6467	6200	4500	3100	17867
1988/89	30967	38433	34567	18967	9500	10333	10333	6467	6200	10100	29667	41933	38567	40800	35100	19967	8000	7233	7233	6467	6200	8700	33167	45100
1989/90	52200	57833	60700	50867	24067	10333	10333	8933	6200	4500	8467	25833	53767	58600	61100	51900	23800	7233	7233	6467	6200	4500	11133	28600
1990/91	44500	61733	75133	71500	46300	15267	10333	9267	9300	7500	6200	3000	45400	63400	75067	71433	46100	12733	7233	6467	6200	4500	3100	3000
1991/92	5600	20033	34367	38500	19633	7600	7233	6467	6200	4500	3100	3833	7967	24767	34500	38533	19633	7233	7233	6467	6200	4500	3100	3000
1992/93	8967	15467	33500	52533	78300	83867	48433	12667	6200	4500	9367	11133	8100	15367	33333	52400	78100	83900	48533	12700	6200	4500	9367	11167
1993/94	25900	36567	55400	91133	111033	74500	14833	6467	6200	4500	3967	6733	25933	36633	55500	91133	111033	74500	14833	6467	6200	4500	3967	6733
1994/95	8500	5433	4500	5700	6000	7233	7233	6467	6200	4500	3100	14467	8500	5433	4500	5700	6000	7233	7233	6467	6200	4500	3100	14433
1995/96	30567	42167	38000	17000	9433	7233	7233	6467	6300	7500	6200	5900	31933	42167	38200	17500	9567	7233	7233	6467	6200	4500	7367	17100
1996/97	25667	42500	57467	67833	71933	39933	10333	9267	9300	7500	6200	6000	37500	46400	57467	68133	70667	38900	7233	6467	6200	13467	11933	6800
1997/98	6733	7233	7500	8800	7233	7233	7233	6467	6200	4500	3100	3000	6033	4500	7367	5700	6000	7233	7233	6467	6200	4500	3100	3000
1998/99	4867	10867	23233	26967	26433	24333	10333	9267	9300	7500	6200	6000	3633	9867	27033	32567	29633	25567	7233	6467	6200	4500	7867	9667
1999/00	6733	7233	7500	8800	9000	10333	8500	6467	6200	4500	3167	8500	8800	11433	11533	6533	6000	7233	7233	6467	6200	4500	12033	14033
2000/01	11433	16200	28067	29900	32433	29267	18100	13000	9300	7500	6200	6000	13733	17133	28633	29867	30867	26033	16800	13167	11900	10967	6933	6600
2001/02	6733	7233	7500	8800	9000	7367	7233	6467	6200	4500	3100	3000	7433	6300	6200	5700	6000	7233	7233	6467	6200	4500	3100	3000
2002/03	5333	4000	4367	5700	6000	7233	7233	6467	6200	4500	3100	2500	3633	4000	4367	5700	6000	7233	7233	6467	6200	4500	3100	2533
2003/04	2567	10667	13367	6400	3500	4567	5533	5567	5733	4500	0	0	2633	10933	13433	6367	3433	4500	5433	5500	5667	4500	0	0

33,110 - 52,000 ML/Day | 52,000 - 78,000 ML/Day | > 78,000 ML/Day

Figure 12 – Base Case and NoMExCO Murray River @ Lock7

Base Case

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1891/92	28900	50333	60433	43067	15500	4300	1933	2733	2433	1867	5300	11267
1892/93	22633	21200	25900	20067	14700	7300	2567	2233	1667	4100	9500	23533
1893/94	33267	41200	44967	46333	40067	14400	3467	2833	6600	11767	18333	29533
1894/95	40067	54833	71533	99000	113167	67600	9667	4533	3800	5400	8933	8367
1895/96	13800	19367	27000	18633	5967	2600	1600	3767	4333	5500	9033	8600
1896/97	10467	7867	5767	2733	1633	1733	3567	3400	3200	3800	4733	5700
1897/98	7667	10767	15633	7300	2333	1467	1500	4133	2767	3533	7600	8700
1898/99	10367	14433	15100	7067	3167	3133	3900	4300	5133	5700	8900	11300
1899/00	19567	15367	9200	3767	2933	5500	6567	7400	9733	10700	11767	14200
1900/01	24667	34200	36200	19033	4500	1567	1700	2633	3533	5767	7567	7133
1901/02	8900	9633	18833	12733	5533	3900	4967	6267	8333	7533	5367	5400
1902/03	5833	3633	4267	3800	3000	4533	4267	5567	5967	5867	8533	8733
1903/04	20000	19167	17033	13133	5700	3700	5033	4733	3000	4133	3467	4933
1904/05	16733	25567	21600	15033	7667	3600	3600	4367	3533	5900	9033	8400
1905/06	26667	32933	20167	8633	4067	1867	1533	3333	7100	7733	6800	16600
1906/07	31800	40767	45567	58667	67200	31233	4033	2800	2133	3933	6367	7133
1907/08	8167	10700	7700	2767	2833	3533	2300	3767	3367	2900	6933	7533
1908/09	9167	9200	12467	8767	3233	2167	2700	4167	5600	6333	12167	23867
1909/10	31067	41367	52933	33133	5600	3467	5333	3633	5233	4533	5533	7467
1910/11	13500	16333	26900	28133	11167	4433	4267	9067	5900	4667	6600	22833
1911/12	29567	29100	14367	5200	2100	3467	2433	4000	4300	4300	5000	6600
1912/13	8733	11433	22067	12300	6767	5567	3900	4067	6333	6567	7800	8067
1913/14	8233	5867	6267	6100	3400	1733	1400	2667	5033	5667	7667	6900
1914/15	5967	3533	3667	2233	3067	7633	8233	9400	8100	7267	7400	8267
1915/16	20933	30233	33200	31000	11633	4500	5500	5400	3633	6700	7433	7100
1916/17	22133	33733	45133	54800	62333	56900	27233	9067	4700	4233	11100	35333
1917/18	63667	104267	152067	198733	210567	150167	40033	8000	6100	6100	25533	37733
1918/19	51900	66433	72567	56867	14033	2000	1500	4867	4300	4700	6833	7633
1919/20	8533	5600	4233	5200	7067	7667	5200	3500	4400	8033	9000	7967
1920/21	16233	29733	40200	42400	22333	7233	3133	4233	4833	4967	6500	11467
1921/22	19267	29967	39767	45500	28633	6133	2067	2633	1767	2833	6133	6933
1922/23	8267	14100	18967	8567	2467	2267	1433	2067	2333	3200	5967	15067
1923/24	32400	43133	42667	33800	20833	8867	5033	5400	4900	6567	8233	9000
1924/25	9433	19000	32500	38667	38967	36533	14500	6500	3733	2767	5500	13967
1925/26	29433	30600	33133	24000	6800	2033	1467	2400	3967	8900	17700	19967
1926/27	25800	34333	38600	32000	13467	4433	1733	2700	1933	2167	5133	6733
1927/28	7567	9700	7333	4833	4700	5167	7700	9433	7233	6700	10267	19300
1928/29	20400	12400	5167	10800	7500	2800	1433	2967	3667	7400	10133	8333
1929/30	8333	7233	7033	4533	4167	7100	4433	3500	3867	6800	8000	7400
1930/31	6967	11800	10933	9800	7600	10333	7267	4200	4633	11500	26933	44400
1931/32	71033	104800	104933	70067	25867	5500	2033	4433	4567	11700	15700	22633
1932/33	31633	38400	43400	41300	15700	4467	3233	2767	2267	2733	5600	7967
1933/34	13933	19367	25300	12867	5667	8200	5533	5367	4867	5567	8200	6000
1934/35	8500	17567	25900	35633	43867	47033	24533	5700	2900	6333	14967	18867
1935/36	28467	39233	50767	49867	25633	5633	6033	4567	2867	4233	7767	7633
1936/37	18667	34433	43300	23933	5633	5800	6000	4333	2433	2400	5233	7133
1937/38	6667	4600	6433	6767	4367	5567	4667	4067	3433	6167	9200	6433
1938/39	6733	6467	4833	2233	2667	6600	8000	11167	12700	20367	22300	27433
1939/40	36467	46700	57567	56867	41867	16967	4233	2900	1833	5033	9333	6900
1940/41	5300	3533	4200	3233	4667	6067	11033	6833	6200	4700	5500	6733
1941/42	8767	8633	7333	5800	3133	2600	2967	4433	5100	7033	12067	21833
1942/43	33600	38000	37800	23100	6567	2700	1767	2733	1800	5167	8333	7267
1943/44	7500	8267	10467	7067	3433	1933	2833	5300	7667	8333	8067	7967
1944/45	7833	4900	3600	2667	2367	5300	6467	9033	8833	7400	6600	6833
1945/46	6933	9067	8900	5667	3867	2533	4267	7467	5600	5900	6300	7000
1946/47	15600	25067	13267	4067	3900	5767	4667	5933	7267	7333	5267	6200
1947/48	14433	23967	26967	23467	13100	7300	3233	4067	2867	4700	9367	10033
1948/49	11667	6500	3800	4067	5167	5467	3400	4200	5967	6133	6800	7600
1949/50	7767	7800	8367	17867	25100	11200	3233	7400	11500	23133	35900	28600
1950/51	22567	25667	30467	23000	22867	22267	6100	5400	3367	3800	9600	23400
1951/52	32533	42533	47167	38967	23767	6300	1933	2367	2300	5967	15900	35033
1952/53	61133	86800	90000	81767	80600	68667	32900	6767	2500	2733	6100	9467
1953/54	19467	34667	48167	61933	65733	37733	7433	4500	2233	4200	8233	7600
1954/55	7533	6500	6100	5033	7133	14200	7333	6333	5367	4533	7367	17500
1955/56	30233	57167	108433	147267	116300	52733	8567	4467	18467	37633	66200	119700
1956/57	184100	240567	249400	196200	139667	87067	15933	4233	2800	3700	5467	6467
1957/58	9400	10267	6667	3100	3267	5067	4167	3767	2700	2600	4967	9633
1958/59	15400	34667	47933	48200	39600	21867	5800	4267	3833	5733	8967	7200
1959/60	6567	5933	5467	7900	9300	8433	4800	4800	2933	4067	16100	27200
1960/61	30967	40300	58467	69467	57067	18033	4233	2767	4433	7300	9667	7367
1961/62	10800	18400	19133	13833	6033	8900	10100	5400	3400	3333	7333	11533
1962/63	15033	16933	15600	12467	4700	3433	3733	3700	3700	5133	9500	14167
1963/64	19467	26000	23733	15933	7333	3533	1833	3200	2367	5533	10733	10067
1964/65	26900	39633	46633	57367	67133	38433	5033	2133	1633	2767	5467	6633
1965/66	7667	14033	21567	10867	5400	5533	4167	4400	5100	6467	6933	7433
1966/67	8067	12267	23767	19900	8900	11500	6533	3933	2467	2500	5033	6367
1967/68	6233	4433	6233	7467	6800	7033	6033	6400	8067	7600	13033	28567
1968/69	30633	31900	32533	15400	6067	6467	4800	8233	10167	9367	10833	10767
1969/70	19200	25167	31500	24667	9467	5067	4000	3767	4267	8933	12800	12300
1970/71	19000	28800	47500	64333	55433	21867	5833	5667	11467	8400	13200	13767
1971/72	14200	14533	23367	25167	29767	28767	9333	5167	3067	3567	6200	6433
1972/73	6700	6433	6833	4500	3000	1733	1867	9633	8133	10433	18333	23900
1973/74	29600	40867	63100	89800	92500	35067	18100	13867	7433	16267	42000	63300
1974/75	68633	79133	128833	169933	175900	123667	22300	3200	3333	3900	6433	7767
1975/76	17433	38867	64533	109333	161533	143433	42333	5667	2333	2733	6433	7767
1976/77	6067	3600	3533	6867	13500	6467	2500	3733	3600	4500	7233	9000
1977/78	15033	9633	5533	2533	2100	1367	2200	2600	4700	7167	7000	11167
1978/79	24000	33033	36567	35167	24233	8800	3800	3233	2267	4433	9500	8200
1979/80	5867	5333	22033	31867	31233	8100	1633	2033	2033	5200	8933	7900
1980/81	10133	15267	12367	6833	5133	6533	5400	4967	4900	5667	7667	12233
1981/82	37167	68233	106667	93300	23433	5767	4833	4367	4467	5133	6300	6400
1982/83	5533	2767	2900	1900	2800	5367	5267	7100	10133	8900	10167	10467
1983/84	18500	30067	41000	43833	16400	4733	7867	10633	6400	4733	9433	7467
1984/85	6467	25267	41033	49267	36733	7567	1700	2200	1733	3733	6233	7533
1985/86	6667	21300	25933	11133	4200	4800	3067	3100	1933	3000	6933	7567
1986/87	27000	39333	40800	38900	31700	16667	6900	4167	3000	3833	6800	11600
1987/88	25567	31700	21967	7000	5033	6800	5233	4433	3300	5500	9600	17400
1988/89	28000	31533	30100	16367	6267	6867	5100	3200	5400	15267	30533	38433
1989/90	44000	48833	54033	48800	20800	6300	2733	4167	3133	4733	9533	12600
1990/91	30700	51867	68567	62300	29900	6767	4267	2600	1667	3467	6000	6733
1991/92	14333	25733	36467	42100	19233	3933	2233	3267	2367	3600	7833	9167
1992/93	9500	16100	34800	60433	90800	95000	47300	11200	5300	6533	10467	11533
1993/94	26933	39233	63367	106133	129200	79900	10733	6467	6300	5333	6367	7000
1994/95	9067	5867	4100	4633	6867	5767	5633	4833	3700	4533	7833	23800
1995/96	35100	46133	38667	15767	10600	7467	4867	4367	3700	4500	5967	7433
1996/97	26100	44933	64767	76667	78533	36500	4867	3867	3667	3700	5300	6833
1997/98	6467	4533	7633	5233	2833	1933	1700	3333	2300	5700	8433	6733
1998/99	8133	11433	18700	14600	7867	3367	2233	3500	5300	6700	6267	7600
1999/00	9000	11800	12400	7433	5533	4167	2767	4233	3267	4667	8400	8567
2000/01	10733	15300	28033	30300	32233	21833	5533	5833	3833	4933	6033	6300
2001/02	7767	6767	6700	5833	4600	3033	1833	4333	3767	4900	6667	6467
2002/03	6300	3767	4133	2667	4200	7567	6300	6067	7267	7200	6500	5333

NoMExCO

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1891/92	28900	50333	60433	43067	15500	4300	1933	2733	2433	1867	5300	11267
1892/93	22633	21200	25900	20067	14700	7300	2567	2233	1667	4100	9500	23533
1893/94	33267	41200	44967	46333	40067	14400	3467	2833	6567	11767	18300	29533
1894/95	40067	54833	71533	99000	113167	67600	9667	4533	3800	5400	8933	8367
1895/96	13800	19367	27000	18633	5967	2600	1533	3700	4333	5500	9033	8600
1896/97	10467	7867	5767	2733	2100	2733	4133	3467	3200	3567	4700	5733
1897/98	7667	10767	15633	7300	2333	1300	1467	4033	2733	3667	7567	8667
1898/99	10367	14433	15100	7067	3167	3100	3833	4267	5467	5767	8833	11267
1899/00	19567	15367	9200	3733	2667	5467	6667	7567	9867	10767	11733	14200
1900/01	24667	34200	36200	19033	4500	1567	1700	2600	2933	4933	7067	7000
1901/02	8933	9633	18933	12800	5567	2467	3667	5733	7867	7467	5600	5400
1902/03	5700	3600	4267	3800	2900	4667	5000	7200	7033	5300	8133	8667
1903/04	20000	19167	17033	13300	5833	3733	5000	4733	3067	4167	3800	5567
1904/05	16900	25600	20400	13933	7267	3367	3567	4267	4000	5967	8967	8667
1905/06	26733	32933	20167	8600	3833	1867	1700	3533	7133	6600	6667	16733
1906/07	31833	40767	45767	59200	68367	31500	4033	2800	2133	3933	6367	7133
1907/08	8167	10700	7700	2767	2833	4000	2600	4067	3400	3033	6900	7500
1908/09	9167	9200	12467	8767	3233	2200	2800	4100	5833	6233	12133	23900
1909/10	31067	41367	52933	33133	5600	3467	4900	3467	5233	4533	5500	7467
1910/11	13500	16333	26900	28100	10933	4433	4267	9033	5933	4667	6567	22833
1911/12	29567	29100	14367	5233	2067	3400	2367	3967	4433	4133	5267	6533
1912/13	8600	11433	22067	12267	6733	5600	3833	4067	6300	6567	7800	8067
1913/14	8233	5867	6267	6133	3433	1833	1433	2533	5833	6267	7867	6933
1914/15	5967	3533	3667	2233	3033	7667	8233	9333	8067	7200	7400	8267
1915/16	20933	30233	33200	31000	11633	4400	5067	5233	3633	7267	8000	7233
1916/17	22100	33733	45133	54867	62567	57133	27467	9100	4700	4233	11100	35333
1917/18	63667	104267	152067	198600	209867	149300	39600	8000	6100	6100	25533	37733
1918/19	51900	66433	72567	56867	14033	2000	1500	4967	4367	4700	6833	8033
1919/20	9400	6100	4367	5233	7067	7667	5200	3500	5100	8333	9033	7967
1920/21	16233	29733	40200	42400	22333	7200	3133	4233	4833	4967	6500	11467
1921/22	19267	29967	39767	45467	28133	5800	1900	2600	1767	2833	6133	6933
1922/23	8233	14100	18967	8600	3433	4500	2633	2267	2867	4767	7100	15400
1923/24	32433	43133	42667	33833	20300	8600	4967	5400	4900	6567	8233	9000
1924/25	9433	18667	32267	38200	37900	34633	13233	6333	3733	2767	5500	13967
1925/26	29433	30600	33133	24000	6800	2033	1467	2400	3967	8900	17700	19933
1926/27	25800	34333	38600	32000	13467	4433	1733	2700	1933	2167	5133	6733
1927/28	7567	9700	7333	4833	4533	5067	7667	9433	7233	6700	10267	19300
1928/29	20400	12400	5167	10800	7533	2833	1433	2967	3667	7400	10133	8333
1929/30	8333	7233	7033	4600	4100	6900	4300	3467	3933	6600	7833	7367
1930/31	7000	11800	10933	9933	7833	10267	6000	3233	4267	11433	26933	44400
1931/32	71167	105600	105600	70367	25900	5500	2033	4433	4567	11700	15700	22633
1932/33	31633	38433	43467	41333	15733	4633	3367	2800	2267	2733	5600	7967
1933/34	13900	19367	25300	12867	5667	8200	5533	5367	4867	5567	8200	6000
1934/35	8500	17567	25900	35600	43800	46933	24467	5700	2900	6333	14967	18867
1935/36	28467	39233	50767	49867	25633	5633	6033	4567	2867	4233	7767	7633
1936/37	18667	34433	43300	23933	5633	5800	6300	5033	2767	2633	5300	7133
1937/38	6667	4933	6433	7333	5567	5600	4567	4067	3633	5933	8633	6267
1938/39	6733	6467	4867	2267	2733	6533	7700	11100	12467	20200	22267	27433
1939/40	36467	46933	58133	57267	41933	16967	3933	2433	1767	4633	9000	6800
1940/41	5267	3533	4200	3100	4500	5967	10967	6833	6200	5833	5400	6567
1941/42	8767	8633	7233	5433	2933	2700	2967	4833	6233	6633	11400	21767
1942/43	33633	38000	37767	23000	6300	2600	1933	2833	1867	5467	7767	7033
1943/44	7467	8267	10467	7033	3400	1900	2133	4800	7167	8000	8067	8033
1944/45	7867	4900	3567	2633	2233	6200	7300	9167	8900	7700	6667	6767
1945/46	6933	9067	8900	5667	3667	2467	4300	7500	5567	6000	6300	7000
1946/47	15600	25067	13267	4033	3900	5767	4500	5733	6933	7100	5200	6167
1947/48	14433	23967	26967	23467	13000	7300	3333	4133	2900	4700	9367	10033
1948/49	11667	6500	3767	4067	5167	5433	3267	4133	5967	6133	6800	7600
1949/50	7767	7800	8333	17833	25033	11167	3233	7400	11433	23133	35900	28567
1950/51	22567	25667	30467	23033	22867	22233	6100	5400	3367	3800	9600	23400
1951/52	32533	42667	47633	39400	23833	6300	1933	2367	2300	5967	15900	35033
1952/53	61133	86800	90000	81767	80600	68667	32900	6767	2500	2733	6100	9467
1953/54	19467	34667	48167	61933	65733	37733	7433	4500	2233	4200	8233	7600
1954/55	7533	6500	6100	5033	7133	14200	7333	6333	5367	4533	7367	17500
1955/56	30200	57167	108433	147267	116300	52733	8567	4467	18467	37633	66200	119700
1956/57	184100	240567	249400	196200	139667	87067	15933	4233	2800	3700	5467	6467
1957/58	9400	10267	6667	3100	3300	5367	4233	3767	2733	2600	4967	9633
1958/59	15400	34667	48000	48267	39500	21600	5733	4267	3833	5733	8933	7200
1959/60	6567	5933	5433	7900	9300	8433	4800	4800	2933	4067	16100	27200
1960/61	30967	40300	58467	69467	57067	18033	4233	2767	4433	7300	9667	7367
1961/62	10800	18400	19133	13833	6033	8767	10000	5367	3400	3333	7333	11533
1962/63	15000	16933	15600	12467	4700	3433	3733	3700	3700	5133	9500	14167
1963/64	19467	26000	23733	16200	7467	3600	1867	3200	2367	5533	10733	10067
1964/65	26933	39700	46667	57367	67133	38433	5033	2133	1600	2767	5467	6633
1965/66	7667	14033	21567	10900	5400	5533	4433	4600	5133	6467	6933	7433
1966/67	8067	12267	23767	19900	8900	11500	6533	3933	2467	2500	5033	6367
1967/68	6233	4433	6267	7600	6833	7033	5933	6267	8100	7767	13000	28533
1968/69	30633	31900	32533	15400	6067	6467	4900	8233	10167	9367	10833	10767
1969/70	19200	25167	31467	24533	9433	5067	4000	3767	4267	8933	12800	12300
1970/71	19000	28800	47500	64333	55433	21867	5833	5667	11467	8400	13167	13767
1971/72	14200	14533	23367	25167	29767	28933	9467	5167	3067	3567	6200	6433
1972/73	6700	6433	4900	2567	2933	1867	1833	9600	8133	10433	18333	23900
1973/74	29600	41533	64433	92467	94567	35233	18100	13867	7433	16267	42000	63300
1974/75	68633	79100	128833	169933	175900	123667	22300	3200	3333	3900	6433	7767
1975/76	17433	38867	64533	109333	161533	143433	42333	5667	2333	2733	6400	7767
1976/77	6067	3600	3533	6867	13500	6467	2500	3733	3600	4500	7233	9000
1977/78	15033	9633	5533	2533	2167	1933	2767	2900	5233	7567	7200	11200
1978/79	23933	33000	36567	35233	24700	8933	3800	3233	2267	4433	9500	8200
1979/80	5867	5333	22033	31833	31167	8067	1633	2033	2033	5200	8933	7900
1980/81	10133	15267	12367	6833	5233	6567	5400	4967	4933	5767	7767	12267
1981/82	37167	68233	106667	93333	23433	5767	4833	4033	4267	5033	6233	6400
1982/83	5533	2767	2900	1933	1267	4533	5000	6300	9433	8800	10167	10467
1983/84	18500	30067	41000	43867	16300	4833	7967	10533	6367	4733	9433	7467
1984/85	6467	25267	41100	49433	36867	7600	1700	2200	1733	3733	7133	7567
1985/86	6300	21167	25933	11133	4700	5467	4300	3933	2200	2867	6833	7533
1986/87	27000	39333	40800	38900	31667	16633	6900	4167	3000	3833	6800	11600
1987/88	25567	31700	21967	6967	5000	6800	5233	4400	3300	5533	9633	17400
1988/89	28000	31533	30100	16400	6300	6933	5267	3267	5400	15267	30533	38433
1989/90	44000	48833	54167	49267	21267	6333	2733	4167	3133	4733	9533	12567
1990/91	30700	51867	68567	62333	29933	6767	4267	2600	1667	3467	6000	6733
1991/92	14333	25733	36467	42100	19233	3933	2233	3267	2367	3600	7833	9167
1992/93	9500	16100	34733	60300	90600	95067	47467	11233	5300	6533	10467	11567
1993/94	26933	39233	63367	106100	129200	79900	10733	6467	6300	5333	6367	7000
1994/95	9067	5867	4100	4633	6067	4933	5333	4733	2933	3867	7700	23800
1995/96	35100	46133	38933	16267	10733	7467	4467	4033	3567	4467	5933	7433
1996/97	26100	45067	65100	77300	78933	36533	4867	3867	3667	3700	5300	6833
1997/98	6467	4533	7633	5367	3733	4300	3600	3933	2333	5700	8433	6733
1998/99	8133	11433	18700	15333	8167	3433	2300	3500	5300	6667	6267	7600
1999/00	9000	11800	12400	7400	5400	4233	3067	4467	3200	4633	8400	8567
2000/01	10733	15300	28033	30300	32200	21867	5533	5833	3833	4900	6033	6300
2001/02	7767	6767	6667	5800	4567	2900	1767	4300	3433	4233	6400	6467
2002/03	6300	3767	4133	3133	5367	8067	6767	7167	8133	7300	5933	4833

33,110 - 52,000 ML/Day

52,000 - 78,000 ML/Day

> 78,000 ML/Day

Figure 13 – Base Case and NoMExCO Murray River Upstream Wentworth Weir

4.3.3 Salinity

As water storage reduces during drought because of evaporation, surface water salinity increases with the concentration of salts. Salinity of the surface water in an extended drought may make it unsuitable for some irrigation, such as for horticulture, and the quality of water supplied may not be of the standard required, irrespective of availability of supply. Changes in the long term average and median end of month salinity concentrations resulting from each of the key modelled options are presented in Tables 12 to 15 [3]. In some cases long term average salinity concentrations are biased by individual salinity readings. These high readings typically occur for very small lake volumes. In order to ensure that this did not unduly affect the conclusions with respect to salinity changes as a result of each option, salinity exceedence curves have been produced to compliment the results of Table 12 and 13. These can be found in Appendix 7.

Table 12 – Longterm Average End of Month Salinity (EC)

	ECWeth	ECPam	ECMen	ECCawn	ECw32	ECLowDarl	ECAnnab	ECusTandou
Base Case	376	616	1280	1604	429	418	378	602
M0	381	859	1581	2237	412	380	337	521
M1	380	771	1646	2032	414	389	354	550
M2	384	1129	1063	2038	403	351	293	448
M3	380	854	1298	2464	416	390	346	535
NoMC	385	1351	0	0	417	417	52	208
NoCExMO	376	448	1501	0	467	461	35	235
NoCEnMO	380	404	1567	0	432	432	34	217
0.5M	370	573	1411	952	417	408	351	559
NoMExCO	375	715	435	868	389	370	384	543
NoMEnCO	381	438	365	1082	373	462	261	548
PInc	370	546	1624	1811	429	422	423	663

Table 13 – Longterm Average End of Month Salinity Increase (EC)

	ECWeth	ECPam	ECMen	ECCawn	ECw32	ECLowDarl	ECAnnab	ECusTandou
M0	5	244	302	633	-17	-37	-41	-81
M1	4	155	366	428	-15	-29	-24	-53
M2	8	513	-217	434	-25	-67	-85	-155
M3	4	238	18	860	-13	-28	-31	-68
NoMC	9	735	-1280	-1604	-11	0	-325	-394
NoCExMO	0	-168	221	-1604	39	44	-343	-367
NoCEnMO	4	-212	288	-1604	3	14	-343	-386
0.5M	-6	-43	131	-652	-12	-9	-27	-44
NoMExCO	-1	99	-845	-736	-39	-48	6	-60
NoMEnCO	5	-178	-915	-522	-56	44	-116	-54
PInc	-6	-70	344	207	0	4	45	60

[3] It should be noted that the EC changes presented in the summary tables of Appendix 3 for various locations in the Lower Murray Darling system represent the total salt load divided by the total flow volume over the full simulation period and NOT changes in end of month salinities.

Table 14 – Longterm Median End of Month Salinity (EC)

	ECWeth	ECPam	ECMen	ECCawn	ECw32	ECLowDarl	ECAnnab	ECusTandou
Base Case	354	365	415	640	386	387	334	570
M0	356	380	363	551	379	369	0	451
M1	354	381	377	564	380	373	0	472
M2	356	376	341	488	377	356	0	398
M3	352	374	392	589	381	373	0	481
NoMC	361	1349	0	0	359	359	0	240
NoCExMO	355	376	483	0	421	420	0	277
NoCEnMO	356	369	436	0	405	405	0	281
0.5M	347	363	394	605	378	379	194	556
NoMExCO	348	397	383	657	352	346	0	583
NoMEnCO	356	395	357	528	354	402	0	507
Plnc	350	370	443	688	392	393	0	615

Table 15 – Longterm Median End of Month Salinity Increase (EC)

	ECWeth	ECPam	ECMen	ECCawn	ECw32	ECLowDarl	ECAnnab	ECusTandou
M0	2	15	-52	-88	-7	-17	-334	-119
M1	0	16	-39	-76	-7	-14	-334	-99
M2	2	11	-75	-151	-10	-31	-334	-172
M3	-1	9	-24	-51	-5	-13	-334	-89
NoMC	8	984	-415	-640	-28	-28	-334	-330
NoCExMO	1	11	68	-640	34	33	-334	-293
NoCEnMO	2	4	21	-640	19	19	-334	-289
0.5M	-7	-2	-21	-35	-8	-7	-140	-14
NoMExCO	-6	32	-33	17	-34	-40	-334	13
NoMEnCO	2	30	-58	-112	-33	15	-334	-64
Plnc	-4	5	27	49	5	6	-334	45

Modelled options produce changes in salinity concentrations both within and downstream of the lakes scheme. This is discussed in the following sections.

Changes in Lake Salinity

Restoration of Lakes Menindee and Cawndilla to more natural wetting and drying cycles result in increased average salinity levels in the remaining lakes. This is due to these remaining lakes being less frequently utilised as a result of increased unregulated flows meeting demands, and the South Australian dilution flow trigger of 1,300GL being triggered less often. Consequently, there are greater periods of time when demands are low and the opportunity for concentration of salts through evaporation within the lakes is more frequent.

Restoration of Lake Menindee to natural wetting and drying appears to result in an improvement in average salinity in Lakes Cawndilla and Wetherell. However, inspection of the exceedence curves for this option reveals that results are biased by a number of extremely large monthly salinity concentrations. Median salinity levels for Lake Cawndilla and Lake Pamamaroo increase and median salinity levels for Lake Wetherell are largely unchanged.

Enhancement of the Lake Menindee restoration option through an increase in the Cawndilla outlet capacity results in improved average salinity levels in Lake Pamamaroo but a worsening of median salinity levels. Lake Pamamaroo volumes remain higher for longer periods of time as a result of Lower Darling and Murray demand now being able to be met to a greater degree from outflows from Lake Cawndilla. Whilst this results in a salinity increase for large Lake Pamamaroo volumes through lower lake utilisation, this is more than offset by the large decrease in time that the lake spends at lower levels where salinity concentrations are higher.

Restoration of Lake Cawndilla to a more natural wetting and drying cycle results in a reduction in average salinity in Lake Pamamaroo, but an increase in median salinity. There is also an increase in average and median salinity in Lake Menindee and negligible change in Lake Wetherell. Median salinity levels in Lakes Menindee and Pamamaroo increase as both storages have greater periods of time when demands are low and the opportunity for concentration of salts through evaporation are more frequent. Increasing the Menindee outlet capacity for this option results in an increased rate of draw down of Lake Menindee which in turn increases the time that the storage spends with low volumes and high salt concentrations. This is turn results in an average salinity increase from both the base case and the existing Menindee outlet configuration option.

Enhancement of the Lake Cawndilla restoration option through an increase in the Lake Menindee outlet regulator capacity results in an improvement in average salinity levels in Lake Pamamaroo. The release of water at a greater rate through the enlarged Menindee outlet reduces the demand on Lake Pamamaroo. Whilst this results in a salinity increase at higher lake volumes through lower lake utilisation, this is more than offset by the large decrease in time that the lake spends at lower levels where salinity concentrations are higher.

Rapid emptying of the lakes when in New South Wales control appears to result in increased lake average salinity levels for all but one option. Median salinity levels are largely unchanged for Lakes Wetherell and Pamamaroo, and decrease for Lakes Cawndilla and Menindee. Rapid emptying options seek to achieve savings through reductions in surface area. However, a consequence of rapid emptying is that the lakes spend a greater proportion of time at low levels where evaporative losses can lead to much higher salt concentrations.

<u>Changes in Downstream Salinity</u>

Downstream of the scheme, average and median salinity levels generally decrease in both the Lower Darling and in the Murray for the rapid emptying options. This is due to reduced lake evaporation losses leading to greater volumes available for dilution.

Restoration options, that involve Lake Cawndilla increase salinity concentrations in the Lower Darling and Murray. Prior to restoration these increased salt loads would have been discharged from Lake Cawndilla into the Darling Anabranch.

Restoration of Lake Menindee to more natural wetting and drying reduces salinity levels in the Lower Darling due to increased volumes of water available for dilution. However, enhancement of this option through enlargement of the Cawndilla outlet regulator to the Lower Darling results in increased salinity levels as a consequence of this water now entering the Lower Darling in preference to the Darling Anabranch. Of interest is the apparent salinity increase in the Murray. Reasons for this are thought to be due to the substantial alteration in the South Australian dilution flow pattern.

Restoration of both Lake Menindee and Lake Cawndilla combines the effects of increased salt loads into the Lower Darling as a result of less frequent use of Lake Cawndilla, and increased dilution flows from less frequent use of Lake Menindee. The result is a reduction in salinity in both the Lower Darling and the Murray.

4.4 Variation in Dilution Flow Release Patterns

Dilution flows from the Menindee Scheme are dependent on volumes in Menindee, Hume and Dartmouth storages. The minimum trigger volume in Menindee Lakes is 1,300 Gigalitres. Inspection of the combined storage surface area versus volume relationship for the lake scheme (see Figure 14) indicates that the change in surface area for volumes in this range is small. Consequently alteration of the dilution flow pattern from 58 Gigalitres per month to a pattern in which a greater volume is realised over a smaller window is unlikely to appreciably reduce the evaporative area of water remaining in the scheme. Therefore no significant savings from this type of approach are likely to be realised. Consequently no further assessment of this option was conducted.

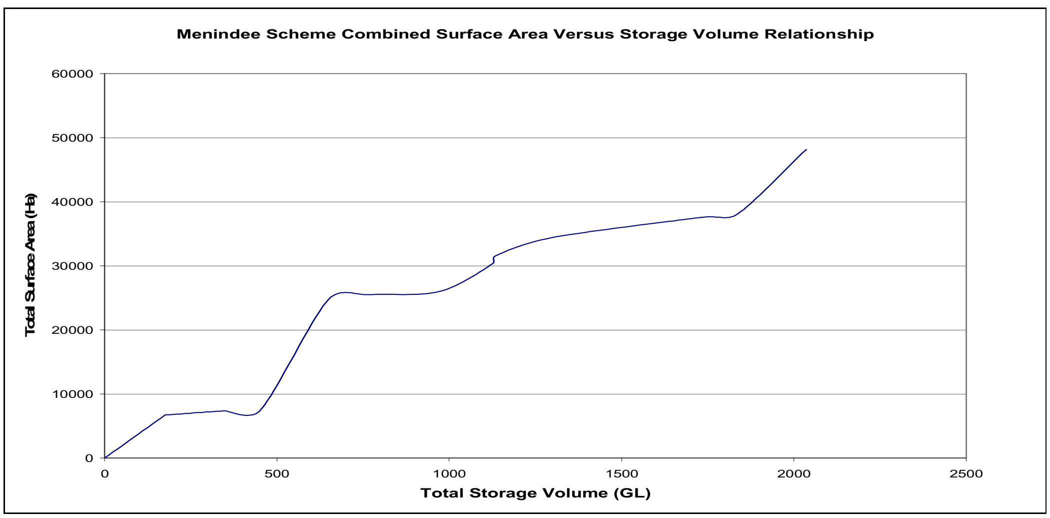

Figure 14 – Menindee Scheme Surface Area versus Volume Relationship

4.5 Potential Water Savings from Privately Owned Storages

Results from the case study analysis of options for reducing evaporative losses from off river storages are presented in Table 16. Findings are discussed in the following sections.

Table 16 - Water Savings from Privately Owned Storages (Namoi Case Study)

	Base Case	Purchase All Supplementary Water Licenses (Option 1)	No OFS, 1,000,GL in each dam (Option 2)	No Evap on OFS (Option 3)
General security (GL/Yr)	199	215	204	188
Supplementary (GL/Yr)	36	0	0	33
Floodplain harvesting (GL/Yr)	14	19	0	11
Rainfall runoff harvesting (GL/Yr)	77	77	7	71
Groundwater (GL/Yr)	34	35	36	29
End of System Flow (GL/Yr)	704	717	730	716
Average Area planted (Ha)	44,970	45,150	47,000	47,143
Sustainable area (Ha)	42,038	41,601	39,171	44,588
Keepit + Split Rock evaporation	49	47	73	47
OFS evaporation	79	77	0	0

4.5.1 Purchase of All Supplementary Licenses

As can be seen from Table 15, reduced access to supplementary water is offset by increased general security and floodplain harvesting. This is as a consequence of no corresponding lowering of the plan limit for the valley in the model. As a result evaporation in off-river storages is hardly reduced at all. Reduced access to supplementary water does however increase the Namoi end of system flows by 13 Gigalitres per annum.

If reduced access to supplementary water is accompanied by a reduction in the valley plan limit, a greater increase flow would be observed in the river and users would be forced to improve there efficiency in order to ensure maintenance of existing production levels. This would in all likelihood be through a reduction in farm storage evaporation.

4.5.2 Removal of Off-River Storage

Removal of off river storage capacity and a corresponding increase in the capacity of Keepit and Split Rock Dams results in increased evaporative losses from Keepit and Split Rock. However, this is more than offset by the reduction in evaporation from off-river storages. The total saving in evaporation from this option is 55 Gigalitres per annum. The major impact from this saving strategy is the large decrease in valley diversions. Therefore enlargement of Keepit and Split Rock cannot offset the impacts of removal of off-river storage.

4.5.3 Stopping Evaporation from Off-River Storages

Under this option evaporation from off river storages was assumed to be able to be reduced to zero. Rainfall directly into off-river storages was assumed to still be possible.

The extra water in the off river storages as a result of reduced evaporation allows users to divert less water and plant a greater area. An additional benefit is that the average volume in Keepit and Split Rock Dam also increases with little change in major storage evaporation.

5 DISCUSSION OF NON MODELLED RESULTS

5.1 Use or Creation of Upstream Storage Capacity

5.1.1 Instream Storage in The Upper Darling and Floodplain Storage at Menindee

Instream Storage in the Upper Darling

Storing water in an instream storage with a small surface area immediately upstream of the Menindee Scheme will result in reduced evaporative losses when compared to the equivalent volume being stored at the Menindee Lakes Scheme. Furthermore, the additional delivery losses are likely to be small and the ability to relocate water from the inefficient lakes scheme into the instream storage is likely to be easier if the location of the storage is in the vicinity of Menindee.

When volumes exceed the capacity of this instream storage, an operational decision will need to be made with respect to whether the instream storage is emptied and all water is stored in the lakes scheme, or alternatively whether only the volume in excess of the instream storage capacity is stored in the lake scheme. If the latter occurs then the usefulness of the additional in stream storage capacity is diminished by the increase in total surface area.

This is best shown by Figure 15 which compares the combined storage volume surface area relationships for two cases. Case 1 represents the present arrangement where water is set aside in dry times to meet Broken Hill town water supply and High Security and Riparian requirement and a drawdown sequence occurs using water in Lake Pamamaroo and then Lake Wetherell. Case 2 represents storing this same water in an instream storage in the vicinity of the scheme (at Bourke), Lake Wetherell and Lake Pamamaroo . The draw down sequence for this case would be Lake Pamamaroo first, then relocation of the water into the instream storage, then drawing down the instream storage, and then Lake Wetherell. The instream storage has a capacity of 46 GL as presented in Table 5 in the previous chapter.

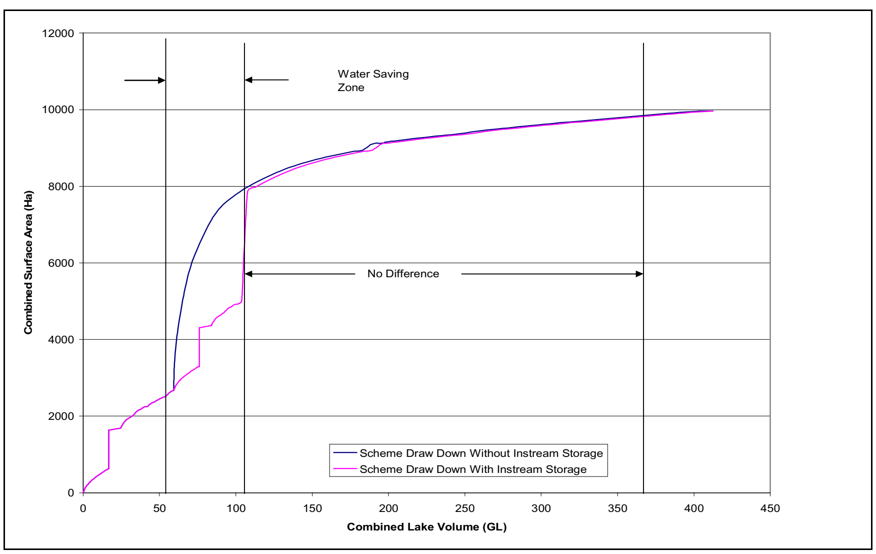

Figure 15 – Combined Storage Area versus Volume Relationship

As can be seen from Figure 15, savings through reductions in evaporation using the instream storage in Case 2 are only realised in the range of approximately 60 to 110 Gigalitres. In this zone the combined Case 2 storage surface area is less than that of Case 1 and water is not required to be stored in Lake Pamamaroo. For volumes in excess of 110 Gigalitres water is required to be held in Lake Pamamaroo resulting in surface areas equivalent to that of Case 1. Given that stored volumes are frequently in excess of 110 Gigalitres this translates to only a small long-term saving.

In conclusion, the small volume of instream storage offered upstream of the scheme together with the small volumetric range in which savings are apparent, mean that it is likely to be less attractive than some other drought security options. One such option is the creation of complimentary floodplain storage at Menindee.

Floodplain Storage at Menindee

Use of a floodplain storage in the form of a ring tank together with the previous instream storage allows water savings to be realised over a larger range of stored volumes, and reduces the need to hold drought reserves in the shallow lakes. This is particularly the case when ring tanks depths approach 6 metres.

The storage area relationship for scheme drawdown utilising water stored in an upstream instream storage, a floodplain ring tank at Menindee, and Lake Wetherell is displayed in Figure 16. The storage area relationship for scheme drawdown storing this same volume using only Lake Pamamaroo and Lake Wetherell is also shown. The ring tank is 6 m deep with a volume of 150 Gigalitres as presented in Table 6.

As can be seen the range of storage volumes over which water savings can be made is considerably larger than that of Figure 15 when only upstream instream storage is utilised.

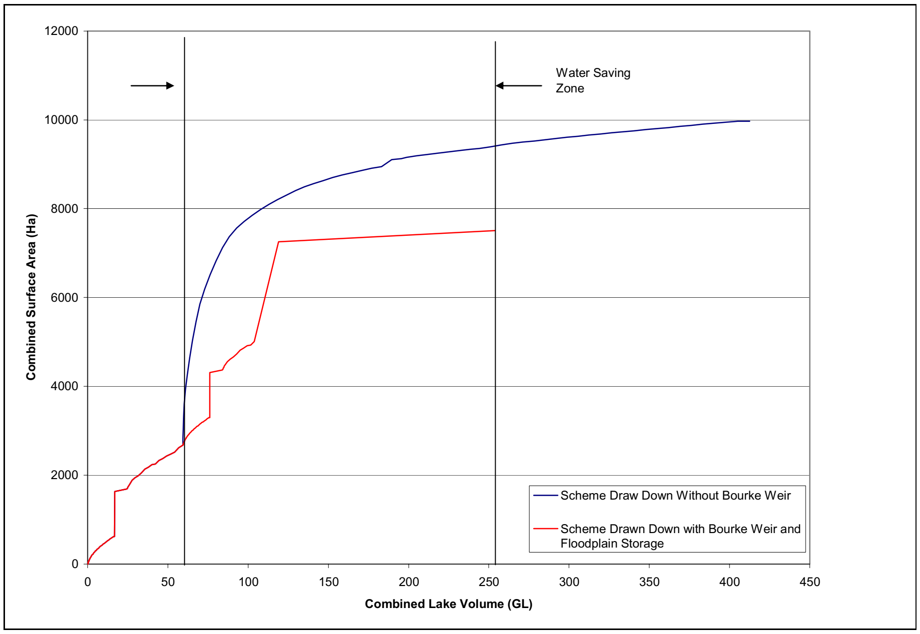

Figure 16 – Combined Storage Area Versus Volume Relationship

If the combination of Lake Wetherell and instream and floodplain storage shown in Figure 16 were used in preference to the Lake Wetherell and Lake Pamamaroo combination, 225 Gigalitres as opposed to 275 Gigalitres (refer to Figure 1) is required to meet Broken Hill, and High Security and Riparian requirements over 18 months. This is an evaporative saving of 55 Gigalitres. The distribution of resources required to achieve this is shown in Figure 17.

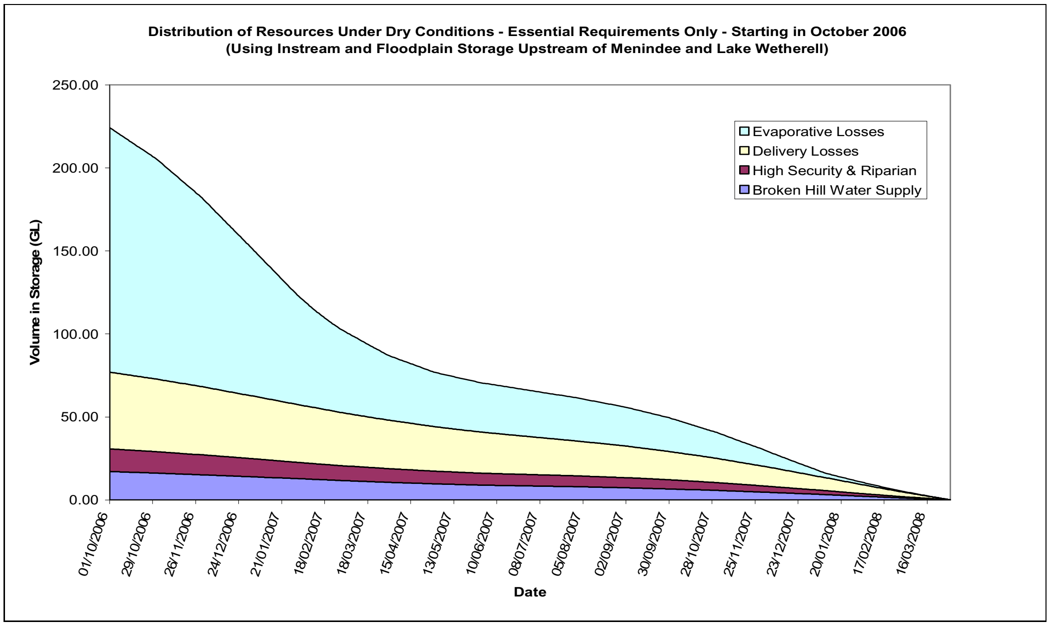

Figure 17 – Distribution of Resources Under Dry Conditions

Although this evaporative saving of 55 Gigalitres appears large it must be remembered that scheme storage is seldom in this range and that in terms of a long-term average this saving volume is considerably lesser and in the order of only 6 Gigalitres per annum.

5.1.2 Improved Use of Existing Smaller Deeper Lakes

The analysis of the proceeding section has demonstrated that creation of additional stored volumes through instream and floodplain storage have to approach 165 Gigalitres for a surface area of 5,000Ha before any appreciable evaporative savings can be made. An assessment of the saving associated with better use of existing smaller deeper lakes for drought supplies has been made. Lake Tandure has been assumed to be able to be utilised as drought security storage. Full supply capacity has been increased from the present 89 Gigalitres (RL 62.3 metres) to 129 Gigalitres (RL 64.3 metres). This assumes the construction of associated levee works and a drawdown sequence of Lake Pamamaroo, then Lake Tandure, then Lake Wetherell.

If a combination of Lake Wetherell, Lake Tandure and Lake Pamamaroo storage were used in preference to the current Lake Wetherell and Lake Pamamaroo combination, 191 Gigalitres as opposed to 275 Gigalitres (refer to Figure 1) is required to meet Broken Hill, and High Security and Riparian requirements over 18 months. This is an evaporative saving of 84 Gigalitres. The distribution of resources required to achieve this is shown in Figure 18.

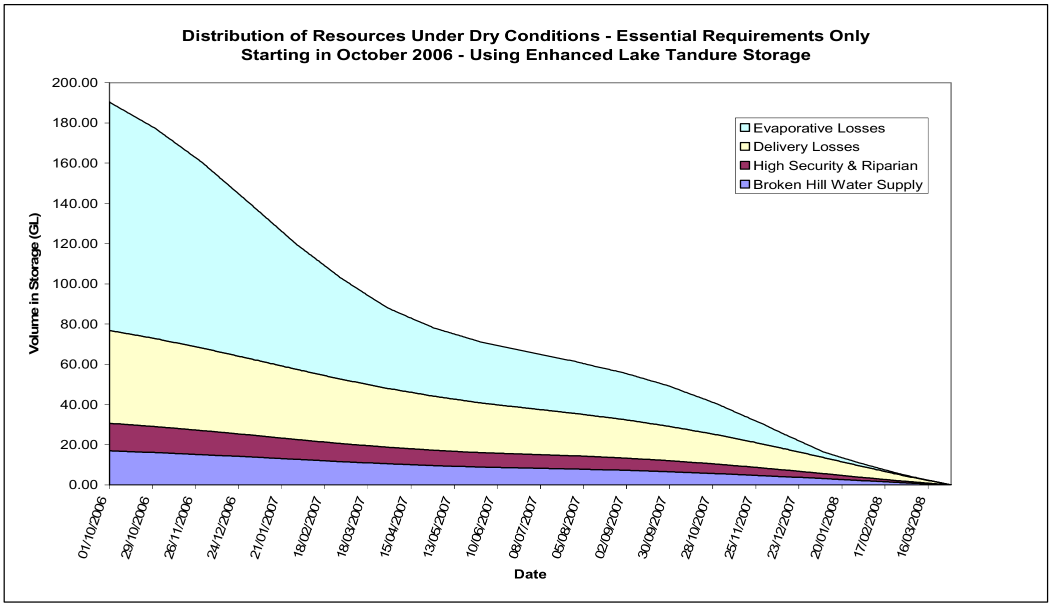

Figure 18 – Distribution of Resources Under Dry Conditions

As with the previous additional storage assessment in section 5.1.1 this evaporative saving of 84 Gigalitres is seldom realised due to the scheme seldom being in this storage range. Consequently, in terms of a long-term average this saving volume is considerably lesser and in the order of only 9 Gigalitres per annum.

5.1.3 Tributary Storages

In order to gain an appreciation of the suitability of using tributary storage in preference to Menindee scheme storage, an analysis of the losses associated with flow events along the Namoi and Barwon Darling river systems was undertaken. Small events in which there are no irrigation extractions and ungauged tributary inflows are difficult to find. Consequently, only two events for the Namoi River and one event for the Barwon-Darling were analysed.[4]

Irrigation extractions during the time of each event were not present meaning and losses are mostly attributed to the filling of in river weir storages, seepage into the bed and banks of the river and evaporation from the river surface. The progression of these events down each system is shown in Figures 19 and 20.

[4] Note: At the time of writing this report a sustained release from Pindari Dam is being made in order to deliver water to meet downstream town water supply requirements along the Barwon Darling River. The losses associated with this event should be determined, and used as further input into the determination of delivery losses in dry times.

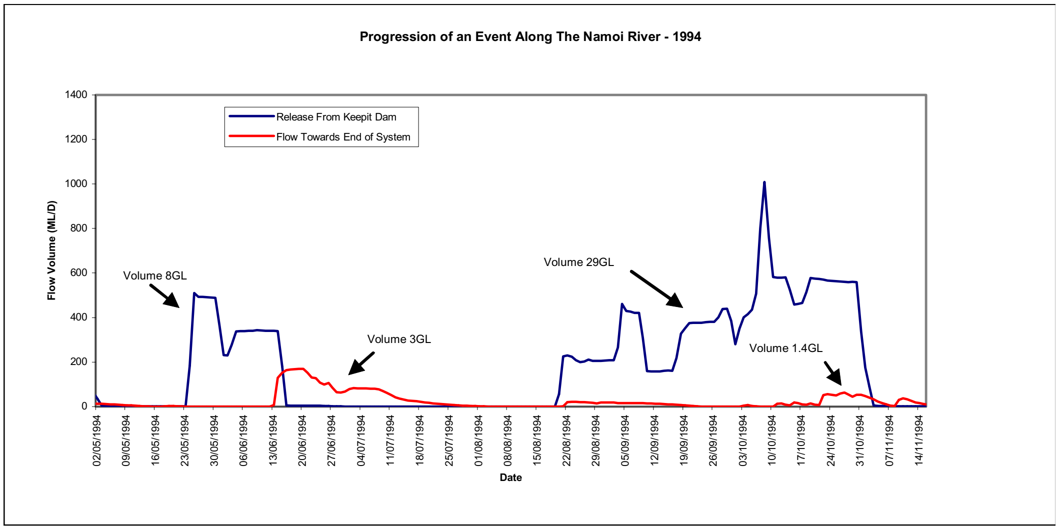

Figure 19 – Progression of Event Along the Namoi River

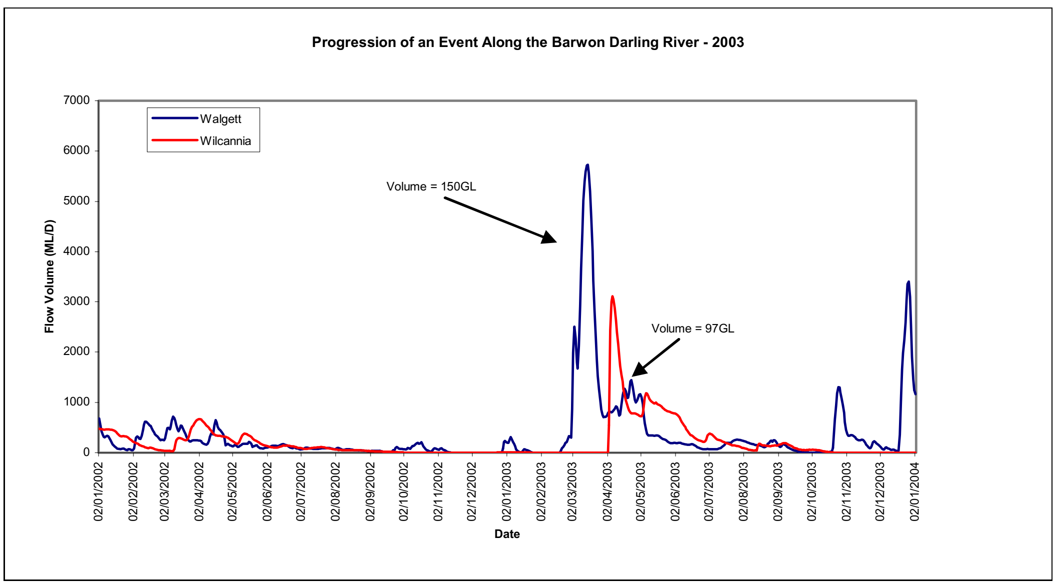

Figure 20 – Progression of Event Along the Barwon Darling River

It can be seen from the figures that large losses are experienced along both the Namoi and Barwon Darling River systems. Losses in volume for the two Namoi events in Figure 19 are 62% for the winter event and in excess of 90% for the spring event. Both of these events occurred after a period of prolonged low flows. Losses for the Barwon Darling section of the river are in the order of 35% with an initial loss of approximately 30 Gigalitres (20%) attributable to filling of the many weirs along the Barwon Darling River and the remaining 15% associated with seepage and evapo-transpiration.[5]

[5] Losses in the Barwon Darling have only been calculated to Wilcannia, as this is the last reliable gauging point. Additional losses are likely to be incurred between Wilcannia and Menindee.

In many years the river conditions for these historic events are likely to be similar to those that would occur at times when water from the upstream storages is required for Lower Darling Water Users. Although the recent advent of environmental flows and increased end of system targets mean that losses may be slightly reduced in the case of the Namoi River from those observed in Figure 19. In addition, there may also be some years where losses can be reduced by “piggy backing” releases for scheme supply on dam environmental releases or unregulated flushes that have filled up the many weir pools along the Darling River. However, this will only be of use in years where these flushes would not have reached the Menindee Scheme.

Additional, evaporation losses attributable to storage of water in the upstream major dams is likely to be negligible due to small increases in existing dam surface areas and the required volume only being utilised at times of during times of dry conditions and low resources in Menindee Scheme.

A preliminary assessment of delivery losses associated with differing storage and delivery volumes for Keepit Dam for the Lower Darling in critical supply years was undertaken using the information from these observed events as a guide. Losses of 50% in the Namoi and an initial loss of 30 Gigalitres (for Weir filling) and a continuing loss of 15% were assumed in the Barwon Darling. In addition, information provided by State Water operational staff was also considered. Results of this assessment are presented in Table 17.

Table 17 – Possible Delivery Loss Scenarios

Keepit Released Volume (GL)	Indicative Menindee Delivered Volume (GL)	Comment
100	17	
250	80	Delivered volume equivalent to 18 Month Volume for Broken Hill, HS & Riparian, Lower Darling Delivery Losses
400	150	Delivered volume equivalent to 18 month volume for Broken Hill, HS & Riparian, Lower Darling Delivery Losses plus irrigation and water quality.

Inspection of Table 17 together with Figures 1 and 2 indicate that losses associated with either delivery of water from Keepit Dam and evaporation from Menindee Lakes is of a similar order of magnitude. The analysis also does not include any additional losses that will be incurred through temporary storage of delivered volumes within Lake Wetherell and has not assigned an environmental benefit to the losses associated with delivering water from upstream.

5.2 Use or Creation of Downstream Storage Capacity

5.2.1 Instream Storage in the Lower Darling

The small volume of instream storage in the Lower Darling (refer to Table 7) means that it usefulness in terms of storage and reduction in evaporative losses is severely limited. Consequently no further assessment of this option has taken place.

5.2.2 Instream Storage in the Murray

Additional Lock storage in the Lower Murray is not sufficient by itself to achieve significant savings. However, it could provide benefits in a refined operation strategy that allows Menindee to be emptied more rapidly and Murray Lock storage to be used as a mitigation measure. However, such a strategy would need to ensure that increased salinity and environmental impacts from increase Lock storage levels and volumes did not occur.

6 CONCLUDING REMARKS

This report has presented the results of preliminary hydrologic analysis of key water saving options within the Darling Basin. More detailed hydrologic assessment of options that appear to have merit will be required in order to fully appreciate the range of hydrologic, socio-economic and environmental implications.

Hydrologic analysis of key options has indicated that that significant water savings have been found to be possible both at the Menindee Scheme and elsewhere in the Darling Basin. However the consequences of this with respect to alterations in diversion volumes, increased salt concentrations and flow changes appears to be high.