DWLBC REPORT

Riverland Salt Disposal Management Plan

2007/22

Government of South Australia
Department of Water, Land and Biodiversity Conservation

Riverland Salt Disposal Management Plan

Infrastructure and Business Division
Department of Water, Land and Biodiversity Conservation

February 2008

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FOREWORD

South Australia's unique and precious natural resources are fundamental to the economic and social wellbeing of the State. It is critical that these resources are managed in a sustainable manner to safeguard them both for current users and for future generations.

The Department of Water, Land and Biodiversity Conservation (DWLBC) strives to ensure that our natural resources are managed so that they are available for all users, including the environment.

In order for us to best manage these natural resources it is imperative that we have a sound knowledge of their condition and how they are likely to respond to management changes. DWLBC scientific and technical staff continues to improve this knowledge through undertaking investigations, technical reviews and resource modelling.

Rob Freeman
CHIEF EXECUTIVE
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ACKNOWLEDGEMENTS

The South Australian Steering Committee on Salt Interception would like to acknowledge the input and contributions of the various agencies, funding authorities and service providers that have contributed to the development of this plan.

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EXECUTIVE SUMMARY

The Riverland Salt Disposal Management Plan (RSDMP) has been developed to set a direction for the management and disposal of saline water intercepted by salinity mitigation works in the Riverland area of South Australia.

The recommendations made in this plan encompass the Morgan to Lock 3 reach of the River Murray (including Stockyard Plain Basin) and the Loxton to Border reach (including Noora Basin). The Pyap to Kingston reach is predicted not to require disposal infrastructure in the foreseeable future.

Most of the natural salt in the groundwater is stopped from entering the River Murray by effectively operating salt interception schemes. Apart from an alternative management strategy of exporting salt from the Murray-Darling Basin via the river or, for example, a pipeline to the sea, salt needs to be managed within the basin landscape. This is currently being achieved by disposing of intercepted hypersaline water to evaporative, aquifer-controlled salt management basins. The rate of release to the aquifer will vary according to the geological setting.

The plan discusses the schemes that will be required to manage saline water intercepted by Comprehensive Drainage Schemes (CDS) and Salt Interception Schemes (SIS), both currently operating and proposed schemes. The RSDMP estimates inflow volumes to Stockyard Plain and Noora basins until 2100.

Inflow to Stockyard Plain Basin currently exceeds its maximum design capacity and, based on future projected inflows, this will continue to be the case. To accommodate the additional volumes it is likely that the existing disposal basin will need to be expanded, or a new disposal site established.

On the strength of existing information, the operation of Noora Basin, over the next 100 years, is not expected to exceed the capacity of the basin. This prediction includes the inflows from the proposed SIS at Murtho, Loxton and Pike River.

Key issues identified in the RDSMP are the need to:

- Accommodation of the disposal volume being piped to Stockyard Plain Basin.
- Monitor the operational behaviour of Noora Basin.
- Develop and implement a broad-based monitoring framework to improve the understanding of existing basin performance (Noora and Stockyard Plain) and to monitor the impacts on their environs.
- Continue investigations into alternative options of salt management.

The RSDMP seeks to maximise the effective use of current methods of salt management and to further investigate alternative non-land based disposal options for intercepted saline water.

1. PROJECT BACKGROUND

1.1 INTRODUCTION

The South Australia River Murray Salinity Strategy includes a key ***milestone*** to 'develop a River Murray regional saline and drainage waters disposal management plan' (DWR 2001).

As a result, there have been ongoing assessments of regional saline and drainage water disposal management options and these have been consolidated into the Riverland Salt Disposal Management Plan (RSDMP).

The ***objective*** of the RSDMP is to set a direction for the management and disposal of the volume of saline water generated by salinity mitigation works in the Riverland area of South Australia.

The recommendations made in this plan encompass the Morgan to Lock 3 Reach (Stockyard Plain Basin) and the Loxton to Border Reach (Noora Basin) of the River Murray considering a period of 100 years. This plan will be subject to periodic review, as required.

1.2 RIVERLAND SALT DISPOSAL MANAGEMENT PLAN

The management and disposal of saline groundwater within the Riverland has developed over a period of many decades. The key actions were:

- The commissioning of Noora Basin in October 1982 to receive irrigation drainage water from the floodplain disposal basins at Berri and Disher Creek generated from Comprehensive Disposal Schemes (CDS).
- The commissioning of a second disposal basin, at Stockyard Plain, in 1990 to receive intercepted saline water from Woolpunda Salt Interception Scheme (SIS).
- Saltloads entering the River Murray in the different reaches of the river led to the construction of various interception schemes. The ongoing operation of these schemes has highlighted the need for a salt disposal management plan; hence the development of this RSDMP was initiated.

For the purpose of better defining the necessary strategies for the River Murray in South Australia, two reaches where salt management is required have been identified. These are:

- The Morgan to Lock 3 Reach – Stockyard Plain Basin services the reach from Morgan - Lock 3 and takes into consideration the Woolpunda, Qualco-Sunlands and Waikerie (I, IIA and Waikerie Lock 2 (proposed)) schemes.
- The Loxton to Border Reach – Noora Basin will service the reach from Loxton to the Border (south side of the River Murray). It takes into account Bookpurnong SIS and proposed SIS at Murtho, Pike River and Loxton and irrigation drainage from Renmark and Berri (CDS).

In addition, a groundwater management scheme is being investigated for Chowilla, and the monitoring of the operation and performance of existing disposal schemes and investigations into alternative options for salt management are continuing (e.g. Aquaterra 2005; DWLBC 2005c; KBR 2005; SKM 2005; Collingham 2005a,b,c, 2006, 2007). A *Project Business Plan* and *Execution Plan* have been prepared for the implementation of the RSDMP.

The current SIS and disposal basins are shown in Figure 1.

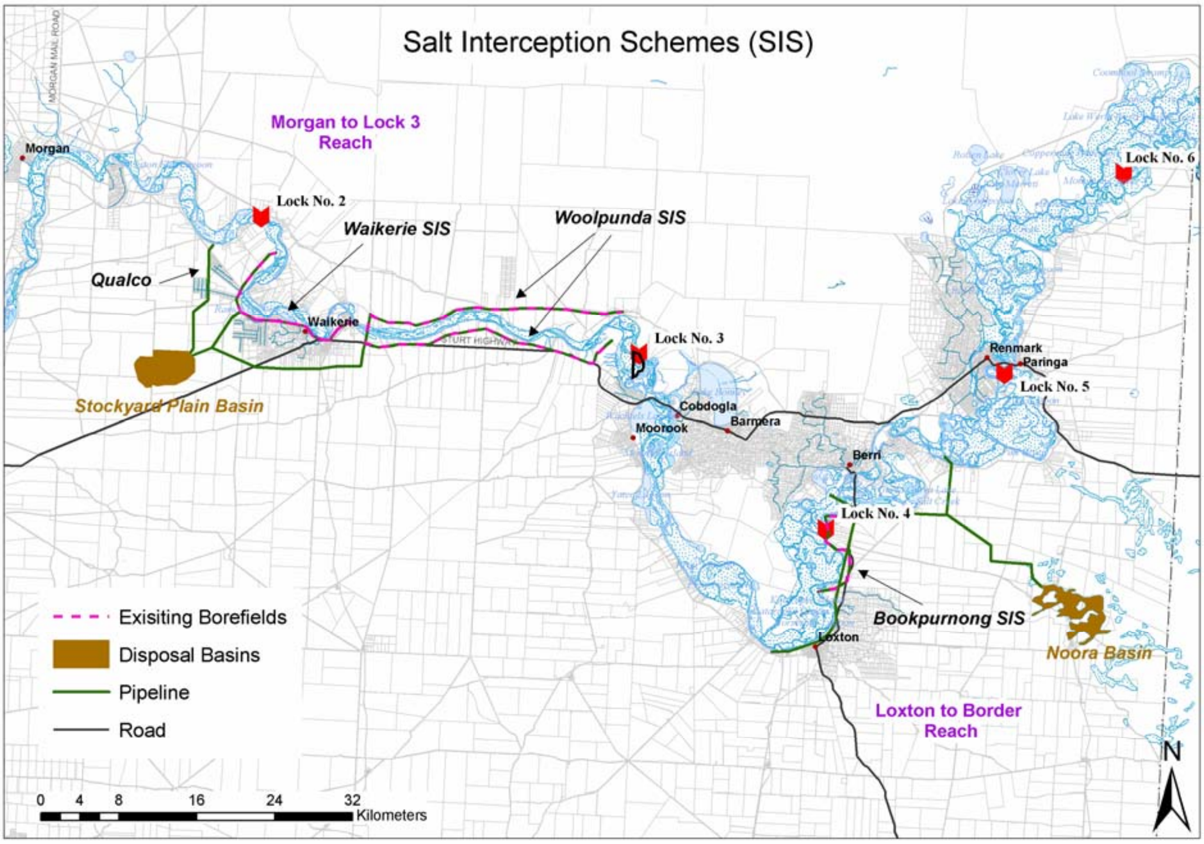

Figure 1. Existing Disposal Basins and Salt Interception Schemes (SIS)

1.3 RSDMP PROJECT CRITERIA

South Australia, New South Wales, Victoria and the Commonwealth are signatories to the *Murray-Darling Basin Agreement*. The purpose of this Agreement is to promote and co-ordinate effective planning and management for the equitable, efficient and sustainable use of the water, land and other environmental resources of the Murray-Darling Basin. Schedule C of the Agreement promotes works and measures by the contracting governments to reduce average salinity in the River Murray at Morgan, and provides for assessment of the potential and actual impact of works and measures in terms of their salinity effects.

The Murray–Darling Basin Commission's Basin Salinity Management Strategy (BSMS) commits the partner governments to the *Basin Salinity Target* which aims to maintain the average daily salinity at Morgan at a simulated level of less than 800 EC[1] for at least 95% of the time during the benchmark period (Section 3.5.2; MDBC 2005).

[1] EC – electrical conductivity unit where 1 EC = 1 microSiemens per centimeter (ųS/cm) at 25^{o}C

1.3.1 PRE- AND POST-1988 SALT

In 1988 the Salinity and Drainage (S&D) Strategy was adopted by the Murray-Darling Basin Commission (MDBC 1988). It provided the mechanism to allow the partner governments to invest collectively and share credits from salt mitigation projects irrespective of their location in the Murray–Darling Basin; it is known as the Joint Works Program. The program targeted salt mobilised by actions such as irrigation that were implemented prior to 1988 as well as naturally occurring saline inflows such as occur in the Woolpunda area.

The MDBC Salinity Audit of 1999 showed that, despite the efforts of the S&D Strategy, further action was necessary as large salt loads had already been mobilised and could negate the benefits provided by the S&D Strategy (MDBC 1999). As a result, the partner governments to the MDBC adopted the Basin Salinity Management Strategy (BSMS) 2001–15 (MDBC 2001) and agreed to a further 61 EC of joint salinity mitigation works for the first seven years of the strategy (later amended to nine years).

Of the 61 EC, 31 EC was allocated to address the salinity impacts prior to 1988 and 10 EC was allocated to each of the three basin states, South Australia, Victoria and New South Wales, to offset their accountable actions post-1988.

The BSMS Mid-term Review could have implications for current priorities and changes may be required. The outcome of the review will be known by December 2007.

In addition to the agreed program of joint works as specified in the BSMS, each State is accountable for the salinity impact of irrigation development implemented since 1988.

1.3.2 INQUIRY INTO SALINE WATER DISPOSAL BASINS

The Natural Resource Management Committee of the Parliament of South Australia held an enquiry into saline water disposal basins in South Australia in October 2005 (Natural Resources Committee 2005a,b). The Committee made recommendations, a number of which are included in the RSDMP, namely:

- Continuing investigations into finding effective and economically feasible alternative methods for the management and disposal of intercepted saline water.
- Establishment of a more extensive monitoring program at Stockyard Plain Basin.
- Investigation into the feasibility of increasing the disposal capacity of the infrastructure and facilities at Stockyard Plain Basin (in preference to establishing new disposal basins).

The requirements described in 1.3.1 and 1.3.2 will continue to drive the on-going need to implement salt interception schemes and will determine the methods of salt disposal that are employed.

2. MORGAN TO LOCK 3 REACH

2.1 CURRENT SCHEMES DISPOSAL REQUIREMENTS

In the reach from Morgan to Lock 3 the salt interception schemes (Woolpunda SIS, Waikerie I-IIA SIS and Qualco-Sunlands Groundwater Control Scheme (GCS)) currently require the disposal of a total of ~303 L/s of saline water. The water is disposed to Stockyard Plain Basin. Figure 2 shows the location of current and future schemes in the Morgan to Lock 3 Reach.

2.1.1 WOOLPUNDA SIS – CURRENT

The Woolpunda SIS was commissioned in 1990 under the MDBC's S&D Strategy. It currently intercepts ~165 L/s of groundwater, reducing river salinity by an average 190 t/d or 40.8 EC at Morgan (MDBC 2003). Initially, the Woolpunda SIS was operated at a higher rate of 230 L/s for a few years in order to achieve groundwater drawdown targets. The scheme was anticipated to intercept at a rate of 170 L/s when commissioned. Improvements in scheme efficiency that are currently being implemented should result in a further reduction in the pumping rate to 150 L/s by 2010 (AWE 2006b).

The Woolpunda SIS is a joint works scheme.

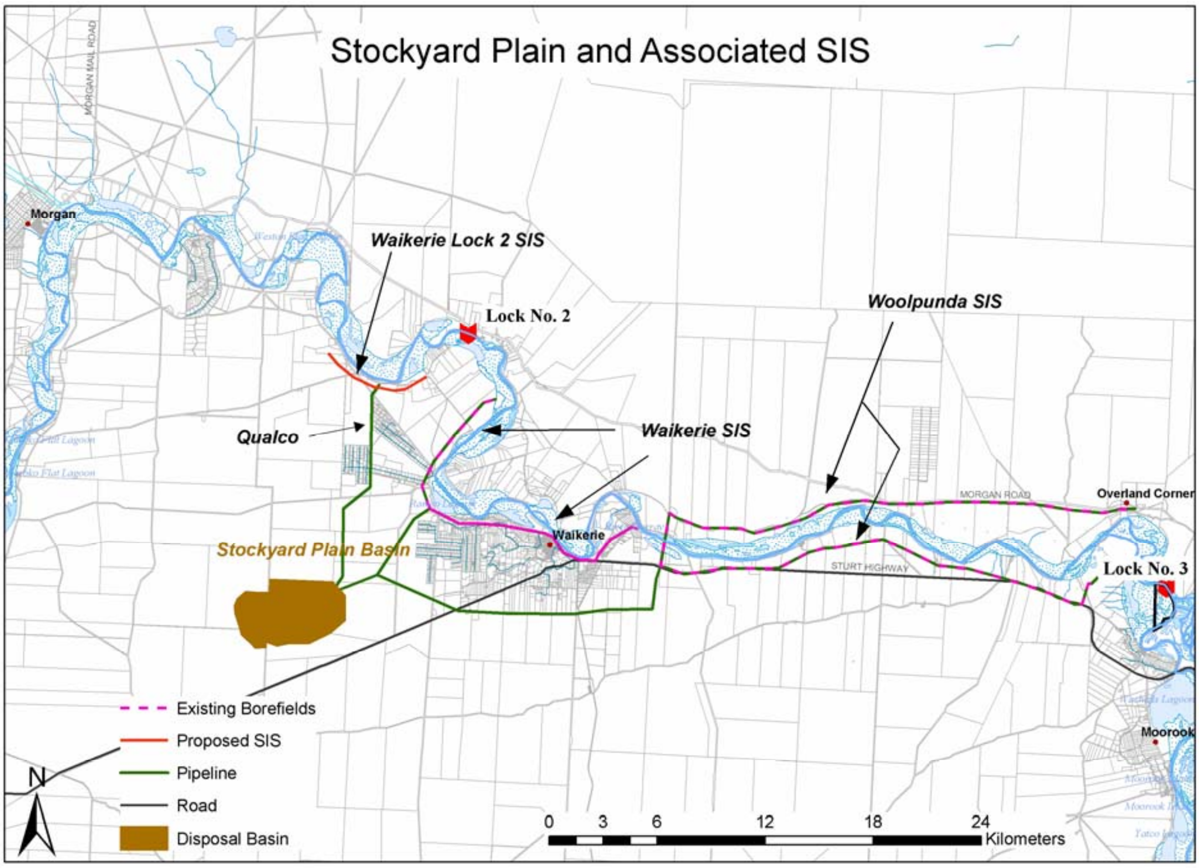

Figure 2. Morgan to Lock 3 Reach

2.1.2 WAIKERIE I AND IIA SIS – CURRENT

There were two stages in the development of the Waikerie SIS, Waikerie I commissioned in 1992 and Waikerie IIA commissioned in 2003. Both stages were established under the MDBC's S&D Strategy. They currently intercept a total of 103 L/s and reduce river salt load by ~90 t/d. Salinity benefits from this scheme is 12.7 EC at Morgan (AWE 2005b).

Waikerie I and IIA are joint works schemes.

2.1.3 QUALCO-SUNLANDS GCS – CURRENT

The Qualco-Sunlands Groundwater Control Scheme (GCS) was commissioned in 2001. This scheme currently reduces the salt load to the river by 19 t/d or a 4.8 EC benefit to offset South Australia's accountable actions. The scheme currently pumps at the rate of 35 L/s (Aquaterra 2007).

Qualco-Sunlands GCS is operated by local irrigators through The Qualco-Sunlands Ground Water Control Trust. The Trust was established under the *Ground Water (Qualco-Sunlands) Control Act 2000* and is entitled to deliver up to 100 L/s or a maximum of 2840 ML/annum to the disposal basin (s.24). The Act expires on 30 September 2030 at which time the assets of the Trust pass to the State (s.79).

2.2 FUTURE SCHEMES DISPOSAL REQUIREMENTS

In order to maintain sustainable SIS, the future disposal requirements to Stockyard Plain Basin are considered.

The total projected disposal volume going to Stockyard Plain Basin by 2010 is estimated at 310 L/s. The disposal volumes generated from the SIS in this reach are estimated at 380 L/s in 2050 and 395 L/s in 2100 (see Table 1).

2.2.1 WOOLPUNDA SIS – FUTURE

Irrigation development established in the Woolpunda area since 1988 will progressively impact on the River Murray from about 2030 (Aquaterra 2007). The groundwater model includes additional pumping rates to account for this development, and to maintain the lowest predicted saltloads, namely 68 L/s for 2050 and 80 L/s for 2100 (AWE 2006b; Aquaterra 2007).

Requests have been made to establish irrigation in the high impact zone behind the Woolpunda SIS. This is not currently allowed under Salinity Zoning Policy unless the salinity impacts are offset. The capacity of the Woolpunda scheme is currently under review. If capacity is available, a salinity impact zone might or could be created to offset the salinity impacts of post-1988 irrigation development and South Australia would need to negotiate with the MDBC for access to the scheme to offset the impact of existing post-1988 and new irrigation development.

Table 1. Current and potential future disposal volumes (L/s) for Stockyard Plain Basin

Scheme	Current	2010	2030	2050	2100
Current					
Waikerie I and IIA [1]	103	103	103	103	103
Qualco [3]	35	35	35	35	35
Woolpunda [4]	165	150	150	150	150
Totals	*303*	*288*	*288*	*288*	*288*
Future					
Waikerie Lock 2 [2]	0	22	22	22	22
Waikerie I and IIA (Post 1988 impact)	0	0	0	2	5
Woolpunda Post-1988 irrigation development (includes delayed impact of 1988–2007 development and prior commitment)	0	0	60	68	80
Totals	*0*	*22*	*82*	*92*	*107*
Total current + future	**303**	**310**	**370**	**380**	**395**

1 AWE (2005b)

2 AWE (2006a); Results from accredited groundwater model Morgan to Lock 3 (Aquaterra 2007)

3 Forward, P. (pers. comm. based on operational data)

4 AWE (2006b)

2.2.2 WAIKERIE I AND IIA SIS – FUTURE

There is no post-1988 impact to this reach of the River Murray until beyond 2044 (Aquaterra 2007). The reach is predicted to generate 2.6 t/d at the rate of 2 L/s in 2050 and 4.8 t/d at the rate of 5 L/s in 2100 (Aquaterra 2007). There is available capacity in the disposal main pipe of the Waikerie SIS that could support additional drainage for future irrigation development in this area.

2.2.3 QUALCO-SUNLANDS GCS – FUTURE

There is no additional future irrigation development proposed in the Qualco-Sunlands GCS area beyond the volume of drainage already agreed.

2.2.4 WAIKERIE LOCK 2 SIS – FUTURE

The Waikerie Lock 2 SIS is proposed as an extension of Waikerie I and IIA. The Waikerie Lock 2 Approval Submission has been presented to the MDBC (DWLBC 2007b). Current figures indicate a pumping volume of 22 L/s with a 39.2 t/d or 9.4 EC benefit to the river at Morgan, if fully commissioned.

The scheme would be constructed as a shared works under the MDBC’s BSMS. South Australia will be responsible for 6% of the salt load reduction (average amount to 2035) which is 1.3 L/s due to post-1988 irrigation development (DWLBC 2007b).

3. STOCKYARD PLAIN BASIN

3.1 BACKGROUND

Stockyard Plain is a broad, low-lying area located 15 km southwest of Waikerie (see Fig. 2). In the early 1980s a series of shallow gypsum-rich depressions within this plain were identified as a prospective site for a disposal basin for the Woolpunda SIS (Collingham and Newman 1986).

The basin encompasses a number of natural shallow depressions with floor elevations as low as 24 m AHD[2] and has a design top water level of 31 m AHD. High ground naturally confines the basin on the north and south, while earth embankments, each about 1.5 km long, were built to limit the spread of water to the east and west. The maximum available pond area is about 7 km^2 and, with the basin operated at 31 m AHD, the current design capacity is 300 L/s (Collingham 2006).

Stockyard Plain Basin is owned and operated by the Murray-Darling Basin Commission.

3.1.1 DISPOSAL VOLUMES

The current inflow to the basin from the Woolpunda SIS is about 165 L/s, from the Waikerie SIS about 103 L/s, and from Qualco-Sunlands about 35 L/s, giving a total of about 303 L/s. The average inflow during the first 15 years of the basin's life has been about 300 L/s due to initially high level of pumping of the schemes to accelerate the rate of groundwater lowering (Forward. P, SA Water, pers. comm.). The current and potential future disposal volumes to Stockyard Plain Basin over a 100 year period are shown in Table 1.

It is predicted that the future disposal volume to Stockyard Plain Basin will increase to ~395 L/s by 2100 (Table 1) due to the impact of post-1988 irrigation development in the Woolpunda SIS area.

The MDBC will be responsible for around 70% of the flow generated and South Australia will be responsible for ~30%. The potential longer term flows from the current and proposed SISs may exceed the capacity of Stockyard Plain Basin by ~90 L/s (refer to Table 1), particularly if irrigation development is allowed behind these schemes.

Given the existing and likely future salt loads to the River Murray in the Morgan to Lock 3 SIS, an alternate mechanism to cater for the future disposal volumes will be required. The State of South Australia will need to make a decision on the means to be used in the future to dispose of interecepted saline water for salt management.

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[2] AHD - Australian Height Datum is the datum used for the determination of elevations in Australia. The determination uses a national network of benchmarks and tide gauges, and sets mean sea level as zero elevation.

3.1.2 DISCUSSION

The inflow of intercepted saline water to Stockyard Plain Basin exceeds the basin's current design capacity. This will limit any future irrigation development in the Morgan to Lock 3 Reach of the river. Alternative disposal options will be required if development is allowed to continue. The proposed future options to address this are to:

1. Dispose of larger volumes, about 395 L/s, to the basin over the next 100 years. At present, it is uncertain how this will affect the useful life of the basin. Monitoring will be required to better understand the basin's long-term operation.
2. Expand the design capacity of Stockyard Plain Basin by ~100 L/s. Any increase in operating water level would require the construction of additional banks. An increase in operating level may involve a trade-off of cost versus volume in order to achieve the greatest benefit; the costs involved in expanding the capacity of the basin will need to be determined. In addition, local impacts could be significantly increased (e.g. waterlogging of surrounding land, impacts on native vegetation).
3. Increase the area of the current basin. This is physically possible and would result in an improved basin in terms of evaporative disposal versus incremental river impacts as detailed by Collingham (2006). However, this option would result in inundation of existing native vegetation to the west of the basin and would require approval from the Native Vegetation Council. This option, if fully adopted, would inundate a total area of ~14 km^2 (Collingham 2006).
4. Establish a new disposal basin near Stockyard Plain. Further investigation of this option will depend upon the outcome of the feasibility of adopting options (b) or (c). A scoping study, including sociological parameters, will be required to investigate the feasibility of establishing a new basin.

All four options for accommodating future disposal volumes require further investigation.

4. LOXTON TO THE BORDER REACH

4.1 CURRENT SCHEMES DISPOSAL REQUIREMENTS

In the Loxton to the Border Reach there is currently a need to dispose of ~119 L/s from Comprehensive Drainage Schemes (CDS) (Berri and Disher Creek Disposal Basins) and Bookpurnong SIS. The water is disposed to Noora Basin. Figure 3 shows the location of current and future schemes in the Loxton to Border Reach.

4.1.1 CDS CONTRIBUTIONS – CURRENT

Noora Basin was established to dispose of irrigation drainage water from the CDS stored at Berri and Disher Creek Disposal Basins. Records show that a total volume of drainage water from the two basins equivalent to a continuous flow of 40 L/s has been disposed to Noora Basin over the past six years. Flows will remain at this rate or less into the future (DWLBC 2006e).

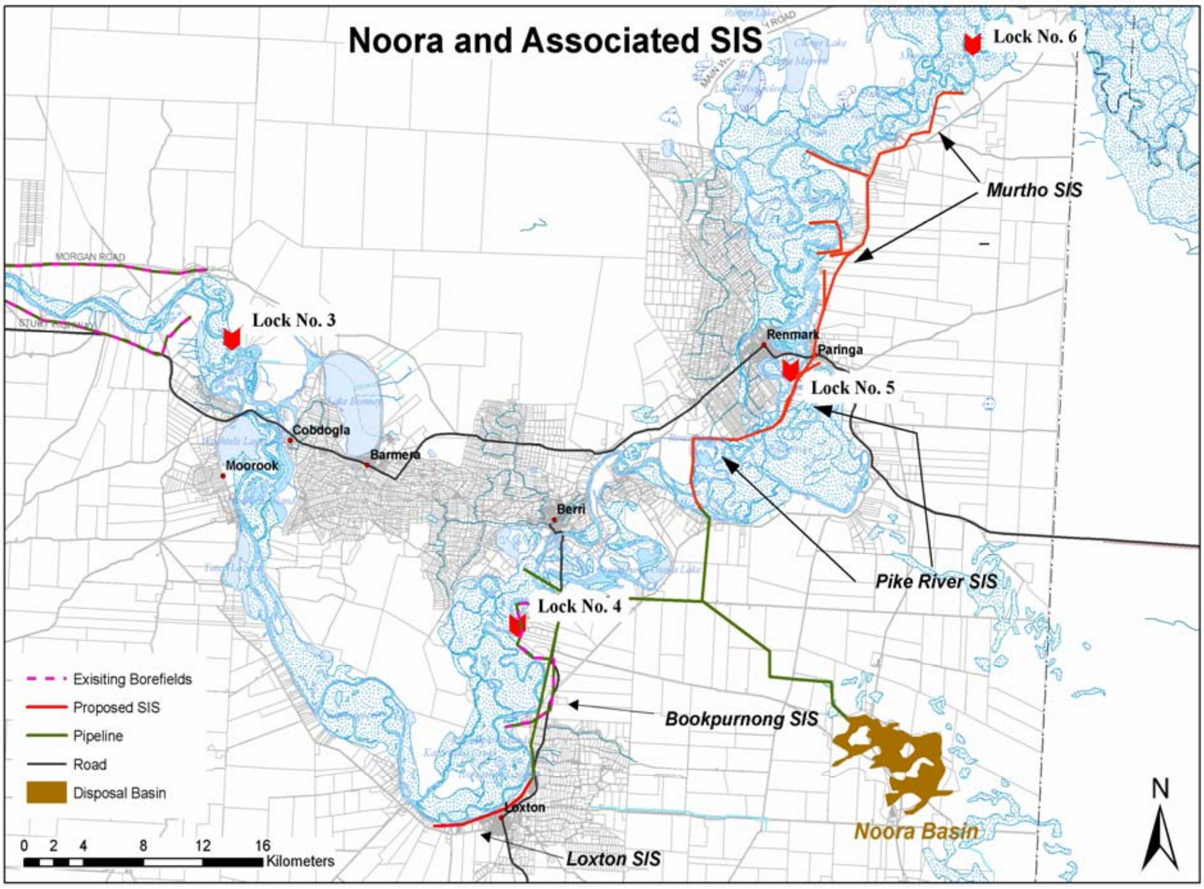

Figure 3. Loxton to the Border Reach

4.1.2 BOOKPURNONG SIS – CURRENT

Bookpurnong SIS was established under the MDBC's Basin Salinity Management Strategy (BSMS) and was commissioned in September 2006. It currently intercepts ~79 L/s of groundwater, reducing river salinity by an average of 87.2 t/d. The 2005–35 30 year average river salinity reduction is estimated to be 21.8 EC with a 14.8 EC MDBC component and 7 EC allocated to South Australia to offset the impact of 1988–2003 irrigation development at Bookpurnong.

Currently the South Australian Government and the MDBC share ownership of the scheme proportional to the ownership of credits generated, namely MDBC 14.8 EC (68%) and South Australia 7.0 EC (32%).

Bookpurnong SIS is a shared works scheme.

4.1.3 LOXTON SIS – CURRENT

Loxton SIS is being constructed in accordance with the MDBC's BSMS and is expected to be commissioned in mid-2009 with an initial flow rate to Noora Basin of 79 L/s. The 2005–35 30 year average river salinity reduction is estimated to be 18.7 EC or 65 t/d. ~4 EC is to offset the impact of post-1988 irrigation developments (2005b).

The South Australian Government and the MDBC share ownership of the scheme proportional to the ownership of credits generated, namely MDBC 18.7 EC (98%) and South Australia 0.4 EC (2%).

Loxton SIS is a shared works scheme.

4.2 FUTURE SCHEMES DISPOSAL REQUIREMENTS

In order to maintain river salinity levels in the Loxton to the Border Reach, the future disposal requirements to Noora Basin are considered.

The total projected disposal volume to Noora Basin by 2010 is estimated at 214 L/s. The disposal volumes generated from the SIS and the CDS in this reach are estimated at 302 L/s in 2050 and 383 L/s in 2100 (see Table 2).

4.2.1 CDS CONTRIBUTIONS – FUTURE

The basin capacity quarantined for CDS water is to be maintained at 40 L/s (DWLBC 2006e).

4.2.2 BOOKPURNONG SIS – FUTURE

The modelling assessment for the Bookpurnong SIS indicates that the infrastructure would readily cope with future irrigation development in the area. In fact, it is likely that given the low rate of expansion, the disposal volume will be lower than is currently predicted. Bookpurnong SIS is currently pumping at a rate of 79 L/s; this will decrease to 35 L/s in 2010 and then will increase to 54 L/s by 2100 (DWLBC 2005b).

Table 2. Current and potential future disposal volumes (L/s) for Noora Basin

Scheme	Current	2010	2030	2050	2100
Current					
Berri Basin	10	10	10	10	10
Disher Creek	30	30	30	30	30
Loxton	0	79	57	58	63
Bookpurnong	79	35	47	51	54
Totals	*119*	*154*	*144*	*149*	*157*
Future					
Pike River (proposed)	0	0	63	70	93
Bookpurnong (Aluminium hydroxide bores only)		10	7	8	8
Murtho (proposal before the MDBC)	0	50	58	75	125
Totals	*0*	*60*	*128*	*153*	*226*
Total – current + future	**119**	**214**	**272**	**302**	**383**

*All numbers from DWLBC (DWLBC 2005a,b; 2006a,c). Compiled by Todd Hodgkin, REM, December 2006.

Currently a part of Bookpurnong has been excised from the scheme due to the precipitation of aluminium hydroxide ($AlOH_3$) which clogs the pumps. The Bookpurnong SIS will be extended in the future if this problem is satisfactorily resolved will discharge an additional 7–10 L/s to Noora (DWLBC 2005d).

4.2.3 LOXTON SIS – FUTURE

The majority of the land behind the Loxton SIS is already irrigated so the likelihood of increased flow due to irrigation development is low. The Loxton SIS is expected to pump at a rate of 79 L/s in 2010; this will subsequently decrease - estimated rates are 57 L/s in 2030 and 63 L/s in 2100 (DWLBC 2005b).

4.2.4 MURTHO SIS – FUTURE

Conditional approval has been granted to the Murtho SIS (DWLBC 2007a). The submission to the MDBC demonstrates that the 2005–35 30 year average river salinity reduction is 20.2 EC (99.4 t/d) with 0.4 EC of this required to mitigate the impact of post-1988 irrigation development in the Murtho area (DWLBC 2005a).

It is proposed that the South Australian Government and the MDBC share ownership of the scheme proportional to the ownership of credits generated, namely initially MDBC 19.8 EC (98%) and South Australia 0.4 EC (2%). Murtho SIS is expected to pump at a rate of 50 L/s in 2010. Inflows are expected to increase from 58 L/s in 2030 to 125 L/s in 2100 (DWLBC 2006a).

4.2.5 PIKE RIVER SIS – FUTURE

The draft technical assessment for the Pike River SIS demonstrates that the average river salinity reduction for the 30 year period 2005–35 is estimated to be ~107 t/d or 22 EC, of which ~2 EC is to mitigate the impact of post-1988 irrigation development in the Pike River area (DWLBC 2006a).

If the scheme is constructed as is currently proposed, the South Australian Government and the MDBC would share the ownership, MDBC 20 EC (90%) and South Australia 2 EC (10%). The Pike River SIS is expected to pump at a rate of 63 L/s in 2030, gradually increasing to 70 L/s in 2050 and 93 L/s in 2100 (DWLBC 2006a). However, other options are also being considered including changes in irrigation management which could result in a decrease in the predicted flows.

4.2.6 CHOWILLA SIS – FUTURE

It is not proposed that saline water from the Chowilla groundwater management scheme will be pumped to Noora Basin. Other land-based disposal options and deep aquifer disposal are being investigated for this scheme. A desktop study has examined the feasibility of disposal of saline water from Chowilla by injection into the deeper Renmark Group aquifer (DWLBC 2005c). The study recommended that the investigation of injection continue in a phased approach to minimise cost and risks. A monitoring bore has been completed in the Renmark group aquifer and a study to assess potential for clogging of injection wells and the surrounding aquifer is in progress. If the outcome of the study is positive a trial injection will be carried out. This study is expected to be completed by the end of 2009.

5. NOORA BASIN

5.1 BACKGROUND

Noora Basin is located ~20 km east of Loxton (Fig. 3). The basin was commissioned in 1982 with a land area of 3600 ha. It was originally designed to service the Berri and Renmark Irrigation Area CDS. It would receive drainage water, as required, from the Berri and Disher Creek Basins (both of which are located on the floodplain of the River Murray) in order to keep the water level in those basins below river level, thus preventing the displacement of highly saline groundwater to the river.

The role of Noora Basin has altered in recent years. It currently receives water from the CDS and Bookpurnong SIS. It is proposed that intercepted saline irrigation water from a number of proposed SIS will also be pumped to this basin. The current design capacity for Noora Basin operating at 19.0 m AHD is 435 L/s comprising a 100 year long-term average of 395 L/s from SIS and 40 L/s from CDS (DWLBC 2006c).

Noora Basin is owned and operated by the Government of South Australia.

5.1.1 DISPOSAL VOLUMES

Current and future potential disposal volumes to Noora Basin are given in Table 2.

Groundwater and surface water modelling of Noora Basin is being carried out to clarify the risk of salt accumulation and identify any impact of basin operation on regional groundwater. DWLBC is working on this project and the report should be completed during August 2007 (DWLBC 2006c,d; also see Collingham 2007).

5.1.2 DISCUSSION

Noora Basin has a current design capacity of 435 L/s. The estimated inflow by 2100 is 383 L/s, and therefore the basin has the capacity to accommodate additional water from localities other than those that are currently in operation or planned.

There is a need to develop and implement a monitoring framework to assess the performance and behaviour of Noora Basin and identify potential impacts on regional groundwater and the environs of the basin. Key indicators that have been identified for the monitoring framework (this is currently being developed) include surface water and groundwater, operational factors, and vegetation and fauna.

The estimated disposal volumes to Noora Basin are catered for by the existing infrastructure until at least 2050. Monitoring of inflow volumes will be required to identify any trends towards sustained higher flows (DWLBC 2006b).

6. ALTERNATIVE OPTIONS FOR SALT MANAGMENT

Non-land based salt disposal options, including desalination, disposal to the sea via a pipeline, irrigation of salt tolerant crops, have, to date, been found to be largely not feasible, due to either high costs (capital and/or operational) or technical constraints. Further investigations are still occurring into some of the options. The useful life of the disposal basins could be prolonged if future assessments show that the 'alternate' options can provide a technically sound and economical disposal solution and can reduce the volume of saline water pumped to disposal basins. Examples of alternative disposal options are described below.

6.1 ALTERNATIVE MANAGEMENT OPTIONS

6.1.1 PIPELINE TO THE SEA

A study was undertaken for the MDBC in 1990 to investigate the feasibility of constructing a saline outfall for the Murray-Darling Basin via a pipeline to the sea. The preliminary study did not make any firm recommendations but suggested that some of the identified options warranted further evaluation. These included a proposal to connect the Sunraysia (the Merbein-Mildura-Red Cliffs irrigation area) by pipeline to the South Australian Riverland (at Loxton) to collect intercepted saline groundwater. The pipeline would then go via Stockyard Plain Basin to the Southern Ocean. The study concluded that the cost of a saline outfall could not be justified solely on economic grounds and that very significant social and environmental benefits would be required before further consideration of the option was warranted (GHD et al. 1990).

A feasibility study is currrently underway to establish whether it is cost-effective to dispose of saline water from Stockyard Plain Basin to the sea (Phase 1). The findings of the study are expected later in 2007. Further studies beyond Phase 1 will depend on the findings of the Phase 1 investigations and could include *inter alia* measures to optimise the use of Stockyard Plain Basin (MDBC 2007).

6.1.2 SALT HARVESTING

The salts and other minerals that can be extracted via mechanical means or by crystalisation in evaporation basins are increasingly being harvested for agricultural, industrial and domestic uses. There are significant capital costs associated with setting up salt harvesting schemes including the construction of appropriately lined evaporation ponds. On-going operational and maintenance costs are also required.

A study by CSIRO (2004a) of water samples from 12 salt interception works in the Murray-Darling Basin found that careful management of the water, for example by sub-dividing a basin into ponds and the transfer of the brine and bitterns during the evaporation process, would be required to recover acceptable quality salts for commercial sale. The study found that gypsum could be recovered from all sites tested in South Australia. Halites from Stockyard Plain are likely to meet the pre-wash market specifications for Ca and SO_4 and halites from Noora and Bookpurnong would be suitable for marketing with a little washing. The potential production of halites are estimated at 50 000 t/y from Noora Basin and 100 000 t/y from Stockyard Plain (this figure takes into account the combined input from Waikerie and Woolpunda). Little or no Epsom salt can be produced at either basin due to the low magnesium levels in the waters. The study suggested that further evaluations should be made, including the economic prospects for salt harvesting from the basins (CSIRO 2004b).

6.1.3 DEEP AQUIFER INJECTION

This process relies on the disposal of intercepted saline groundwater into wells screened in a deep aquifer where the return impacts on salinity are acceptable. Studies have shown that there is a low potential to use the Renmark Group aquifer at Stockyard Plain for this purpose due to unfavourable geology (AWE 2005a). However, deep aquifer injection into the Remark Group aquifer at Chowilla is being investigated by DWLBC and, if current trials are successful, disposal by this method may become an option for groundwater management at Chowilla (DWLBC 2005c; also see 4.2.6).

6.1.4 DESALINISATION

Desalinisation is a process that removes dissolved minerals (including salt) from water sources such as seawater, brackish water or treated wastewater. The two most common methods of desalinisation use membranes or distillation (URS 2002).

Desalinisation using membranes uses the ability of membranes to differentiate and selectively separate salts and water. The most commonly used method is Reverse Osmosis. In this process pressure is applied to the feed water allowing the water to move through a semi-permeable membrane leaving the salts behind. For desalinisation using distillation, the feed water is heated to produce water vapour which is then condensed to produce water of a high quality.

Both reverse osmosis and distillation result in the production of highly saline reject water (termed concentrated brine) requiring disposal. The amount of water discharged to waste from reverse osmosis varies from 20–70% of the feed flow, depending on the salt content of the feed water and plant operation parameters. For both processes, as a general rule, the higher the salinity of the feed water, the higher the capital and operating costs.

Energy costs account for about 40% of the total operating cost of a reverse osmosis unit. The second large portion of the cost (largely fixed costs) is equipment, namely membranes, pressure vessels, pumps, energy recovery turbine, and pre-treatment stages, including large area media filtration. Efficient operation of the unit is the key to reducing the total cost of the water produced (Semiat 2000).

The capital and operating cost of a desalinisation unit at Stockyard Plain Basin has not been determined. However, it is likely that the use of desalinisation technology will not eliminate the need for disposal basins but it could prolong the life of the basins.

6.1.5 ENHANCED EVAPORATION

Technology is available to enhance evaporation rates from waterbodies. For example, spray evaporation uses a modified snow-maker to spray water into the air, and recirculating evaporation uses a solar-powered pump to draw water from depth and spread it in a laminar fashion over the surface.

Both technologies have high capital and operating costs and are condidered to be most useful where storage basin surface area is at a premium (Jorgensen, c. 2005).

6.1.6 IRRIGATION OF SALT TOLERANT CROPS

With some modifications to irrigation practices and/or with dilution, saline water can be used for irrigating some horticultural crops, including perennial tree crops. Some plant species will tolerate up to 3500 mg/L TDS (URS 2002).

The salinity levels of the disposed water at Noora and Stockyard Plain basins is greater than the limit for the sustainable irrigation of any plant species. Therefore, it is unlikely that the option of using this water for the irrigation of salt tolerant crops will have any significant bearing on the disposal strategy for either basin.

6.1.7 COMPLEMENTARY INITIATIVES

Complementary salt management initiatives include:

- Aquaculture – can be used to add value to salt management processes. Costs vary with the size of the enterprise and the species being farmed. Management problems at trial sites have generally related to the difficulty in managing water quality within the aquaculture basins.
- Solar ponds – an emerging technique that collects and stores solar energy via a salinity gradient in the depth of the water. The process is still in at an evaluation stage in Australia as a commercial source of electricity in remote areas (URS 2002).

7. IDENTIFIED RISKS

7.1 IDENTIFIED RISKS

The identified risks for the two reaches of the River Murray are discussed below.

7.1.1 MORGAN TO LOCK 3 REACH

Stockyard Plain Basin disposal volume is exceeding the current design capacity of 300 L/s. In the short-term, there is no immediate reason for concern but it is uncertain to what extent operating the basin at this volume will reduce its useful life. Additional disposal capacity should be investigated to mitigate this risk.

Options that should be pursued are:

- Expansion of the operating level and/or area of the existing basin.
- Establishment of an additional disposal basin.
- Continuing investigations into the use and adoption of alternative disposal options (e.g. pipeline to the sea, salt harvesting, deep aquifer injection, etc.).

7.1.2 LOXTON TO BORDER REACH

The disposal volume to **Noora Basin** is not expected to exceed its current design capacity of 435 L/s. However, as the basin has never been inundated to its maximum capacity, it is not possible to predict or monitor its future behavior nor the impact on its environs. For this reason, a monitoring program is essential to enable sound future management decisions to be made.

Key indicators have been identified for the monitoring framework which is being developed. These include:

- Surface water and groundwater.
- Operational factors.
- Vegetation and fauna.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 MORGAN TO LOCK 3 REACH

To ensure the long-term sustainable disposal capacity for the **Morgan to Lock 3 Reach** Stockyard Plain Basin needs to receive inflows of at least 300 L/s. The basin is currently receiving 303 L/s and will continue to exceed its current design capacity of 300 L/s when Waikerie Lock 2 SIS is commissioned (the approval submission has been presented to MDBC). The impacts due to post-1988 and prior commitment irrigation development suggest that disposal requirements will increase to an estimated 370 L/s by 2030 and 395 L/s by 2100.

It is recommended that further investigations be undertaken into:

- The impact of the additional flows into Stockyard Plain Basin.
- Augmenting the operating level and/or area of the existing basin.
- Establishing a new basin near Stockyard Plain.
- Constructing a pipeline to dispose of saline water from this reach to the sea.

8.2 LOXTON TO BORDER REACH

Noora Basin has not received substantial volumes of water since it was commissioned over 20 years ago. All current assessments on the performance of the basin are based on models. Therefore it is important to develop a monitoring framework to monitor the performance, behaviour and impacts of the basin.

To ensure the long-term sustainablilty of the disposal capacity for the **Loxton to Border Reach** it is recommended that:

- Noora Basin be operated to a maximum elevation of 19.0 m AHD giving a design capacity of 435 L/s.
- The basin capacity quarantined for CDS water be maintained at 40 L/s.
- A monitoring framework should be developed to monitor the future behavior of the basin and its impact on its environs.

A monitoring framework is currently being developed and will include key indicators such as operational factors, regional surface and groundwater, vegetation and fauna. The long-term monitoring program will contribute towards assessing the performance, behaviour and impacts of the basin on the environs, and will assist in identifying future management requirements for the basin.

In addition, further investigations should continue into alternative options of salt management, especially where they could provide a technically sound and economical disposal solution and reduce the volume of saline water pumped to the disposal basins.

UNITS OF MEASUREMENT

Units of measurement commonly used (SI and non-SI Australian legal)

Name of unit	Symbol	Definition in terms of other metric units	Quantity
day	d	24 h	time interval
gigalitre	GL	10^6 m^3	volume
gram	g	10^{-3} kg	mass
hectare	ha	10^4 m^2	area
hour	h	60 min	time interval
kilogram	kg	base unit	mass
kilolitre	kL	1 m^3	volume
kilometre	km	10^3 m	length
litre	L	10^{-3} m^3	volume
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
microgram	μg	10^{-6} g	mass
microlitre	μL	10^{-9} m^3	volume
milligram	mg	10^{-3} g	mass
millilitre	mL	10^{-6} m^3	volume
millimetre	mm	10^{-3} m	length
minute	min	60 s	time interval
second	s	base unit	time interval
tonne	t	1000 kg	mass
year	y	365 or 366 days	time interval

~	approximately equal to
δD	hydrogen isotope composition
$\delta^{18}O$	oxygen isotope composition
^{14}C	carbon-14 isotope (percent modern carbon)
CFC	chlorofluorocarbon (parts per trillion volume)
EC	electrical conductivity (µS/cm)
pH	acidity
ppm	parts per million
ppb	parts per billion
TDS	total dissolved solids (mg/L)

GLOSSARY

Act (the) — In this document, refers to the *Natural Resources Management Act* (SA) *2004*.

Anabranch — A branch of a river that leaves the main channel.

ANZECC — Australia New Zealand Environmental Consultative Council.

Aquifer — An underground layer of rock or sediment that holds water and allows water to percolate through.

Aquifer, confined — Aquifer in which the upper surface is impervious and the water is held at greater than atmospheric pressure. Water in a penetrating well will rise above the surface of the aquifer.

ASR — Aquifer, storage and recovery. The process of recharging water into an aquifer for the purpose of storage and subsequent withdrawal.

Aquifer test — A hydrological test performed on a well, aimed to increase the understanding of the aquifer properties, including any interference between wells, and to more accurately estimate the sustainable use of the water resource available for development from the well.

Aquifer, unconfined — Aquifer in which the upper surface has free connection to the ground surface and the water surface is at atmospheric pressure.

Aquitard — A layer in the geological profile that separates two aquifers and restricts the flow between them.

Arid lands — In South Australia, arid lands are usually considered to be areas with an average rainfall of less than 250 mm and support pastoral activities instead of broadacre cropping.

Artificial recharge — The process of artificially diverting water from the surface to an aquifer. Artificial recharge can reduce evaporation losses and increase aquifer yield. *(See natural recharge, aquifer.)*

Basin — The area drained by a major river and its tributaries.

Benchmark condition — Points of reference from which change can be measured.

Biological diversity (biodiversity) — The variety of life forms: the different life forms including plants, animals and micro-organisms, the genes they contain and the *ecosystems (see below)* they form. It is usually considered at three levels — genetic diversity, species diversity and ecosystem diversity.

Bore — *See well.*

Buffer zone — A neutral area that separates and minimises interactions between zones whose management objectives are significantly different or in conflict (e.g. a vegetated riparian zone can act as a buffer to protect the water quality and streams from adjacent land uses).

Catchment — That area of land determined by topographic features within which rainfall will contribute to runoff at a particular point.

Data comparability — The characteristics that allow information from many sources to be of definable or equivalent quality, so that this information can be used to address program objectives not necessarily related to those for which the data were collected. These characteristics need to be defined but would likely include detection limit precision, accuracy, bias, and so forth (ITFM — Intergovernmental Task Force on Monitoring Water Quality, Data Collection Methods Task Group

DEH — Department for Environment and Heritage (Government of South Australia).

DES — Drillhole Enquiry System. A database of groundwater wells in South Australia, compiled by DWLBC.

DHS — Department of Human Services (Government of South Australia).

Dryland salinity — The process whereby salts stored below the surface of the ground are brought close to the surface by the rising watertable. The accumulation of salt degrades the upper soil profile, with impacts on agriculture, infrastructure and the environment.

DWLBC — Department of Water, Land and Biodiversity Conservation (Government of South Australia).

EC — Electrical conductivity**.** 1 EC unit = 1 micro-Siemen per centimetre (µS/cm) measured at 25°C. Commonly used to indicate the salinity of water.

Ecology — The study of the relationships between living organisms and their environment.

Ecosystem — Any system in which there is an interdependence upon, and interaction between, living organisms and their immediate physical, chemical and biological environment.

Environmental values — The uses of the environment that are recognised as of value to the community. This concept is used in setting water quality objectives under the Environment Protection (Water Quality) Policy, which recognises five environmental values — protection of aquatic ecosystems, recreational water use and aesthetics, potable (drinking water) use, agricultural and aquaculture use, and industrial use. It is not the same as ecological values, which are about the elements and functions of ecosystems.

EWS — Engineering and Water Supply Department (Government of South Australia). Now SA Water

Floodplain — Of a watercourse means: (a) the floodplain (if any) of the watercourse identified in a catchment water management plan or a local water management plan; adopted under Part 7 of the *Water Resources Act 1997*; or (b) where paragraph (a) does not apply — the floodplain (if any) of the watercourse identified in a development plan under the *Development Act 1993*, or (c) where neither paragraph (a) nor paragraph (b) applies — the land adjoining the watercourse that is periodically subject to flooding from the watercourse.

GL — Gigalitre. One thousand million litres (1 000 000 000).

Greenhouse effect — The balance of incoming and outgoing solar radiation which regulates our climate. Changes to the composition of the atmosphere, such as the addition of carbon dioxide through human activities, have the potential to alter the radiation balance and to effect changes to the climate. Scientists suggest that changes would include global warming, a rise in sea level and shifts in rainfall patterns.

Groundwater — *See underground water.*

Habitat — The natural place or type of site in which an animal or plant, or communities of plants and animals, lives.

Hydrogeology — The study of groundwater, which includes its occurrence, recharge and discharge processes, and the properties of aquifers. *(See hydrology.)*

Hydrology — The study of the characteristics, occurrence, movement and utilisation of water on and below the Earth's surface and within its atmosphere. *(See hydrogeology.)*

Impact — A change in the chemical, physical, or biological quality or condition of a water body caused by external sources.

Indigenous species — A species that occurs naturally in a region.

Infrastructure — Artificial lakes; dams or reservoirs; embankments, walls, channels or other works; buildings or structures; or pipes, machinery or other equipment.

Irrigation — Watering land by any means for the purpose of growing plants.

Lake — A natural lake, pond, lagoon, wetland or spring (whether modified or not) and includes: part of a lake; and a body of water declared by regulation to be a lake; a reference to a lake is a reference to either the bed, banks and shores of the lake or the water for the time being held by the bed, banks and shores of the lake, or both, depending on the context.

MDBC — Murray–Darling Basin Commission.

ML — Megalitre. One million litres (1 000 000).

Native species — Any animal and plant species originally in Australia.

Natural recharge — The infiltration of water into an aquifer from the surface (rainfall, streamflow, irrigation etc.). *(See recharge area, artificial recharge.)*

Natural resources — Soil; water resources; geological features and landscapes; native vegetation, native animals and other native organisms; ecosystems.

NRM — Natural Resources Management**.** All activities that involve the use or development of natural resources and/or that impact on the state and condition of natural resources, whether positively or negatively.

NHT — Natural Heritage Trust.

Obswell — Observation Well Network.

Permeability — A measure of the ease with which water flows through an aquifer or aquitard. The unit is m^2/d.

PIRSA —Primary Industries and Resources South Australia (Government of South Australia).

Ramsar Convention — This is an international treaty on wetlands titled 'The Convention on Wetlands of International Importance Especially as Waterfowl Habitat'. It is administered by the International Union for Conservation of Nature and Natural Resources. It was signed in the town of Ramsar, Iran in 1971, hence its common name. The convention includes a list of wetlands of international importance and protocols regarding the management of these wetlands. Australia became a signatory in 1974.

Recharge area — The area of land from which water from the surface (rainfall, streamflow, irrigation, etc.) infiltrates into an aquifer. *(See artificial recharge, natural recharge.)*

SA Geodata — A collection of linked databases storing geological and hydrogeological data, which the public can access at the front counters of PIRSA and its regional offices. Custodianship of data related to minerals–petroleum and groundwater is vested in PIRSA and DWLBC, respectively. DWLBC should be contacted for database extracts related to groundwater.

SA Water — South Australian Water Corporation (Government of South Australia).

Surface water — (a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any another manner, (ii) or after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) that has been collected in a dam or reservoir.

Underground water (groundwater) — Water occurring naturally below ground level or water pumped, diverted or released into a well for storage underground.

WAP — Water allocation plan. A plan prepared by a CWMB or water resources planning committee and adopted by the Minister in accordance with Division 3 of Part 7 of the Act.

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