The Department of Water, Land and Biodiversity Conservation

Chowilla Anabranch System Surface Water Information Summary

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Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation

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Cover Photographs

H. J. Johnstone, Australia 1835-1907, *Evening shadows, backwater of the Murray, South Australia*, 1880, London or Paris, oil on canvas, 120.6 x 184.1 cm; Gift of Henry Yorke Sparkes. Art Gallery of South Australia, Adelaide (with permission June 2004).

Ian Overton, *A backwater on Monoman Island, Chowilla Floodplain*, March 2003, (© CSIRO, with permission June 2004).

FOREWORD

South Australia's water resources are fundamental to the economic and social wellbeing of the State. Water resources are an integral part of our natural resources. In pristine or undeveloped situations, the condition of water resources reflects the equilibrium between rainfall, vegetation and other physical parameters. Development of surface and groundwater resources changes the natural balance and causes degradation. If degradation is small, and the resource retains its utility, the community may assess these changes as being acceptable. However, significant stress will impact on the ability of a resource to continue to meet the needs of users and the environment. Degradation may also be very gradual and take some years to become apparent, imparting a false sense of security.

Management of water resources requires a sound understanding of key factors such as physical extent (quantity), quality, availability and constraints to development. The role of the Knowledge and Information Division of the Department of Water, Land and Biodiversity Conservation is to maintain an effective knowledge base on the State's water resources, including environmental and other factors likely to influence sustainable use and development, and to provide timely and relevant management advice.

Bryan Harris
Director, Knowledge and Information Division
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SUMMARY OF RECOMMENDATIONS

Flow

RIVER MURRAY

All salt load data using River Murray EC differences be based on flows at AW426200 (River Murray, D/S Rufus River) until such time as a more appropriate flow measurement is available.

The methods and techniques used to calculate flows at Lock 6 be reviewed with the aim of developing revised practices to increase the reliability and accuracy of flow data.

CHOWILLA FLOW TO RIVER MURRAY

An investigation take place to establish a suitable site and method for continuously measuring and recording flow in the lower reach of Chowilla Creek.

ANABRANCH SUBSYSTEM FLOWS

Flow gaugings continue to be made over a range of flow conditions at key sites including site numbers 2, 1D, 7B, 10, 18, 21, 26, 30, plus the lower reach of Chowilla Creek at Sites 31 and 36 combined or at Site 40 (see Appendix F for site locations).

Flows from salt load hot spots be measured under suitable conditions.

Wherever possible flow gaugings be taken at ‘standard’ locations.

All previous gaugings taken in the anabranch area be entered into Hydstra TS against appropriate Hydstra site identifiers and all new gaugings be entered against the appropriate site ID as standard practice.

The option of deploying continuous acoustic Doppler equipment at key anabranch sites be investigated.

Salinity and salt loads

RIVER MURRAY

EC profiles be taken at AW426704 and AW426705 at a range of flow conditions to confirm the salinity characteristics of the stream cross-section.

Daily EC readings at Lock 6 continue and DWLBC technical personnel provide support to SA Water personnel to ensure appropriate quality assurance.

EC profiles be undertaken at Lock 6 over a range of flow conditions.

LINDSAY RIVER ANABRANCH

Flow, salinity, salt load and level data for Victorian sites in the Lindsay–Mullaroo Anabranch system be sought from the appropriate authority on an ongoing basis.

CHOWILLA ANABRANCH SUBSYSTEM

Continuous salinity and flow recording equipment be installed at key anabranch sites including Site 20 on Punkah Creek and Site 21 on Slaneys Creek.

Continuous salinity and flow recording equipment be installed at Site 1C at the mouth of Salt Creek at Bank K.

EC profiles be undertaken at all continuously monitored EC sites over a range of conditions.

During flow and salinity studies, multiple depth EC samples be taken at all key salinity monitoring sites.

Elevations, water levels, bathymetry

A review be undertaken to determine the best level datum for the anabranch area, all historical level data be adjusted where necessary to conform to the adopted level system, and all existing gauge boards and water level recorders be adjusted to this same datum as necessary.

All available level data for anabranch inlet systems be collated and if necessary a new survey conducted to obtain up to date detailed data.

1 INTRODUCTION

The Chowilla Anabranch is one of the most important floodplain–wetland systems in Australia. The area, on the South Australia–New South Wales border and mostly to the north of the main River Murray channel (Figure 1), forms part of South Australia's Riverland Wetland of International Importance declared under the 1971 Ramsar Convention. It is one of six significant ecological assets under the Murray-Darling Basin Commission's Living Murray Initiative.

The 17,700 ha area is a unique remnant of lower Murray floodplain. It has not been intensively developed and it retains much of its distinctive natural character of high biodiversity value wetlands in a semi-arid environment.

The area has been the subject of numerous scientific studies and investigations since the mid-1960s when pastoral leases were acquired by the South Australian Government in preparation for constructing Chowilla Dam. The dam was never constructed but significant engineering, geological and soils studies formed part of the preliminary dam-site investigations.

These investigations led, in part, to the recognition of high levels of salinity emanating from Chowilla Creek into the River Murray following large flooding events. By the early 1970s surface water flow and salinity studies through the anabranch system were aiming to quantify salt loads and reveal the salinity processes within the floodplain area.

In November 1991 the Murray-Darling Basin Commission considered recommendations of the Chowilla Working Group for implementing an integrated management plan for the area (Sharley and Huggan 1995).

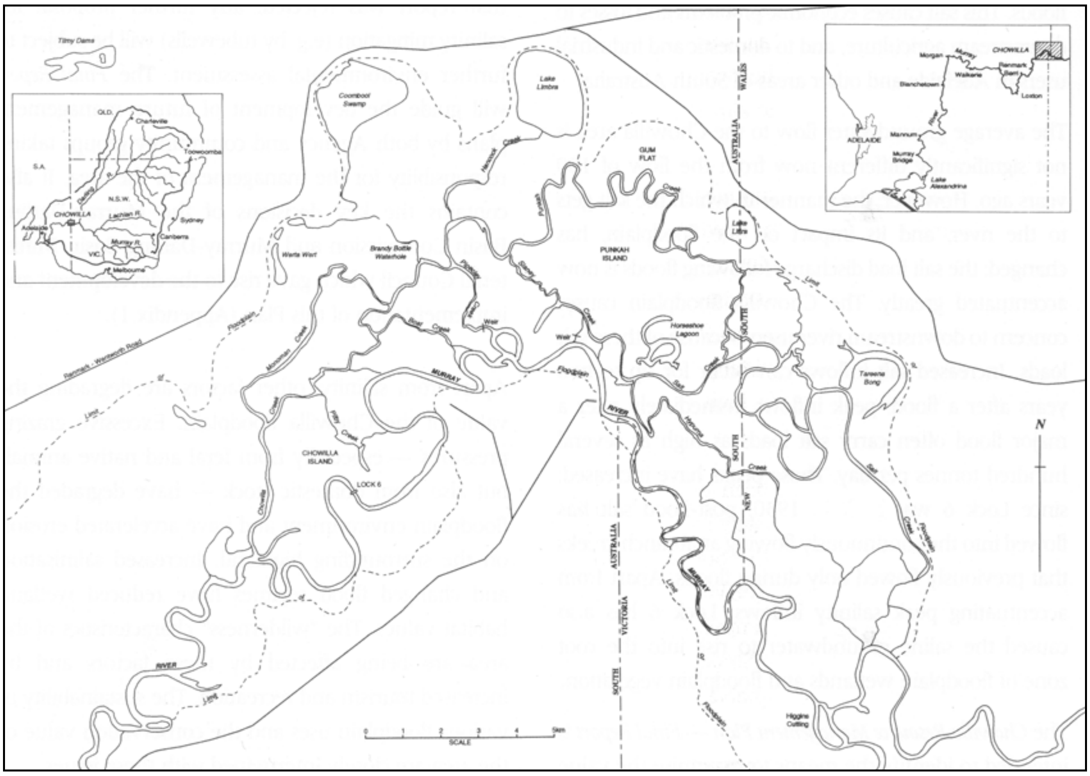


Figure 1 **Location of the Chowilla Anabranch (after Sharley and Huggan 1995).**

Since that time a wide range of scientific investigations and studies throughout the area has extended the understanding of its complex processes.

Together with the results of groundwater and other natural resource investigations, the surface water information compiled in this report will form the basis of planning for a range of environmental flow initiatives and salt interception scenarios that will help restore environmental values of the anabranch and manage salinity in the River Murray.

2 AIM

This report reviews surface water flow and salinity related investigations, studies and projects undertaken in the Chowilla Creek Anabranch from the early 1970s to present.

The revised results from this project are intended be used, in conjunction with groundwater information, to identify potential saline groundwater recharge areas and sources of surface salinity following floodplain inundation. This information will assist in the development of salt interception scheme designs.

Specific requirements of this project were to:

- collate historical data and reports
- identify major data gaps
- identify indicative salt load ranges
- identify indicative sources of these salt loads (recharge areas)
- make recommendations for addressing major data gaps.

3 METHODOLOGY

This report summarises previously collected surface water data and information, which were held in a variety of formats and systems. Most this material was collected by the Department of Water, Land and Biodiversity Conservation (DWLBC) River Murray Hydrometric Services Unit and stored in the Riverland office at Berri.

The initial task was to source and collate all available original data and other reference material. Some summary information had been entered into digital files but almost no detailed data was in digital format.

The data had to be stored digitally within a structure that would provide a mechanism to calculate salt loads and other required information. A spreadsheet was thus created to contain all available detailed flow, salinity and water level data. Almost all detailed data had to be entered from original hard copy field sheets. Once data was in the digital spreadsheet, it was checked and validated against original field sheets and other independent data sources where available.

All available data and data processing methods were reviewed and, where necessary, revised to ensure that all resulting information was produced using appropriate uniform methods.

Data in the spreadsheet was arranged to allow calculations of salt load for standard subsystems within the anabranch as well as the overall total anabranch. The spreadsheet was designed to produce the greatest number of component results from the available data while applying uniform processes.

The flow, salinity and salt load results produced are summarised in this report. They may differ from previously published results that had not undergone as rigorous a data validation process and may have been produced at different times using different data processing methods.

4 HISTORICAL DATA AND REPORTS

4.1 Information summary report

Smith (2003) compiled an up-to-date catalogue of published reports and datasets associated with surface water investigations in the Chowilla Anabranch area. The catalogue forms a precursor to this more detailed information of this project which includes a review and revision of the data.

4.1.1 HYDSTUDY SPREADSHEET

A major source of information is the spreadsheet file ***Hydstudy.xls*** (Smith 2003) produced by DWLBC River Murray Hydrometric Services around 1994 to summarise flow and salinity studies in the Chowilla system since 1972. This spreadsheet was also used to calculate total anabranch salt loads and anabranch segment salt loads for each study. The original detailed sources of this data include SA Water and DWLBC hard copy operational files, dockets, plans and photos most of which are located in the DWLBC Riverland office at Berri. The results produced with this spreadsheet formed the basis of previously published Chowilla Anabranch hydrology information (Sharley and Huggan 1995).

Hydstudy.xls summarised 37 studies undertaken between June 1972 and February 1991. A number of flow and salinity studies have been completed since then and a number of previously unrecorded early studies have also been identified.

Appendix A of Smith (2003) included detailed readings at individual monitoring sites from 1986 to 1991, information previously held only in hard copy format in project files at Berri. A digital copy of this appendix was combined with the original *Hydstudy.xls* file to form the basis of a single spreadsheet, ***Chowilla_Flow_&_Salinity_Studies_Data.xls***, containing all available detailed data for all flow and salinity studies to date (see Section 8.1 Detailed Dataset).

4.2 Additional reports

In the process of collating the available Chowilla Anabranch surface water information a number of additional reports not listed in Smith (2003) were located. These reports have been registered in the Surface Water Library (Appendix A).

CSIRO Land and Water (previously Division of Water Resources), located at the Waite Campus, The University of Adelaide, has also been involved in ongoing studies in the Chowilla Anabranch since the early 1990s. Of the numerous reports and journal articles published by CSIRO, a number related to surface water processes in the Chowilla area have been obtained and registered in the Surface Water Library (Appendix B).

For completeness a 'reference list' of Chowilla related publications produced by DWLBC, CSIRO and other sources as prepared by Stokes (2004) is included as Appendix C.

4.3 Digital datasets

4.3.1 HYDSTRA TIME SERIES

Hydstra Time Series (Hydstra TS) data management software is a technical data storage, processing and reporting system used by DWLBC to manage time series surface water data. It also holds detailed information about the monitoring sites at which time series data is collected and a range of other data and information associated with a site. Daily readings of water level and salinity and results of daily calculated flows made by SA Water operational personnel along the River Murray are stored in Hydstra TS as time series records. River Murray and Chowilla Anabranch flow gaugings made by DWLBC River Murray Hydrometric Unit personnel are also held in this system.

4.3.2 RIVERLAND REGIONAL FILES

Various other digital files containing Chowilla Anabranch flow, salinity, water level and other associated data are held on the Riverland Region, Berri office computer network (see Appendix D for a summary by subject).

5 TOTAL SALT LOAD TO RIVER MURRAY

One of the primary objectives of surface water investigations has been to quantify the total salt load emanating from the Chowilla Anabranch and entering the River Murray.

5.1 Calculation of total salt load using daily read EC data

Previously published salt load information (Sharley and Huggan 1995) was based on the difference between the electrical conductivity (EC; a measure of salinity levels) at Templeton, downstream (D/S) of Chowilla Creek, and the EC at Lock 6, upstream (U/S) of Chowilla Creek together with derived flow at gauging station AW426200, River Murray D/S Rufus River (see Figure 2).

Monthly average salinity and flow figures have been used to produce monthly average salt load rates representing the total contribution of the Chowilla Anabranch System.

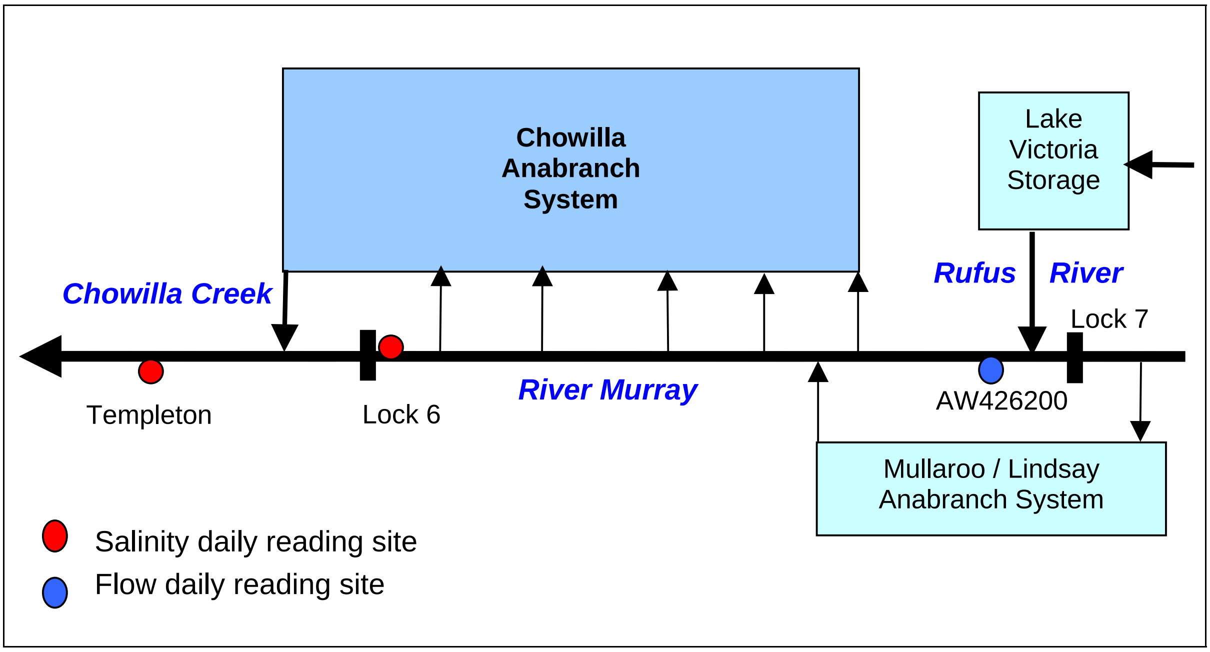


Figure 2 Salt load monitoring — Daily readings

A number of assumptions are implicit in the calculation of salt load using this data:

- Lock 6 U/S and Templeton daily EC reading must be a reasonable representation of the mean EC in the river cross-sections at those locations.
- Flow data derived at the gauging station AW426200 must be a reasonable representation of the total flow in the River Murray downstream of the confluence with Chowilla Creek.
- There is no additional salt load contributed by the Lock 6 to Templeton reach that is not emanating from Chowilla Creek.

5.1.1 DATA USED — DAILY EC READINGS

5.1.1.1 Templeton — AW426632 (602.9 km)

Daily read EC data is available in Hydstra TS from the start of monitoring on 5 November 1973 to the close of this site on 8 January 2003.

EC readings were generally made three times per week (Monday, Wednesday and Friday) by SA Water Lock 6 personnel or by DWLBC hydrographic personnel from Berri. The sampling point was located on the left (southern) bank of the River Murray downstream of Dix Cutting which tended to direct most flow towards the left bank providing good mixing.

EC profiles at this site show that the sampling location provided a good representation of average stream salinity at low to medium flows but was less representative at high flows (B Porter 2004, pers comm).

Routine daily EC readings stopped when a continuous EC probe at AW426704 D/S Chowilla Creek was established. Recent run-of-river surveys suggest that salt loads of 5–10 tonnes per day (t/d) were beginning to emerge from the southern side of the river between Lock 6 and Templeton (B Porter 2004, pers comm). Measuring downstream salinity of the Chowilla system at Templeton would thus overestimate the salt load contribution of the system.

5.1.1.2 Lock 6 Upstream — AW426510 (619.8 km)

Daily EC data is available in Hydstra TS from the start of routine EC readings by SA Water personnel on 2 November 1973 to the present.

Lock 6 personnel take an EC reading at this site seven days per week. Up to 5 February 1991 samples had sometimes been taken from the right bank (northern side) just upstream of the lock chamber; at other times they had been taken from a more central point on the weir. Samples from the bank are not considered representative of the whole cross-section of the stream as this is an area of non-flowing water, trapped upstream of the lock chamber gates. In addition saline groundwater discharge from the adjacent bank would be expected to increase salinity in the zone immediately next to the bank. No EC profile has been done at this site.

5.1.2 DATA USED — DAILY FLOW CALCULATION

5.1.2.1 River Murray D/S Rufus River — AW426200 (696.0 km)

Daily derived flow data is available in Hydstra TS from 5 April 1968, when the site began, to the present. Before this site was installed, flow figures were reported for ‘Downstream of Rufus River’ which was the sum of Lake Victoria outlet flow (through Rufus River) and Lock 9 (68 km U/S river distance) flow. This data, available in hard copy format in imperial units, is considered to be a poor representation of flow at this site due to the distance from the actual measurement locations and the associated travel time and flow attenuation.

AW426200 is operated by a contractor for a Victorian government agency on behalf of the MDBC. Flows derived from this site form the basis of the calculation of ‘Flow to SA’ (see

Section 5.1.2.2), the measure of River Murray flow into South Australia and the defined measurement of South Australia's entitlement under the Murray-Darling Basin Agreement (Murray-Darling Basin Commission 1992). SA Water Lock 7 personnel also take daily staff gauge readings from which the flow is derived using a stage–discharge relationship (see below) table provided by the D/S Rufus River site operator.

Previously published Chowilla Anabranch salt load data used the flow at gauging station AW426200 (Sharley and Huggan 1995) but it could be confused with the Flow to SA figure which is also derived daily. Flows calculated at AW426200 are only those of the main stream of the River Murray downstream of Rufus River. Another significant component of River Murray streamflow into South Australia is through the Lindsay–Mullaroo Creek Anabranch system, bypassing AW426200 and rejoining the River Murray just downstream of Salt Creek, the uppermost inlet to the Chowilla Anabranch (see Figure 3).

The actual volume of water entering South Australia (Flow to SA) across the South Australian–Victorian border is not directly measured but calculated daily using the flow at AW426200 plus the flow through the Lindsay–Mullaroo Anabranch together with an allowance made for losses and extractions in this anabranch (Section 5.1.2.2).

Streamflow

Flow data at this site is based on a stage–discharge relationship (or rating curve) derived from a series of flow gauging measurements (discharge) taken regularly at a variety of levels (stages) since the gauging station was established. The rating is generally considered to be reliable at low to medium flows but less reliable in high flows that extend beyond the main river channel which forms the stage–discharge control at this site.

Low flows at this site are affected by changing stream channel conditions, particularly stream bed sand movement; the relationship between stage and stream discharge also varies. A 'family' of stage–discharge relationships has been established for these changing conditions and frequent flow gaugings are required to check and adjust the stage–discharge relationship.

Flows at this site are also affected by discharge from Lake Victoria via Rufus River which enters the River Murray immediately opposite this site. High flows from Rufus River elevate water levels at the gauging station creating an inconsistency with the developed stage–discharge relationship.

Travel time to SA from Rufus River

AW426200 is 84 km upstream of the confluence with Chowilla Creek and yet when salt returns from the Chowilla Anabranch to the River Murray are cited, no allowance is made for flow travel times over this reach. The effect of not applying a correction for travel time would be most significant at times of rapidly changing flows, particularly immediately after a high flow event when flows drop very rapidly. This is unfortunately coincidental with periods of the highest salt load being emitted from the floodplain systems. Even using monthly mean intervals of data the salt load results can be compromised by the lag effect of the travel time.

No reliable travel time information is available for this reach but in entitlement (low) flows a rate of 1 km/day (d) would be expected for the lower reach adjacent to the Chowilla Anabranch and 3–4 km/d for the reach U/S of Chowilla (B Porter 2004, pers comm). This would mean that flow from the gauging station to the Chowilla reach could take approximately 20 days.

Evaporative losses

When used as the basis for calculating Chowilla Anabranch salt load increase to the River Murray no allowance is made for evaporation or other losses from the main stream of the River Murray between gauging station AW426200 and the Chowilla Creek confluence.

5.1.2.2 Flow to SA calculation

When the flow in the River Murray at AW426200 is **less than 26,800 megalitres (ML)/d** the flow in the Mullaroo Creek at gauging station AW414211 (see Figure 3) is added to the AW426200 flow and a volume of 250 ML/d for estimated losses and diversions in the Lindsay–Mullaroo Anabranch system is subtracted.

The Mullaroo Creek gauging station is located just upstream of Lock 7. Mullaroo Creek flows into the Lindsay River Anabranch system that rejoins the River Murray just upstream of the South Australian–Victorian border and downstream of Salt Creek the most upstream of the Chowilla Anabranch inlets (see Figure 3).

Flow data at Mullaroo Creek, AW414211, as used in the current Flow to SA calculation, began on 12 February 1977 and is derived from a stage–discharge relationship established over many years of flow gaugings. The rating is generally considered reliable at low to medium flow while it is contained within the stone embankment that forms the control at this site. This station is currently operated and maintained by a contractor for the Victorian Government. No continuous recorder is located at this site. A staff gauge is used to measure water level that is converted to a flow using the established stage–discharge relationship. SA Water Lock 7 personnel take daily gauge board readings used for the calculation of daily flows.

When flow in the River Murray at AW426200 is **greater than 26,800 ML/d** the flows for AW426200 are used and Mullaroo Creek flows are ignored.

Figure 3 provides a schematic diagram of the River Murray system and the components used to derive the Flow to SA volumes.

The daily flow formulas are:

Low flows (flow at AW426200 < 26,800 ML/d):

Flow to SA = ***flow @ AW426200 + flow @ GS414211 – 250 (ML/d)***

High flows (flow at AW426200 > 26,800 ML/d):

Flow to SA = ***flow @ AW426200 (ML/d)***

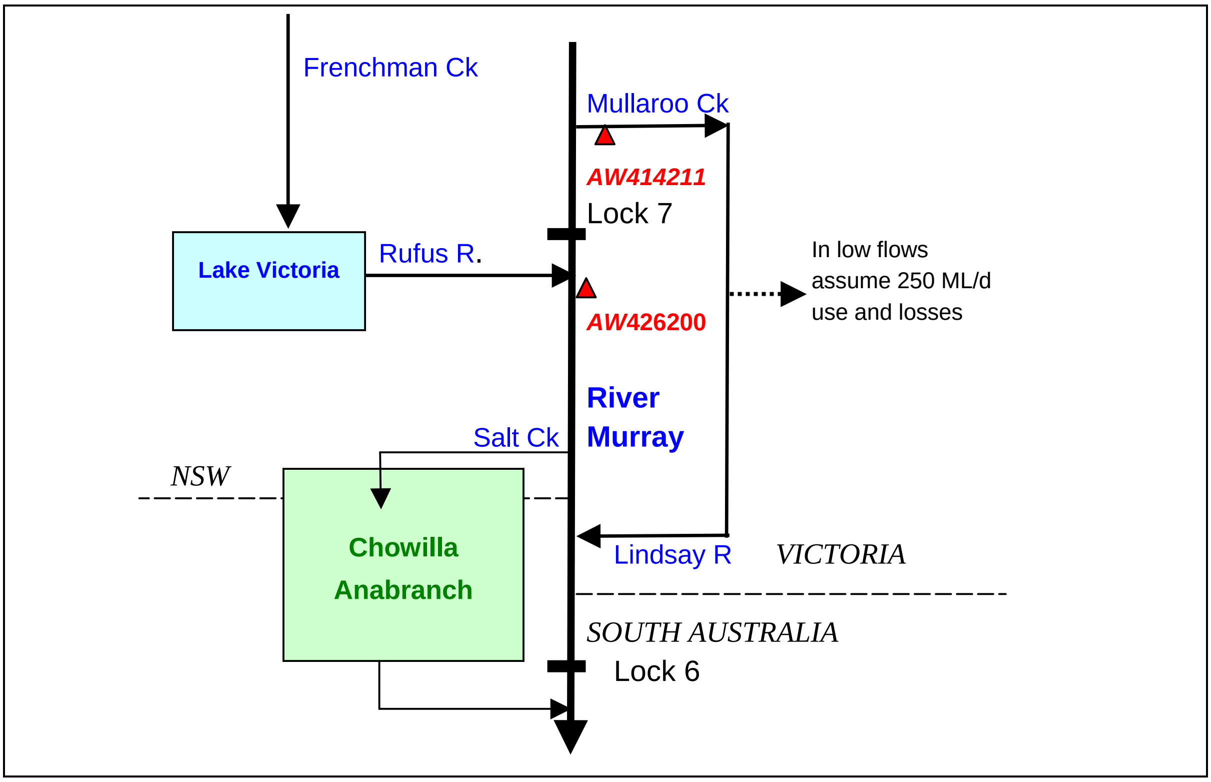


Figure 3 **Schematic diagram of Flow to SA components**

5.1.2.3 River Murray @ calculated flow to SA — A4261001 (virtual site at SA border)

Daily derived flow data is available in Hydstra TS from 12 February 1977 to present.

Before 12 February 1977 flow to South Australia was calculated by adding Lock 9 flow to Lake Victoria outlet flow.

5.1.3 SALT LOAD CALCULATION

Templeton and Lock 6 U/S daily EC data provides the best available historical data for calculating salt loads for the Chowilla system before February 2001 when continuous EC recorders were established (see Section 5.2.1).

However the selection of the most appropriate flow figure to be used with the daily read salinity data requires some further consideration. While the Flow to SA figure includes (at low ranges) an allowance for the Lindsay–Mullaroo Anabranch system it is based on the flow at gauging station AW426200 and thus includes within it all the poor characteristics of that location. Salt load figures derived from Flow to SA (A4261001) flow data, instead of gauging station AW426200 flow, were analysed as part of this project and it was found that their use increased the calculated salt load by +5% on average.

Before this project, the River Murray Hydrometric Services Unit calculated monthly mean salt load increase by using an Excel spreadsheet '**CHOWSALT.xls'** based on average monthly EC readings at Templeton and Lock 6 U/S, and flow at AW426200 extracted from Hydstra TS.

A review of base data stored in the Hydstra TS as part of this project found a number of missing periods in the Templeton EC dataset, generally around November–January. These missing periods skewed the monthly average figures produced by Hydstra TS, weighting the average figures on the readings before and immediately after the gap.

As these missing periods were generally times of higher flow the resulting salt loads could be significantly in error. Critical missing periods in the Templeton daily EC dataset were patched wherever possible using Lock 5 daily EC data as a guide. Adjustments were made for travel time and the expected EC increase between Lock 6 and Lock 5 by graphically overlaying the two datasets using Hydstra TS Workbench with appropriate comments and data quality codes inserted within the revised time series record. Figure 4 is a Hydstra HYXPLOT of Lock 5 daily EC verses Templeton daily EC showing a good correlation between the two sites particularly at lower EC ranges.

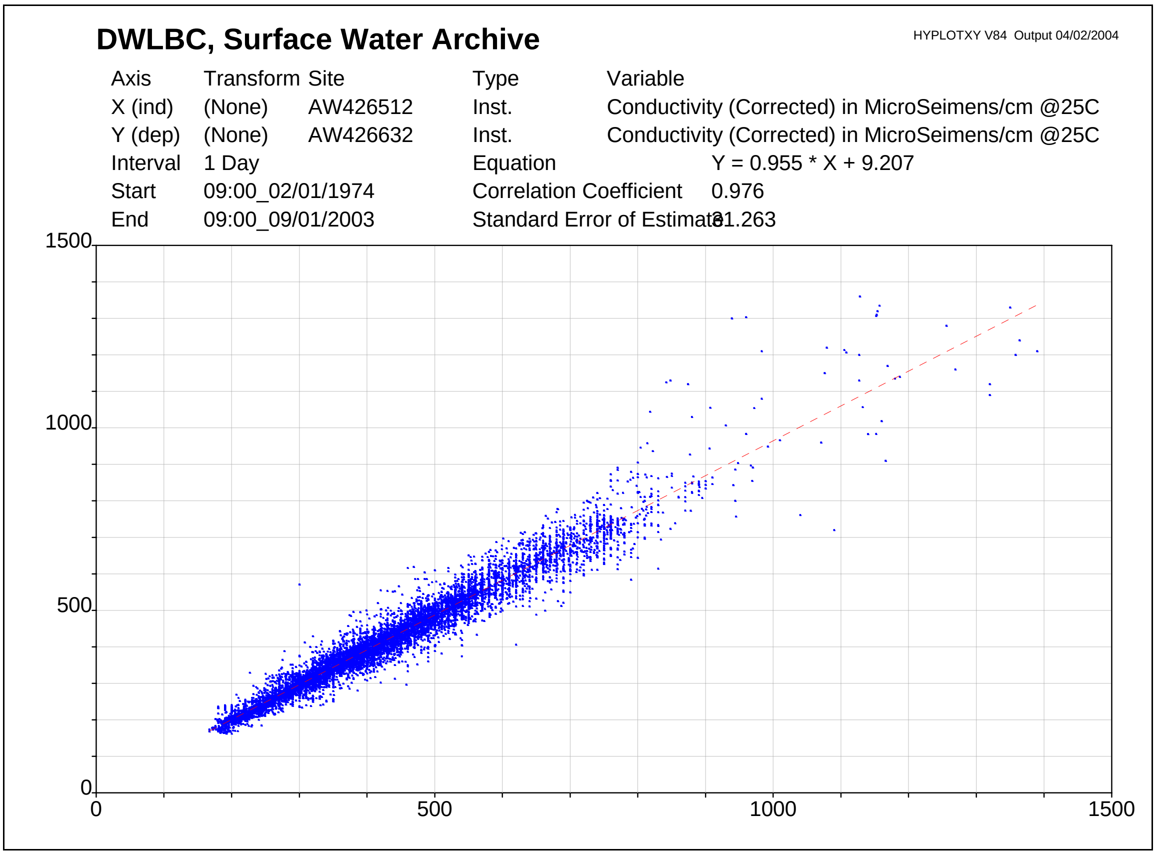


Figure 4 **Lock 5 (AW426512) daily EC vs Templeton (AW426632) daily EC**

A review of *CHOWSALT.xls* results found that earlier calculations of mean monthly figures had been manually averaging only figures entirely within a single monthly period. No account had been taken of the period after the last reading of a month and before the first reading of the next month. Templeton EC readings were spaced, at best, two to three days apart. If the EC had changed significantly in this disregarded period, the salt load figures would be incorrect (see Figure 5). The true monthly mean figure should include interpolated values forming the boundaries of the monthly period.

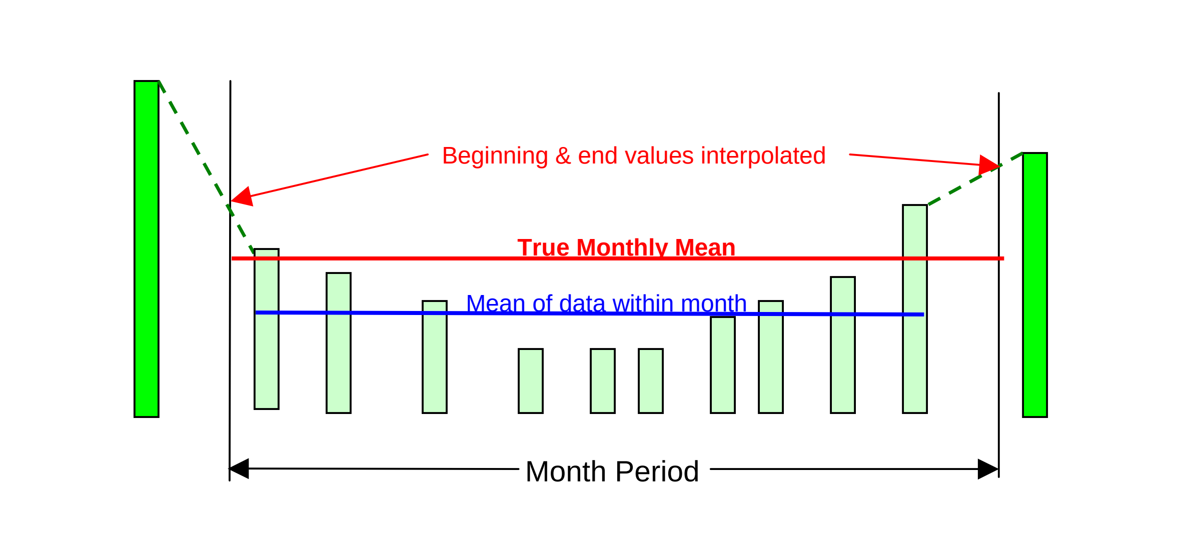


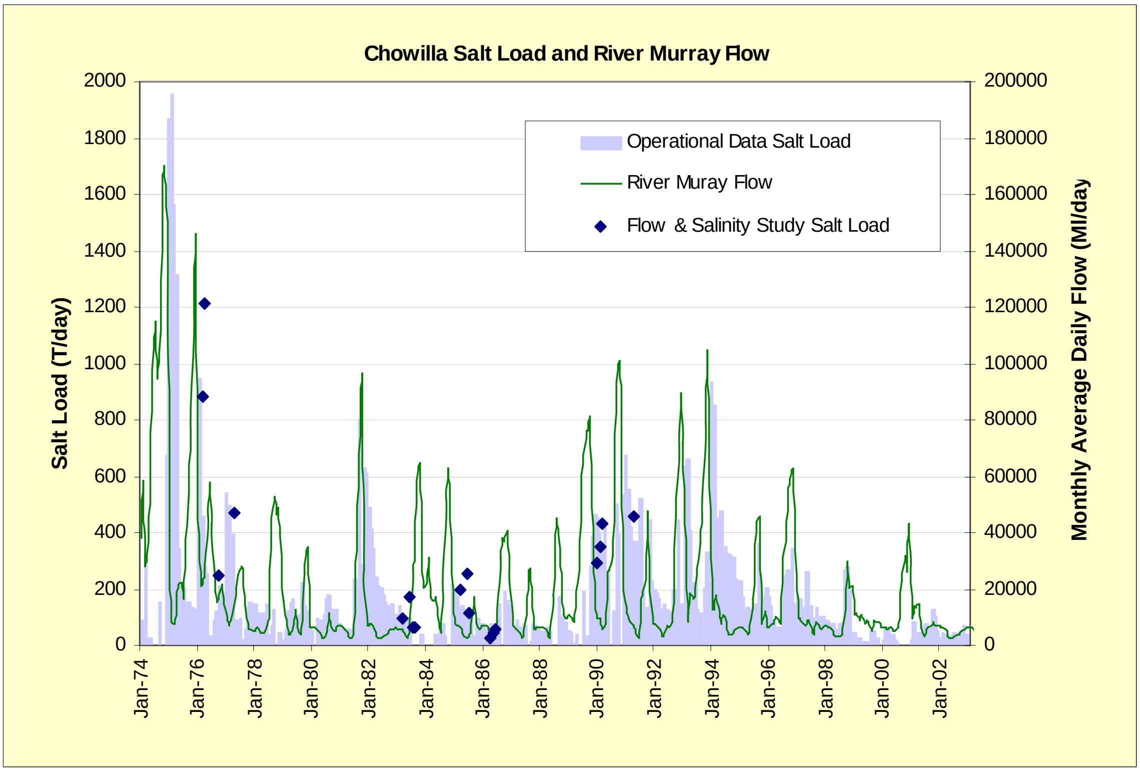
Figure 5 True monthly mean

A new spreadsheet '***Chowilla_Monthly_EC_Flow_Saltload.xls***' was produced to recalculate the salt load increase figures based on the revised and patched Hydstra TS EC data using a standard methodology. Monthly mean EC and flow figures were extracted from Hydstra TS using the true monthly mean method (see Figure 5). As expected the combination of the patching and recalculated monthly means produced some differences in salt load results between the original spreadsheet and the new spreadsheet. The most significant difference was that, following the 1994 flood, the value of the peak salt load increased from 1803 t/d to 1954 t/d. The general pattern and scale of the salt load increase, however, did not significantly change (see Figure 6) and overall average figures remained similar (Table 1).

Table 1 Salt load increase summary stats — December 1973 to December 2002

Parameter	Measurement	Unit	Date
Maximum EC difference (Templeton–Lock 6)	427	EC	February 1975
Median EC difference (Templeton–Lock 6)	19	EC	
Mean EC difference (Templeton–Lock 6)	31	EC	
Maximum flow at AW426200	169,717	ML/d	November 1974
Minimum flow at AW426200	2,386	ML/d	June 1982
Maximum salt load	1,954	t/d	February 1975
Median salt load	100	t/d	
Mean salt load	149	t/d	

All figures are for averaged monthly periods.



Note: The peak salt load increase occurred immediately following the 1974 high flow.

Figure 6 Chowilla salt load increase and River Murray flow Dec 1973–Dec 2002

5.1.4 SALT LOAD RECESSION

A modelled salt load recession curve following both 100,000 ML/d and 60,000 ML/d events was included in Sharley and Huggan (1995, p 101). It was based on flow and salinity study results up to 1993 and suggests a base load of about 50 t/d.

The salt load recession that followed the October 1981 high flow of 105,000 ML/d provides the best example of actual 'recorded' salt load recession data. The monthly mean salt load peaked at 800 t/d in October 1981, falling to 60 t/d in May 1983, 21 months later, just before another high flow began (see Figure 7).

Analysis of a number of actual salt load recessions, including the 1981–1984 event, suggest a base load of 50 t/d being reached after 4 years of constant recession, provided no additional intervening flow events occurred (see Figure 8). Salt loads since the high flow event (above 60,000 ML/d) of late 1998 to late 2002 indicate a steady state base load of about 40 t/d towards the end of this period.

A salt load of 40–50 t/d appears to be an appropriate range for the steady state base load given the level of uncertainty of the monthly mean salt load dataset.

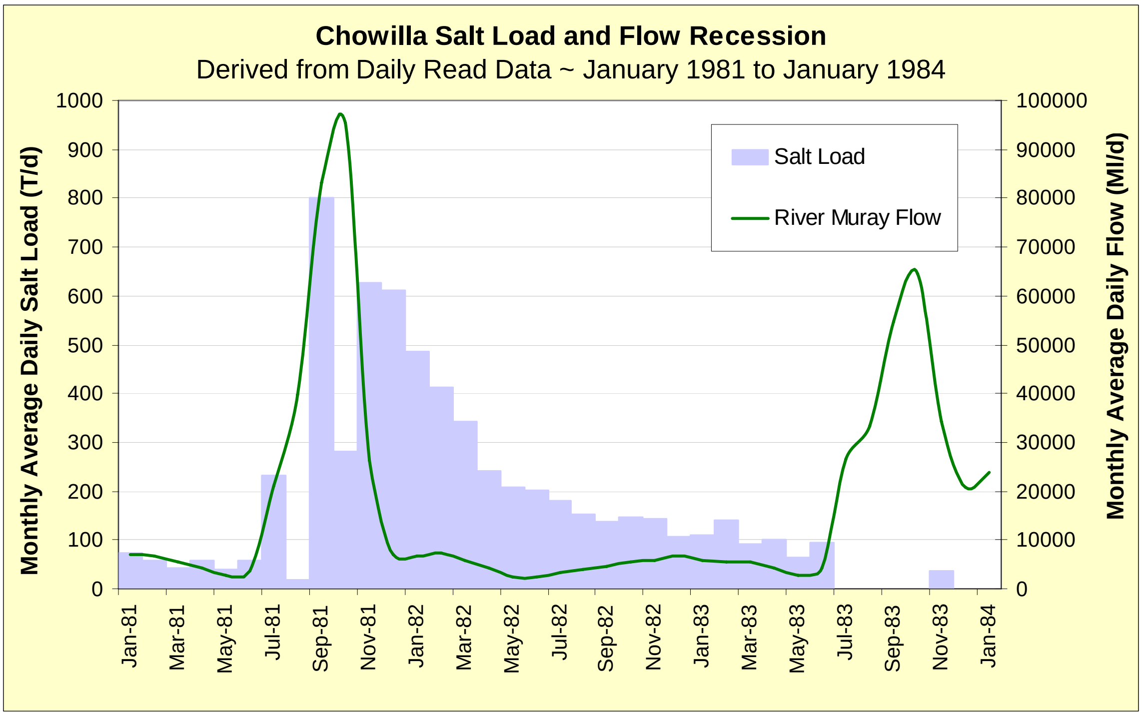


Figure 7 Salt load recession 1981–82

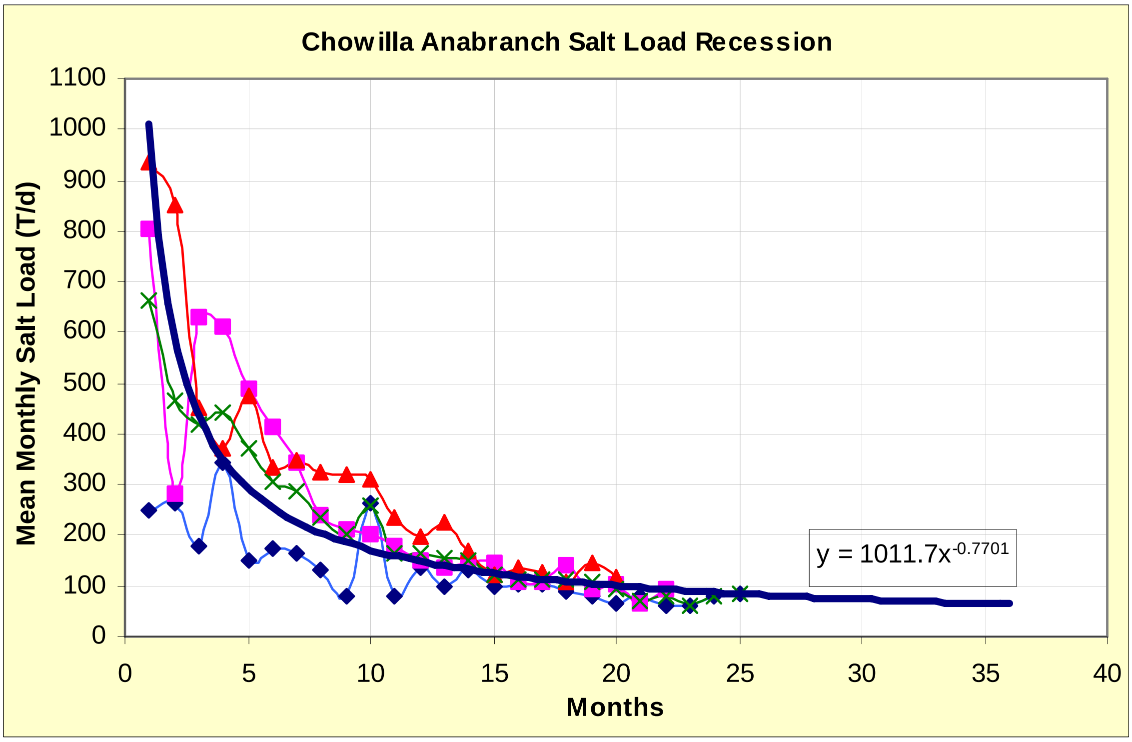


Figure 8 Salt load recession curve

5.2 *Calculation of total salt load using continuous EC data*

5.2.1 CONTINUOUSLY RECORDED EC DATA

In February 2001 two new continuously recording salinity monitoring sites were established specifically for the purpose of monitoring the increase in EC in the River Murray resulting from the Chowilla Anabranch. The sites are located in the River Murray 0.3 km upstream (AW426705) and 4.0 km downstream (AW426704) of the confluence of Chowilla Creek and the River Murray (see Figure 9).

These sites consist of an EC sensor and data logger mounted on a floating pontoon positioned midstream (see Figure 10). Before the sites were established, EC profiles were used to determine their suitability for representing the whole stream cross-section.

River Murray D/S Chowilla Creek — AW426704 (609.0 km)

Continuously recorded EC data is available in Hydstra TS from 15 February 2001 to present.

River Murray U/S Chowilla Creek — AW426705 (612.3 km)

Continuously recorded EC data is available in Hydstra TS from 15 February 2001 to present.

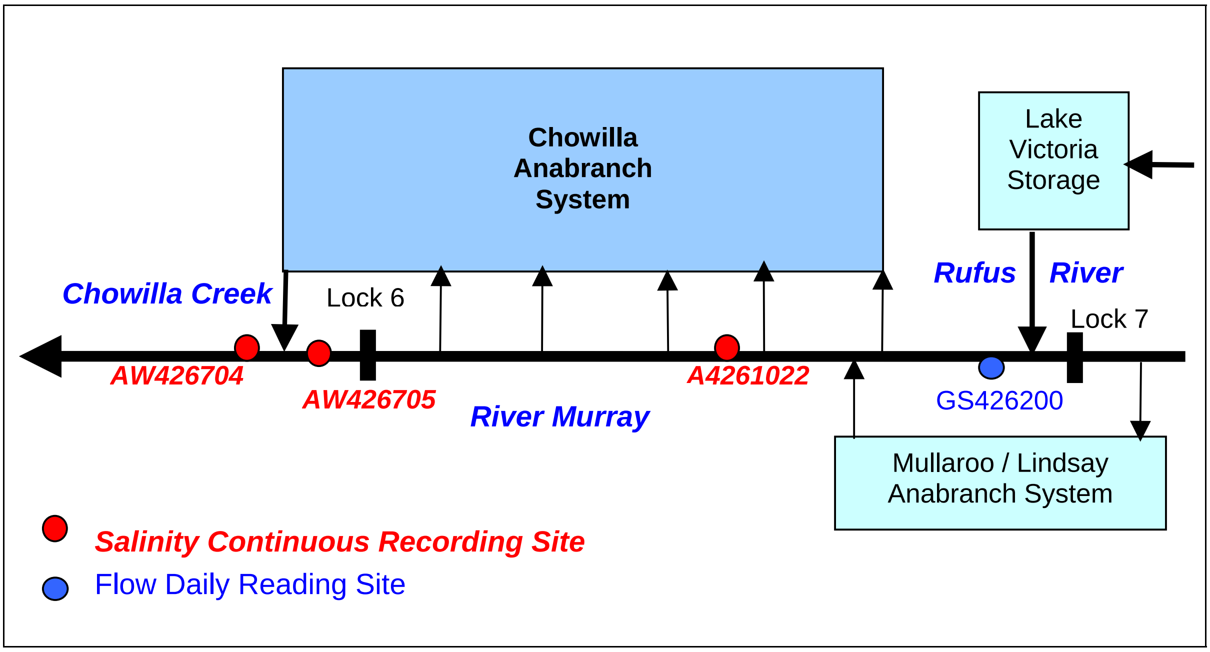


Figure 9 **Salt load monitoring — Continuous EC recorders**

Figure 10 A4261022 continuous EC recorder pontoon

An EC recording pontoon was also established in the River Murray just downstream of the SA–Victoria border (AW4261022) in August 2002 (see Figures 9, 10). This site was positioned principally to monitor the salinity of water crossing the border into SA. Being close to the upper end of the Chowilla reach, it also provides an indication of the salinity of water entering Salt Creek and Hyperna Creek from the River Murray. It is, however, downstream of Lindsay River and will therefore include any salt load, and associated EC increase, originating from the Lindsay–Mullaroo Anabranch (see Figure 9).

Murray R U/S Old Customs House — A4261022 (637.1 km)

Continuously recorded EC data is available in Hydstra TS from 8 August 2002 to present.

5.2.2 CONTINUOUS RECORDED EC COMPARED TO DAILY READ EC

Monthly mean EC measured at the pre-existing daily EC reading site was compared with the new continuous recording locations in the *Chowilla_Monthly_EC_Flow_Saltload.xls* spreadsheet (see Appendix E for a summary).

A review of data from these sites shows the following:

- The new continuous recorder site downstream of Chowilla Creek varies from the Templeton daily read site, 6.1 km downstream, by +7 to –18 EC averaging –1 EC. The large EC differences in October–November 2001 are due to poor or missing data at Templeton.
- The new continuous recorder site upstream of Chowilla varies from the Lock 6 U/S daily read site, 7.5 km upstream, by +24 to +1 EC averaging +11 EC. The rise in EC between these two locations is supported by run-of-river studies (B Porter 2004, pers comm). Salinity can be expected to rise immediately downstream of a weir because the head of groundwater it creates induces saline seepage immediately downstream of the weir.
- The new continuous recorder site U/S of the Old Customs House (at the SA–Vic border) varies from the Lock 6 U/S daily read site, 17.3 km downstream, by +20 to –10 EC averaging +7 EC. Some increase can be expected over this distance but the period of mutual data is currently too short to draw any specific conclusions.

The effect of using monthly mean EC data based on the continuous recorders in place of the daily read sites is a decrease in salt load ranging from –4 t/d to –94 t/d averaging –30 t/d (–61%) for the period of mutually available data.

This difference is mainly due to the increase in EC between Lock 6 and the new U/S Chowilla continuous recorder site. Using the continuous recording sites excludes the reach immediately downstream of Lock 6 and the associated salt load. However, the period of mutual record is only 22 months from March 2001, a period of continuous low flows (average 6100 ML/d), and low salt load increase (average 19 t/d) and a longer period of more variable conditions is required to make any meaningful comparisons.

The site at Templeton was abandoned in January 2003 but daily readings have continued at Lock 6 U/S. A longer period of comparing the new continuous recorder U/S Chowilla and Lock 6 U/S daily EC data is needed so that historical salt load data based on daily EC readings can be adjusted to supplement the new continuously recorded EC dataset.

5.3 Preliminary uncertainty analysis in daily EC data

Anecdotal evidence suggested that historical daily data used to calculate salt loads generated by the Chowilla Anabranch was prone to large uncertainties and may not be appropriate for estimating salt returning to the River Murray for modern assessment and reporting purposes (P Stace 2004, pers comm).

A preliminary analysis of two key daily datasets, Lock 6 U/S and Templeton, attempted to quantify the uncertainty associated with daily salinity data and to provide a clearer perspective on the wider historic and modern River Murray hydrometric dataset collected by operational (SA Water) personnel.

5.3.1 PROCEDURE

The two datasets (only 1975–1996 available in Hydstra TS) were first tested to reveal if they were statistically different. If the data proved statistically indistinguishable then they could not be used to confidently estimate salt tonnage from Chowilla. Uncertainties in the data were quantified using advice from an appropriately experienced field technician and compound uncertainties were derived using standard techniques. Flow from D/S Rufus River was then analysed to investigate possible associations between frequency of flow events and EC uncertainty. All data and analyses are contained in the attached computer file ***EC_Uncertainty.xls***.

5.3.1.1 Statistical analysis

The Lock 6 and Templeton EC datasets were tested for similarity using Chi-Squared and Kolmogorov-Smirnov tests as described in Press *et al* (1999).

5.3.1.2 Uncertainty in EC estimates

Estimates of the uncertainties associated with the most significant aspects of salinity data collection at Templeton and Lock 6 U/S were quantified by Mr Peter Stace, a qualified hydrographer with 30 years experience, 10 years supervising River Murray hydrographic operations (see Table 2).

Estimations were made of the systematic errors associated with how closely the EC value recorded at the monitoring site represented the average EC across the river cross-section, and the random errors inherent in instrument specifications and operator error (Quality Assurance).

Uncertainty in River Murray streamflow at D/S Rufus River was also estimated (Table 3) but project time constraints did not allow further analysis. The data is only presented here to highlight issues and the need for similar work elsewhere along the River Murray.

5.3.1.3 Combination of EC errors

Random and systematic error estimates were combined into an overall uncertainty estimate using a root sum of squares procedure as described in Australian Standard AS 3778.4.6–1991 (Standards Australia 1991, section 10.6) and Bos (1989). Total uncertainty was equated to the square root of the combined squares of all random and systematic errors (see below).

$$X_{ECSystematic} = \pm (X_{Profile}^2 + X_{InstSpecs}^2)^{½}$$

$$X_{ECRandom} = \pm (X_{QA}^2)^{½}$$

The single random error (Quality Assurance) makes combination of errors straightforward.

$$X_{ECTotal} = \pm (X_{Systematic}^2 + X_{Random}^2)^{½}$$

$$= \pm (X_{Profile}^2 + X_{InstSpecs}^2 + X_{QA}^2)^{½}$$

$X_{ECRandom}$ = Total random errors identified in Table 2.

$X_{Systematicl}$ = Total systematic errors identified in Table 2.

$X_{ECTotal}$ = Total uncertainty in EC measurement.

5.3.1.4 Flow frequency

Salt returns from Chowilla are a function of River Murray streamflow (Sharley and Huggan 1995; Section 8 this report). At *normal* flows the difference between EC data at Lock 6 and Templeton tends to be small and any uncertainties are likely to be relatively large. Variations in EC uncertainty were reviewed with different flows events by completing a standard frequency analysis of D/S Rufus River streamflow data (see Section 2, Pilgram 1998).

5.3.2 RESULTS AND DISCUSSION

5.3.2.1 Statistical analysis

Plots of the Chi-Squared and Kolmogorov-Smirnov tests are shown in Figures 11 and 12 respectively.

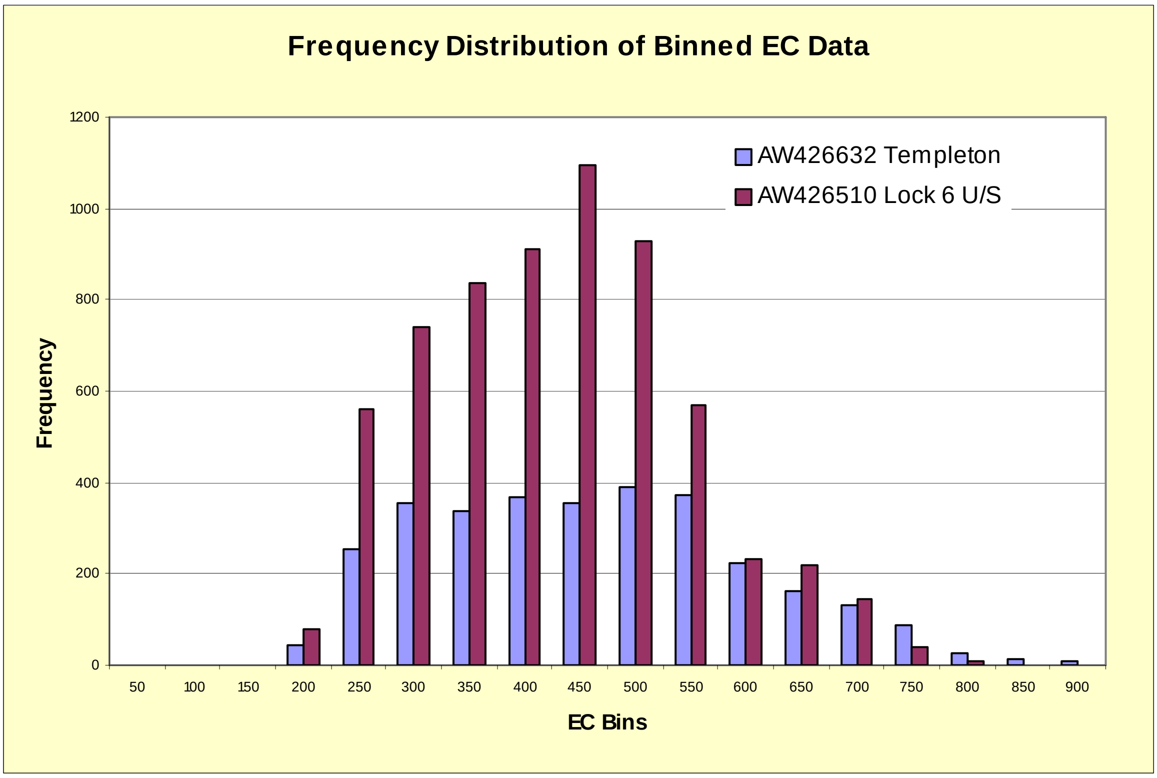


Figure 11 **Binned Chi-Squared EC frequency data**

Lock 6 (6365 points) and Templeton (3122 points) datasets had sufficiently large numbers of points to produce robust Kolmogorov-Smirnov frequency distributions, while the Chi-Squared test was configured for datasets with different sample size (Press *et al* 1999).

Both the statistical tests indicated that as complete datasets both represented different distributions at a high level of significance ($\alpha < 0.01$). This would suggest that the historic datasets were sufficiently different in character to be used in estimating salt returns.

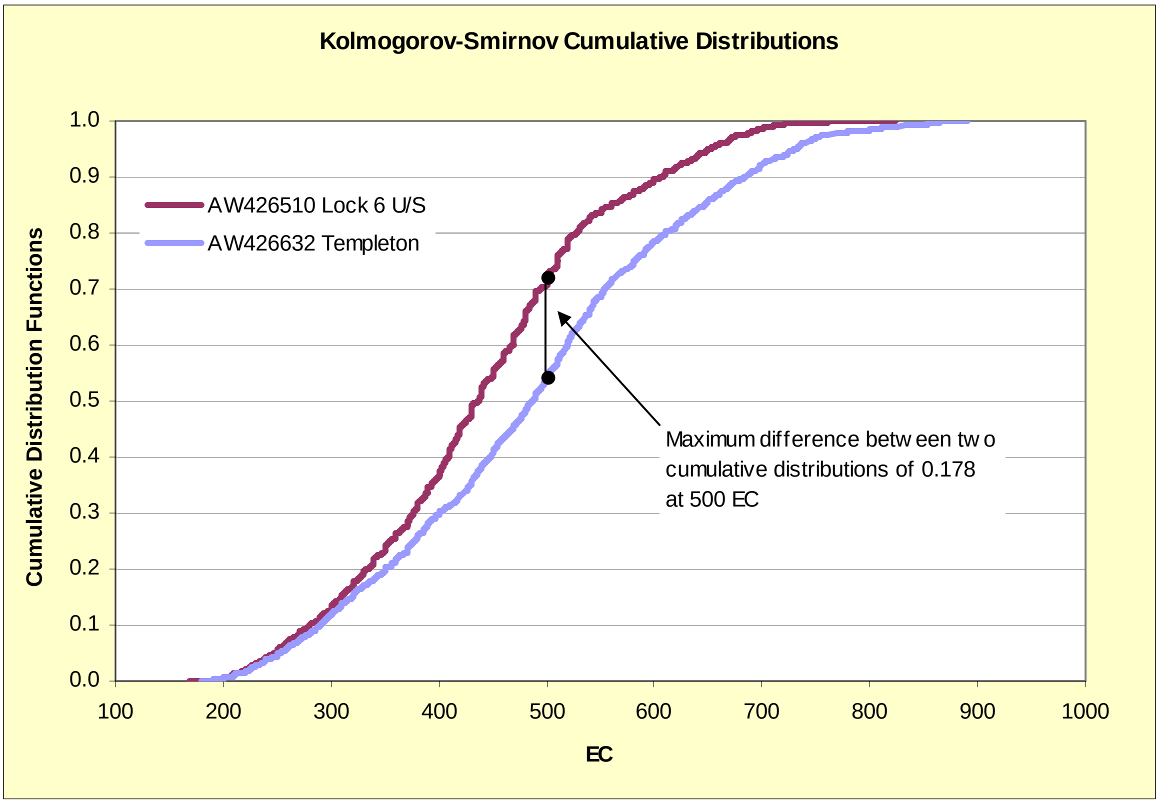


Figure 12 Cumulative K-S EC frequency data

5.3.2.2 Uncertainty estimates

Estimates of the uncertainties associated with the most significant aspects of salinity data collection at Lock 6 and Templeton are shown in Table 2. The size of the error estimates is considered conservative.

Lock 6 data is expected to contain a significant systematic uncertainty to 1991 when many readings were made adjacent to the river bank, a site that could reasonably be expected to vary from the average EC across the river by at least 15% (P Stace 2004, pers comm). After 1991 a more suitable site was chosen in the middle of the river that would not be expected to vary from the average river EC by more than 5%.

Instrument errors are simply a historical reality associated with technical developments over the years. Before about 1985, a Kent Bridge meter could be expected to deliver an estimate of the sample EC to within 10%; modern instruments are much more precise (within 1%).

Random errors arise when poorly trained officers take measurements. With more training in quality managed hydrographic methods, operational technicians can improve the quality of the data collected. Without it, great variations in data are possible as are poorly calibrated or maintained instruments, and inappropriate operation or techniques. All the data analysed was collected by operational personnel with limited hydrographic training with a conservative uncertainty of 5%. In practice this figure may range up to 20%.

Table 2 Uncertainty estimates of Lock 6 U/S and Templeton EC data

SITE	PROFILE[1]	INSTRUMENT SPECS[1]	QUALITY ASSURANCE[2]	COMMENTS
Lock 6 Upstream	up to ± 15% to 5/2/1991± 5% (400 EC = 380-420 EC)	± 10% to 1985	5% – limited operational QA	Kent Bridge EC meter to 1985; EC sampled on unrepresentative site on river bank to 1991
	± 5% after 5/2/1990	± 5% 1985 1990	2% – managed hydrographic QA	
		± 1% after 1990		
Templeton	± 5%	± 10% to 1985	5% – limited operational QA	Kent Bridge EC meter to 1985
		± 5% 1985 1990	2% – managed hydrographic QA	
		± 1% after 1990		

1 systematic error

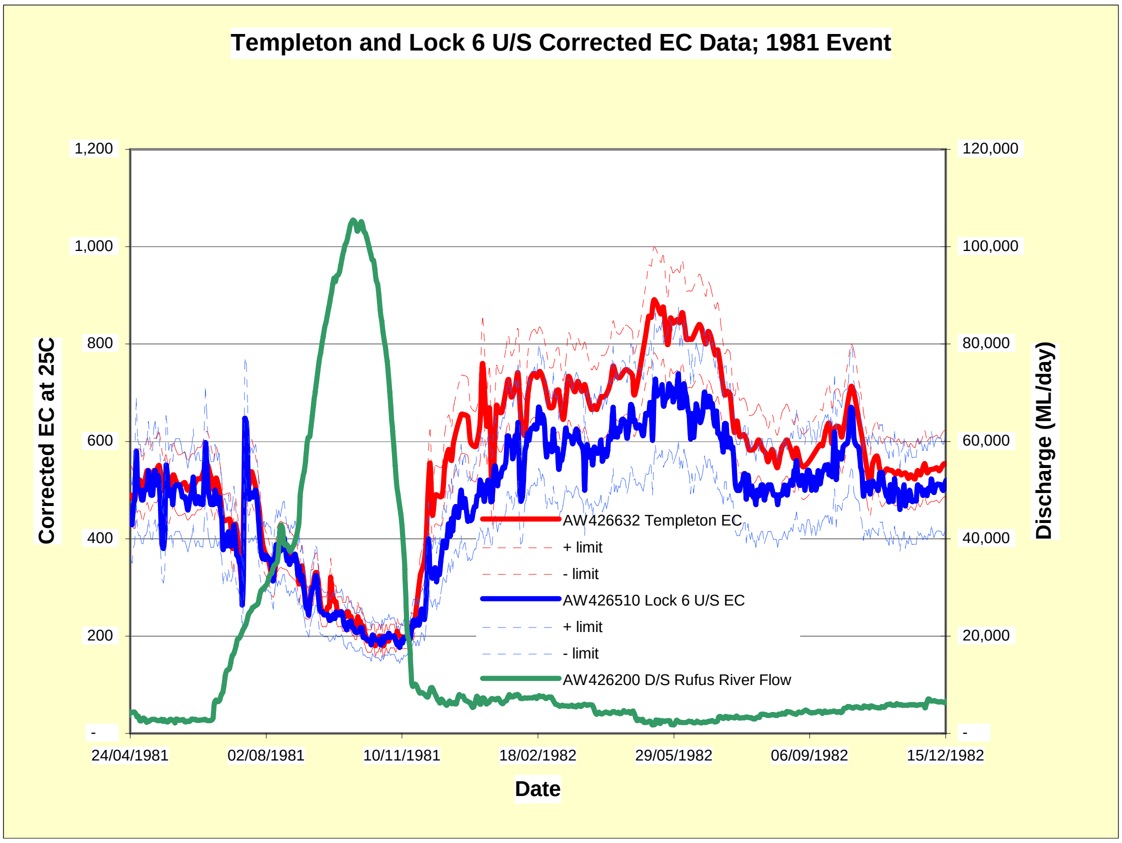
2 random error

Table 3 Uncertainty estimates of flow data

SITE	FLOW RANGE	SITE[1]	STAGE[1]	INST SPECS[1]	RATING[1]	TRAVEL TIME[1]	QUALITY ASSURANCE[2]
River Murray D/S Rufus River flow	Within channel flows up to 40,000 ML/d	± 5%	± 20 mm	± 15%	± 3%	± 10%	± 5% – limited operational QA
	Within channel flows >40,000 ML/d	± 10%	± 20 mm	± 15%	± 10%	± 10%	± 5% – limited operational QA

1 systematic error

2 random error



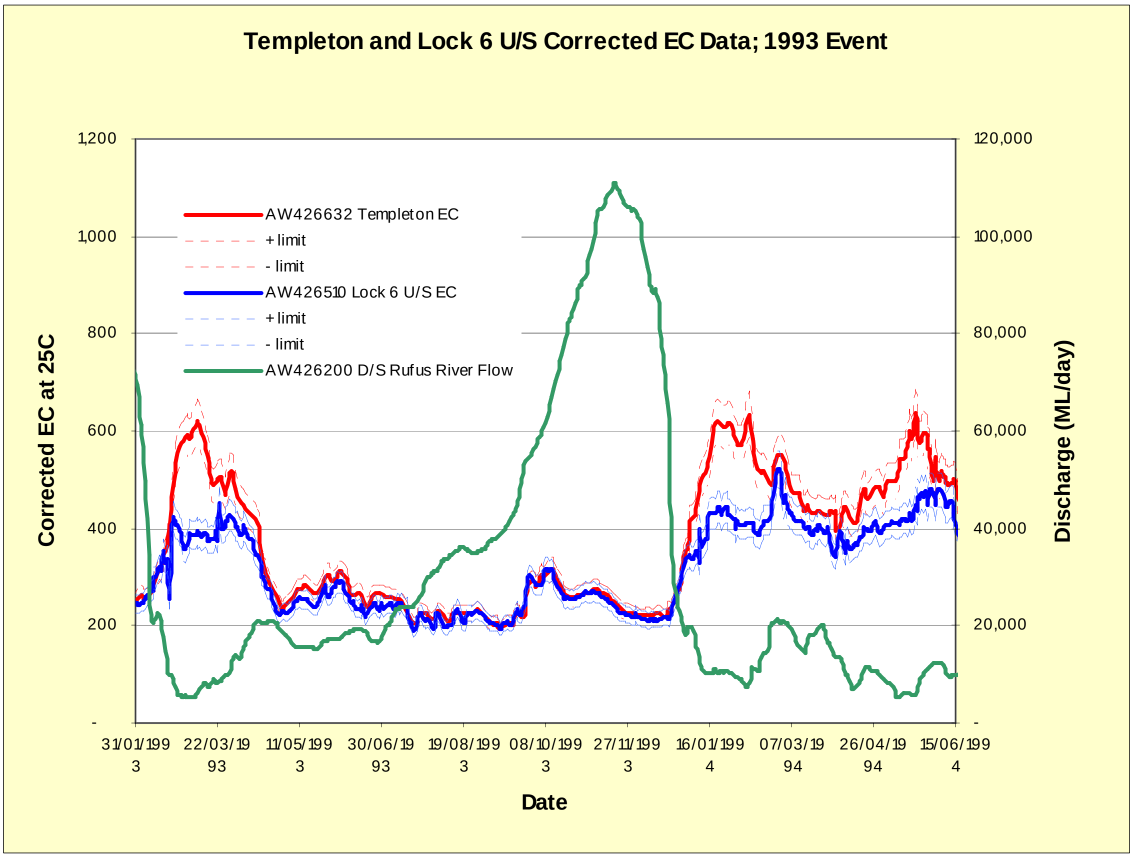


Figure 13 **River Murray streamflow and Lock 6 & Templeton EC for two flood events**

The plot of the flow from D/S Rufus River and EC with uncertainty error bars (Figure 13) in 1981 and 1993 shows the reduction in the uncertainty range with improved monitoring over time. However, despite statistically significant differences between the Lock 6 and Templeton datasets as a whole (see above), they only show resolution beyond a common uncertainty range and into distinct datasets following River Murray streamflow events of at least 30,000–40,000 ML/d (Figure 13).

This would suggest that difficulties may be expected when using daily data to estimate salt loads from Chowilla, under in-channel flow conditions, typically less than approximately 35,000 ML/day (Sharley and Huggan 1995, pp 92–94). This reinforces the comments made in Section 5.1 on the data quality of the two EC datasets, River Murray streamflow D/S of Rufus River (see also Table 3) and issues with base salt load estimation using daily data.

5.3.2.3 Flow frequency

In the frequency plot of River Murray streamflow D/S Rufus River for the period investigated (Figure 14), the two red lines mark the flow range 30,000–40,000 ML/d. This range has been identified as the level at which Lock 6 and Templeton EC data becomes sufficiently resolved from uncertainty estimates to produce reliable salt load estimates.

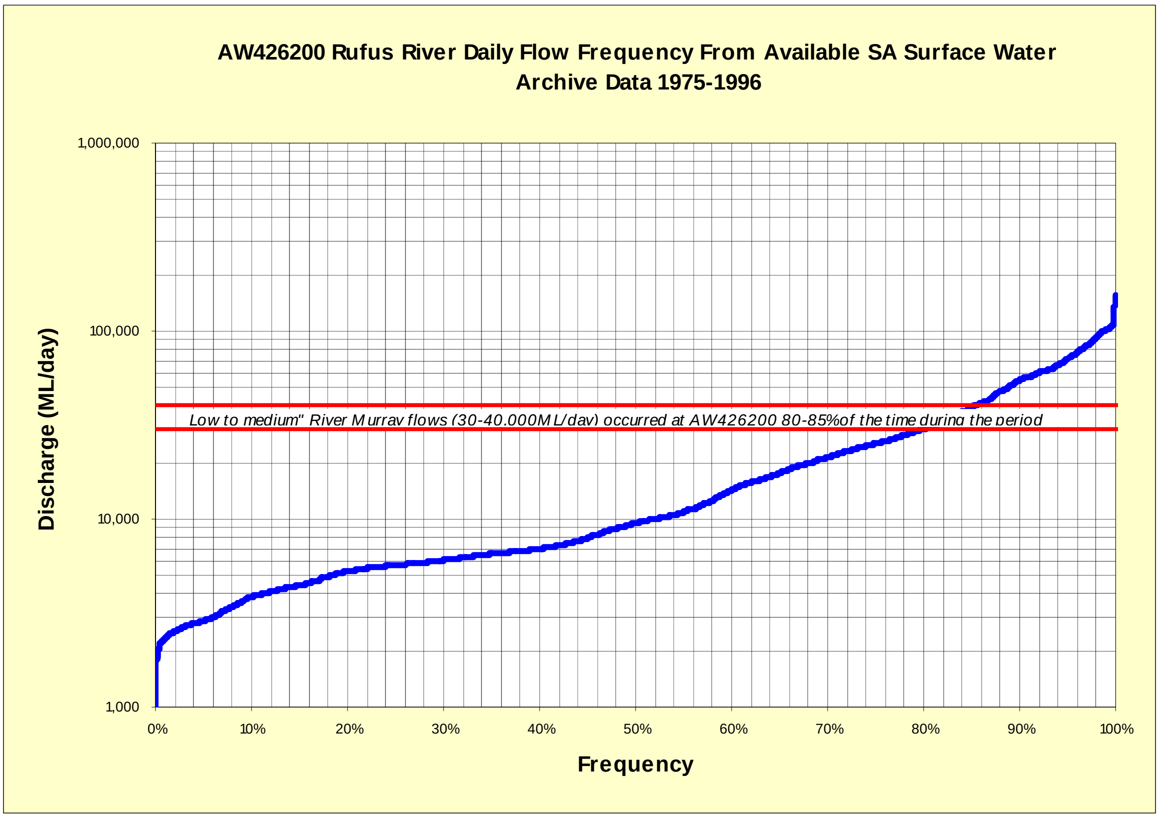


Figure 17 River Murray D/S Rufus River streamflow frequency 1975–1996

For the period 1975–1996, streamflows were less than or equal to 30,000–40,000 ML/d for 80–85% of the time. This would suggest that base salt load estimation from Chowilla may be considered unreliable for that period.

5.3.3 CONCLUSIONS AND RECOMMENDATIONS

Daily EC data at Lock 6 and Templeton is least affected by uncertainties in monitoring techniques following flood events of greater than 40,000 ML/day, which generate salinities greater than 500 EC for recession periods of up to a year.

While the Chi-Squared and Kolmogorov–Smirnov tests indicated that as entire datasets Lock 6 and Templeton are sufficiently distinct to make meaningful salt load estimates from Chowilla, compounded uncertainty in daily EC monitoring techniques suggest that these estimates may be unreliable for 80% of the period between 1975–1996.

The uncertainty could easily be greater considering the data quality issues presented in Section 5.1, including misaligned EC data collection at Lock 6 and Templeton, and inherent problems in River Murray flow estimation.

It is recommended that all hydrological analysis, especially those using daily data, routinely include a similar analysis to that described here.

5.3.3.1 Recommended improvements to the method

- Expand the statistical analysis for difference on the paired EC datasets into different flow regimes. Analyse the EC data associated with both in-channel and over-bank flows (above and below approximately 35,000 ML/d) with particular regard for the periods before and after floods.
- Quantify uncertainty in River Murray flows at Chowilla and combine it with EC errors to produce a direct estimate of uncertainty in salt loads.
- Complete a similar analysis of uncertainty for continuously collected data, with appropriate consideration for the different nature of the data.
- Measure hydrological parameters directly and continuously wherever possible to minimise uncertainty. Select appropriate equipment prudently and deploy it carefully in full consideration of the characteristics of available sites. Operate and maintain equipment systematically, preferably according to quality assurance principles, to ensure maximum possible reliability in the data.

6 CHOWILLA CREEK FLOW

6.1 Calculated flow

Determining the total volume of River Murray flow passing through the Chowilla Anabranch under varying river conditions is critical to understanding the characteristics of the floodplain systems. Previous published material (Sharley and Huggan 1995) attempted to quantify the volume of flow through Chowilla by subtracting the monthly mean of daily calculated flow at Lock 6 from monthly mean of daily calculated flow at gauging station AW426200 (D/S Rufus River). Figure 15 shows the estimated flow and percentage of River Murray flow passing through the Chowilla Anabranch compared to River Murray flow at AW426200 and Lock 6 from January 1995 to July 2003. During high flow periods when the weir is removed, flow data for Lock 6 is not available and flow through the Chowilla Anabranch cannot be calculated.

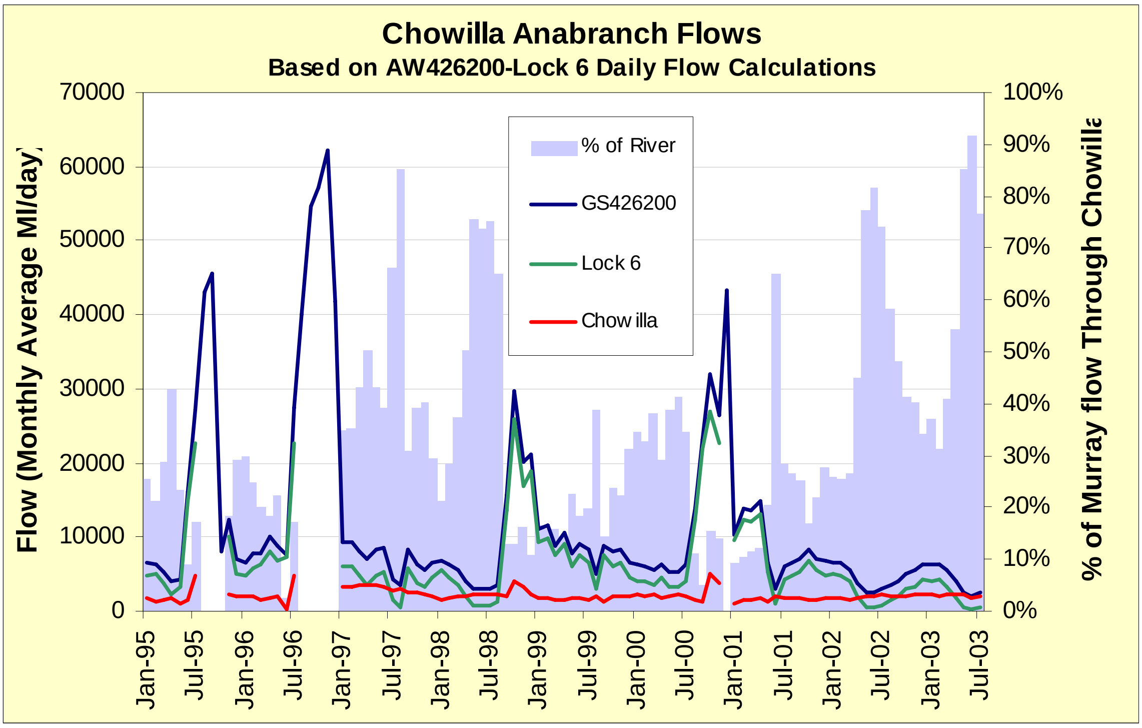


Figure 15 **River Murray flow through Chowilla Anabranch**

Comparing the calculated percentage of River Murray monthly mean flow passing through Chowilla against the total monthly mean flow in the river (Figure 16) shows that, at low flows, most water flows into the anabranch, bypassing Lock 6. Up to 90% of total River Murray flow can pass into the anabranch in very low river flow conditions (< 2500 ML/d). By contrast only 10% of the total river flow bypasses through the anabranch in higher river flows (> 25,000 ML/d).

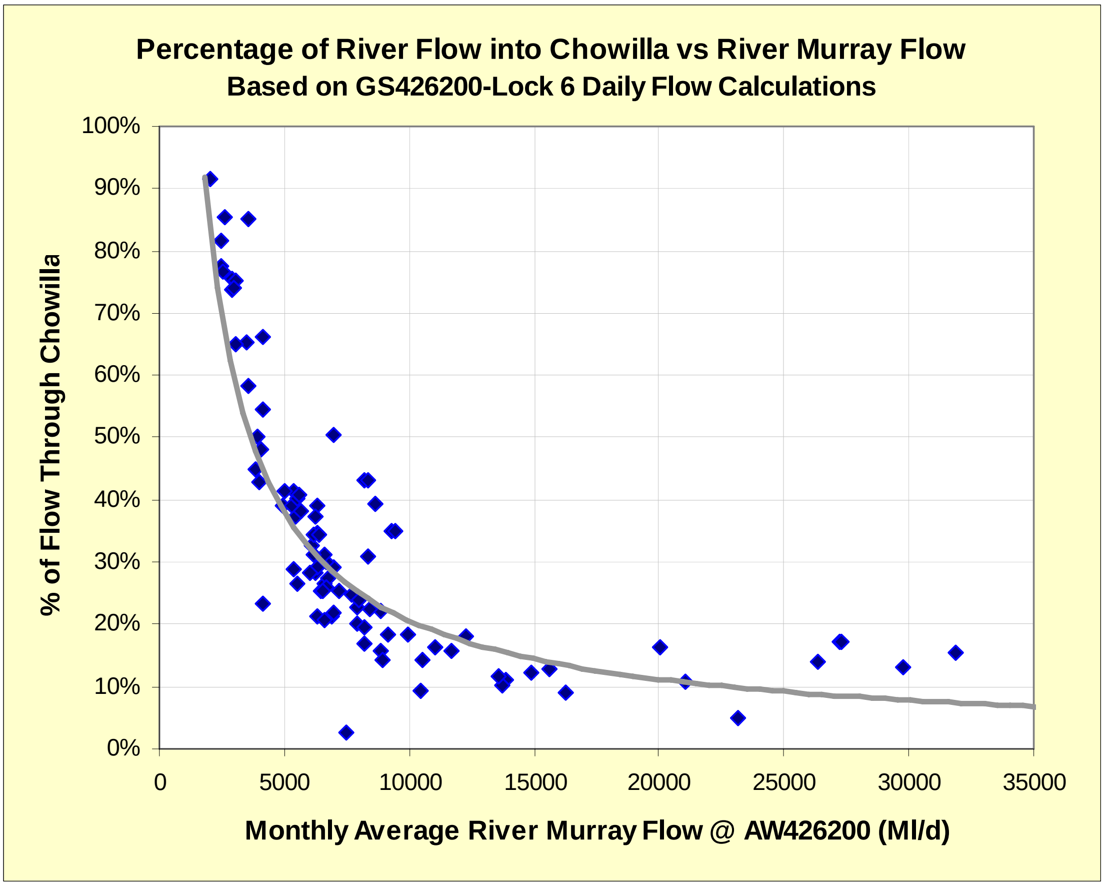


Figure 16 Percentage of River Murray flow through Chowilla (based on daily data)

Using mean monthly flow figures tends to absorb some of the effect of travel time between AW426200 and Lock 6 but this method can only provide an approximation of flow through the system on a monthly interval.

Direct measurements of flow in the lower reach of Chowilla Creek provide actual flow values at a specific time on a particular day. Over 40 flow gaugings have been made in the lower reach of Chowilla Creek as part of individual flow and salinity studies. A comparison of Chowilla Creek measured flow with Lock 6 daily calculated flow for the same day, produces a similar result to using mean monthly daily calculated flow data but is not affected by travel time and monthly averaging (see Figure 17).

Flow gauging results in the lower reach of Chowilla Creek can be relied upon to provide an accurate measure of flow from the Chowilla Anabranch. The daily calculated flow figure for Lock 6, however, is based on water level observations and measurements or estimations of the crest level of the weir stop logs and boule panels. These values are entered into a SA Water weir flow calculation program (*Lockflow*), which has not been calibrated for the Lock 6 structure. The nature of the structures, the methods used to collect the data and the difficulty in accounting for leakage through the weir, also combine to create a significant range of uncertainty in the results.

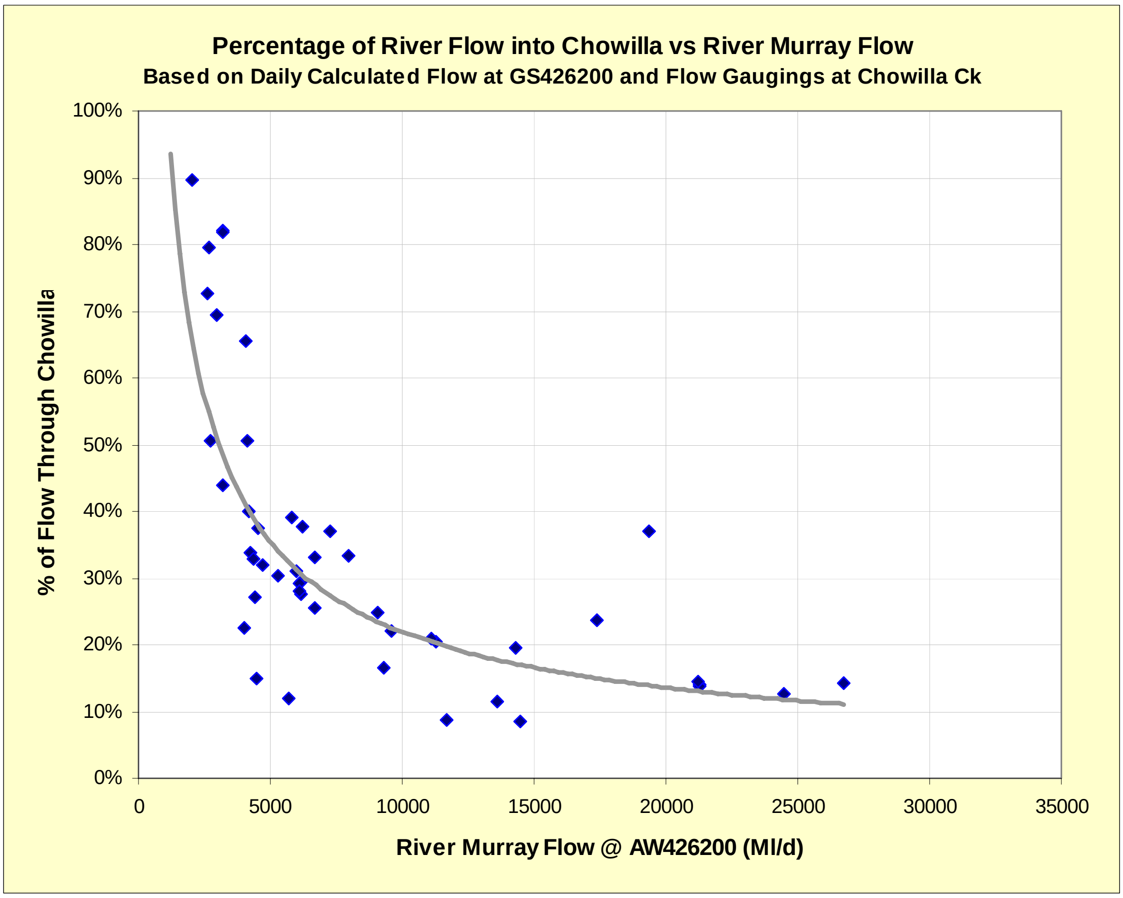


Figure 17 Percentage of R Murray flow through Chowilla – based on flow gaugings

6.2 Measured flow

Flow gauging measurements were made on 14 January 2004 at the River Murray U/S Wompinni Station (U/S Salt Creek and Chowilla Anabranch), Lindsay River U/S of River Murray, Chowilla Creek at the bridge, and River Murray U/S Chowilla Creek (Figure 18). Even during this period of steady low flow when minimal travel time effects would occur, there were discrepancies with the calculated flow figures, some quite large (Table 4).

Of particular note is the difference in Chowilla Creek between measured flow (2,186 ML/d) and calculated flow (based on the calculated Flow to SA minus the flow at Lock 6). The daily calculated flow overestimates Chowilla Creek flows by 46% (Table 4). This is in part due to the daily flow for Lock 6, which underestimates flow by 27% (Table 4). The remaining portion of overestimation of Chowilla Creek flow is likely to be due to the effect of travel time from D/S Rufus River to Lock 6.

This is the only set of flow measurements taken that provide this level of comparison. However, the results do support some long-term concerns about the accuracy of results from the *Lockflow* program and the suitability of using flows from AW426200 for the Chowilla reach (see Section 9).

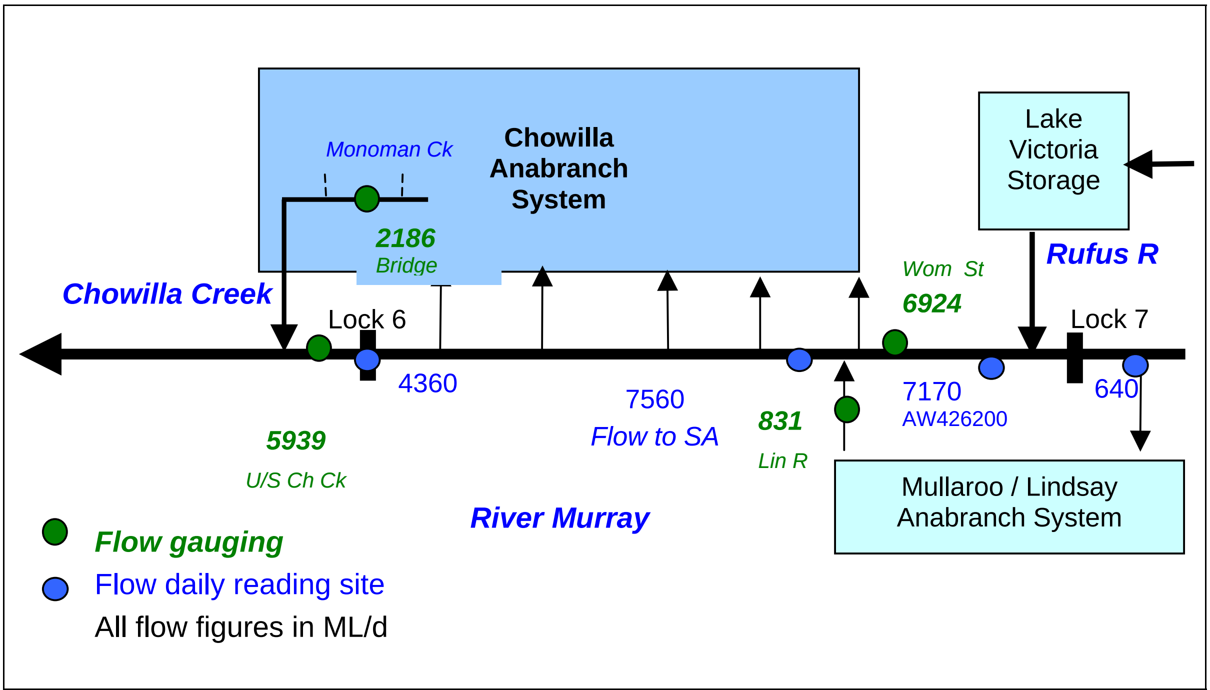


Figure 18 Flow gaugings and daily read flows, 14 January 2004

Table 4 Comparison of measured flows and daily calculated flows

Measurement or calculation localities	Measured (ML/d)	Calculated (ML/d)	Diff (ML/d)	Diff (%)
River Murray D/S Rufus River flow				
R Murray U/S Wompinni Station – gauging	6924			
Daily calculated flow at AW426200		7170	246	(3.6)
Flow to SA				
R Murray U/S Wompinni Station – gauging	6924			
Lindsay River U/S R Murray – gauging	831			
Flow to SA	7755	7560	195	(2.5)
River Murray Lock 6 flow				
R. Murray U/S Chowilla Ck – gauging	5939			
Daily calculated flow at Lock 6		4360	1579	(27)
Chowilla Anabranch flow				
Chowilla Creek at bridge[1] – gauging	2186			
Daily calculated Flow to SA		7560		
Daily calculated flow at Lock 6		4360		
Daily calculated flow Chowilla Anabranch		3200	1014	(46)

1 Negligible flow in Monoman Creek

7 EVAPORATION LOSSES

Water losses from the system need to be considered when quantifying surface water flow through the Chowilla Anabranch. Current land use includes some grazing but extractions for stock use are assumed to be very small and do not need to be further considered within the context of overall surface water flows. Evaporation losses in the anabranch and in the main River Murray between gauging station AW426200 and the confluence with Chowilla Creek have a much larger impact but they have not previously been reported.

This section provides a basic estimate of evaporation losses that influence the calculation of flow through the anabranch, beginning with estimates of water surface area.

7.1 Surface water area

7.1.1 CHOWILLA ANABRANCH

At normal 'pool' level and low River Murray flow of 3,100 ML/d, the area of backwaters and creek systems in South Australian portion of anabranch totals 192 ha (E&WS Water Resources Branch 1974).

An additional estimated 15% of the floodplain extends into NSW.

Total anabranch surface water area (SA and NSW) at '*normal pool level*' ≅ **220 ha.**

Inundation areas derived from satellite photography for River Murray flow conditions of 35,000 ML/d to 300,000 ML/d are provided in Sharley and Huggan (1995, pp 95–98).

7.1.2 RIVER MURRAY — MAIN STREAM

At normal 'pool' level and low River Murray flow of 3,100 ML/d the areas of the main river channel from the SA–Victoria border to Lock 4 are provided in Table 5 (reproduced from E&WS Water Resources Branch 1974).

Table 5 River Murray surface areas

Reach	Length (km)	Area (ha)	Area/km
SA–Vic border to Lock 6	17.7	228	12.9
Lock 6 to Lock 5	57.4	836	14.6
Lock 5 to Lock 4	46.4	715	15.4

The estimate of the area of the main stream upstream of the SA–Victoria border to gauging station AW426200 is based on the same area/km factor as that for the reach from the border to Lock 6.

Surface area SA–Vic border to AW426200 = Reach length (696.0 – 637.5) ∗ 12.9 = ***755 ha***

Total area for AW426200 to Lock 6 reach estimated as 228 + 755 = 983 ha (round up to **1,000 ha**)

7.2 Calculation of evaporation loss

Evaporation loss is calculated by the equation:

$$\text{Evaporation loss} = \text{Reach surface area} * ((\text{Evaporation} * \text{Pan Coefficient}) - \text{Rain})$$

The nearest meteorological station to the AW426200 to Lock 6 reach with both evaporation and rainfall data is located at Lake Victoria.

Average total annual evaporation at Lake Victoria Meteorological Station, AW426904 (old numbering), from 1974 to 2003 extracted from Hydstra TS is **2,003 mm** with a mean monthly total of 168.5 mm.

Average total annual rainfall at Lake Victoria Bureau of Meteorology Station, M047016 (new numbering), from 1974 to 2003 extracted from Hydstra TS is **234 mm** with a mean monthly total of 19.7 mm.

Annual total evaporation exceeds annual total rainfall by a factor of 8.5.

7.2.1 CHOWILLA ANABRANCH

Evaporation loss in the Chowilla Anabranch is calculated as:

$$220 * 10{,}000\,((2.003 * 0.7) - 0.234) = 2{,}569{,}820\ m^3/year$$

$$= 2{,}570\ ML/year$$

$$= \mathbf{7\ ML/d}$$

A loss of 7 ML/d within the anabranch system is considered to be inconsequential given the uncertainty of the estimation of flows through the system.

7.2.2 RIVER MURRAY MAIN STREAM

Evaporation loss in the main stream of the River Murray from AW426200 to Lock 6 is calculated as:

$$1{,}000 * 10{,}000\,((2.003 * 0.7) - 0.234) = 11{,}681{,}000\ m^3/year$$

$$= 11{,}681\ ML/year$$

$$= \mathbf{32\ ML/d}$$

Note: This estimate of evaporation loss in the River Murray from AW426200 to Lock 6 does not include losses from backwaters in this reach. A figure of 250 ML/d losses and extractions from the Lindsay–Mullaroo system is incorporated into the calculation of the ‘Flow to SA’ figure.

A loss of 32 ML/d within the main stream of the River Murray between AW426200 and Lock 6 is considered to be inconsequential given the uncertainty of the estimation of flows in this reach.

8 FLOW AND SALINITY STUDIES

Almost every study, of the numerous 'flow and salinity' studies in the Chowilla Anabranch area since 1972, has collected different types of data with different methods, and used different locations and sites for monitoring . Different aims and objectives existed at different times and thus studies took different approaches. Some studies concentrated on a particular part of the anabranch system and collected detailed densely spaced data; other studies collected widely spaced data over the whole of the floodplain area.

Since January 1985 a standard set of site numbers and locations (see Appendix F) has generally been used but before then several different site identification numbering systems were used.

8.1 Detailed dataset

Before this project no single data system contained the detailed individual field readings at individual monitoring sites within the anabranch. To enable salt loads to be recalculated by a uniform method for individual segments of the anabranch, all available detailed data was entered into the single spreadsheet '***Chowilla_Flow_&_Salinity_Studies_Data.xls***' (see Section 3 Methodology).

The final spreadsheet file, containing all available detailed data, includes 107 individual studies assigned to a single date, each having a range of data collected at a variety of the more than 70 sites used since the early 1970s. Data included salinity from some of the 6 EC record locations or 80 manual EC sample locations, water level from some of the 4 recorded or 20 manually read locations, and stream flow from some of the 3 daily calculated flow or 18 flow gauging locations.

8.1.1 DATA SOURCES

Raw data for studies between June 1972 and June 1991 were generally held in project files in the Riverland Regional office at Berri, and are of varying quality. Hard copy raw data of studies undertaken since June 1991 have not been located.

Digital data was copied from three pre-existing spreadsheet files:

- ***HYDSTUDY.xls*** contained a summary of most studies between June 1972 and February 1991 and some individual readings at specific key sites (see Section 4).
- A spreadsheet forming 'Appendix A' of Smith (2003) included some detailed individual readings at specific sites dates.
- ***CHOWOBS.xls*** a Riverland Region data file contained additional salinity and level data for a small number of key sites.

Additional detailed data for studies, possibly including additional complete studies, may be held in a number of Riverland Region dockets or drawings including SA Water/E&WS dockets located at Berri.

Dockets and plan references cited in various flow and salinity study project files include:

- EWS 1711 / 83
- EWS 730 TC3 / 84
- EWS 6503 / 71
- RR 453 / 75
- LD 453 / 75
- Plan UMR 75-13

Of the 107 sets of data identified 56 have been validated against hard copy data. No hard copy data has been found for the remaining 51 studies, which were generally limited studies including routine salinity and level readings at a few specific sites. Since no flow gaugings were undertaken salt loads cannot be calculated for these studies. They have been included in this spreadsheet for completeness of the overall dataset and for water level and salinity figures that are of use in their own right.

8.2 Total Chowilla Anabranch salt load increase

Data collected as part of some flow and salinity studies enables the total salt load increase emanating from Chowilla Anabranch to be calculated. This calculation requires: the flow and salinity of water leaving the anabranch (Chowilla Creek D/S of Monoman Creek, Site 40; see Appendix F) and salinity entering the anabranch (River Murray U/S of Salt Creek M Bank, Site 1; see Appendix F).

Appendix G summarises salt load results from all flow and salinity studies with appropriate data. These results have also been included on Figure 6 to enable a comparison of Chowilla Anabranch salt load increase, derived from flow and salinity study data, with monthly mean salt load increase in the River Murray between Lock 6 and Templeton, derived from monthly mean operational data. The flow and salinity study results are based on measurements made on an individual day and are in effect an instantaneous direct measurement of salt load increase. The operational data provides a monthly mean calculation of salt load increase in a reach of the River Murray which includes the Chowilla area.

8.3 Chowilla Anabranch components

The Chowilla Anabranch can be subdivided into three components with different characteristics (Sharley and Huggan 1995, p 87). The schematic in Appendix F shows the systems and the bank locations.

Outer Creek system – Salt Creek from Banks K, L and M, including the Salt Creek Anabranch, Tareena Bong and Anderson Creek, and Punkah Creek including Lake Littra and Gum Flat. This system forms the outer ring on the eastern and north-eastern extremity of the floodplain with generally slow flowing streams. Total stream length is approximately 46 km.

Inner Creek system – Hyperna Creek from Bank J, I Bank Creek joining Salt Creek from the Salt Creek Anabranch past Horseshoe Lagoon joining Slaneys Creek from Bank G weir and Slaneys Southern Anabranch terminating at the confluence with Punkah Creek to form Chowilla Creek. This system forms the inner segment of creeks with generally faster flowing streams with relatively short flow distances from the main river. Total stream length is approximately 28 km.

Lower Creek system – Chowilla Creek from the confluence with Punkah Creek and Slaneys Creek then joined by Pipeclay Creek form Bank D weir, and Boat Creek from Bank C then flowing to the confluence with the River Murray downstream of Lock 6. Also included in this component is Monoman Creek which forms a loop with Chowilla Creek and the Coombool, Werta Wert and Lake Limbra swamp systems. This part of the anabranch includes both short faster flowing creeks from the main river and slower moving bypass creeks and swamp system. Total stream length is approximately 36 km.

8.3.1 CHOWILLA ANABRANCH COMPONENT FLOWS

The volume of flow passing through each component of the system during River Murray flows below 25,000 ML/d is relatively constant with, on average, the Outer Creek system carrying 17% of the total anabranch flow, the Inner Creek system 32% and the Lower Creek system contributing a further 51%. Figures 19, 20 and 21 show the percentage of flow contributed by each system based on flow gaugings taken during flow and salinity studies compared to River Murray daily derived flow at the gauging station AW426200.

With increased River Murray flow, the Outer Creek system increases slightly, the Inner Creek system remains relatively unchanged and the Lower Creek system reduces its contribution. The percentage of overall River Murray flow through the anabranch was presented in Section 6.1, Figures 15–17.

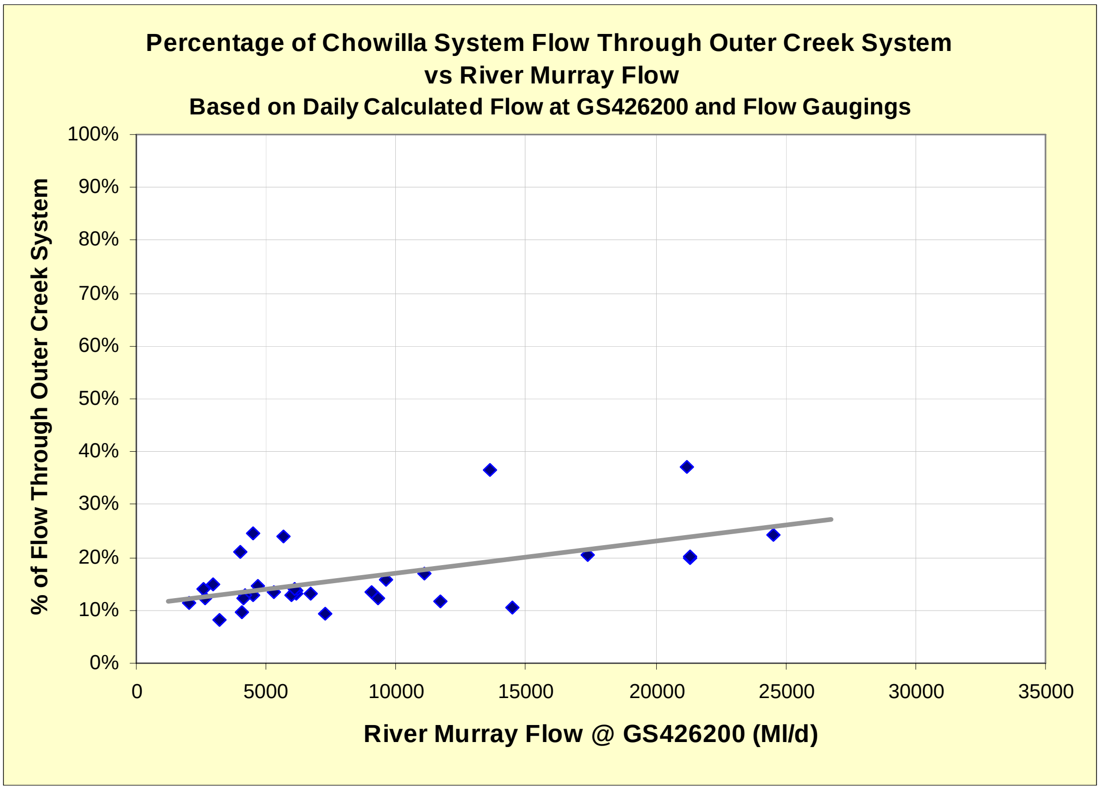


Figure 19 Percentage of anabranch flow through Outer Creek system

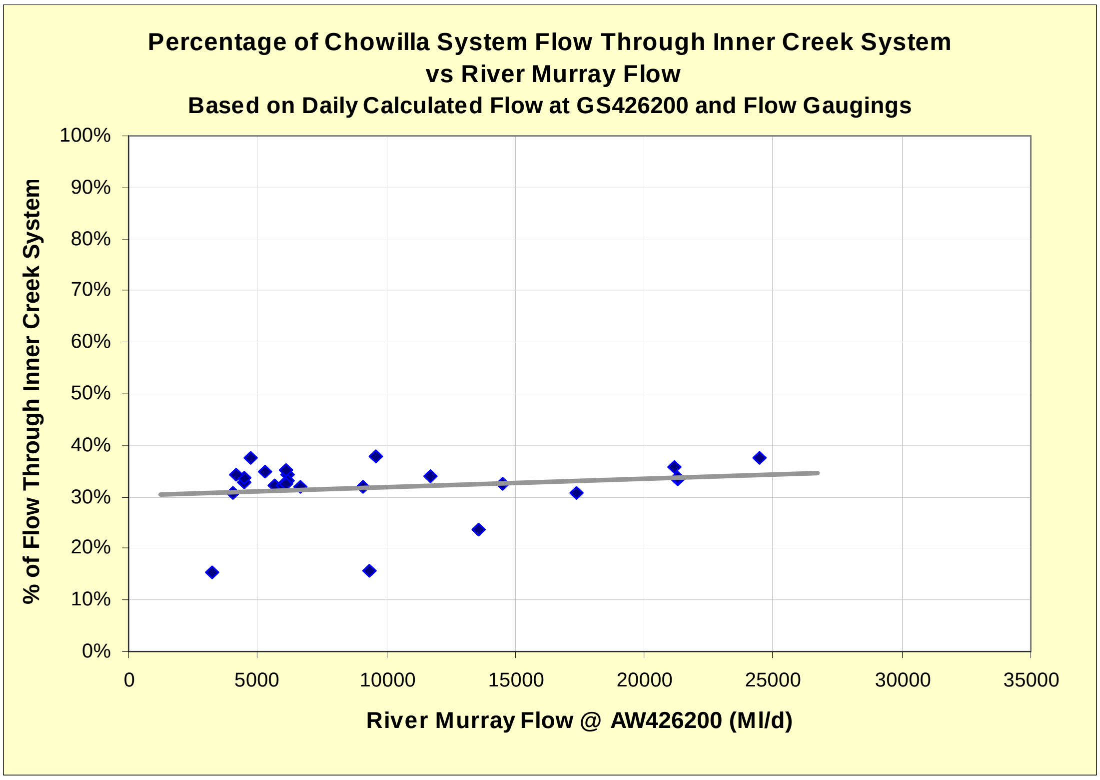


Figure 20 Percentage of anabranch flow through Inner Creek system

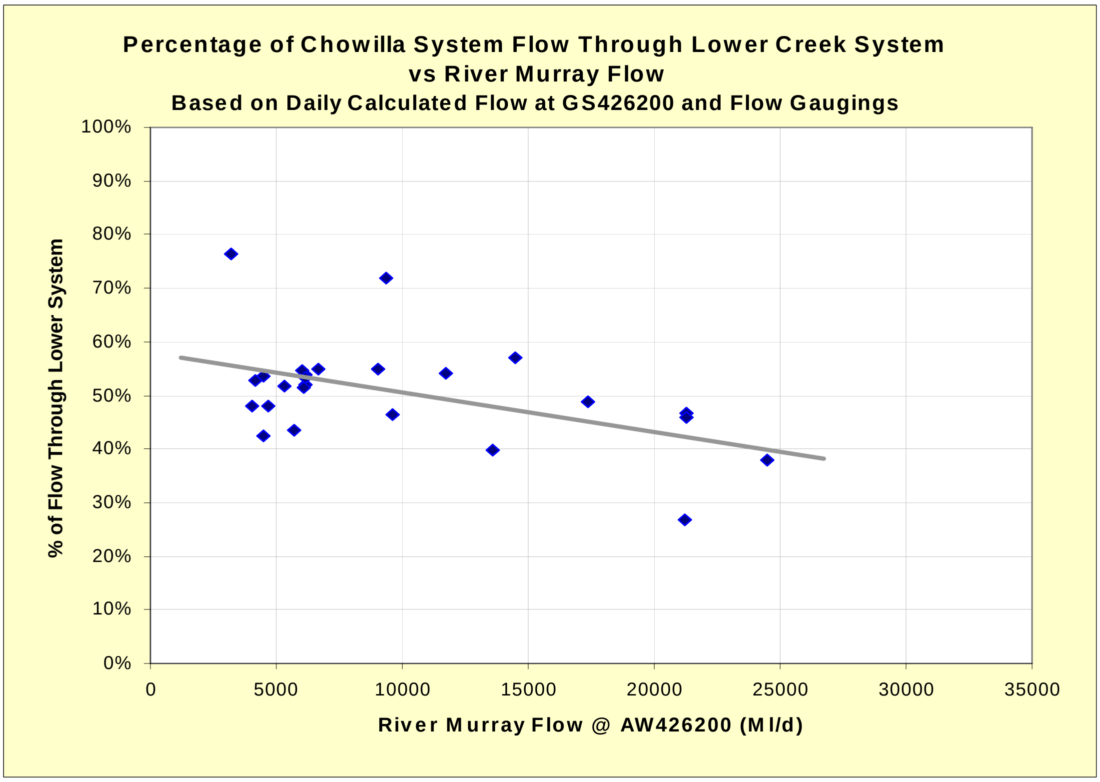


Figure 21 **Percentage of anabranch flow through Lower Creek system**

8.3.2 CHOWILLA ANABRANCH COMPONENT SALT LOADS

During flow and salinity studies since 1972 about 40 different surface water monitoring sites within the anabranch have been used for collecting water level, flow or salinity readings. Various piezometers and bores were also commonly visited and groundwater level observations made.

The range of sites visited during an individual study varied depending on requirements at that time. To enable salt loads within any reach to be calculated the average salinity at the top and bottom of the reach and the average flow within the reach are required. Some studies provide salt load figures not only for the whole anabranch system and the three main subsystems but also enable salt loads to be calculated for specific reaches of streams within the subsystems. Some studies did not include any flow gaugings at the subsystem level and no salt loads can be derived.

All available flow and salinity study subsystem salt load figures have been recalculated using the spreadsheet *Chowilla_Flow_&_Salinity_Studies_Data.xls* and are summarised in Table 6. Where available the total of the individual subsystem figures can be compared to 'Anabranch salt load increase (Site 1–40)' calculated from the difference in salinity upstream of the anabranch and the salinity in the lower reach of Chowilla Creek and the measured flow in Chowilla Creek. 'River Murray salt load increase', calculated from the salinity difference in the River Murray upstream and downstream of Chowilla Creek and the flow in the River Murray at gauging station AW426200, is also provided.

Table 6 Subsystem salt load increase summary

Stream system	Units	No. of obs	Mean	Median	Max	Min
River Murray flow @ D/S Rufus River (AW426200)	ML/d	38	8152	6055	24500	3220
Previous peak flow (>60,000 ML/d)	ML/d				183,000	68300
Days since last peak	days				850	34
Salt Creek (Site 1–5) salt load increase	t/d	15	24	10	99	7
Punkah Creek (Site 5–18) salt load increase	t/d	14	37	15	125	10
Punkah Creek (Site 18–20) salt load increase	t/d	18	7	2.5	35	0
Punkah Creek (Site 5–20) salt load increase	t/d	14	45	17	155	11
OUTER Creek system salt load increase	**t/d**	**24**	**153**	**30**	**1262**	**19**
Hyperna Creek (Site 1–7A) salt load increase	t/d	12	11	3	54	2
Salt Creek (Site 5–8A) salt load increase	t/d	3	8	5	18	0
I Bank Creek (Site 1–7B) salt load increase	t/d	12	0	0	1	0
Salt Creek (Site 10–11) salt load increase	t/d	5	18	2	81	0
Slaneys Ck (Site 12–21) salt load increase	t/d	12	9	1	76	0
INNER Creek system salt load increase	**t/d**	**25**	**83**	**15**	**468**	**2**
Pipeclay Creek salt load increase	t/d	26	9	6	31	0
Boat Creek salt load increase	t/d	21	2	1	10	0
Monoman Creek salt load increase	t/d	24	19	2	155	0
Chowilla Creek (Site 20A–33) salt load increase	t/d	11	164	32	1044	2
LOWER Creek system salt load increase	**t/d**	**16**	**366**	**86**	**2052**	**12**
% total system salt load in Outer Creek system	%		37%	33%	58%	9%
% total system salt load in Inner Creek system	%		14%	14%	27%	3%
% total system salt load in Lower Creek system	%		49%	52%	79%	19%
TOTAL Chowilla subsystems salt load increase	**t/d**		**669**	**260**	**3782**	**38**
Chowilla Anabranch salt load increase (Site 1–40)	**t/d**	**27**	**420**	**79**	**3770**	**26**
River Murray salt load increase (AW426200 flow)	**t/d**	**34**	**312**	**105**	**1939**	**7**

Note: The sum of individual components within a subsystem may not equal the total of the whole subsystem as not all components may have been measured. All subsystem total figures are calculated directly from salinity increase and flow figures for the whole subsystem.

8.4 Salinity hot spots

During various flow and salinity studies a number of very high surface water salinities have been recorded at specific locations including:

- Tareena Bong (Sites 47, 48)
- Salt Creek Southern Anabranch (Site 6)
- Punkah Creek Anabranch U/S Slaneys Creek (Site 19)
- Slaneys Southern Anabranch
- Monoman Creek (Sites 34, 36, 39).

8.4.1 TAREENA BONG, SALT CK SOUTHERN ANABRANCH, PUNKAH CK

Following a high flow of 68,300 ML/d on 15 October 1984, which would have inundated just over one-third of the floodplain, surface water salinity readings of up to 63,000 EC were measured at a number of sites (Table 7). At all of these sites water was flowing from floodplain areas that would have been inundated by the previous high flow event. Some floodplain areas become separated from the creek system as water levels drop but these 'hot spots' continue for an extended period to drain concentrated saline water into the anabranch system.

Table 7 Hot spot salinities following October 1984 high flow

Location description	Units	1984		1985			
		20 Nov	04 Dec	15 Jan	17 Apr	07 May	08 May
River Murray flow at AW426200	ML/d	60,300	17,400	7,960	4,080	3,210	3,220
Flow: rising/falling/steady	R/F/S	S	F	S	S	S	S
Days since last peak	days	36	50	92	184	204	205
Tareena Bong near outlet (Site 47)	**EC**	**245**	**391**	**1,464**	**22,600**		**55,000**
Salt Ck South Anabranch (Site 6)	**EC**					**56,300**	**63,000**
Punkah Ck Anabranch (Site 19)	**EC**		**362**				**11,500**

8.4.2 SLANEYS SOUTHERN ANABRANCH

The Slaneys Southern Anabranch runs parallel to Slaneys Creek and is fed from Bank E and Bank F. A number of measurements taken following a River Murray high flow of 163,000 ML/d on 14 December 1975, which would have inundated virtually all of the floodplain area, showed an increase in salinity to over 4,300 EC over 400 days later, when the stream had all but ceased to flow. Table 8 shows flow and salinity readings and calculated salt loads for Slaneys Southern Anabranch and Slaneys Creek at Site 21 and River Murray flow and salinity data. The anabranch consistently produces higher salinities than Slaneys Creek but the small flow of about 100 ML/d only produces relatively small salt loads. As River Murray flows subside the anabranch is reduced to a trickle of high salinity water. It is an example of a stream that eventually stops flowing after a floodplain inundation event and then stores salt within its channel until the next flushing flow.

Table 8 Slaneys Southern Anabranch hot spot salinities 1975–76

Location description	Units	1976			1977
		29 Jan	10 Feb	09 Aug	28 Feb
River Murray flow at GS426200	ML/d	21,300	21,300	21,200	9,330
Days since peak flow of 163,000 ML/d	days	46	58	239	442
Inflow salinity	EC	343	424	450	633
Slaneys Ck U/S Chowilla Ck (Site 21)	ML/d	1,000	1,000	1,100	240
Slaneys Ck U/S Chowilla Ck (Site 21)	EC	780	910	544	805
Slaneys Ck salt load increase (Site 21)	t/d	240	267	57	23
Slaneys Anabranch U/S Chowilla Ck	**ML/d**	**100**	**100**	**110**	**trickle**
Slaneys Anabranch U/S Chowilla Ck	**EC**	**900**	**1,090**	**580**	**4,310**
Slaneys Anabranch salt load increase	**t/d**	**31**	**37**	**8**	**4**

8.4.3 MONOMAN CREEK

Monoman Creek is a location at which very high salinities have been recorded at times of low River Murray and Chowilla Anabranch flow . During low flow conditions segments of many of the streams exhibit significant variation in salinity through their profile; surface salinities may be relatively low, but samples taken near the stream bed can show significantly higher salinity.

Sampling by SA Water Lock 6 personnel at Monoman and Chowilla bridges from December 1984 to February 1991 illustrates salinity stratification. Top (just below surface) and bottom (just above stream bed) EC readings were taken at both sites three times per week. Data from this study is stored in the spreadsheet ***CHOWMON.xls***.

Figure 22 shows the upper EC readings at both Chowilla Creek and Monoman Creek bridges from December 1984 to February 1991 together with the water level at Chowilla Creek bridge. Monoman Creek is consistently higher in salinity than Chowilla Creek and increases more significantly in times of low flow.

Figure 23 shows in more detail the period of December 1988 to June 1991 when Monoman Creek ceased flowing for several months. Monoman Creek upper and lower readings are plotted along with water level at the Chowilla Creek bridge. During times of little or no flow, stream bed EC rises very significantly; once water levels rise and flows recommence, almost no difference evident between the upper and lower readings as the accumulated salinity is flushed downstream to the River Murray.

Salinities in Chowilla Creek varied by up to 199 EC between top to bottom locations; salinities in Monoman Creek varied by as much as 21,107 EC between top to bottom locations (see Table 9).

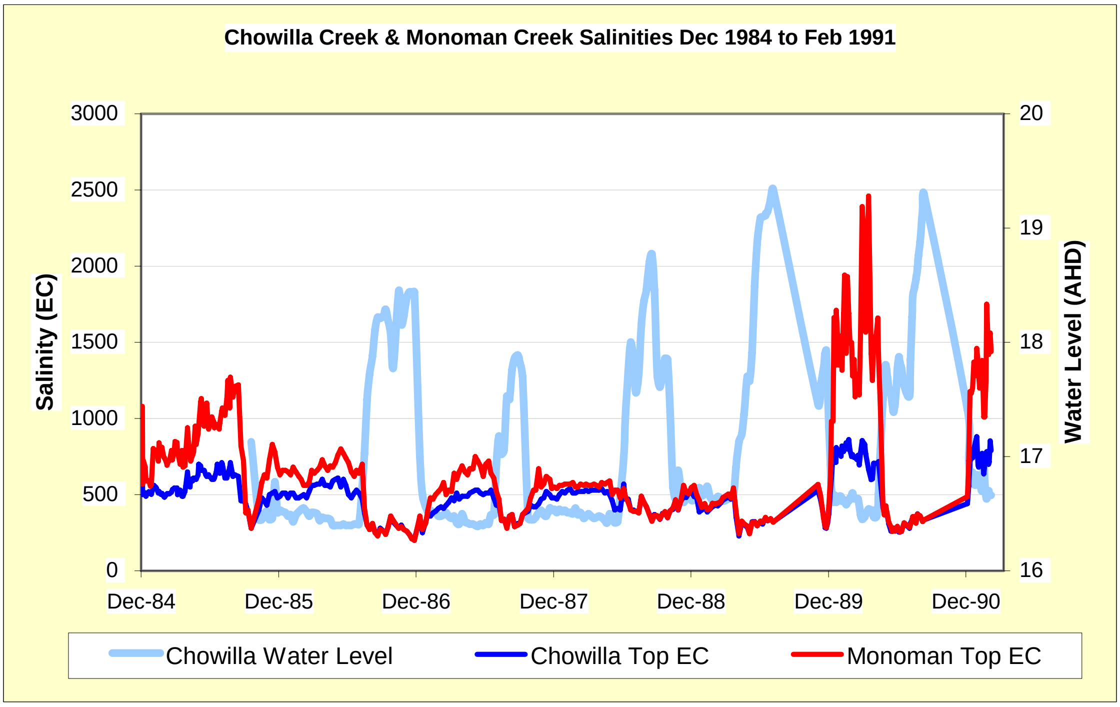


Figure 22 Chowilla and Monoman Creek salinities, 1984–1991

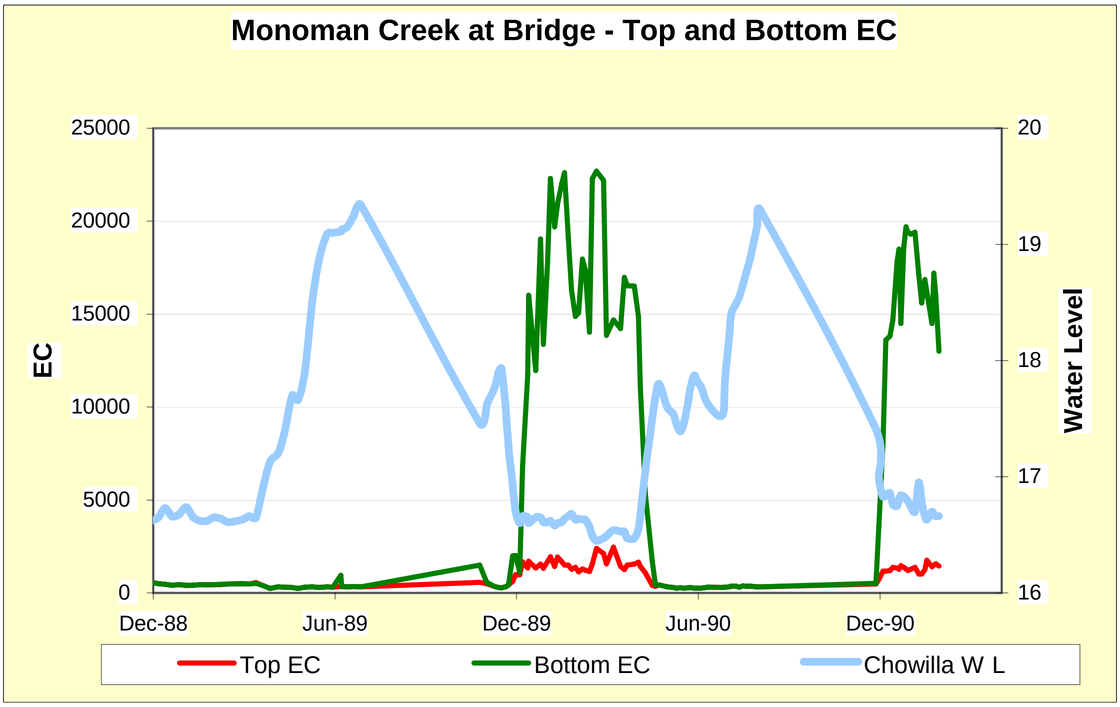


Figure 23 Monoman Creek top and bottom salinities during no flow

Table 9 Summary of difference in top and bottom EC readings

	Chowilla Creek EC difference	Monoman Creek EC difference
Maximum	199	21,107
Mean	11	2,251

8.5 Elevations, water levels, bathymetry

The long history of problems with survey levels in the Chowilla area are due in part to the relative remoteness of the area. Survey marks are few and far between, and an early level survey error of two feet (0.61 m) at survey marks along the NSW–SA border has combined with unstable soils throughout the floodplain to make accurate level fixing of local reference points used for measurement of both surface water and groundwater levels unreliable.

8.5.1 SURFACE WATER LEVELS

Many level surveys have been conducted in the floodplain area to establish more reliable level controls. Most of this work has been undertaken the SA Water, Riverland Region. It is understood that a reliable set of levels is now available but historical surface water data have not yet been adjusted.

Whilst all available water level readings have been included in the '*Chowilla_Flow_&_Salinity_Studies_Data.xls'* spreadsheet file all of this data is 'as read' on the day of the study and this data may require adjustment.

DWLBC Berri 'Chowilla' files '***gauge board levels punkah.xls'*** and '***Chowilla Gauge Board Adjustments.doc***' provide a summary of levels taken in mid-2003 to gaugeboards at Monoman Creek, Chowilla Creek and Punkah Creek (see Appendix D).

8.5.2 BATHYMETRY

In addition to surface and groundwater level readings taken throughout the anabranch system, a number of sets of streambed level data have also been collected (see files designated 'BATH' in Appendix D). More recent bathymetric work has also been undertaken in Chowilla Creek and lower Punkah Creek reach as part of groundwater investigations. Pre-weir construction ground surface and streambed levels across the floodplain area are found in the 1909–1914 map sets (Engineer-in-Chief's Department 1914).

Levels at the inverts of the inlets to streams entering the floodplain are important in understanding the dynamics of flow within the system. ***BANKLEVL.xls*** holds details of natural bank levels prior to construction of Lock 6, design level of banks constructed together with Lock 6, and stream invert levels (lowest point in bank) measured in September 1993. Water levels corresponding to River Murray flows of 3,000 ML/d and 35,000 ML/d are also included.

The summary of bank and inlet levels in Appendix H is shown as a graph in Figure 24. Had the banks been constructed and maintained at the original design levels, there would be no flow into the anabranch system at river flows of 3,000 ML/d. At 35,000 ML/d there would be flow through all banks; currently banks B, F, H, J and M have no or little flow through them at this level.

Photos of banks and weir taken on 28 March 2003 when River Murray flow was 6,000 ML/d are contained in the file '***Chowilla Banks & Weirs.doc'***. Photos of stream monitoring sites, banks and weirs at a River Murray flow of 35,000 ML/d taken in July 1988 are included in '***Levelling Chowilla Creeks 35000ML-D.doc'***

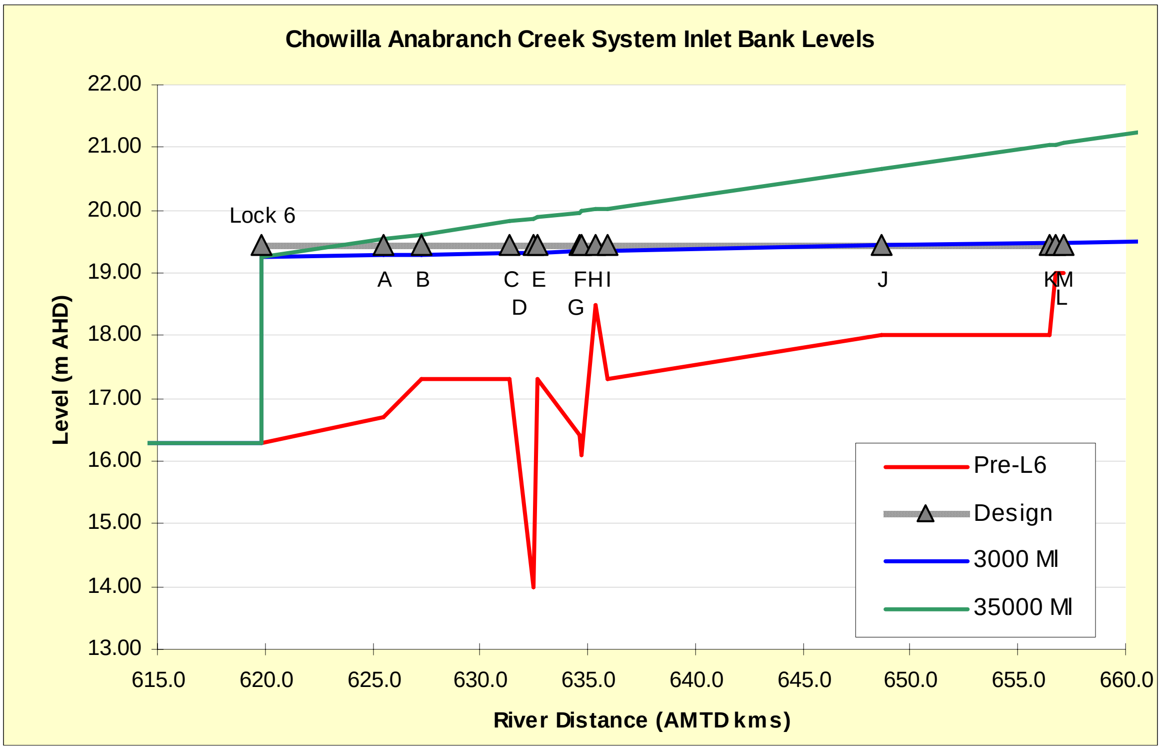


Figure 24 Inlet Bank Levels

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Flow

9.1.1 RIVER MURRAY

Currently the best available method to produce ongoing time related salt loads representing the contribution of the whole Chowilla Anabranch System to the River Murray is to use the mean monthly flows for the River Murray at gauging station AW425200 (D/S Rufus River) and the difference in salinity continuously measured by the EC pontoons located in the River Murray upstream and downstream of Chowilla Creek. This method will need to continue until such time as a more accurate continuous measurement of flow representing the River Murray downstream of Chowilla Creek is available.

To maintain a standard approach and consistency of long-term information it is recommended that all salt load data using River Murray EC differences be based on flows at AW426200 (River Murray, D/S Rufus River) until such time as a more appropriate flow measurement is available.

In the longer term it is recommended that the calculation of total Chowilla Anabranch salt loads be based on River Murray flow from a location that is more representative of the flow in the Chowilla reach. The options that would provide more reliable flow data for River Murray salt load calculations, in addition to calculation of flow volume through the Chowilla Anabranch System (see Figure 25), are discussed below.

Option 1 — River Murray downstream of Chowilla Creek confluence

Measuring the flow in the River Murray downstream of its confluence with Chowilla Creek (Location A, Figure 25) and using the current EC recorders located in the River Murray upstream and downstream of Chowilla Creek would provide a direct measurement of salt load increase contributed by the Chowilla Anabranch. The installation to measure flow would need to be located within a short distance of the mouth of Chowilla Creek as the first offtake to the Ral Ral Creek Anabranch system begins just 4 km downstream. The site would also need to measure flow in what is a typical segment of the lower River Murray with wide shallow cross-sections and slow water velocity. Stage/discharge relationships are not possible in these conditions and stream flow would have to be measured by some form of velocity measurement together with a stage/cross-sectional area relationship. Ultrasonic velocity measuring equipment has been used in similar situations in the River Murray but the equipment is significantly more expensive than that for stage/discharge methods, is more difficult to install and maintain, and still requires ongoing flow gaugings for calibration of the site. Experience so far within DWLBC and other agencies of this type of equipment over cross-sections of this size have been mixed and it would seem to need further development before it could be accepted as a serious option in this circumstance.

An alternate option is to measure flow at Lock 6 (Location B, Figure 25) and the lower reach of Chowilla Creek (Location C , Figure 25). These measuring points could complement Option 1, providing check measurements, or be used to replace Option 1.

Option 2 — Lock 6

SA Water currently calculates flow over Lock 6 weir daily using the *Lockflow* program based on observed gauge board readings of water level upstream and downstream of the weir and detailed measurement that defines the level of the top crest of the stop log and boule panel sections of the weir. Flow figures derived from this process have been shown to include significant errors (see Section 6.2).

Flow measurement at Lock 6 could be made more reliable and accurate by:

- continuously recording upstream and downstream water levels to better define weir head changes within a daily period
- measuring stop log and boule panel crests before and after every change
- accounting for weir leakage more accurately
- determining weir coefficients specifically applicable to Lock 6 with a series of flow gaugings.

Revising the *Lockflow* program to accommodate these changes and store the detailed weir crest data in a more robust and modern package would also be of benefit.

It is recommended that the methods and techniques used to calculate flows at Lock 6 be reviewed with the aim of developing revised practices to increase the reliability and accuracy of flow data.

Option 2 — Chowilla Creek

In addition to knowing the flow at Lock 6 a flow measurement in Chowilla Creek upstream of the confluence with the River Murray (Location C, Figure 25) would be required. Measuring flow in the lower reach of Chowilla Creek would also provide a direct measure total outflow from the Chowilla Anabranch System. This option is discussed in more detail in Section 9.1.2.

Option 3 — River Murray upstream of Salt Creek

Establishing a continuous flow monitoring site just upstream of Salt Creek (Location D, Figure 25) would provide total River Murray flow data before any flow enters Chowilla Anabranch. Flow measurement at this location would face the same problems as Option 1 and would probably be a difficult and relatively expensive option.

It would also be necessary to measure flow in the Lindsay River (Location D_1, Figure 25) before it joins the River Murray. A Victorian monitoring site already exists in this reach (see Figure 26) but details of flow derivation are unknown.

Flow at Lock 6 (Location B, Figure 25) would also be required to calculate the volume of flow through the Chowilla Anabranch.

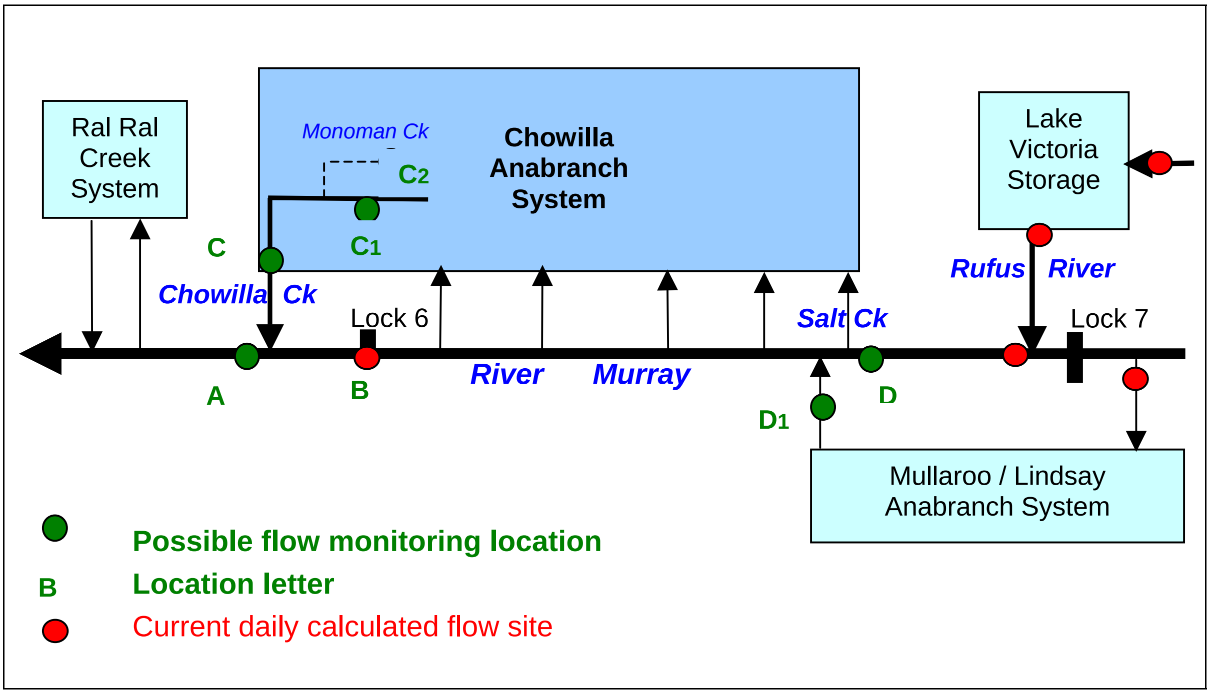


Figure 25 Flow monitoring options

9.1.2 CHOWILLA FLOW TO RIVER MURRAY

Flow gaugings in the lower reach of Chowilla Creek have been taken from time to time as part of flow and salinity studies. These measurements only provide an instantaneous measurement of flow, and thus salt load, at that time. Continuous recording of flow and EC in the lower reach of Chowilla Creek would provide the most direct continuous measurement of salt load for the whole Chowilla Anabranch and a greater level of understanding of this dynamic system.

Continuous recording of flow in lower Chowilla Creek would require continuous velocity measurement technology; a stage–discharge relationship would not be possible without a very costly large weir or flume structure. Continuous measurement and recording of velocity using either horizontal path time-of-travel or vertical Doppler acoustic devices would be more economical if there was a suitable stream cross-section. There are two possible locations for a flow measurement site in Chowilla Creek downstream of Monoman Creek (Location C, Figure 25); or at Chowilla Creek bridge (Location C1, Figure 25) together with additional flow monitoring in Monoman Creek at the bridge (Location C2, Figure 25) or further upstream at the stone crossing where the stream cross-section is smaller.

It is recommended that an investigation take place to establish a suitable site and method for continuously measuring and recording flow in the lower reach of Chowilla Creek.

If the flow at Lock 6 can be estimated more accurately and reliably (see Section 9.1.1) and flow can be accurately measured in lower Chowilla Creek, then the combination of the two flows would provide an estimate of River Murray flow entering South Australia, and a useful comparison with flow derived from gauging station AW426200 (D/S of Rufus River).

9.1.3 ANABRANCH SUBSYSTEM FLOWS

Flows within the anabranch system have been measured from time to time using flow gauging techniques during surface water studies. Key sites, such as those representing subsystem components, need to be measured over a variety of conditions whenever possible to increase the understanding of subsystem flow dynamics.

It is recommended that flow gaugings continue to be made over a range of flow conditions at key sites including site numbers 2, 1D, 7B, 10, 18, 21, 26, 30, plus the lower reach of Chowilla Creek at Sites 31 and 36 combined or at Site 40 (see Appendix F for site locations).

It is also recommended that flows from salt load hot spots be measured under suitable conditions.

Wherever possible flow gaugings should be taken at 'standard' locations.

Results of all flow gaugings should be entered into Hydstra TS as the final archive of this data. Not all previous gaugings at sites within the anabranch have been entered into Hydstra TS; some sites do not have a parent site record in Hydstra to which gauging results can be attached. In addition, in some cases, gaugings for a number of separate sites have been entered under a single Hydstra site record creating multiple, very different, flow results for a single day.

It is recommended that all previous gaugings taken in the anabranch area be entered into Hydstra TS against appropriate Hydstra site identifiers. Some new Hydstra sites will need to be created. All new gaugings should be entered against the appropriate site ID as standard practice.

As part of this project all available original hard copy discharge measurement field sheets were organised into individual site ID folders; errors and omissions in the Hydstra TS gaugings table were identified in preparation for the River Murray Hydrometric Unit to make the required corrections.

Flow gaugings will continue to be required within the anabranch system as part of flow and salinity studies, but they only represent flow at a single point in time. Equipment for continuous measurement and recording of flow using ultrasonic, acoustic Doppler technology is now available at relatively low cost. However, the limitations of this equipment may make it unsuitable for the conditions in the streams of Chowilla Anabranch and, as with all such devices, it needs to be calibrated to the individual site. Calibration generally uses flow gaugings over a range of flow conditions to establish a relationship between the recorded velocity and actual mean cross-sectional velocity and cross-sectional area. Provided it functions adequately, and suitable cross-sections can be found at required sites, this type of equipment in conjunction with continuous EC recorder would provide continuous total salt loads at selected key sites.

It is recommended that the option of deploying continuous acoustic Doppler equipment at key anabranch sites including Site 20 on Punkah Creek and Site 21 on Slaneys Creek be investigated.

9.2 Salinity and salt loads

9.2.1 RIVER MURRAY

For the time being continuous monitoring of EC in the River Murray upstream and downstream of Chowilla Creek confluence (AW426574 and AW426575), using the pontoon located mid-stream, should continue to be used with the flow measured at gauging station AW426200 to calculate River Murray salt load increase. Once a more direct continuous measurement of Chowilla Creek salt load is available (see Section 9.2.3) the use of the two EC recorders upstream and downstream of the Chowilla Creek confluence should be reviewed. In the interim, additional cross-section salinity profiles should be taken at both EC recording pontoons during a variety of flow conditions to ensure that the recorded data is representative of the whole stream.

It is recommended that EC profiles be taken at AW426704 and AW426705 at a range of flow conditions to confirm the salinity characteristics of the stream cross-section.

Daily operational EC readings by SA Water at Lock 6 should continue in order to establish a better comparison with historical data. In addition this data will provide a basis for determining any salt load increase in the reach downstream of Lock 6 to the Chowilla Creek confluence. EC profiles need to be undertaken at a range of flows at Lock 6. Current methods used by SA Water operational personnel in collecting water samples and measuring the EC, including instrument calibration, should be reviewed and appropriate standard quality controls applied. This could be achieved through an ongoing program of technical support to SA Water operational personnel from DWLBC technical personnel.

It is recommended that daily EC readings at Lock 6 continue and that DWLBC technical personnel provide support to SA Water personnel to ensure that appropriate quality assurance is maintained.

EC profiles need to be undertaken at Lock 6 over a range of flow conditions.

9.2.2 LINDSAY RIVER ANABRANCH

Quantifying the salt load entering the River Murray from the Lindsay River Anabranch would assist in the understanding of salt load dynamics in the Chowilla Anabranch and in the River Murray upstream of Lock 6. A number of monitoring sites (see Figure 26) have been established in the Lindsay–Mullaroo Anabranch system (Department of Sustainability and Environment 2004) but no data has been sought and precise details of the available parameters is not known.

It is recommended that flow, salinity, salt load and level data for Victorian sites in the Lindsay–Mullaroo Anabranch system be sought from the appropriate authority on an ongoing basis.

Having flow and salinity data for the Lindsay System available would also assist in assessing salinity data recorded at Site A4261022 (River Murray U/S of Old Customs House) EC recording site.

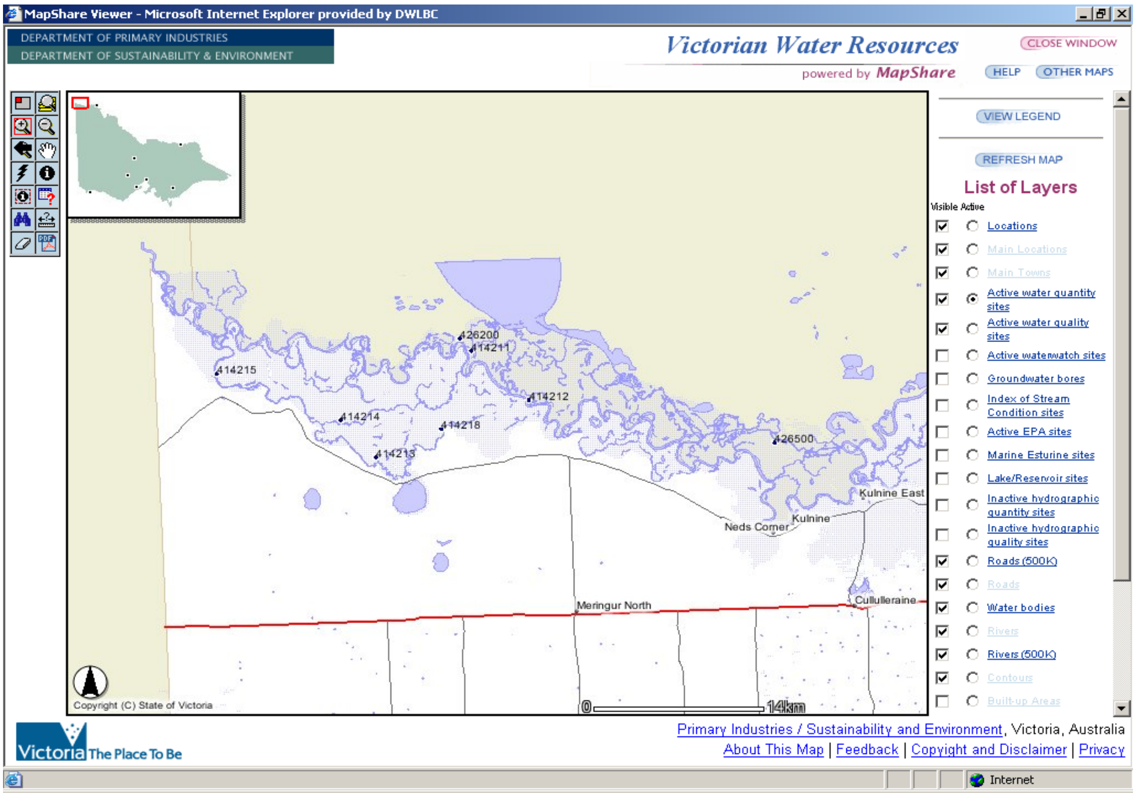


Figure 26 **Victorian operated Lindsay–Mullaroo sites**

9.2.3 CHOWILLA CREEK

Provided that flow can be continuously recorded in the lower reach of Chowilla Creek (see Section 9.1.2), continuous measurement and recording of EC at this location would provide a direct measure of total salt load emerging from the Chowilla Anabranch system. In addition, if continuous salinity of water entering the system was available the salt load increase for the whole anabranch system could be reliably determined. The existing EC recording pontoon A4261022 (Murray R U/S Old Customs House) measures the salinity of the River Murray downstream of the Lindsay River system and together with Lock 6 daily EC could be used to represent the salinity of water entering the Chowilla system via Banks A to I. Banks J to M are upstream of the Lindsay River confluence and river salinity could be significantly different from readings downstream of Lindsay River. An additional salinity recorder may be required to represent the salinity of flow into the outer Chowilla Creek system. This additional EC recorder could be located in Salt Creek near Bank K through which most flow occurs (see Section 9.2.4).

9.2.4 CHOWILLA ANABRANCH SUBSYSTEM

Continuous EC is currently being recorded at three sites within the anabranch system (see Table 10).

Table 10 Anabranch continuous EC recording sites

Flow & salinity study site no.	Hydstra site ID	Location
5	A4261027	Salt Ck SA–NSW border
18	AW426580	Punkah Ck @ sheep bridge
31	AW426535	Chowilla Ck @ bridge

Additional EC recorders at Site 20, Punkah Creek U/S Slaneys Creek and Site 21, Slaneys Creek U/S Chowilla Creek, would provide an overall picture of salinity increases within each of the subsystem components. With the addition of continuous flow measurements at Site 20 and 21, using ultrasonic methods (e.g. Mindata Starflow logger), continuous salt loads within the subsystems could be estimated.

It is recommended that continuous salinity and flow recording equipment be installed at key anabranch sites including Site 20 on Punkah Creek and Site 21 on Slaneys Creek.

To enable salt load increases for the whole Chowilla Anabranch or segments of the system to be calculated, the salinity of water entering the system needs to be known. As discussed in Section 9.2.3, the existing EC recorder A4261022 in the River Murray U/S Old Customs House and Lock 6 daily EC reading can be used to represent the salinity of inflows through Banks A to I but not for the Banks J to M upstream of A42610022 and the confluence of Lindsay River. A continuous salinity recorder located in Salt Creek Bank K near the mouth with the River Murray would provide a salinity that would represent the inflow upstream of the Lindsay River confluence. The addition of continuous flow recording would provide a direct measure of salt load entering through Bank K to the outer creek system.

It is recommended that continuous salinity and flow recording equipment be installed at Site 1C at the mouth of Salt Creek at Bank K.

A range of equipment is now available for more accurately measuring and recording EC in the field. However, the information gained is only worthwhile if it represents the whole stream, and a single point salinity reading within the cross-section may not be representative. Many of the streams in the anabranch are slow moving and poorly mixed, with denser, higher salinity water tending to congregate at the bottom of the stream profile. Selecting a sampling point, or points, that identify and quantify salinity stratification is essential for determining accurate salt loads and defining localised salinity processes. Therefore salinity cross-section profiles must be undertaken at all salinity recording sites at a range of conditions and that multiple depth EC samples be taken during any studies particularly in low flow conditions.

It is recommended that EC profiles be undertaken at all continuously monitored EC sites over a range of conditions.

During flow and salinity studies multiple depth EC samples should be taken at all key salinity monitoring sites.

9.3 Elevations, water levels, bathymetry

Gauge boards have been established at various sites within the anabranch to assist in flow and salinity studies. In addition continuous water level is currently recorded at the five sites shown in Table 11.

Table 11 Continuous water level recording sites

Flow & salinity study site no.	Hydstra site ID	Location
5	A4261027	Salt Ck SA–NSW border
18	AW426580	Punkah Ck @ sheep bridge
31	AW426535	Chowilla Ck @ bridge
7A	AW426598	Salt Ck @ U/S Horseshoe Lagoon
7B	AW426600	I Bank Ck @ U/S Punkah Ck

The historical level datum issues discussed in Section 8.5 cast doubt on the consistency of all level data collected in this area.

It is recommended that a review be undertaken to determine the best level datum for the anabranch area, that all historical level data be adjusted where necessary to conform to the adopted level system, and that all existing gauge boards and water level recorders be adjusted to this same datum as necessary.

More detailed and up to date level data for anabranch inlet weirs and banks is required to define when flow starts and stops at each inlet. More recent data may be available from SA Water.

It is recommended that all available level data for anabranch inlet systems be collated and if necessary a new survey conducted to obtain up to date detailed data.

GLOSSARY

acoustic Doppler current profiler (ADCP)

Equipment that can be used for measuring the flow in a stream using ultrasonic technology. It can be operated from a boat moving slowly across the stream and provides detailed data of water velocity through the stream profile in addition to stream bed definition.

anabranch

A secondary river channel, often running parallel to the main channel that rejoins the main channel further downstream.

confluence

The location where two streams join to form a single channel containing the combined flow of both streams.

control

The feature within a river reach that regulates flow for any given water level. Along any reach, the controlling feature may vary with changes in water level. Specially designed weirs and other structures are frequently used to create a controlling section at stream monitoring sites.

Section control: When the controlling feature causes a transition from subcritical to supercritical flow, immediately upstream of the transition is a section where water level is uniquely related to flow – an ideal situation for establishing a stage–discharge relationship, because for any water level there is only one corresponding rate of flow.

Channel control: When the controlling feature does not cause a transition from subcritical to supercritical flow, upstream or downstream conditions influence the hydraulic gradient resulting in varying rates of flow for any given water level.

discharge measurement

See flow gauging.

electrical conductivity (EC)

Water's ability to conduct electric current is directly related to the total dissolved solids (TDS) present in the water. Electrical conductivity (EC) is widely used as an indicator of water salinity and is reported in micro-Siemens per centimetre (µS/cm). EC is temperature sensitive and increases with increasing temperature. Conductivity values are usually adjusted (or compensated) to the value that would occur if the water temperature was 25°C as a standard temperature thus allowing comparisons between EC readings.

1 EC unit = 1 µS/cm measured at 25°C.

EC profile

A series of EC measurements taken at varying depths and distances across a stream cross-section to show the distribution of salinity through the cross-section and identify salinity stratification. EC profiles are used to identify the most suitable locations for salinity monitoring sites and to develop more detailed understanding of localised salinity and stream mixing processes.

flow gauging

A measurement of flow at a particular stage (water level) for purposes of establishing the relationship between water level and flow in a particular river reach. Also called discharge measurement.

gauging station

A gauging station is a specific type of monitoring site where stream flow is measured and a variety of other environmental parameters may also be measured. The data collected may be individual readings at varying intervals or continuously recorded using a variety of instrumentation. Typically, a stage–discharge relationship would be developed based on flow control at the site by taking flow gaugings over a range of flow conditions. In some cases a station may include water velocity measuring instruments, which together with stream cross-sectional area measure water flow.

Hydstra TS

Hydstra TS is a software product widely used to store, analyse and present time series environmental monitoring data.

monitoring site

A location at which one or many environmental parameters are measured by individual readings taken at varying intervals or continuous recording using a variety of instrumentation.

Ramsar

The Convention on Wetlands, signed in Ramsar, Iran, in 1971, is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. There are presently 138 Contracting Parties to the Convention, with 1,369 wetland sites, totalling 119.6 million hectares, designated for inclusion in the Ramsar List of Wetlands of International Importance (Ramsar Convention Secretariat 2004).

rating

See stage–discharge relationship.

reach

A relatively short section of a river usually having some related characteristic such as between two weirs or the same flow regime.

run-of-river survey

A technique used to help identify areas of high salt load increase within a stream reach. EC readings are made at a frequent rate along the reach, sometimes continuously, and define salinity levels along the reach. The series of readings is repeated several times over a period of time, usually one series per day for four or five days. Using a knowledge of flow velocity, usually obtained from flow gaugings, the movement of water and any subsequent increase in salinity can be determined by overlaying the results of each data series with an offset for the appropriate travel times. The results show salinity increase for each set distance point, typically each kilometre, within the reach and identify specific segments with higher salinity increases. Matched with hydrological data and other information this technique is used to identify salinity sources and monitor salinity reduction programs.

stratification

A situation where less dense water overlies denser water. In extreme cases distinct layers can form within the stream profile with little or no mixing or interaction between the layers. In slow flowing or stationary water more saline water, which is denser, can accumulate in the bottom of a stream. Often it has seeped into the stream through the bed and banks from the surrounding groundwater.

time series

A series of variable values recorded against time; in the context of water resource monitoring, records of water-related environmental variables, such as water level or water salinity, against the time the readings were taken.

The time interval between recording can be seconds, hours, days or longer, provided that the recorded values give a reliable representation of the actual changes in the variable at the required level of accuracy: if the variable does not change rapidly a time-series can be made up of manual observations such as a manual reading of groundwater levels; if the variable changes rapidly very frequent readings are required and continuously recording devices are used.

A wide range of variables can be recorded as a time-series including any level or counter type data that varies with time. Examples include water level, flow rate, velocity, salinity, turbidity, temperature, wind speed, rainfall, wind direction, flow volume, battery voltage, gate opening, pump status.

total dissolved solids (TDS)

The quantity (by mass per unit volume) of residue left by evaporation, giving one of the best indications of the salinity of the water.

salt load

A rate at which salt (dissolved solids) passes a point on a river reach. Salt load is usually expressed in units of mass per unit time, such as tonnes per day (t/d).

stage

The water level measured as a height above an arbitrary datum.

stage–discharge relationship

Associates water level (stage) with flow (discharge) for a specific reach of river where a control feature is present. The relationship is often established over time by making flow gaugings at all ranges of water level when they occur. The relationship can also be based on adopted hydraulic principals when a pre-calibrated gauging weir is used as the controlling feature. Also known as a rating curve.

SI units

Name of unit	Symbol	Definition in metric units	
millimetre	mm	10^{-3} m	length
metre	m		length
kilometre	km	10^{3} m	length
hectare	ha	10^{4} m^{2}	area
microlitre	µL	10^{-9} m^{3}	volume
millilitre	mL	10^{-6} m^{3}	volume
litre	L	10^{-3} m^{3}	volume
kilolitre	kL	1 m^{3}	volume
megalitre	ML	10^{3} m^{3}	volume
gigalitre	GL	10^{6} m^{3}	volume
microgram	µg	10^{-6} g	mass
milligram	mg	10^{-3} g	mass
gram	g		mass
kilogram	kg	10^{3} g	Mass

Abbreviations

Abbreviation	Name	Units of measure
ADCP	acoustic Doppler current profiles	
D/S	downstream	
DWLBC	Department of Water, Land and Biodiversity Conservation	
E&WS	Engineering and Water Supply Department	
EC	temperature adjusted electrical conductivity *(microSiemens per centimetre at 25 degrees Centigrade)*	µS/cm @ 25^{c}C
GPS	global positioning system	
MDBC	Murray-Darling Basin Commission	
t/d	tonnes per day; a measure of the mass of salt passing a point on a stream in one day	tonnes/day
U/S	upstream	

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APPENDICES

APPENDIX A ADDITIONAL DWLBC INTERNAL REPORTS

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Six page report describing installation of new water level EC recording instruments within anabranch.

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APPENDIX D RIVERLAND REGION DIGITAL FILE SET

Category description	Code
River Murray flow, salinity, water levels, salt load data and calculations	RM
Chowilla Anabranch flow, salinity, water levels, salt load data and calculations	CA
Flow gauging data at individual sites	FG
GPS waypoint data, location data	GPS
Bathymetry, stream bed levels, echo soundings, bank levels	BATH
Ground water data, pump test results	GW
Special projects – not surface water or groundwater studies	SP
Photos and images	PI

File name	File type	Contents description	Code
BANKLEVL.XLS	Excel	Chowilla Creek Banks and Creek Inlet Invert Level	BATH
chowbottom depth.xls	Excel	Chowilla Creek bed depth sounding survey, 9/09/2003.	BATH
Chowilla Banks & Weirs.doc	Word	Chowilla Banks & Weirs 28/03/2003. River Flow into SA 6000 ML/d. Photos and comments.	BATH
Chowtop depth.xls	Excel	Chowilla Ck bed depth sounding survey, 29/04/2003.	BATH
Chowtop depths.xls	Excel	Chowilla Ck bed depth sounding survey, 29/04/2003. Sounding data.	BATH
ECHOSOUN.XLS	Excel	Echo Sounder Digitised Data for Salt/Punkah Ck. Original data was in file CHOWCK1.WQ1. File used to 'digitise data into Hydstra Time Series format.	BATH
Chow Rof R EC 280403.xls	Excel	Run of River survey Chowilla Creek 29/4/2003, 6/5/2003, 7/5/2003 – EC data.	CA
Chow RR May2003.xls	Excel	Run of River survey Chowilla Creek May 2003 - Salt load Calculations.	CA
Chow Survey May 2003.xls	Excel	Run of River survey Chowilla Creek May 2003 - blank field sheet.	CA
Chowilla Gauge Board Adjustments.doc	Word	New levels and Gauge Board adjustments 2003. (also see: gauge board levels punkah.xls)	CA
CHOWMON.XLS	Excel	Top and Bottom EC readings and Water Level data from Chowilla Creek and Monoman Creek bridges. Data collected by Lock 6 personnel December 1984 to February 1991.	CA
CHOWOBS.XLS	Excel	Water Level and Salinity data from Chowilla Ck, Monoman Ck, Salt Ck, Punkha Ck. Feb 1986 to Jan 1989. Chowilla Ck gaugings Jan 1995 to Jan 1998.	CA
CHOWREP.DOC	Word	MDBC Chowilla Resource Management Plan 1995.	CA

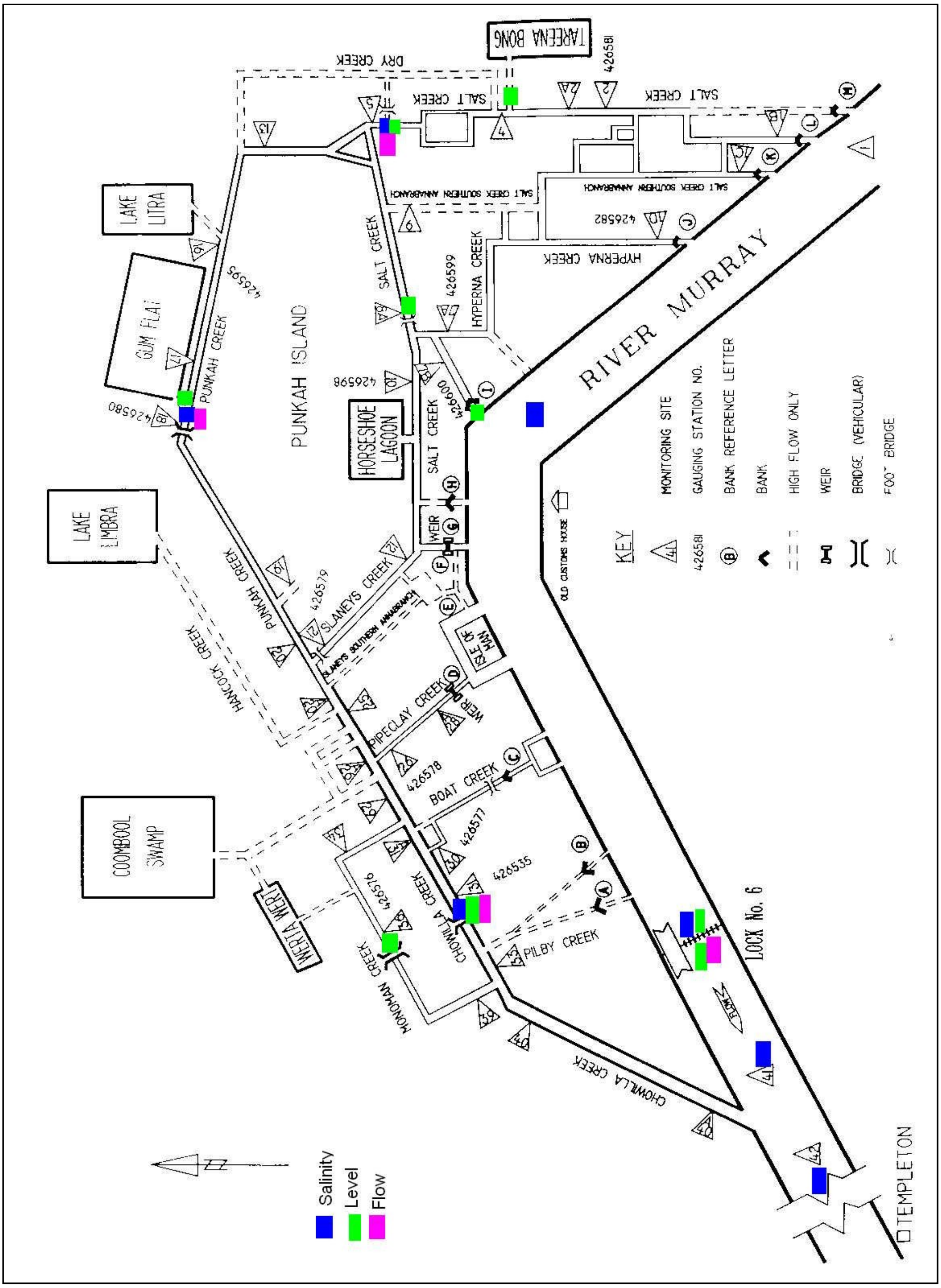
File name	File type	Contents description	Code
		Original draft of Hydrology chapter.	
CHOWREPall.DOC	Word	Brief report '*Chowilla Monitoring*' by Riverland Region describing new continuous water level and salinity recording equipment installed at specific sites from late 2002 to early 2003. (also see: *'INSTALLATION NOTES ON SITE 5 CHOWILLA A4261027.doc*')	CA
gauge board levels punkah.xls	Excel	Gauge board survey data 27/5/2003.	CA
HYDSTUDY.XLS	Excel	Summary of flow and salinity studies and calculation of salt loads. 14/6/1972 to 5/2/1991. The resulting salt load data has been used in numerous published reports including the Chowilla Resource Management Plan 1995.	CA
INSTALLATION NOTES ON SITE 5 CHOWILLA A4261027.doc	Word	Brief report by Riverland Region describing new continuous water level and salinity recording equipment installed. Site 5 (Salt Creek) April 2003. (also see: '*CHOWREPall.DOC*')	CA
MERITDAT.XLS	Excel	Lake Merriti water levels and EC data. 1994 to 1996.	CA
XSECT40.XLS	Excel	EC Profile at Chowilla Creek, SITE 40, 22/11/1989.	CA
Chow bridges.xls	Excel	Chowilla, Monoman, Hyperna bridge flows 18/02/2003.	FG
GAUGINGCHOWILLA.xls	Excel	Review of Chowilla Ck gaugings vs Flow to SA and Lock 6.	FG
GAUGINGS.CSV	CSV Text	Hydstra output – Gaugings for AW426580.	FG
GAUGINGS027.CSV	CSV Text	Hydstra output – Gaugings for A4261027.	FG
GAUGINGS535.CSV	CSV Text	Hydstra output – Gaugings for AW426535.	FG
Sheep Bridge Summary 230603.xls	Excel	ADCP gauging at AW426580 on 23/6/2003.	FG
Sheep Bridge Summary 270503.xls	Excel	ADCP gauging at AW426580 on 27/5/2003.	FG
SHEEPYARD SUMMARY.xls	Excel	ADCP gauging at AW426581 on 27/5/2003.	FG
Site 5 230603 Summary.xls	Excel	ADCP gauging at A4261027 on 23/6/2003.	FG
Site 5 270503 Summary.xls	Excel	ADCP gauging at A4261027 on 27/5/2003.	FG
SITE20A270503SUM.xls	Excel	ADCP gauging at Site 20A on 27/5/2003.	FG
SUMMARY230603.xls	Excel	ADCP gauging at AW426535 on 23/6/2003.	FG
SUMMARYbrg280503.xls	Excel	ADCP gauging at AW426535 on 28/5/2003.	FG
Chow Bounds.xls	Excel	GPS Waypoints. Ral Ral Ck to border.	GPS

File name	File type	Contents description	Code
Chow Ext.xls	Excel	GPS Waypoints Chowilla Area.	GPS
CHOW92pumpTEST.xls	Excel	Groundwater pump drawdown test March-April 1992 – Recorded piezometer level data.	GW
Chowilla Piezo Details 240103 XL.xls	Excel	Chowilla Area piezometers. Location Easting + Northing and ref point levels.	GW
CHOWLEVS.XLS	Excel	Chowilla piezometers H12, H6 from 26/11/1990 to 25/09/1997.	GW
CHOWMAP.XLS	Excel	Piezometer locations?	GW
Proposed Wells (details - Accessability).xls	Excel	Proposed Wells for Chowilla SIS Investigations.	GW
Pump test calcs.XLS	Excel	Chowilla, Lake Littra Pump test 1992. Calculation of flow rates of pump test.	GW
Chowilla Schemattic.jpg	Image	Scanned image of Chowilla Anabranch schematic diagram.	PI
I.O.F. close up.JPG	Image	Photo of Isle of Man. Date unknown.	PI
Isle Of Man Landing.JPG	Image	Photo of Isle of Man. Date unknown.	PI
Photos	Sub-Directory	Contains various JPG image files – sites in Chowilla.	PI
AVGQ2SA.XLS	Excel	Average Monthly Flows to S.A. for current and natural conditions. Data source MDBC 15/09/1993.	RM
Chow loads.xls	Excel	Murray River Monthly Salt Load from Chowilla calculation using EC pontoon data. Jan 2001–Oct 2003. (also see: *Chow Pontoon SaltLoads.xls*)	RM
Chow Pontoon SaltLoads.xls	Excel	Murray River monthly salt load from Chowilla calculation using EC pontoon data. Jan 2001–Aug 2003. (also see: *Chow Loads.xls*)	RM
CHOWSALT.XLS	Excel	Calculation of monthly salt load increase in River Murray based on daily EC and flow data. The resulting salt load data has been used in numerous published reports including the Chowilla Resource Management Plan 1995.	RM
LOCK6WL.XLS	Excel	Lock 6 U/S and D/S water levels 1927 to 1936. Published reports including the Chowilla Resource Management Plan 1995.	RM
RECESION.XLS	Excel	Chowilla Salt Load Recession Curve. Published in the Chowilla Resource Management Plan 1995.	RM
Chow Ntem proposed.doc	Word	Document containing map of proposed NATREM project sites in Chowilla area.	SP
Chow ntem proposed.jpg	Image	Map of proposed NATREM project sites in Chowilla area.	SP
CHOWFISH.XLS	Excel	Results of Chowilla Fish Studies surface water monitoring Lake Littra Oct 1989 to Aug 1991.	SP

APPENDIX E MONTHLY MEAN EC AT DAILY READ AND CONTINUOUSLY RECORDED SITES

Site	D/S Rufus	Templeton	Lock 6 U/S	D/S Chowilla	U/S Chowilla	U/S Old Customs House	D/S Chowilla–Templeton	U/S Chowilla–Lock 6	U/S Old Customs Hs–Lock 6
Distance	696	602.9	619.8	609	612.3	637.1	(6.1 km)	(7.5 km)	(17.3 km)
Site ID	AW426200	AW426632	AW426510	AW426704	AW426705	A4261022			
Parameter	Flow (ML/d)	Daily read EC	Daily read EC	Recorded EC	Recorded EC	Recorded EC	EC Difference	EC Difference	EC Difference
Mar-2001	13567	343	340	344	345		1	5	
Apr-2001	14900	342	337	342	339		-1	2	
May-2001	6583	342	329	344	339		2	10	
Jun-2001	3041	395	354	392	375		-3	21	
Jul-2001	5998	376	354	371	361		-5	7	
Aug-2001	6633	359	346	362	353		4	7	
Sep-2001	7160	377	363	377	370		0	7	
Oct-2001	8216	397	369	379	372		-18	3	
Nov-2001	6984	436	410	420	414		-16	4	
Dec-2001	6750	431	418	433	424		1	6	
Jan-2002	6657	455	448	459	455		4	6	
Feb-2002	6531	481	470	484	475		3	5	
Mar-2002	5521	485	476	492	485		7	9	
Apr-2002	3885	471	452	469	465		-3	13	
May-2002	2470	432	409	434	424		2	16	
Jun-2002	2446	412	388	412	409		0	21	
Jul-2002	2995	396	371	398	394		1	23	
Aug-2002	3584	346	327	349	341		2	15	
Sep-2002	4085	359	344	363	358	351	4	14	8
Oct-2002	4974	316	300	314	309	290	-2	9	-10
Nov-2002	5537	227	204	227	218	196	0	14	-8
Dec-2002	6369	181	169	185	179	177	4	10	8
Jan-2003	6235	*ceased*	174	185	184	185		11	11
Feb-2003	6199		219	238	221	240		1	20
Mar-2003	5605		210	230	224	224		14	14
Apr-2003	4144		252	271	266	254		13	2
May-2003	2637		232	257	257	248		24	16
Jun-2003	2036		288	321	307	293		19	5
						Max	7	24	20
						Min	-18	1	-10
						Median	1	10	8
						Mean	**-1**	**11**	**7**

APPENDIX F CHOWILLA ANABRANCH SCHEMATIC



APPENDIX G FLOW AND SALINITY STUDY TOTAL SALT LOAD INCREASE IN CHOWILLA ANABRANCH

Study date	R.Murray flow (ML/day)	Rise, fall, steady	Previous peak flow (ML/day)	Previous peak flow date	Number of days since peak	Salt load (t/day)
14-06-1972	11,300	R	77,200	22-11-1970	570	79
01-02-1973	5,680	S	77,200	22-11-1970	802	65
28-02-1973	4,480	S	77,200	22-11-1970	829	66
21-03-1973	4,030	S	77,200	22-11-1970	850	55
24-02-1975	13,600	S	183,000	05-11-1974	111	3770
28-02-1975	11,700	S	183,000	05-11-1974	115	2232
29-01-1976	21,300	F	163,000	14-12-1975	46	881
10-02-1976	21,300	S	163,000	14-12-1975	58	1214
09-08-1976	21,200	F	163,000	14-12-1975	239	246
28-02-1977	9,330	R	163,000	14-12-1975	442	467
25-01-1983	5,300	S	105,000	11-10-1981	471	97
15-04-1983	4,220	S	105,000	11-10-1981	551	212
21-04-1983	4,350	S	105,000	11-10-1981	557	125
31-05-1983	3,170	S	105,000	11-10-1981	597	66
14-06-1983	2,750	S	105,000	11-10-1981	611	95
23-06-1983	4,420	S	105,000	11-10-1981	620	32
15-01-1985	7,960	S	68,300	15-10-1984	92	194
17-04-1985	4,080	S	68,300	15-10-1984	184	252
07-05-1985	3,210	S	68,300	15-10-1984	204	113
08-05-1985	3,220	S	68,300	15-10-1984	205	116
26-02-1986	6,690	S	68,300	15-10-1984	499	26
10-03-1986	6,150	R	68,300	15-10-1984	511	48
11-03-1986	6,170	R	68,300	15-10-1984	512	58
12-03-1986	6,110	R	68,300	15-10-1984	513	43
13-03-1986	6,000	S	68,300	15-10-1984	514	39
14-03-1986	6,130	S	68,300	15-10-1984	515	39

21-04-1986	4,710	S	68,300	15-10-1984	553	48
22-04-1986	4,510	S	68,300	15-10-1984	554	67
23-04-1986	4,180	S	68,300	15-10-1984	555	63
15-11-1989	24,500	R	85,200	12-10-1989	34	309
22-11-1989	26,730	R	85,200	12-10-1989	41	280
18-12-1989	14,290	F	85,200	12-10-1989	67	348
31-01-1990	9,070	S	85,200	12-10-1989	111	429
05-02-1991	9,620	F	103,510	18-10-1990	110	457

Note: Salt loads are calculated from measured flow in the lower reach of Chowilla Creek and the difference in salinity in the River Murray upstream of the Chowilla Anabranch and the salinity in the lower reach of Chowilla Creek.

APPENDIX H ANABRANCH BANK AND INLET LEVELS

Bank letter	Creek name	Structure type	AMTD Kms	Top of bank level Pre L6	Top of bank level design	River level 3,000 Ml/d	River level 35,000 Ml/d	Flow at Pool Level ?	Comment
	Chowilla Ck	Nil	612.0			16.30	16.30		Chowilla Ck
	Lock 6 D/S	Weir	619.8			16.30	16.30		Lock 6 D/S
	Lock 6 U/S	Weir	619.8		19.46	19.25	19.25		Lock 6 U/S
A	Pilby Ck Sth	Stone pitched embankment	626.2	16.70	19.46	19.29	19.56	No	New weir under construction
B	Pilby Ck Nth	Stone pitched embankment	627.0	17.30	19.46	19.30	19.60	No	
C	Boat Ck	Stone pitched embankment	631.4	17.30	19.46	19.33	19.82	Yes	Bank in poor condition - 3 inlets
D	Pipeclay Ck	Weir – Stop Logs	632.5	14.00	19.46	19.33	19.87	Yes	Flow through leaky stop logs
E	Slaneys (South)	Stone embankment	632.7	17.30	19.46	19.33	19.88	Yes	Flow through rock embankment
F	Slaneys (South)	Stone pitched embankment	634.6	16.40	19.46	19.35	19.97	No	
G	Slaneys Ck	Weir – Stop Logs	634.7	16.10	19.46	19.35	19.98	Yes	Flow through leaky stop logs
H		Stone pitched embankment	635.4	18.50	19.46	19.35	20.01	No	High level flow only (3500 ML+)
I		Stone pitched embankment	635.9	17.30	19.46	19.35	20.04	Yes	Bank washed away
J	Hyperna Ck	No bank constructed	648.7	18.00	19.46	19.44	20.66	Yes	Small flow at pool level
K	Salt Ck Sth	No bank constructed	656.5	18.00	19.46	19.49	21.04	Yes	Major inflow for Salt Ck
L	Salt Ck	No bank constructed	656.7	19.00	19.46	19.49	21.05	Yes	Minor flow
M	Salt Ck Nth	No bank constructed	657.1	19.00	19.46	19.49	21.07	No	Entrance silted up

Filename:	ChowillaSurfaceWaterInfoReport_FinalDraft.doc
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Subject:	
Author:	Peter Stace
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