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A RISK ASSESSMENT OF THE IMPACT OF FARM DAMS ON STREAMFLOW IN CATCHMENTS ON KANGAROO ISLAND

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EXECUTIVE SUMMARY

This study was part of a wider, multi-agency study into the natural resources of Kangaroo Island. The prime focus of the wider program was the water quality and quantity, and the management required to sustain natural ecosystems, industry and human consumption needs, and other urban and domestic uses. The focus of the study described in this report was to use a risk assessment approach to assess the impact of farm dams on streamflows and the potential threats to ecosystems.

The Kangaroo Island Natural Resources Management Board (KINRMB) and the Department of Water, Land and Biodiversity Conservation (DWLBC) funded this project.

This study adopted a risk assessment approach using a GIS-based model that incorporated simulated mean-annual streamflow captured by farm dams. A rainfall-runoff equation based on the standard hydrological tanh equation was used. The parameters of the tanh equations were derived from annual rainfall and a yield analysis for Middle River Reservoir catchment. This approach was more rapid than developing a detailed daily time-step hydrological model that would require extensive calibration data that did not exist for much of the study area.

Due to the use of a risk assessment approach, the results can be regarded as showing only the general magnitude of impacts and the relative spatial variation. The latter enables the prioritising of further, more detailed, studies from which specific management recommendations can be made. The results are not intended to imply the impacts of proposed developments of farm dams or land use changes, such as forestry, without further hydrological investigation.

The modelling results showed that a large proportion (around 70%) of Kangaroo Island had less than 20% of streamflow removed by farm dams. Although sensitive species may be affected, environmental impacts are expected to be minimal. These areas are mainly in the western end and the south and north coastal areas. Approximately half of these areas are within National or Conservation Parks.

However, much of the remaining area (around 30% of the Island) has very high proportions of streamflow removed by farm dams that is believed to cause significant or major environmental impact. There are many areas and branches of the major creeks that have more than 20–50% of streamflow removed by farm dams, with some areas having greater than 50% of streamflow removed. The areas recommended for further investigation and prioritised management actions are:

- Cygnet River catchment particularly the eastern section; a tributary in the western upstream region caused by a single large farm dam; and many small scattered areas
- the upper parts of the Harriet River, Elenor River, and Wilson River catchments
- large areas within the catchments of Timber Creek; Lake Ada; White Lagoon; Salt Lagoon; Birchmore Lagoon and Red Cliffs
- the north coastal catchments King George Beach; Cape Dutton and Smith Bay.

The use of a relatively simple risk assessment approach inevitably carries limitations. The principle limitations are that impacts on the flow regime were not determined, and the use of a single rainfall-runoff relationship across the whole study area did not address varying runoff with different land uses. These limitations can only be addressed by more detailed hydrological studies in the areas identified with high levels of risks.

The current streamflow monitoring network was strategically designed to capture hydrological characteristics from different parts of the island. The stations have now been operating for a

number of years and the network requires review and evaluation of the quality and appropriateness of the information being collected for its intended purpose of regional resource assessment.

1. INTRODUCTION

1.1 PURPOSE AND SCOPE OF THE STUDY

This study (conducted in late 2004–early 2005) was part of a wider, multi-agency study into the natural resources of Kangaroo Island. The prime focus of the wider program was the water quality and quantity, and the management required to sustain natural ecosystems, primary industries, and human consumption needs, and other urban and domestic uses.

The focus of the study described in this report was to assess the impact of farm dams on streamflows and the potential threats to ecosystems.

The Kangaroo Island Natural Resources Management Board (KINRMB) and the Department of Water, Land and Biodiversity Conservation (DWLBC) funded this project.

1.2 STUDY APPROACH

The rainfall-runoff model used in this study was a GIS-based mean-annual model that incorporated simulated mean-annual streamflow captured by farm dams. A rainfall-runoff equation was used based on the standard hydrological tanh equation. The parameters of the tanh equations were derived from annual rainfall and a yield analysis for Middle River Reservoir catchment.

A simple mean-annual model was used as this was more rapid than developing a detailed daily time-step hydrological model that would require extensive calibration data that did not exist for much of the study area. Although the model and input data used in this were quantitative as far as possible, the model was essentially a risk assessment approach that was simplistic with many assumptions. It is suggested therefore, that the results are regarded as showing areas of potential impacts with a scale of magnitude of those impacts. The results can be used to prioritise further investigations and show where further farm dam development may be permitted.

2. DESCRIPTION OF SURVEY AREA

2.1 OVERVIEW

The study area was the whole of Kangaroo Island, located off the Fleurieu Peninsula in the state of South Australia. There are several large areas of native vegetation, mostly contained within national or conservation parks that cover ~39% of the landmass. Apart from a few towns and small population centres, the remainder of the island is mainly used for primary production. The main crops are sheep for meat and wool, seed potatoes and marron. Forestry is an emerging issue in several parts of the wetter areas. Due to the relative quietness of the island, large national parks, coastal scenery, and well vegetated streams throughout the rural areas, the island is a favourite tourist destination.

Annual rainfall varies from around 500 mm in the lower areas east of the centre of the island, to around 850 mm in the higher regions. Most of the rainfall falls during the cooler winter months.

There are around 8600 farm dams on Kangaroo Island (based on 2001 data) with an estimated combined storage capacity around 18.5 GL. In addition to the farm dams, there are around 560 marron ponds, as well as a water supply reservoir (Middle River Reservoir) and two reservoirs no longer in use (Howard’s Dams in the Willson River Catchment).

The maps show the national and conservation parks, main roads and towns (Fig. 2.1); the distribution of annual rainfall as used in the modelling (Fig. 2.2); and the terrain and major watercourses (Fig. 2.3).

2.2 FARM DAMS

2.2.1 The importance of farm dams

Farm dams are water storage structures generally constructed in rural areas for capturing surface water runoff generated from the catchment area above them. Farm dams have been constructed across most of the area on Kangaroo Island that is outside of national and conservation parks, as shown in Figure 2.4. The water stored in farm dams provides an additional source of water (in addition to water pumped from groundwater and, if available, reticulated supplies) for domestic, stock and irrigation purposes during the summer months.

Farm dams, as well as providing an important source of water, also provide a barrier to streamflow downstream until the dam fills and overflows. This delays the commencement of flow at the beginning of the wet season and reduces the total quantity of water available to users and the environment downstream. These impacts are greater when a large dam is constructed across a stream, and due to the cumulative effect of many small farm dams in one stream reach.

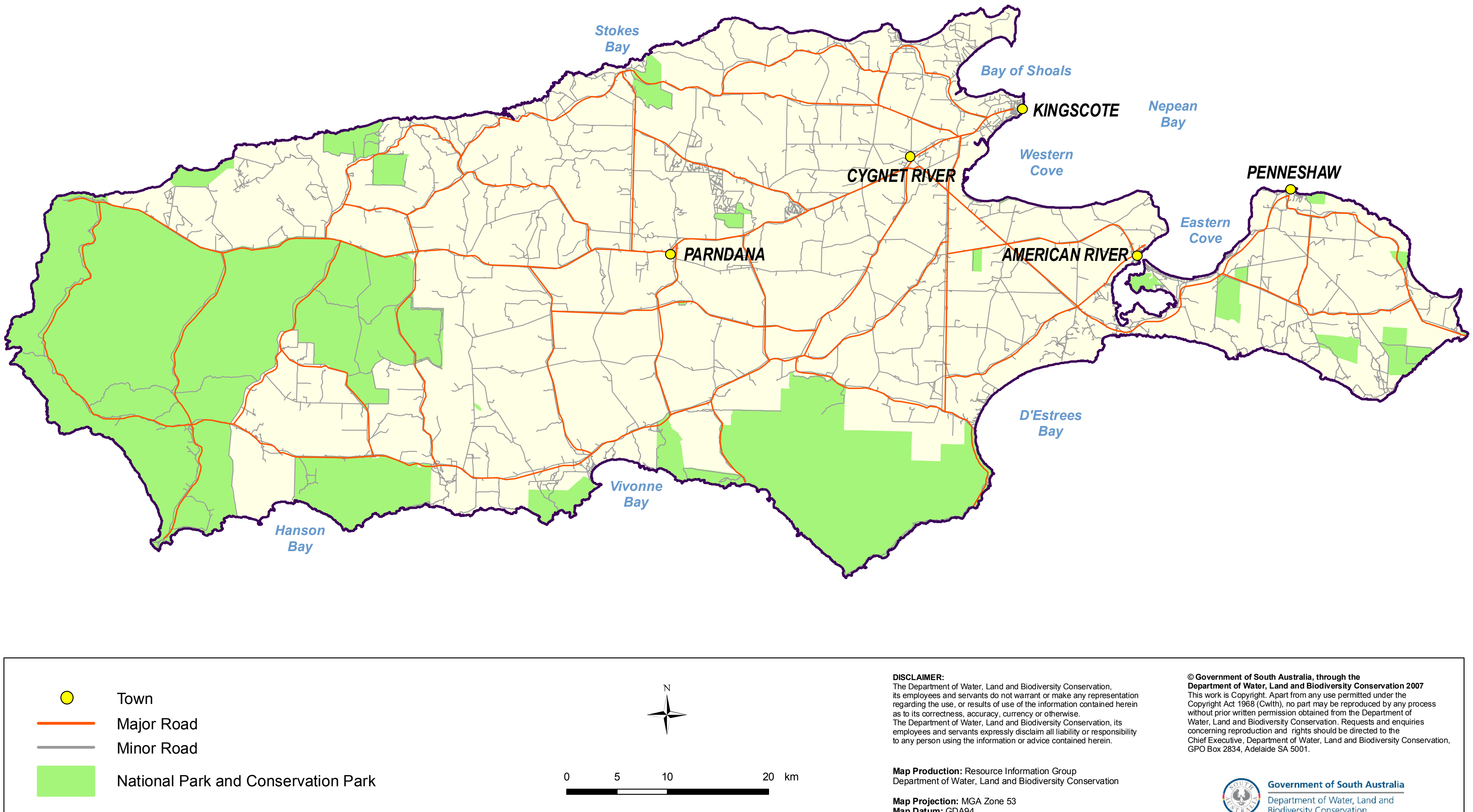
A particularly undesirable impact of farm dams is the effect on the flow regime (including the delay on commencement of streamflow). This has a negative impact on the riverine and water dependent ecosystems. Each habitat within aquatic ecosystems is associated with a community of plants and animals ranging in size from micro-organisms and invertebrates through to the largest species. The life history of plants and animals that inhabit the aquatic, riparian and floodplain environments of river systems are dependent on the flow regimes that maintain these habitats (G. Scholz pers. comm.).

The impact of farm dams on the flow regime is not directly addressed in this study. However it did investigate the impact of farm dams on mean annual flows, from which the effect on water dependent ecosystems can be estimated. The current thinking is that where up to 10% of the annual streamflow is removed this will have minimal impact; 10–20% streamflow removed will cause impacts on sensitive species; 20–50% of streamflow removed will cause a significant impact; and greater than 50% of streamflow removed will cause a major environmental change within 25 years (G. Shulz pers. comm.).

2.2.2 Farm dam data

Farm dam GIS dataset was obtained from the Department of Environment and Heritage. The farm dam outlines were digitised on-screen from ortho-rectified, 1:80 000 scale (2 m pixel), aerial photography flown in mid 2001. The data was produced for mapping purposes and not hydrological purposes. However, an informal examination of the data, when compared with the aerial photography, showed it was generally of reasonable quality for hydrological assessments with some corrections.

The spatial distribution of farm dams, marron ponds and reservoirs are shown in Figure 2.4. The number and total volume of farm dams (excluding identified marron ponds and reservoirs) in each size class are given in Table 2.1.



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Map Datum: GDA94

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Figure 2.1 Major population centres, roads and conservation areas.

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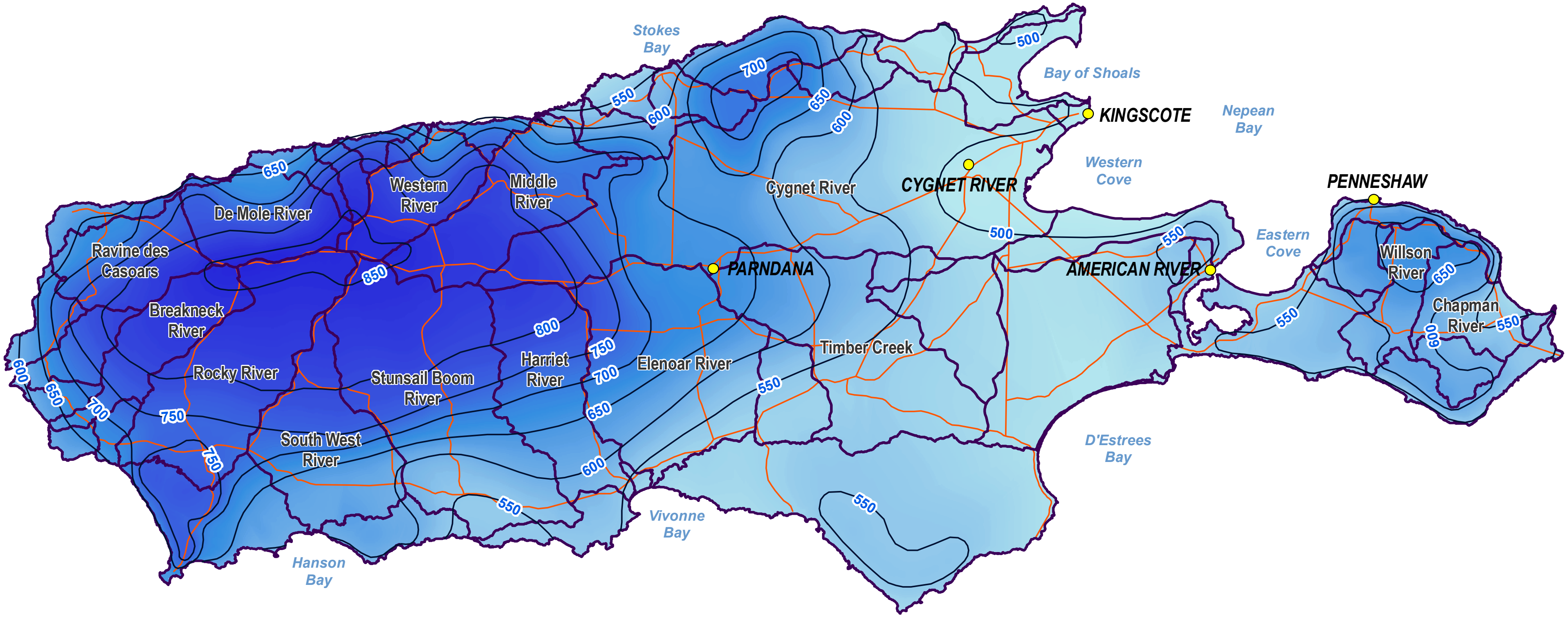

Town
Major Road
600 Rainfall (mm)
Catchment

ANNUAL RAINFALL (mm)

High : 859

Low : 480

N

0 5 10 20 km

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Figure 2.2 Annual rainfall.

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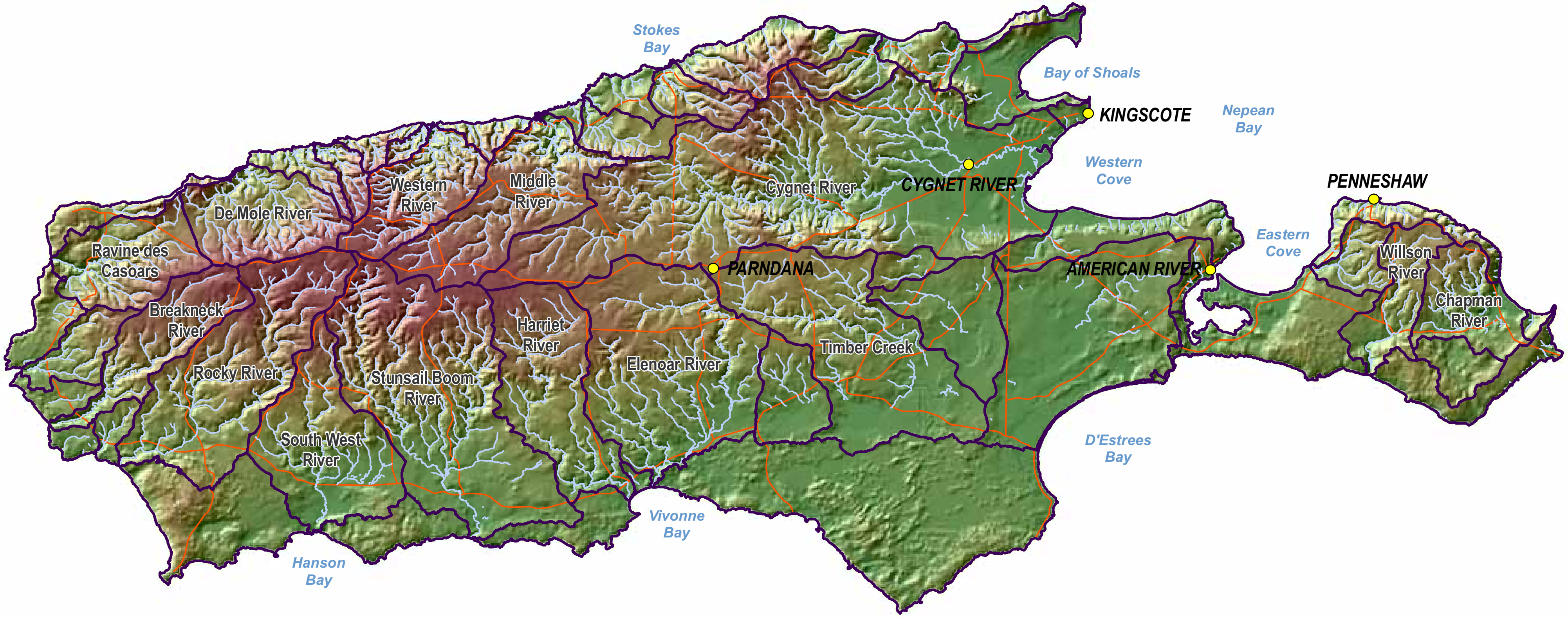

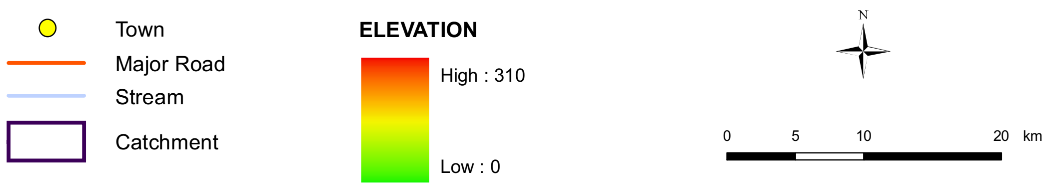

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Figure 2.3 Topography and major catchments.

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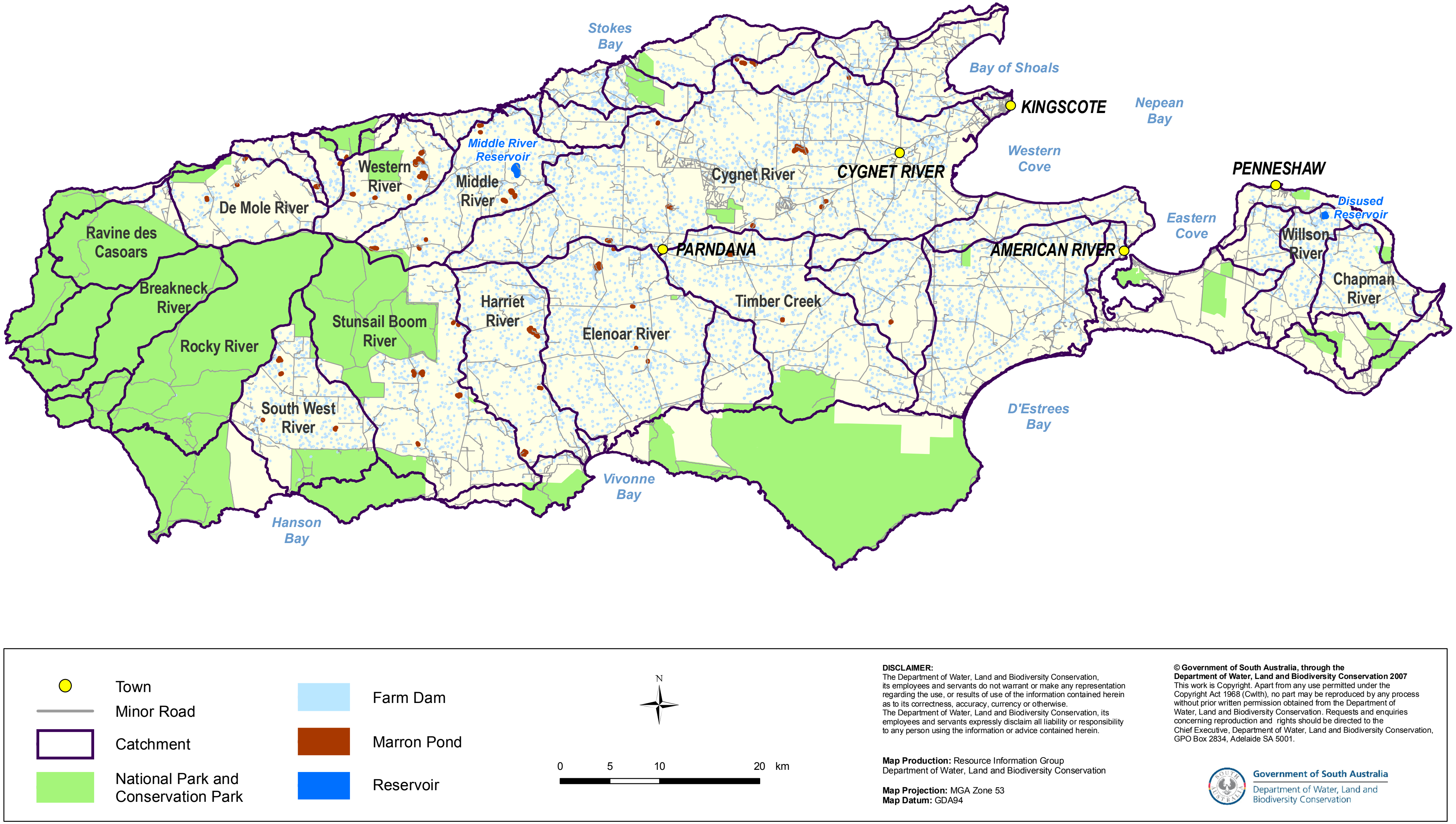

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Figure 2.4 Farm dams, marron ponds and reservoirs.

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Table 2.1 Kangaroo Island farm dam statistics (excluding identified marron ponds and reservoirs)

Size class	Number of dams	Percentage of total number	Combined volume	Percentage of total volume
<0.5 ML	952	11.10	324	1.70
0.5–2 ML	5 321	61.90	6 218	33.50
2–5 ML	1 961	22.80	5 562	30.00
5–10 ML	232	2.70	1 578	8.50
10–20 ML	76	0.90	1 031	5.60
20–50 ML	37	0.40	1 171	6.30
50–100 ML	6	0.07	343	1.80
100–200 ML	4	0.05	471	2.50
>300 ML	4	0.05	1 869	10.10
Totals	**8 593**	**100.00**	**18 567**	**100.00**

The corrections and additions made to the farm dam data were as follows:

- Duck Lagoon (a natural waterbody) and an intermittent wetland area to the southwest were deleted
- the volume of Middle River Reservoir was changed to the volume sourced from SA Water (470 ML)
- a large group of marron ponds in the upper reaches of the Elenoar catchment were added (the treatment of marron ponds is described in a following section)
- some larger dams were added as identified in aerial videography (obtained from a parallel project) and/or field inspection. The volumes of most of these dams were assumed while some were determined from in-field inspection using the rapid field assessment technique (V = 0.4*D*A)
- a large dam in the upper Harriet River catchment was digitised from information provided by Mark Storry, Native Vegetation Group DWLBC
- a field was added to the attribute table and all features classified as farm dams, marron ponds, the Middle River Reservoir or the previous reservoirs in the Wilson River catchment. The marron ponds were identified by shape (rectangular) and their location in groups. Only a small number of marron ponds were subject to field inspection. Therefore, there could be errors in the classification
- volumes and usage figures were added as described in the following sections.

2.2.3 Farm dam volume estimation

The storage volumes of all features identified as farm dams were estimated with a volume-area relationship developed from studies of farm dams mainly in the Mount Lofty Ranges (McMurray 2004b). That study proposed two volume-area relationships: one for areas with intensive development of farm dams (e.g. the Barossa Valley area and part of the Onkaparinga catchment), where many dams had large storage capacities compared to the average; the second for areas with lower levels of farm dam development intensity. In the absence of studies into volume-area relationships for Kangaroo Island farm dams, it was decided to use the second relationship for this study as follows:

for A < 15 000 m^2 V = 0.0002*A^1.25

for A >= 15 000 m^2 V = 0.0022*A

where V = Estimated Volume (ML)

A = Surface Area (m^2)

A number of farm dams on Kangaroo Island are much larger (up to 500 ML and possibly up to 1000 ML) than any from other studied areas within South Australia. Therefore, whichever of the previously derived methods are used for the estimation of volume involves an extrapolation beyond the sample data on which the methods were based. Some of these larger dams were measured with the rapid field assessment method. Others were estimated using assumed depth. There is considerable uncertainty associated with the estimation of all farm dams, particularly these large dams.

If more detailed hydrological studies are to be undertaken on Kangaroo Island, it would be necessary to survey a reasonable number of farm dams, at least with the "rapid field assessment" technique (described in McMurray 2004b), and develop a volume-area relationship using the method outlined in McMurray (2004b).

2.2.4 Farm dam usage estimation

The quantity of water removed from streams by farm dams was estimated as the sum of a winter component and a summer component. For the winter component it was assumed that: (a) there was no extraction for irrigation; and (b) the dams were full, and the quantity of water removed was assumed to be due to evaporation only and based on a constant surface area.

The summer component was calculated from dam volumes and a usage factor. A different usage factor was used for large dams than for other dams, as explained below. The usage factors included an allowance for extractions due to irrigation and evaporation, and were based on another study in the Mt Lofty Ranges (McMurray 2004a) into water usage from farm dams. This study showed water extraction averaged around 17–19%, with similar figures for evaporation in the same study period (summer 2001–02), which was considered cooler and wetter than normal suggesting that the figures of both extraction and evaporation would be higher in a more typical summer. An allowance for leakage was included in the usage factors.

From the foregoing, a usage factor for summer losses of 0.5 of capacity was used for most farm dams. For large dams (>100 ML) a usage factor of 0.8 was used. This was on the basis that from landowner discussions at least some of these large dams are used to supply irrigation water for seed potatoes, a high value crop. Other larger farm dams were observed to be used to supply water to cascades of marron ponds. It was assumed that all these larger farm dams had a high water usage.

It would be possible to use more size-class break points, or a sliding scale. However, this is adding complexity to a very simple model without any data on which to base parameters.

In summary, the calculation of usage from the sum of the winter and summer components was as follows:

Q = (Area * Winter_Evaporation * Pan_Factor) + (Volume * Usage_Factor)

Where Q = mean annual quantity of water removed from streams by farm dams

A Pan Factor of 0.75 was assumed

Usage_Factor = 0.8 for dams >=100 ML, 0.5 for all other dams

A correction factor to rationalise units to ML was used (not shown).

2.3 MARRON PONDS

2.3.1 Importance of marron ponds

Marron is a relatively high value primary product, providing major financially return for many primary producers on Kangaroo Island. The existence of marron ponds could impact on stream flow in the same manner as farm dams (as discussed above). However, in the case of the marron ponds inspected, the ponds were constructed off-stream and water conservation measures were practiced. Water was continually cycled and treated through the ponds by gravity from a header dam or tank. In one case, even leakage from the ponds was trapped and returned to the header dam or tank. Water was delivered to the header dam or tank from a farm dam located on stream. It was assumed in this study that water removed by marron ponds was due to evaporation only.

The GIS data for marron ponds was part of the farm dam GIS dataset as described above. Around 560 marron ponds were identified in the farm dam dataset. The identification was on the basis of shape and location. Marron ponds were assumed to be of a rectangular construction and generally located in groups arranged down slope to permit circulation of water from one pond to another. There could be errors in this identification method, so this number of 560 marron ponds should only be regarded as approximate.

2.3.2 Marron pond volume estimation

The volumes of features identified as marron ponds were estimated, assuming the ponds are basically block-shaped. The volume was estimated with 0.9 x L x W x D, where L x W is the surface area obtained from the GIS data. The factor of 0.9 was included to allow for sloping sides. The GIS determined area was multiplied by 0.8 to allow for “over digitising” the groups of ponds shown as sub-divided blocks, as in practice there is a dividing wall up to 2 m wide. The depth of a typical pond varies from around 1 m up to around 1.5 m along their length. Although large ponds may be deeper, an average depth of 1.25 m was assumed for all ponds. The accuracy of this volume estimation was not important as only usage and not volume was used in the modelling.

2.3.3 Marron pond usage estimation

Discussions on water use practices were had with three of the larger marron producers in the upper reaches of the Harriet River, Elenoar River and Cygnet River catchments. Although details of marron pond management varied between the producers, it was apparent that water conservation was practiced. Seepage from ponds and drainage water was treated and re-cycled. It was assumed, therefore, that the losses from all marron ponds would be due only to evaporation. However, this does not consider the possibility that some smaller producers may not use water conservation practices.

It appeared from discussions with producers and considerations of marron production requirements that the ponds are maintained at or near full capacity, except when drained for nutrient remediation. This is achieved by a constant flow of water from a header tank or dam, through pipes into each down-slope series of ponds and into a settling pond. For the purposes of estimating evaporation losses, the surface area of each pond was therefore assumed to be constant throughout the year.

Leakage from marron ponds is generally collected and returned to settling ponds and no additional allowance was made for this source of loss.

The water removed from marron ponds was calculated on the basis of evaporation losses only, as follows:

Q = (Area *F) * Annual_Evaporation * Pan_Factor

Where Q = mean annual quantity of water removed from streams by marron ponds.

F = a factor to allow for "over digitising" of marron ponds (F = 0.8 was used, see Volume Estimation section).

A Pan Factor of 0.75 was assumed.

Correction factor to rationalise units to ML not shown.

2.4 RESERVOIRS

There are two water-supply reservoirs on Kangaroo Island: Middle River Reservoir, located in the Middle River catchment, is still in service for water supply purposes; and Howard's Dam, a reservoir in the Wilson River catchment, is no longer used for water supply being decommissioned some time previously.

The volume of Middle River Reservoir (470 ML) was obtained from SA Water sources. The usage factor used (0.8) was the same used for the larger farm dams.

The volume of the disused reservoir (Howard's Dam) was treated in this study in the same manner as farm dams. The volume was derived from the same volume-area relationship used for the farm dams, and the usage factor was the same as the farm dams.

2.5 TOPOGRAPHY

Topographic data in electronic format was required to define surface water runoff flow paths (stream networks) for the model. The datasets used were a hydrologically corrected DEM (Digital Elevation Model) and a flow-direction grid derived from the DEM.

The hydrologically corrected DEM was created specifically for this study using the program CatchmentSIM (see references). The source data used was 10 m interval contours and a drainage (stream network) dataset, both in GIS format. Creating a hydrologically corrected DEM is not a straightforward task, especially on Kangaroo Island where there are areas with undefined drainage and areas with multiple internal permanent or intermittent wetlands. An iterative approach was used where the major catchment boundaries and stream networks created from the DEM were judged (against existing GIS datasets) acceptable for the purpose.

There are many areas with small internal catchments, most of which drain into a swamp or small lake. Several of these exist as isolated catchments within larger catchments or on the edge of larger catchments. As many of these are likely to contribute to surface water in the larger catchments (via overflowing or sub-surface paths) the DEM was modified to create a false flow path into the larger catchment. This simplifies the model outputs. It was considered that the majority of likely errors produced by this simplification would be insignificant at the scale of this study. However, uncertainty remains as to the true flow paths and terminal points of surface water in the lagoon catchments north of Cape Gantheaume Wilderness Area. These include Lake Ada, Murray Lagoon, Rush Logoon, White Lagoon and Salt Lagoon.

There were areas along the south coast, with complex sand dune systems, where no attempt was to made to correct the surface water flow paths as represented in the final DEM. The model outputs should be ignored for these areas.

The cell size chosen for the DEM (and for all data used for the modelling used in this study) was 100 x 100 m. This is considered larger than ideal for producing data at 1:50 000 scale. However, it was considered to be a reasonable compromise between accuracy (especially considering other potential sources of error associated with the simple modelling used in this study), data volume and computer processing times.

3. HYDROLOGICAL DATA

3.1 EVAPORATION

Evaporation data was required in order to estimate the evaporation losses from farm dams.

It was thought that the evaporation losses from farm dams would be lower on Kangaroo Island than in the Mount Lofty Ranges. However, a comparison of available data showed that the pan evaporation is similar for the two regions.

The only evaporation station on Kangaroo Island was Bureau of Meteorology station number 22814 Parndana Research Station. This closed in 1984, but had a reasonably complete record from 1969. The only evaporation stations within the Mount Lofty Ranges that had a period of record that overlapped that from the Parndana stations were Bureau of Meteorology station number 23734 at Mt Bold Reservoir, and Bureau of Meteorology station number 23820 at South Para Reservoir. Data from these three stations was obtained for the period 1969–84, as shown in the table below. A double-mass analysis to check for uniformity of recordings was not conducted.

The following evaporation figures were used in the modelling:

- annual evaporation of 1596 mm as determined from the Parndana data (see Table 3.1). This was used in the estimation of water lost from marron ponds (see section 2.3.3)
- winter evaporation of 473 mm as determined from the Parndana data (see Table 3.1). This was used in the estimation of water lost from farm dams during the winter months (see section 2.2.4).

Table 3.1 Monthly mean (period 1969–84) evaporation data for Parndana KI and Mt Bold and South Para Reservoirs MLR

	22814 Parndana	**23734 Mt Bold Reservoir**	**23820 South Para Reservoir**
Jan	249	249	240
Feb	210	227	208
Mar	167	174	160
Apr	114	108	99
May	75	70	60
Jun	53	51	40
Jul	58	55	44
Aug	73	75	60
Sep	88	94	82
Oct	126	137	130
Nov	160	175	171
Dec	223	229	220
Nov–Apr Totals	*1 123*	*879*	*827*
May–Oct Totals	*473*	*483*	*415*
Annual Totals	**1 596**	**1 645**	**1 512**

A plot of the monthly means from the above three stations is shown in Figure 3.1. For the hotter months (November to March) the difference in monthly means is generally less than 10%, with the data from Parndana showing no consistent difference in trend from the other two stations. From this, it was considered reasonable for the evaporation allowance over the summer period to be the same as the Mount Lofty Ranges in McMurray (2004a). In the modelling, evaporation losses from farm dams were incorporated into usage factors (see section 2.2.4) that were the based on data from the Mount Lofty Ranges study (McMurray 2004a).

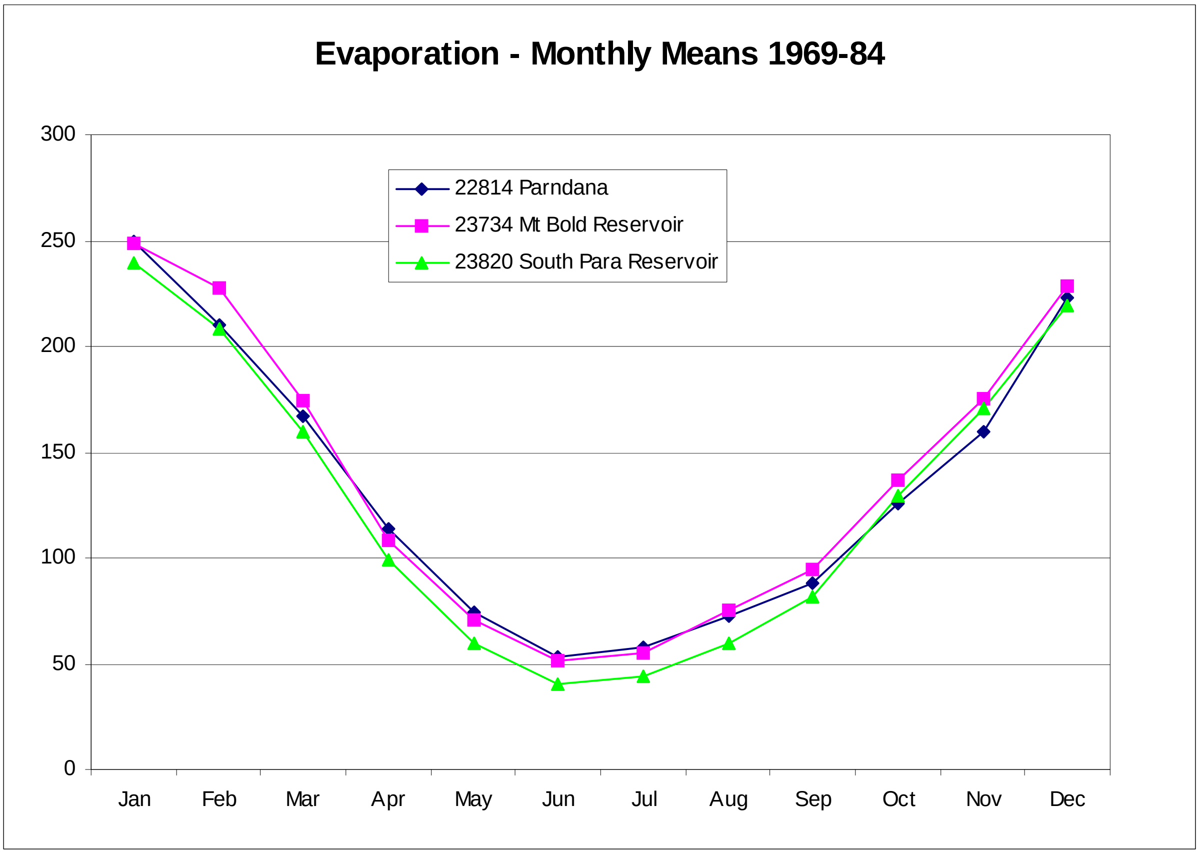


Figure 3.1 Monthly mean evaporation data for Parndana KI and Mt Bold and South Para Reservoirs MLR

3.2 RAINFALL

As the GIS model used in this study was a single step mean annual model, daily rainfall data was not required as is usual for hydrological models. The only requirement was for a single GIS dataset of mean annual rainfall.

Available data sources were as follows:

- state-wide isohyets from DWLBC's GIS library
- nation-wide gridded data purchased from the Bureau of Meteorology
- rainfall monitoring stations (as a GIS point dataset) with annual and mean annual rainfall derived from Bureau of Meteorology data
- rainfall monitoring stations (as a GIS point dataset) with patched annual and mean annual rainfall from the SILO PPD database (see SILO in references)
- a map of isohyets in a report by Bren (2004), for which the source was not established.

The state-wide isohyets from DWLBC's GIS library were generated at a state-wide scale, using an annual gridding method and rainfall station data contained in a "Drizzle" dataset obtained from the BOM in 1995. However, these isohyets were considered unsuitable for use on Kangaroo Island when judged against figures of mean annual rainfall in both the rainfall monitoring site datasets. It was possible that an insufficient number of rainfall stations in this study area were used in the creation process.

The Bureau of Meteorology's gridded data was created using a complex spatial interpolation algorithm (Hutchinson 1995) that considered many aspects including elevation. However, there are potential limitations to the data when it is examined at the scale of the catchments and sub-catchments for this study. The potential limitations were as follows:

- data was based on nation-wide parameters that may not consider characteristics of local climates
- the interpolation process incorporated only rainfall stations where the data was considered to be good quality and with a record covering the Bureau of Meteorology standard 30-year period 1961–90. This results in the data from many stations being rejected. The remaining rainfall stations may be insufficient to adequately represent rainfall at the spatial scales required in this study
- the final grid was produced with a cell size of 5 km. Although this was suitable for the intended spatial resolution of the data, it was considered rather coarse for this study
- although the isohyets generally matched the figures of mean annual rainfall from the monitoring stations, they did not follow what was expected from the general terrain, particularly in the region of the high plateau towards the western end of the island.

Due to the foregoing, and prior to sighting the isohyets in Bren (2004), it was decided to manually digitise isohyets. For this exercise the following data was used as a guide:

- DEM to show the terrain
- mean annual rainfall from the SILO PPD monitoring stations, where these existed
- mean annual rainfall from the Bureau of Meteorology monitoring stations, where SILO stations were not available and where there was a reasonable and recent period of record (generally >20 years within the last 40 years)
- gridded data from the Bureau of Meteorology.

Results from the above were later judged to be similar, in the major aspects, to the isohyets in the Bren (2004) report.

The digitised isohyets were then used in a spatial interpolation procedure to produce gridded data for use in the modelling. The spatial interpolation technique was an iterative two-step process. The two steps consisted of creating a TIN (Triangulated Irregular Network) surface (principally a linear interpolation), followed by gridding using a quintic interpolation algorithm to create the grid. The grid was examined for false peaks and pits, and if there were any, either small changes were made to the isohyets or training lines were added and the interpolation repeated. These steps were repeated until the final gridded data conformed satisfactorily to the original isohyets.

The annual rainfall gridded data and the isohyets produced are shown in Figure 2.2.

3.3 STREAMFLOW GAUGINGS

Stream flow data for the study area was required in order to produce a rainfall-runoff relationship for use in the modelling. DWLBC records show five stream gauging stations on Kangaroo Island and two reservoir or dam level stations. However, at the time of this study (late 2004–early 2005) only one of the foregoing stations had data that could be readily used for determining rainfall-runoff relationship.

A brief description of the seven stream flow and reservoir level stations is given below.

- AW513501 Rocky River @ u/s Gorge Falls. This station has a good in-stream control and a long record. This data could be used to establish a rainfall-runoff relationship. However, the catchment is all natural native vegetation within a national park and is not typical of other catchments on the island.

- AW513502 @ Middle River Dam. This records the level in Middle River Reservoir. Catchment yield was deduced from a water-balance analysis (Tomlinson 1996). This catchment yield analysis data was used in association with annual rainfall to derive a rainfall-runoff relationship based on a tanh equation as described below.

- A5131001 Cygnet River @ Huxtable Forest. A fairly new station with short record with much missing data and no rating. This data was not usable for this study.

- AW513500 Smith Creek @ AMTD 1.6 km. A closed station for which the data has not been digitised and maybe lost.

- AW513507 Cygnet River @ Playford Highway. This station is close to A5131014 below. The site was designed to target mid to high flows. The station had around 5 years of data, however the theoretical rating had yet to be confirmed by field measurements.

- A5131014 Cygnet River @ u/s Koala Lodge. This station is ~100 m upstream of AW513507 above and was designed to target lower flows. The combined data from AW513507 and A5131014 was intended to provide a continuous yield from Cygnet River over the entire range of its flows. There was only 2–3 years of data. The rating for the low flow structure is theoretical and, as yet, there is no rating that combines the two sites to provide a complete, seamless stage-discharge relationship for the entire range of flows.

- AW513503 Willson River @ SE Penneshaw (Dam 1). This station records the level of a small reservoir no longer used for water supply. The data is considered of very poor quality, with an unsuitable flow control. There is no water use data to perform a water balance analysis. This data was considered unusable for use in this study.

From the above analysis of available stream gauging sites it was decided that the only streamflow data that could be used to examine rainfall-runoff relationships for Kangaroo Island was the yield analysis by Tomlinson (1996), for the catchment of the Middle River reservoir (Table 3.2).

This situation will improve in future years with more data from newer stations, provided that the appropriate resources are allocated to maintain the stations and determine ratings for the stream controls. It will also require appropriate resources to analyse the data and produce the required relationships.

3.4 RAINFALL-RUNOFF RELATIONSHIP

3.4.1 Description

The modelling undertaken in this study used an annual rainfall-runoff relationship. Although an annual rainfall-runoff relationship is simple in comparison to the more complex algorithms usually employed in hydrological modelling, they provide a straightforward means of estimating the quantity of runoff (catchment yield) that can be expected from a catchment for a range of rainfall levels. They can be used for comparing the characteristics of different catchments or sub-

Table 3.2 Annual yields for Middle River Reservoir catchment determined by water balance modelling (Tomlinson 1996)

Year	**Yield** (ML)	**Runoff** (mm)
1970	8 269	82
1971	22 404	222
1972	16 491	163
1973	14 936	148
1974	25 305	251
1975	12 607	125
1976	9 050	90
1977	4 644	46
1978	30 450	302
1979	15 605	155
1980	14 588	145
1981	21 780	216
1982	6 377	63
1983	30 202	299
1984	26 160	259
1985	8 885	88
1986	17 479	173
1987	13 621	135
1988	10 616	105
1989	24 198	240
1990	14 517	144
1991	14 137	140
1992	29 682	294
Mean	**17 044**	**169**

catchments; for estimating the quantity of runoff generated in different years; and, as in this study, for providing an estimate of the impact of farm dams on runoff. Two commonly used rainfall-runoff relationships are runoff coefficient and an equation based on the tanh function.

The tanh function (Grayson et al 1996) is a standard hyperbolic function and is frequently used as a simple rainfall-runoff relationship. The relationship takes the following form:

$$Q = (P - L) - F * \tanh[(P - L)/F] + C$$

Where Q = mean annual runoff (mm).

P = mean annual rainfall (mm) averaged across the catchment.

L = Notional initial loss parameter.

F = Notional ongoing loss parameter.

C = Constant to simulate continuous base flow.

(C = 0 except for Tookayerta catchment)

The values of the coefficients L and F need to be fitted to the annual rainfall and annual runoff for the catchment(s) under study.

3.4.2 Tanh Equation for Middle River

For this study the only suitable data of annual runoff for Kangaroo Island was the yield analysis for Middle River Reservoir catchment (as described previously). This data was used together with annual rainfall to derive a tanh rainfall-runoff relationship for use in the modelling.

The total rainfall across the Middle River Reservoir catchment for each of the years 1969–92 was determined in GIS. For this, the catchment was sub-divided in areas approximating Thiessien polygons, with a bias of the higher rainfall station towards the higher south-western end of the catchment where there was no rainfall station data. Data from four nearby stations was obtained, patched and extended (where required) to provide complete years' data from 1969–92 (the period for which the yield analysis was conducted). The data from 22829 Parndana Willang station had a double change of slope in the double mass curve, suggesting a problem that was not investigated. This data was not used. The rainfall stations from which the data was used were 22816 Parndana Allendale, 22835 Parndana Turkey Lane and 22840 Parndana Telhawk.

A plot of the catchment yield (from Tomlinson 1996) against the rainfall for each year is shown in Figure 3.2, together with a plot of a tanh equation derived from the data. Also shown is a plot of the tanh equation derived from Mount Lofty Ranges rainfall and runoff data from several catchments (unpublished internal study). This is shown for comparison purposes. The similarities provided a degree of confidence in the relevance of the tanh equation derived from the Middle River data.

The tanh equation derived from the Middle River data was created by fixing the L parameter and solving to minimise RMS errors to obtain a value for the F parameter. Several values of L were trialled, with the final value chosen subjectively consistent with the procedure described in Grayson et al (1996). The values of L and F for the MLR derived equation were 200 and 650, and for the equation derived from the Middle River catchment data were 140 and 730.

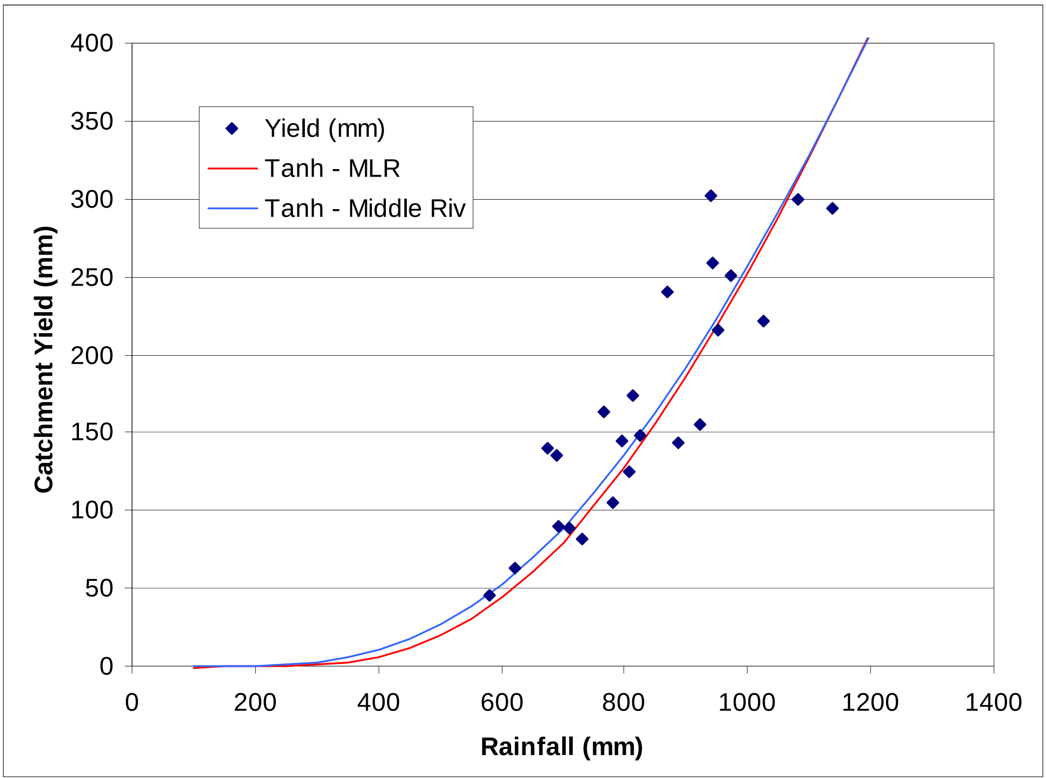


Figure 3.2 Tanh rainfall-runoff relationship derived for Middle River Reservoir catchment and for comparison the relationship derived for the Mt Lofty Ranges

4. MODELLING

4.1 OVERVIEW

The model used in this study was a GIS-based annual yield model. Runoff in all stream reaches was first estimated using the rainfall-runoff relationship described in section 3.4. The model then simulated the removal of water by farms dams due to extractions for irrigation, stock and domestic use, and due to evaporation. The results were presented as the percentage of water removed due to farm dams, with the percentage categories chosen to correlate with environmental stress levels provided by Scholz (pers comm).

The following sections present a very brief outline of the technical aspects of the model. More detailed information can be obtained from documentation provided as part of GIS program packages.

4.2 RASTER DATA

The model was based on a type of GIS data known as raster data, usually referred to as grids. Raster data (or grids) are a rectangle of equal sized cells where each cell has a single numeric value. The rectangular grid can represent any area of the earth's surface. Hence, each cell has coordinates representing its position on the earth's surface.

The study area can be of any shape (such as a catchment boundary), and the size of the grid boundary rectangle is chosen to be large enough to ensure that the study area is completely covered. Cells outside of the study area, but still within the rectangle, have a null value. Other cells in the mesh have numeric values that represent any natural or imaginary phenomenon. Examples include elevation (as in a DEM), land use, soil type, rainfall and runoff. The cells are usually exactly rectangular and can be of any size. The size of the cells is chosen so as to adequately capture the changing phenomenon they represent. Typical cell sizes range from a few metres, or less, for a very high definition DEM (intended to capture subtle changes in elevation) up to 5 km or more, for a continent-wide rainfall grid (intended to show only the major variations in rainfall).

Experience has shown that a cell size of 25 m adequately represents data conforming to standard 1:50 000 scale mapping standards. However, a cell size of 100 m (representing a land area of 1 Ha) was used in this study in order to reduce data volumes and processing times. This cell size was considered adequate for this type of modelling work.

4.3 MODEL DESCRIPTION

The model made use of several hydrological functions incorporated in the GIS program used in this study, together with a function developed in-house. The principle functions used were the flow direction and flow accumulation functions. The flow direction function produced a flow direction grid from the DEM. In the flow direction grid, each cell has a code number that represents the down-slope direction of water flow. The flow direction grid is then used as input to the flow accumulation function that accumulates runoff cell-by-cell down all flow paths. The result is the quantity of runoff (as mm or ML) in every cell due to that cell's runoff and all up-slope contributing cells.

The model incorporated the following steps:

- mean annual runoff is determined from mean annual rainfall using a rainfall-runoff relationship (a tanh hyperbolic function)

- the runoff is accumulated down all flow paths, using the topographic data to determine the direction of flow and junctions of stream branches. This gives the mean annual runoff in all flow paths without farm dams

- assumed water extractions and losses from farm dams are then incorporated to provide the mean annual runoff scenario with farm dams

- The difference between the without-dams and the with-dams scenarios is determined as a percentage and categorised into stress categories ranging from minimal to high or extreme. This provides a guide as to the stream reaches that have various levels of impact. This data can be used to determine the level of stress placed on the riparian ecosystem and stream-fed wetlands.

- The final step (that made use of the in-house developed function) determines the contributing areas or sub-catchments for each stream reach to show areas with various levels of farm dam impacts. These results can be used to determine where farm dam impacts are high, possibly requiring management actions, and also to identify areas where further farm dam development may be possible.

The model is a mean-annual yield model. It is not a time-stepped hydrological model that analyses the effect that farm dams have on the flow regime. The outputs show only the average situation in relation to water removed due to extractions and evaporation from farm dams.

As far as practical, the input data was realistic so that the model results would be quantitative. However, due to the lack of analysis of the flow regime and model limitations, results need to be taken as indicative, rather than definitive, of the affect of farm dams on surface water resources.

The outputs show the spatial distribution of the effects of farm dams, and provide a reasonable indication of the levels of environmental stress caused to areas due to removal of streamflow. This permits the prioritising of remedial actions, and provides an indication of areas where further farm dam development may be permitted, and where further development should be avoided.

5. RESULTS

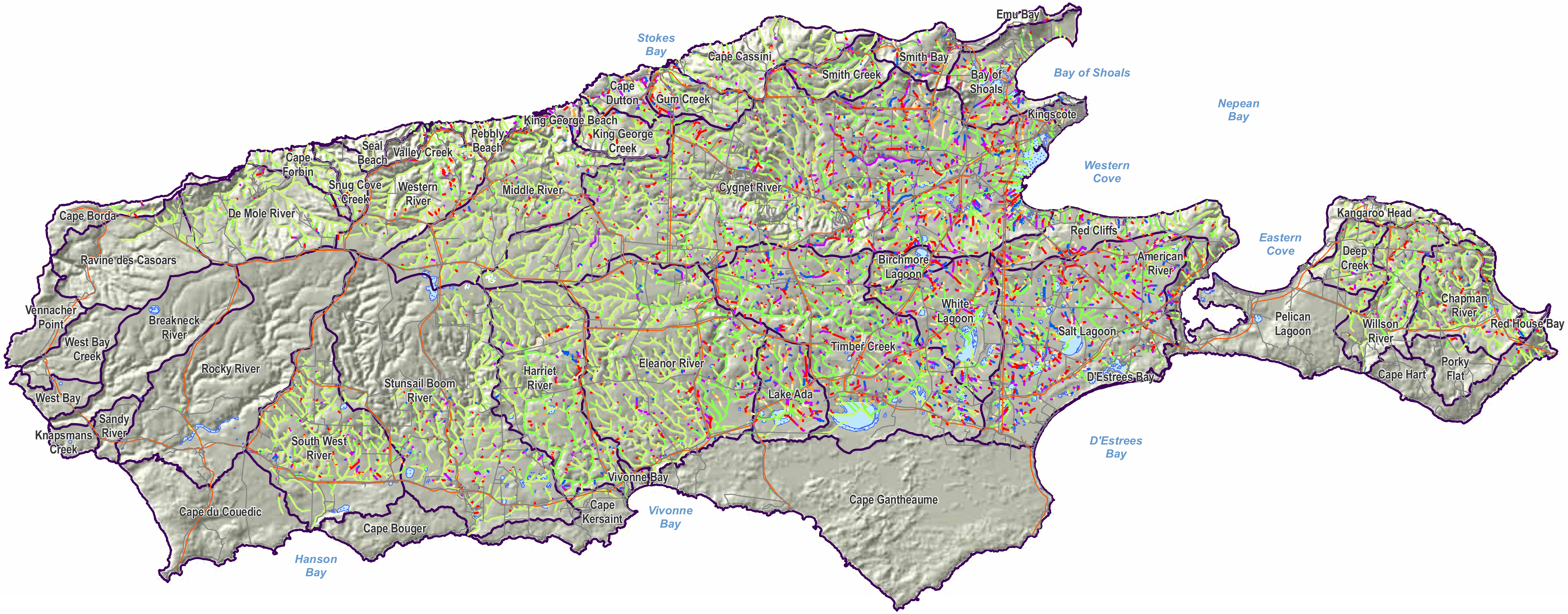
5.1 FORMAT OF THE RESULTS

There are two main types of output from modelling the percentage of water removed due the presence of farm dams as follows.

Stream Stress Levels — This is a GIS stream-base line dataset showing the level of environmental stress on each reach of the stream network. Levels of environmental stress are based on modelled percentages of water assumed to be removed due to usage and evaporation from farm dams. This data and associated maps provide a guide to the level of stress placed on the riparian environment for each stream reach, and allow remedial actions to be prioritised. Results are shown in Figure 5.1.

Catchment Stress Levels — This is a GIS area-based polygon dataset showing the level of environmental stress within stream-reach catchments. The levels of environmental stress are those at the lowest downstream point within each stream-reach catchment. This and associated maps provide a guide to where additional farm dams may or may not be allowed, and also provide a more graphic assessment of the overall stress across the whole study area and the spatial distribution of that stress. Results are shown in Figure 5.2.

The maps incorporated in this report show the whole study area on A3 size maps. These provide a general overview of the model results. In order to see local detail the maps are also available separately as JPEG files and can be printed in whole on large format plotters or in part on standard A3/A4 printers.



Percentage of water captured by farm dams

Major Road	1 - 10%
Minor Road	10 - 20%
Catchment	20 - 25%
Waterbody	25 - 30%
	30 - 50%
	50 - 100%
	>100%

N

0 5 10 20 km

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Map Production: Resource Information Group
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Map Projection: MGA Zone 53
Map Datum: GDA94

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Figure 5.1 Percentage of modelled streamflow captured by farm dams in each stream reach.

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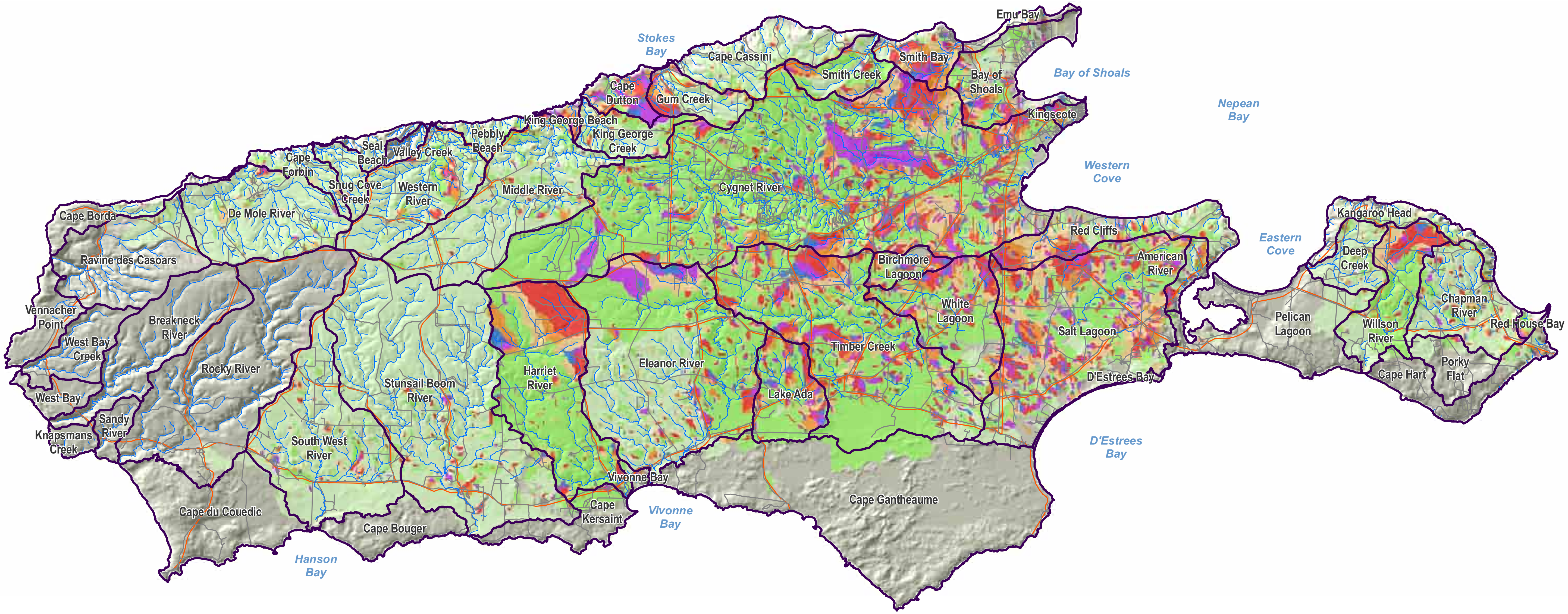

Major Road
Minor Road
Stream
Catchment

Percentage of water captured by farm dams

1 - 10%
10 - 20%
20 - 25%
25 - 30%
30 - 50%
50 - 100%
>100%

N

0 5 10 20 km

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Figure 5.2 Percentage of modelled streamflow captured by farm dams in each stream reach catchment.

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5.2 LEVELS OF ENVIRONMENTAL STRESS

If water is removed from river systems then that water is no longer available for the environment. A greater concern is the alteration to the flow regime caused by water extraction. A full discussion of the environmental effects caused by water removal is beyond the scope of this study. However, it is generally considered that the greater the quantity of water removed (for irrigation, stock and domestic use), the greater the environmental impact or stress.

Some figures have been proposed for the level of potential environmental impacts caused by varying levels of water removal; they are shown in Table 5.1 and were sourced from Scholz (pers. comm.). The levels of environmental impacts for the given range of percentage removal of streamflow are believed to be indicative guidelines at this stage. It is not certain how much science is behind the figures used in this study. Further research on this topic was beyond the scope of this project.

Table 5.1 Levels of environmental impacts considered to be caused by various levels of streamflow removal from streams

Percentage streamflow removed	Likely environmental impact
0–10%	Minimal impact
10–20%	Impacts to sensitive species
20–50%	Significant impact
>50%	Major environmental change within 25 years (>50%)

For this study the percentages of streamflow removed by farm dams were divided into categories of classes based on the figures in Table 5.1. The significant impact category (20–50% streamflow removed) was considered rather wide and was sub-divided into smaller categories (20–25%; 25–30%; and 30–50%).

5.3 RESULTS BY CATCHMENT

Rocky River and Western Catchments

The western catchments include Rocky River, Ravine des Casoars, Breakneck River, West Bay Creek and some small coastal catchments. The majority of these catchments are within Flinders Chase National Park and are covered by native vegetation. As such, there are very few farm dams and thus minimal potential environmental impact.

Cygnet River

The majority of the main channel has less than 10% of streamflow removed, indicating minimal environmental impact due to the presence of farm dams. The final 5 km or so of the main channel, before discharging into Western Cove, has between 10–20% of streamflow removed, indicating a possible impact to sensitive species may exist in this reach.

Brown Creek is a tributary of the Cygnet River and enters the main channel about 2 km west of the township of Cygnet River, around 8 km upstream of the Cygnet River outlet. Brown Creek has greater than 50% of streamflow removed over much of its length, indicating the potential for major environmental change with 25 years from when the extractions commenced (which was not determined in this study). This high stress rating is due to the presence of many farm dams, including four larger dams with greater than 20 ML storage capacity, together with a fairly small catchment area in a region with lower rainfall.

There are many stream reaches in the upper reaches of several tributaries, mainly towards the eastern end of the Cygnet River catchment where the environmental stress level is likely to be significant or have major impacts. The upper part of Gum Creek catchment, which enters the main Cygnet River channel just west of Cygnet River township, is a noteworthy example.

Middle River

There are some short stream reaches where greater than 30% of streamflow is removed, providing potential for significant environmental impact. However, the majority of this catchment is subject to low levels of environmental impact due to removal of streamflow by farm dams, including the reaches below the Middle River Reservoir. This can be attributed to the fact that all the catchment above the reservoir is within the higher rainfall zone, and because the reservoir capacity (470 ML) is not large compared to the mean annual runoff (17 GL for the period 1970–92, see Table 3.3).

Harriet River

The majority of the lower two-thirds of this catchment has less than 10% of streamflow removed by farm dams and minimal environmental impact. There are some short stream reaches with higher levels of environmental impact.

In contrast, the upper one-third of this catchment has much higher levels of streamflow removed, exceeding 100% in two areas with resulting potential significant or major environmental impacts. This is due to two very large farm dams in the upper, higher rainfall, and hence, potentially high runoff areas. These farm dams have estimated capacities of 300 ML and 670 ML, the latter exceeding the capacity of Middle River Reservoir (470 ML).

Elenoar River

The majority of the Elenoar River has less than 10%, or between 10–20%, of streamflow removed, indicating either minimal environmental impact or the potential to impact on sensitive species. However, many of the smaller creek branches where higher quantities of streamflow are removed exceed 50% and have the potential for significant or major environmental impact.

In the northern part of the catchment there are two stream branches that have greater than 20%, or greater than 50% of streamflow removed, with the potential for significant or major environmental impact. These high levels of streamflow removal are caused by a collection of large farm dams, two of which exceed 100 ML in capacity.

Timber Creek

The majority of the main channels of Timber Creek, Little Timber Creek and Curley Creek have between 10–20% of streamflow removed by farm dams, indicating a potential impact to sensitive species. However many of the smaller creek branches where higher quantities of streamflow are removed exceed 50% and have the potential for significant or major environmental impact.

Willson River

The majority of the Willson River has less than 10%, or between 10–20%, of streamflow removed, indicating either minimal environmental impact or the potential to impact on sensitive species. However, the presence of some larger farm dams in the upper parts of the catchment has lead to high levels of streamflow removal, with the potential for significant or major environmental impact.

Other catchments with potential high environmental impact

Other catchments that have areas with potential significant or major environmental impact include the following:

- Lake Ada
- Birchmore Lagoon
- White Lagoon
- Salt Lagoon.

Smaller coastal catchments:

- King George Beach
- Cape Dutton
- Gum Creek
- Red Cliffs.

In each of these catchments there are long reaches of the main channels where the quantity of streamflow removed by farm dams is low, less than 10%, or within the range 10–20%. The potential for environmental impact in these reaches is therefore low or minimal. However, there are many stream reaches, mostly in branches of the main channel, where the quantity of water removed is higher than 20%, with the potential of significant or major environmental impact.

Other catchments with low environmental impact

Other catchments that have the majority of their stream reaches with low levels of stream flow removed include the following:

In the western half of the island:

- De Mole River
- Western River
- South West River
- Stunsail Boom River.

In the eastern end of the island:

- Chapman River
- Deep Creek.

Along the southern coast:

- Cape du Couedic
- Cape Bouger
- Cape Kersaint
- Cape Gantheaume
- Pelican Lagoon
- Cape Hart.

Most of the above south coast catchments are within national or conservation parks and are covered in native vegetation. As with Rocky River and the western catchments, there are very few farm dams and thus an absence of potential environmental impact. In each of the remaining catchments listed above, there is generally low or minimal potential for environmental impact, with the exception of several smaller stream branches that have higher levels of streamflow removed, and hence the potential for significant or major environmental impact. There area also several small coastal catchments, mostly located along the north coast, with low levels of streamflow removed by farm dams.

6. DISCUSSION

6.1 DATA

6.1.1 Streamflow data

The streamflow gauging station in Rocky River was believed to have high quality daily data suitable for hydrological studies in areas with native vegetation. However, at the time of this study (late 2004–early 2005) there was insufficient streamflow data on a daily time step for hydrological studies in areas with cleared or semi-cleared land. The water balance analysis of Middle River Reservoir (Tomlinson 1996) was conducted on a month time step. Although there are some issues relating to determination of low flows, the data was considered adequate for determining a rainfall-runoff relationship.

The current streamflow monitoring network was strategically designed to capture hydrological characteristics from different parts of the island (Greenwood pers comm). Despite the limited number of sites due to high construction costs, the network has the capacity to generate vital information required to manage the island's surface water resources.

After a number of years of successful operation, the established monitoring network should be reviewed to evaluate the quality and appropriateness of the information being collected for its intended purpose of regional resource assessment. This should include a review of data quality, robustness of depth-discharge relationships, including the development of compound relationships for paired high and low flow sites on Cygnet River, and the implications of the gaps left by funding shortfalls.

6.1.2 Rainfall data

The modelling only made use of annual rainfall data. The quantity and quality of this data was considered adequate for the risk assessment modelling used in this study. However, the quality of daily rainfall data, as would be required if more detailed hydrological studies are undertaken, was not assessed in this study.

6.1.3 Evaporation data

There is currently no active evaporation monitoring station on Kangaroo Island. This study utilised data from Parndana monitoring station for an earlier period (1969-1984) and noted a similarity of monthly evaporation data to that from the stations at Mt Bold and South Para in the Mount Lofty Ranges. If more detailed hydrological studies are to be undertaken in the future, these will have to use daily evaporation data from stations outside of Kangaroo Island. A comparison of daily evaporation between Parndana and other stations outside of the Island was not conducted as part of this study.

As evaporation data is an important input to the water cycle, consideration should be given to the issue of monitoring evaporation data on Kangaroo Island, particularly in regard to climate change.

6.1.4 Farm dam data

The majority of the farm dam data available when this study commenced, was based on 2001 aerial photography and was only intended for mapping purposes. The volumes were estimated using a volume-surface area relationship developed for farm dams in the Mount Lofty Ranges.

If more detailed hydrological studies are to be undertaken in the future, updated farm dam data will be required from more recent aerial photography, of appropriate scale, and farm dam outlines will need to be digitised with the purpose in mind. The larger farm dams, at least, should also be bathymetrically surveyed to provide a reasonable value for storage volumes. Consideration should also be given to surveying a reasonable number of farm dams across all size classes, with the volume-surface area relationship investigated using the methods presented in McMurray (2004b).

6.2 POTENTIAL MODELLING LIMITATIONS

No model can be assumed to give highly accurate results. In particular, with the modelling used in this study, there are weaknesses due to the use of a single-step mean-annual yield model, rather than the more detailed daily-step model. These weaknesses and potential sources of error are discussed below.

6.2.1 Use of a mean annual model

A weakness of a mean-annual model is that it is assumed that mean annual rainfall would give mean annual runoff from a single rainfall-runoff relationship, which is not the case in practice. Further, annual yield modelling does not address farm dam impacts on the flow regime. In particular, farm dams capture early season flows that can impact on the breeding of many species. These issues can only be addressed with detailed hydrological modelling, which is usually based on daily time steps.

6.2.2 Marron Ponds

The quantity of water capture by marron ponds was assumed to be due only to evaporation. There may be other sources of loss, but they are probably very small. The sets of marron ponds subject to field inspection were located off-stream and fed from a nearby farm dam. In the modelling, all farm dams were treated equally with a constant usage factor (as explained in section 2.2.4), without any special allowance for associated marron ponds. In practice the effect of marron ponds and associated farm dams may have a different effect, on the capture of streamflow, than assumed in the modelling. This can only be corrected by field inspections of at least the major marron pond enterprises. This was beyond the scope of this study.

6.2.3 Variation of runoff with land use

The model used a single rainfall-runoff relationship across the whole island, without allowance for variations due to factors such as landuse. The rainfall-runoff relationship used in the model was based on the Middle River catchment, which was generally cleared with a scattering of native vegetation and was considered typical of catchments on the island that have farm dams. However, several areas, including whole catchments, are covered in native vegetation that will have lower levels of runoff for a given rainfall. Therefore, any farm dams within catchments with significant areas of native vegetation or established forestry are likely to have a greater level of impact than indicated by the modelling results.

A number of areas are subject to proposed forestry development. The impacts of forestry are to intercept rainfall, reduce recharge of groundwater and reduce streamflow (Zhang et al 2007). The modelling used in this study assessed the impacts of the current level of farm dam development and did not assess the likely impacts of forestry on runoff. The results of this study should not be used to assess the impacts of further farm dam or forestry developments without further hydrological studies.

7. SUMMARY

7.1 RESULTS

The results of the risk assessment modelling showed around 70% of the Island had less than 20% of the modelled streamflow captured by farm dams. This was considered to not cause significant environmental impacts, although sensitive species may be affected. Approximately half of these areas are within National or Conservation Parks.

The remaining 30% of the Island's area, has high (20–50%) to very high (>50%) proportions of the modelled streamflow captured by farm dams. The main concentration of these areas are generally within the lower rainfall areas towards the centre and eastern side of the island. Large areas within several catchments are likely to suffer major or severe environmental impacts. There are also a large number of small areas scattered across the island with very high levels of modelled streamflow captured. These are due mainly to farm dams on short stream branches with low streamflow volumes.

7.2 RECOMMENDATIONS

7.2.1 Further investigations

The catchments that were identified with large areas with high proportions of streamflow captured by farm dams should be subject to hydrological analysis. This is in order to more accurately assess the environmental impacts of the current level of farm dam development, and to enable the assessment of the likely impacts of further developments of farm dam or other water capturing activities (such as forestry).

The catchments that require further investigations and prioritised management actions are as follows:

- Cygnet River catchment, particularly the eastern section; a tributary in the western upstream region caused by a single large farm dam; and many small scattered areas.
- The upper parts of the Harriet River, Elenor River and Wilson River catchments.
- Large areas within the catchments of Timber Creek; Lake Ada; White Lagoon; Salt Lagoon; Birchmore Lagoon and Red Cliffs.
- The north coastal catchments King George Beach; Cape Dutton and Smith Bay.

7.2.2 Monitoring

The suitability of daily rainfall and evaporation data for future hydrological studies was not assessed in this study and should be assessed prior to commencing detailed hydrological studies.

The most crucial data required for detailed hydrological studies is adequate streamflow gauging data. The planned network of streamflow monitoring stations has the potential to provide useful data for regional water resource management. However, at the time of this study, apart from the short period of record, there were several technical issues that rendered the data collected to be unsuitable for the current modelling work.

As a result a study should be undertaken to review the current streamflow monitoring network, including specific issues around instrument reliability and stage-discharge relationships.

7.3 MODEL LIMITATIONS

This study used a risk assessment approach. Therefore the results only provide the general magnitude of impacts and the relative spatial variation of those impacts. Specific limitations to the model were as follows:

- mean annual rainfall does not provide a true value for mean annual runoff
- a mean annual (or yield-based) model does not analyse the flow regime
- a single runoff-rainfall relationship was used across the whole study area and did not include the effect of land use or other possible variables
- model results could not be verified due to absence of suitable streamflow monitoring data at the time of this study (late 2004–early 2005)
- the identification of marron ponds in the spatial data and the true effect on streamflow capture was estimated with limited field inspection.

APPENDICES

Table A.1 Statistics of farm dams – Alphabetical catchment listing

Catchment name	Drainage type	Catchment area (km^2)	Number of farm dams	Combined volume (ML)	Farm dam density (ML/km^2)
American River	Coastal	13	49	58	4.5
Bay of Shoals	Coastal	63	148	222	3.5
Birchmore Lagoon	Closed	18	51	118	6.4
Breakneck River	Exterior	92	0	0	0.0
Cape Borda	Coastal	26	12	15	0.6
Cape Bouger	Undefined	41	0	0	0.0
Cape Cassini	Coastal	65	96	172	2.7
Cape du Couedic	Undefined	105	1	2	0.0
Cape Dutton	Coastal	23	104	327	14.5
Cape Forbin	Coastal	22	45	93	4.3
Cape Gantheaume	Undefined	329	5	14	0.0
Cape Hart	Coastal	47	15	24	0.5
Cape Kersaint	Undefined	38	13	24	0.6
Chapman River	Exterior	73	241	287	3.9
Cygnet River	Exterior	607	1946	4758	7.8
De Mole River	Exterior	104	133	280	2.7
Deep Creek	Exterior	32	119	89	2.8
D'Estrees Bay	Coastal	3	0	0	0.0
Elenoar River	Exterior	263	816	1717	6.5
Emu Bay	Coastal	10	6	6	0.7
Gum Creek	Exterior	33	97	240	7.3
Harriet River	Exterior	152	461	1853	12.2
Kangaroo Head	Coastal	34	62	51	1.5
King George Beach	Coastal	6	32	71	12.6
King George Creek	Exterior	35	97	185	5.3
Kingscote	Coastal	7	14	26	4.0
Knapsmans Creek	Coastal	11	0	0	0.0
Lake Ada	Closed	54	136	343	6.3
Middle River	Exterior	146	424	825	5.7
Pebbly Beach	Coastal	15	42	60	4.0
Pelican Logoon	Undefined	104	26	19	0.2
Porky Flat	Undefined	30	5	9	0.3
Ravine des Casoars	Exterior	96	26	47	0.5
Red Cliffs	Coastal	67	214	279	4.1
Red House Bay	Coastal	4	8	14	3.1
Rocky River	Exterior	216	5	12	0.1
Salt Lagoon	Closed	240	799	1380	5.7
Sandy River	Coastal	15	0	0	0.0
Seal Beach	Coastal	13	11	9	0.7
Smith Bay	Coastal	30	107	193	6.4
Smith Creek	Exterior	34	60	178	5.2
Snug Cove Creek	Exterior	18	34	222	12.0

Catchment name	Drainage type	Catchment area (km^2)	Number of farm dams	Combined volume (ML)	Farm dam density (ML/km^2)
South West River	Exterior	155	351	684	4.4
Stunsail Boom River	Exterior	324	452	699	2.2
Timber Creek	Closed	246	627	1673	6.8
Valley Creek	Exterior	8	8	7	0.9
Vennacher Point	Coastal	30	0	0	0.0
Vivonne Bay	Coastal	4	9	16	3.9
West Bay	Coastal	19	0	0	0.0
West Bay Creek	Exterior	40	0	0	0.0
Western River	Exterior	88	204	426	4.8
White Lagoon	Closed	88	270	502	5.7
Willson River	Exterior	64	211	334	5.2

Table A.2 Statistics of farm dams – Listing by farm dam density (ML/km^2)

Catchment name	Drainage type	Catchment area (km^2)	Number of farm dams	Combined volume (ML)	Farm dam density (ML/km^2)
Cape Dutton	Coastal	23	104	327	14.5
King George Beach	Coastal	6	32	71	12.6
Harriet River	Exterior	152	461	1853	12.2
Snug Cove Creek	Exterior	18	34	222	12.0
Cygnet River	Exterior	607	1946	4758	7.8
Gum Creek	Exterior	33	97	240	7.3
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Elenoar River	Exterior	263	816	1717	6.5
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Smith Bay	Coastal	30	107	193	6.4
Lake Ada	Closed	54	136	343	6.3
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Middle River	Exterior	146	424	825	5.7
King George Creek	Exterior	35	97	185	5.3
Smith Creek	Exterior	34	60	178	5.2
Willson River	Exterior	64	211	334	5.2
Western River	Exterior	88	204	426	4.8
American River	Coastal	13	49	58	4.5
South West River	Exterior	155	351	684	4.4
Cape Forbin	Coastal	22	45	93	4.3
Red Cliffs	Coastal	67	214	279	4.1
Pebbly Beach	Coastal	15	42	60	4.0
Kingscote	Coastal	7	14	26	4.0
Vivonne Bay	Coastal	4	9	16	3.9
Chapman River	Exterior	73	241	287	3.9
Bay of Shoals	Coastal	63	148	222	3.5
Red House Bay	Coastal	4	8	14	3.1
Deep Creek	Exterior	32	119	89	2.8
De Mole River	Exterior	104	133	280	2.7

Catchment name	Drainage type	Catchment area (km^2)	Number of farm dams	Combined volume (ML)	Farm dam density (ML/km^2)
Cape Cassini	Coastal	65	96	172	2.7
Stunsail Boom River	Exterior	324	452	699	2.2
Kangaroo Head	Coastal	34	62	51	1.5
Valley Creek	Exterior	8	8	7	0.9
Seal Beach	Coastal	13	11	9	0.7
Emu Bay	Coastal	10	6	6	0.7
Cape Kersaint	Undefined	38	13	24	0.6
Cape Borda	Coastal	26	12	15	0.6
Cape Hart	Coastal	47	15	24	0.5
Ravine des Casoars	Exterior	96	26	47	0.5
Porky Flat	Undefined	30	5	9	0.3
Pelican Logoon	Undefined	104	26	19	0.2
Rocky River	Exterior	216	5	12	0.1
Cape Gantheaume	Undefined	329	5	14	0.0
Cape du Couedic	Undefined	105	1	2	0.0
Breakneck River	Exterior	92	0	0	0.0
Cape Bouger	Undefined	41	0	0	0.0
D'Estrees Bay	Coastal	3	0	0	0.0
Knapsmans Creek	Coastal	11	0	0	0.0
Sandy River	Coastal	15	0	0	0.0
Vennacher Point	Coastal	30	0	0	0.0
West Bay	Coastal	19	0	0	0.0
West Bay Creek	Exterior	40	0	0	0.0

REFERENCES

Bren L. (2004). Impacts of Plantation Development on the Water Resources of the Middle River Catchment, Kangaroo Island. School of Forest and Ecosystem Science, University of Melbourne, Cheswick, Victoria, Australia.

CatchmentSIM. Chris Ryan. See CRC Toolkit web site. http://www.toolkit.net.au/catchsim.

Grayson R. B., Argent R. M., Nathan R. J., McMahon T. A. and Mein R. G. (1996). Hydrological Recipes: Estimation Techniques in Australian Hydrology. Pp77-83. Cooperative Research Centre for Catchment Hydrology, Melbourne, Victoria, Australia.

Hutchinson M.F. (1995). Interpolating mean annual rainfall using thin plate smoothing splines. Int. J. Geographical Information Systems, vol. 9, no. 4, 385-403.

McMurray D. (2004a). Assessment of Water Use from Farm Dams in the Mount Lofty Ranges South Australia. Department of Water, Land and Biodiversity Conservation, South Australia. Report no. DWLBC 2004/02.

McMurray D. (2004b). Farm Dam Volume Estimations from Simple Geometric Relationships. Department of Water, Land and Biodiversity Conservation, South Australia. Report no. DWLBC 2004/48.

McMurray D. (2006). Impact of Farm Dams on Streamflow in the Tod River Catchment, Eyre Peninsula. Department of Water, Land and Biodiversity Conservation, South Australia. Report no. DWLBC 2006/22.

SILO. See Queensland Department of Natural Resources and Mines' web site for the SILO Patched Point Dataset (PPD). http://www.nrme.qld.gov.au/silo/ppd/PPD.html.

Tomlinson G.W. (1996). Catchment Yield Analyses for South Australian Reservoirs. Department of Environment and Natural Resources. South Australia.

Zhang L., Vertessy R., Walker G., Gilfedder M. and Hairsine P. (2007). Afforestation in a catchment context: understanding the impacts on water yield and salinity. Industry report 1/07, eWater CRC, Melbourne, Australia. ISBN 1876810 09 2, CSIRO and eWater Limited.

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