Eastern Mount Lofty Ranges Water Resource Plan Area Risk Assessment

DEW Technical report 2018/10

Government of South Australia
Department for Environment and Water

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January 2019

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Foreword

The Department for Environment and Water (DEW) is responsible for the management of the State's natural resources, ranging from policy leadership to on-ground delivery in consultation with government, industry and communities.

High-quality science and effective monitoring provides the foundation for the successful management of our environment and natural resources. This is achieved through undertaking appropriate research, investigations, assessments, monitoring and evaluation.

DEW's strong partnerships with educational and research institutions, industries, government agencies, Natural Resources Management Boards and the community ensures that there is continual capacity building across the sector, and that the best skills and expertise are used to inform decision making.

John Schutz
CHIEF EXECUTIVE
DEPARTMENT FOR ENVIRONMENT AND WATER

Acknowledgements

This work is the product of a collaboration between the Environmental Science and Information Group and the Water Group of the South Australian Department for Environment and Water (DEW). Key authors included Noelle Overdevest, Hugh Wilson, Tom Mowbray, Ingrid Franssen and Lisa Stribley. The risk assessment could not have taken place without the valuable contributions of experts in the fields of hydrology, hydrogeology, water quality, ecology, economics, water policy, River Murray operations, and natural resource management. Participating organisations included DEW, the Environment Protection Authority (SA), Department of Primary Industries and Regions SA (PIRSA), SA Water and Natural Resources SA Murray-Darling Basin. We thank Mardi van der Wielen, Andrew Solomon, Steve Barnett, Kumar Savadamuthu, Michelle Benison, Daniel Penney, Steve Kotz, Liz Barnett, Tracey Steggles, Joel Vandepeer, Judith Kirk, Lissa Arcoverde, Kelly Gill, Kenneth Scott, Michelle Bald, Jason Vanlaarhoven, Doug Green, Bernadette Lawson, Brett Ibbotson, Theresa Heneker, Christopher Wright, Patricia von Baumgarten, Lisa Mensforth and Colin Cichon. This work was supported through the National Partnership Agreement for the Implementation of the Murray Darling Basin Plan.

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Abbreviations and acronyms

Actual Title	Abbreviation
Australian Height Datum	AHD
critical human water needs	CHWN
Department of Environment and Heritage	DEH
Department for Environment and Water	DEW
Department of Environment, Water and Natural Resources	DEWNR
Eastern Mount Lofty Ranges	EMLR
Environment Protection Authority (South Australia)	EPA
Environment Protection and Biodiversity Act 1999	EPBC Act
gigalitres	GL
Lower Murray Reclaimed Irrigation Area	LMRIA
long-term environmental watering plan	LTWP
metres with respect to Australian Height Datum	mAHD
Murray–Darling Basin Authority	MDBA
natural resources management	NRM
Natural Resources Management Act 2004 (SA)	NRM Act
priority environmental asset	PEA
Department of Primary Industries and Regions (South Australia)	PIRSA
South Australia	SA
South Australian Murray–Darling Basin Natural Resources Management Board	SAMDB NRM Board
sustainable diversion limit	SDL
The Living Murray program	TLM
water allocation plan	WAP
water-dependent ecosystems	WDEs
water resource plan	WRP
Western Mount Lofty Ranges	WMLR

Summary

A coordinated approach to water use across the Basin States has been adopted through the implementation of the *Murray-Darling Basin Plan 2012* (Basin Plan). The Basin Plan (developed under the Commonwealth *Water Act 2007*) aims to limit water use from the surface and ground waters of the Basin to environmentally sustainable levels to achieve a balance between the environmental, economic and social uses of Basin water resources. A key component of the Basin Plan is the requirement for Basin States to develop water resource plans (WRPs) for identified WRP areas. A WRP sets out the management and planning arrangements for Basin water resources taking into consideration connected resources. The first step in developing a WRP is the identification and assessment of risks to the condition or continued availability of Basin water resources. The risk assessment will inform the WRP development to ensure the WRP measures are fit for purpose and commensurate with risk levels.

This risk assessment was undertaken for one of South Australia's three WRP areas: the Eastern Mount Lofty Ranges (EMLR) WRP area. The EMLR WRP area covers an area of 3,588 km^2 and incorporates both surface and groundwater resources. It lies within the SA Murray-Darling Basin (SA MDB) Natural Resources Management (NRM) region, and consists of four areas prescribed under South Australia's *Natural Resources Management Act* 2004 (NRM Act), three of which are managed under the EMLR water allocation plan (WAP) (EMLR WAP) and one managed through the Marne Saunders WAP.

The risk assessment applied South Australia's risk management framework for water planning and management (DEWNR, 2012), which in turn draws on the Australia/New Zealand Risk Management standard (AS/NZS 31000:2009). Accordingly, the risk assessment process involved the steps of risk identification, risk analysis and risk evaluation, with criteria for each of these steps informed by the risk management context. The risk assessment method was designed to be a participatory process to maximise confidence in outcomes. Engagement with representatives and experts from the then Department of Environment, Water and Natural Resources (DEWNR, predecessor to DEW) (science, policy and regional natural resource management), the Environment Protection Authority of South Australia (EPA) and SA Water occurred through all stages of the process.

Initial engagement focused on developing guiding principles for the assessment process. It was agreed that criteria and processes would be adapted from those developed for SA Murray Region WRP risk assessment (DEWNR, 2015c). Thus the same likelihood and consequence criteria were used for consistent reporting of the significance of risk between the WRP areas in South Australia. Risks were assessed over a ten year timeframe at a spatial scale that facilitated consistent identification and attribution of risk (i.e. sub-areas based on SDL units, resource condition, climatic and landscape characteristics). As with SA Murray Region risk assessment, risks to Aboriginal values and uses are not covered by the present assessment. These risks will be addressed by a separate risk assessment process.

The risk identification process involved expert and stakeholder engagement to build a comprehensive register of risks relevant for the EMLR WRP area. Risk statements were based on the template developed for the SA Murray Region risk assessment (the bow-tie model). Thus each statement outlines a chain of circumstances (i.e. a risk pathway) describing the potential for a risk source to cause changes in water quality or quantity in turn causing environmental, social or economic consequences (including in connected water resources). The bow-tie model was adapted to the EMLR context through revision of risk sources. The output of risk identification was a provisional risk register of 280 risk statements.

Risk analysis to determine the likelihood and consequence of risks involved three phases; prioritisation, participatory analysis, and evaluation of uncertainty. Risk prioritisation involved

development of principles for rapid, high confidence assignment of low risks. This resulted in 115 low risks being removed from the detailed analysis and evaluation process, leaving 165 priority risks to be subjected to more in-depth analysis.

Participatory analysis involved a series of workshops with technical experts and resource managers to rate likelihood and consequence for each priority risk. Workshops were structured to facilitate i) a consistent understanding of the risk assessment context and criteria, ii) a consistent understanding of each risk pathway, iii) identification of the most relevant evidence and knowledge regarding factors affecting each risk, iv) analysis of the effectiveness and implementation of relevant controls, and v) quantification of uncertainty regarding the level of risk. Evaluation of uncertainty (the final stage of the risk analysis process) prioritised risks for a second round of analysis depending on the uncertainty quantified through ratings of likelihood and consequence.

Risk evaluation compared the ratings of likelihood and consequence with risk criteria to rate risks as being low, medium or high. The final risk profile consisted of one high risk, 12 medium risks and 267 low risks. Medium and high risks affect five of the ten sub-areas. The high risk describes the potential for climate extremes, particularly drought, to impact a groundwater dependent ecosystem hosting a population of state-listed fish species (river blackfish). In this case existing preventative controls have limited effectiveness, as they are largely configured to average climate conditions rather than extreme conditions. The potential effectiveness of response-recovery type controls for this risk (e.g. implementation of a drought-action plan) is unknown. Six out of the 12 medium risks are also caused by climate extremes. Other significant sources of risk (i.e. causing medium risk) include demand/take, land use and management of connected water resources.

Infrastructure affecting natural flow regimes was not highlighted as a significant source of risk as the impacts of farm dams are covered through assessment of risks caused by demand/take including interception activities. Similarly, point source pollution was not found to be a significant source of risk in the EMLR WRP area.

In terms of consequences, seven medium risks and one high risk affect water dependent ecosystems. An analysis of treatment opportunities found that a key control for reducing ecological risk is the return of low flows. At the time of the risk assessment, requirements to pass low flows around new dams and diversions were in place for new applications for these activities. A program to secure low flows at key existing dams and diversions had not yet started on-ground implementation, beyond a few trial sites. Full implementation of this control is expected to reduce the identified risks to water dependent ecosystems.

Risks affecting economic use (four medium risks) and human consumption/domestic needs (one risk) were also identified. No significant risks to connected water resources caused by water resource management in the EMLR WRP area were identified.

A high level assessment of opportunities for treatment was undertaken based on the information reviewed by the assessment. However there are some risks where opportunities for treatment may be limited.

1 Introduction

The Murray-Darling Basin, located in south-eastern Australia, covers an area over one million square kilometres and contains one of Australia's most important river systems (the Murray-Darling). The river system not only provides important resources to agriculture irrigators and communities across the four Basin States (New South Wales, Queensland, Victoria, South Australia) and the Australian Capital Territory, but it also provides resources for a variety of ecological processes that support internationally and nationally listed species. Due to the importance of the water resources of the Murray-Darling Basin, a coordinated approach to water use across the Basin States has been adopted through the implementation of the *Basin Plan 2012* (Basin Plan). The Basin Plan (developed under the Commonwealth *Water Act 2007*) aims to limit water use from the surface and ground waters of the Basin to environmentally sustainable levels to achieve a balance between the environmental, economic and social uses of Basin water resources.

One key component of the Basin Plan is the requirement for Basin States to develop water resource plans (WRPs) for identified WRP areas. In total 36 WRP areas are identified under the Basin Plan, with three of these occurring within South Australia. These are (Figure 1):

- SA Murray Region;
- Eastern Mount Lofty Ranges; and
- River Murray.

The purpose of a WRP is to set out the management and planning arrangements for Basin water resources taking into consideration connected resources. Under the Basin Plan (Chapter 10), WRPs must set limits on the quantities of surface and ground waters that can be taken for consumptive purposes and establish rules to ensure environmental and water quality objectives are met.

The first step in developing a WRP is the identification and assessment of risks to the condition or continued availability of Basin water resources (as stated under Chapter 4 of the Basin Plan). This risk identification and assessment process can then be used to ensure that the WRP has regard to the significant risks to the resources of the WRP. The risk assessment also provides a transparent approach for demonstrating that South Australia has had proper regard to particular issues as required by Chapter 10 (WRP Requirements).

The risk assessment presented in this report is aimed at addressing the requirements of Chapter 10 of the Basin Plan for the WRP area identified as the Eastern Mount Lofty Ranges (EMLR). This corresponds to the surface water WRP area denoted as SW7 (Figure 2) and the groundwater WRP area denoted as GW5 (Schedule 4 of the Basin Plan) (Figure 3).

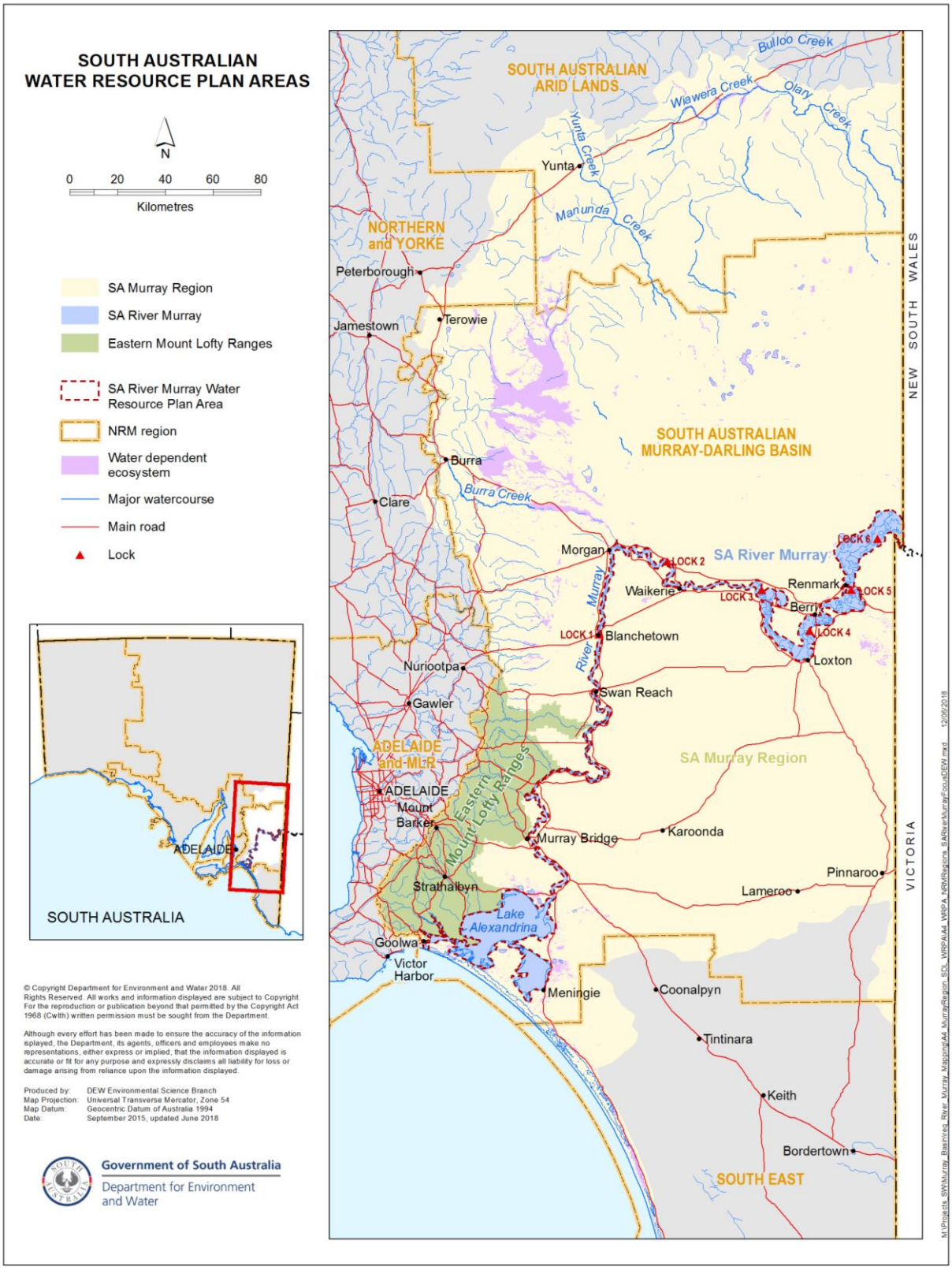

Figure 1. South Australia's water resource plan areas identified by the Basin Plan

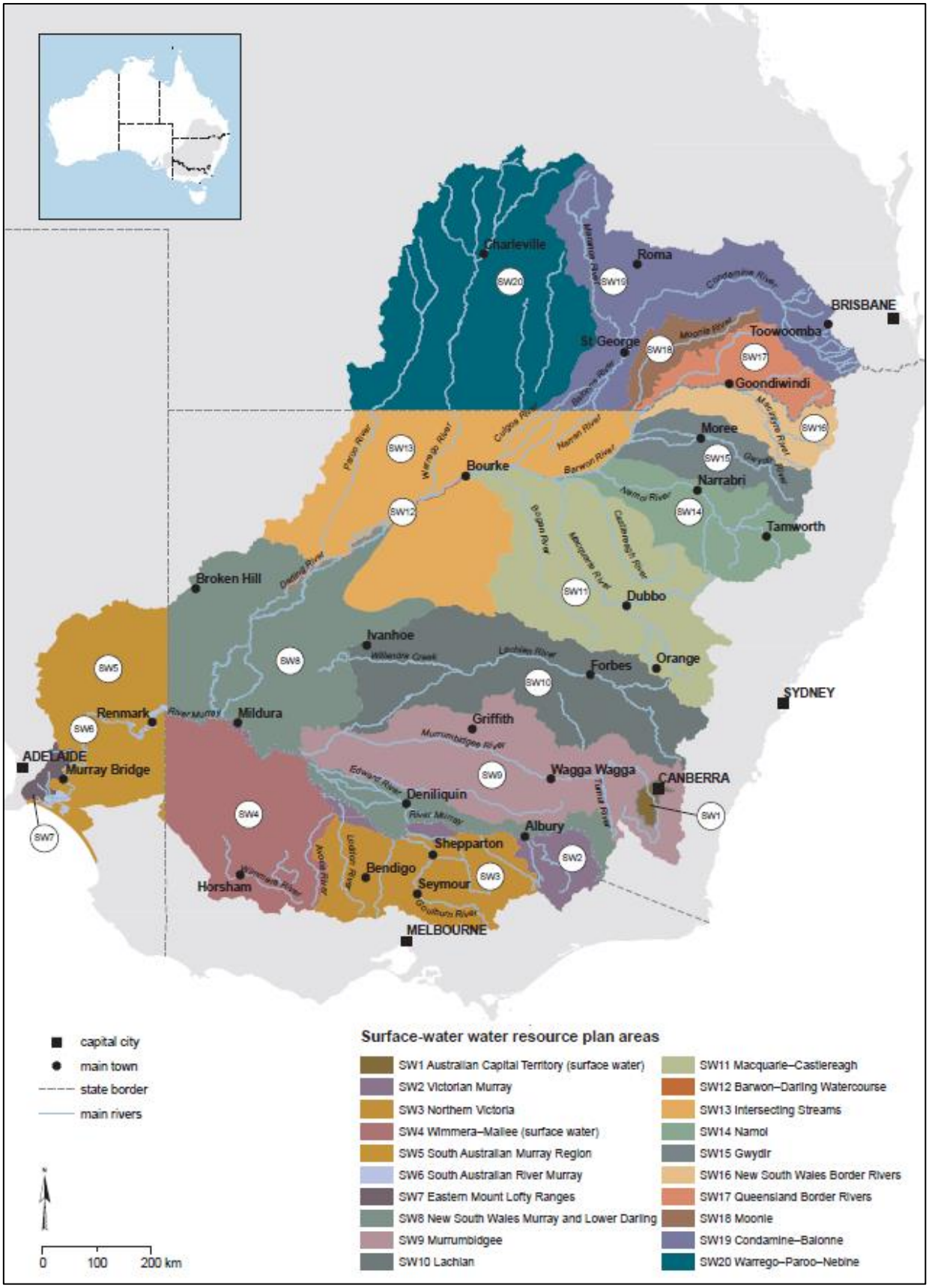

Figure 2. Surface water, water resource plan areas showing SW7 (EMLR WRP Area)

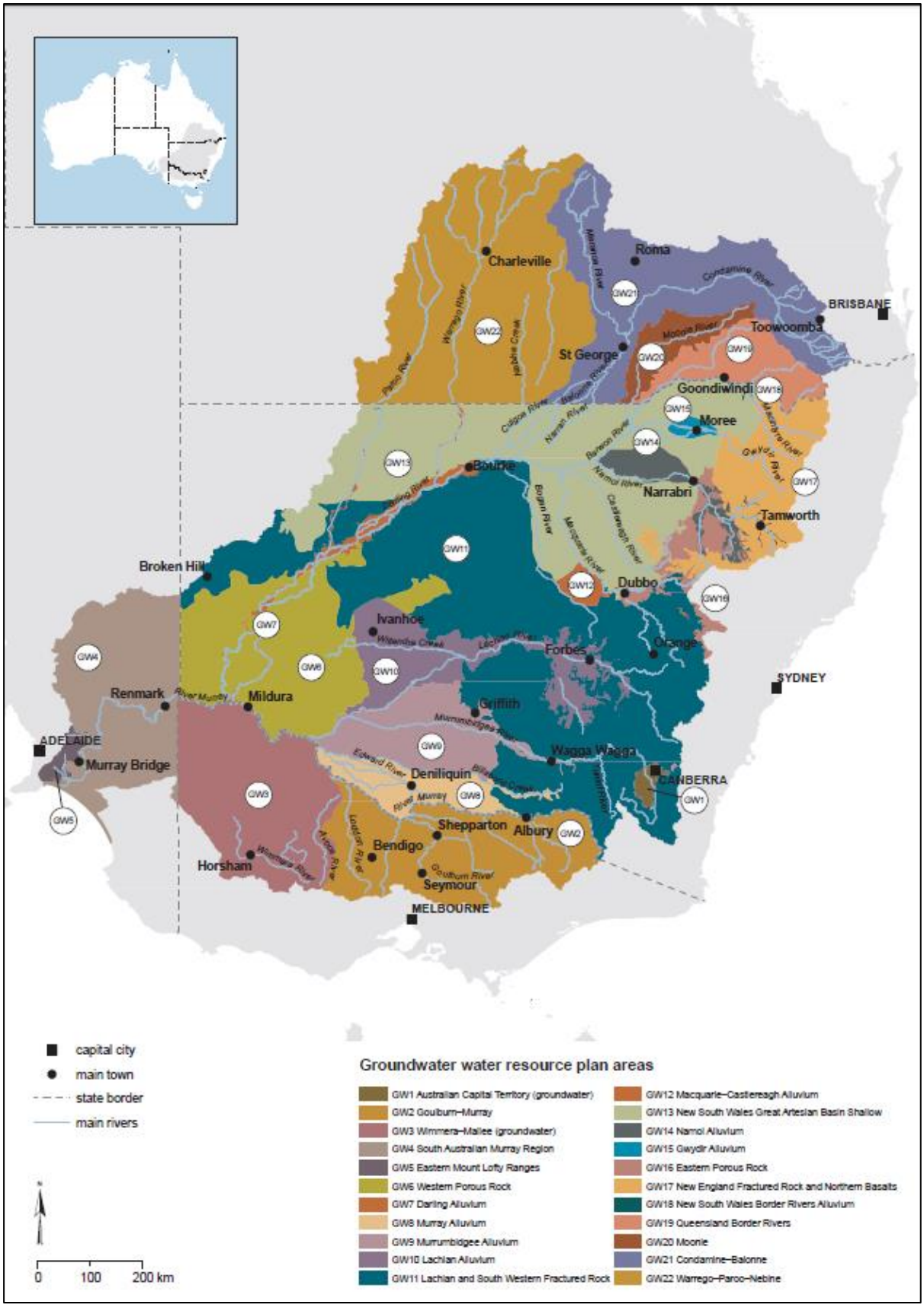

Figure 3. Groundwater water resource plan areas showing GW5 (EMLR WRP area)

2 Background

2.1 Eastern Mount Lofty Ranges Water Resource Plan Area

The EMLR WRP area, as identified in the Basin Plan (and shown in Figure 1) covers an area of approximately 3,588 km^2 and incorporates all surface and groundwater resources within the area. The EMLR WRP area, lies wholly within the SA Murray-Darling Basin (SA MDB) Natural Resources Management (NRM) region and consists of four areas prescribed under South Australia's *Natural Resources Management Act 2004* (NRM Act):

- Marne Saunders prescribed water resources area (PWRA);
- Angas Bremer prescribed wells area (PWA);
- EMLR prescribed watercourses and surface water prescribed area; and
- EMLR PWA.

The last three prescribed areas are all managed under the EMLR water allocation plan (WAP), and are collectively referred to as the EMLR PWRA. Combined, the Marne Saunders PWRA and EMLR PWRA contribute approximately 0.5% of the Murray-Darling Basin's total annual runoff (CSIRO 2007).

For the purposes of this risk assessment the EMLR WRP area was subdivided into sub-areas to ensure that risks would be adequately identified and assessed. These sub-areas were defined based on the surface and groundwater sustainable diversion limit (SDL) resource units listed in Schedule 2 and Schedule 4 (respectively) of the Basin Plan (Figure 4 and 6). Further subdivision was then undertaken to take into account similar characteristics in climatic and landscape properties (surface water sub-areas), aquifer properties (groundwater sub-areas) and management rules. In total, ten sub-areas were defined. A description of each sub-area is provide below, while a summary of the general characteristics of each sub-area is provided in Table 1.

2.2 Surface water sub-areas

2.2.1 SS12 - Marne Saunders surface water

The boundary of the SS12 sub-area is consistent with that of the boundary of the Marne Saunders PWRA. The Marne Saunders surface water sub-area (SS12) is located approximately 70 km north-east of Adelaide (Figure 4) and covers an area of approximately 743 km^2. The sub-area encompasses the catchments of the Marne River (including the North Rhine) and the Saunders Creek. These water resources are used for a range of purposes including domestic, stock, irrigation, industrial and recreational uses, and also support important water-dependent ecosystems (WDEs) (SAMDB NRM Board, 2010). Surface and groundwater within Marne Saunders are strongly interlinked, with baseflow from springs being key water sources for surface waters in some areas including in the Marne River (downstream of Black Hill) and Saunders Creek (near Lenger Reserve) (SAMDB NRM Board, 2010).

The Marne Saunders PWRA is bounded by the Barossa and Western Mount Lofty Ranges PWRAs to the west (both non-Basin resources), the EMLR PWRA to the south, and adjoins the River Murray prescribed watercourse to the east. Areas to the north and parts of the eastern boundary adjoin unprescribed water resources in the SA Murray-Darling Basin (the SA Murray Region WRP area)

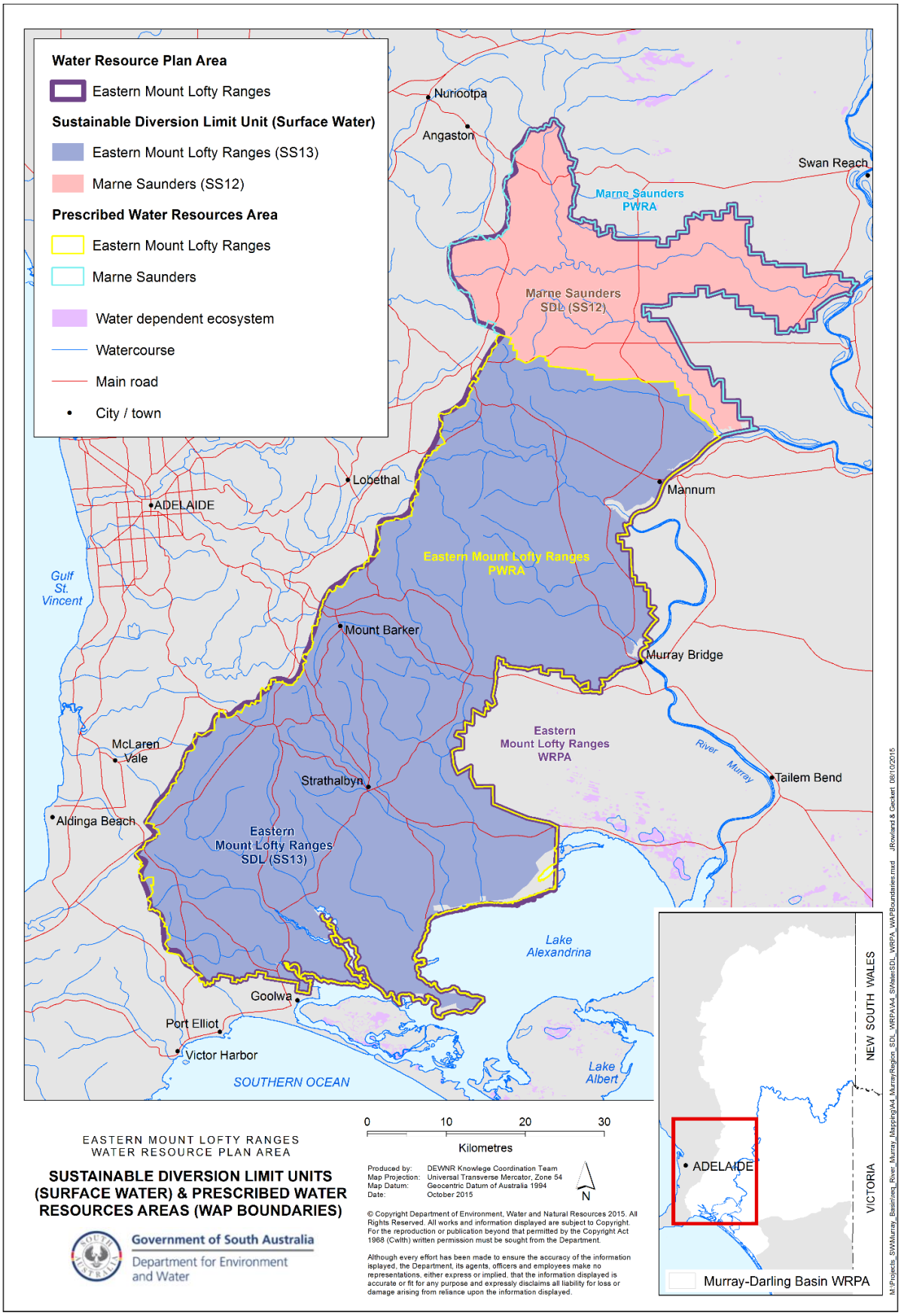

Figure 4. EMLR sustainable diversion limits and prescribed water resources areas

The Marne Saunders sub-area consists of two major landscape regions: the Mount Lofty Ranges (hills zone) and the Murray Basin (plains zone). The hills zone consists of undulating to steep hills of sandstone, siltstone, marble and greywacke with inliers of granite. The plains zone is a basin containing unconsolidated sedimentary deposits lying over the same basement rocks that are exposed in the hills zone. The plains zone contrasts with the hills zone in that it is relatively flat with only some hills that are associated with localised outcrops of underlying basement rocks (e.g. Black Hill) and features associated with watercourses cutting down into the tertiary sediments (SAMDB NRM Board, 2010).

Rainfall is highest along the western edge of the Marne Saunders sub-area where the annual average rainfall is approximately 800 mm. Rainfall declines towards the east in the rain shadow of the Mount Lofty Ranges, down to approximately 280 mm along the eastern boundary of the sub-area. Rainfall, although variable, generally follows a seasonal pattern, falling largely in winter and spring. The Marne River and Saunders Creek begin in the high rainfall hills zone, flowing east down the hills, through gorges and then out onto the low rainfall plains zone to eventually meet the River Murray. Flow from the Upper Marne to the mouth at the River Murray is now uncommon, having occurred most recently in 1992, 1996 and 2004. Flow from the Upper Saunders to the mouth is even more uncommon given the smaller discharge from this area. It is unknown when this last occurred (SAMDB NRM Board, 2010).

There are few watercourses in the lower catchments besides the Marne River and Saunders Creek channels. A few minor tributaries are present, draining from the foothills and also in the incised lower reaches closer to the River Murray. Rainfall in the lower catchments is low and there is little local generation of runoff (SAMDB NRM Board, 2010).

Permanent pools exist throughout the upper watercourses that flow through the Marne Saunders sub-area, most of which are maintained through groundwater baseflow contributions from the fractured rock aquifer. These permanent aquatic habitats are important refuges for aquatic biota and are known to support diverse populations of aquatic plants, aquatic macroinvertebrates and fish (Department for Water 2012a). In the plains zone, baseflow from the regional limestone aquifer provides a key water source in some localised areas where the river channels have been incised down to the level of the water close to the River Murray. This is particularly important in the Marne River downstream of Black Hill and in the Saunders Creek near Lenger Reserve. Four fish species (Chanda perch, river blackfish, purple-spotted gudgeon and catfish) protected under the State *Fisheries Management Act 2007* have historically been found in the lower reaches of the Marne catchment. Of these, only the river blackfish still exists within the Marne Saunders catchments, with the other three species now believed to have disappeared completely. A highly important population of river blackfish is known from the Black Hill Springs. This population is believed to be one of four remaining populations within the South Australian Murray-Darling Basin (Hammer 2004 and Department for Water 2012a). The springs also support other native species such as mountain galaxias, carp gudgeon and dwarf flathead gudgeon and the introduced gambusia and carp.

Two species of fish (Murray hardyhead and Murray cod) listed as vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) had previously been recorded from within the Marne River Catchment, however these are now believed to have disappeared from the catchment.

Plants with a dependence on groundwater also exist along watercourses within the Marne-Saunders surface water sub-area and largely consist of river red gums (*Eucalyptus camaldulensis*) (Department for Water 2012a).

2.2.2 SS13 - EMLR surface water sub-areas

The EMLR surface water area (SS13) is contiguous with the southern boundary of the Marne Saunders surface water sub-area (SS12). The EMLR area covers an area of 2,845 km^2 and incorporates the

eastern slopes of the Mount Lofty Ranges. The ranges fall away in the east to the broad Murray Plains and eventually to the River Murray and Lake Alexandria in the south-east. The western and south-western extent of the EMLR area is bound by the Western Mount Lofty Ranges PWRA (non-Basin resources). Average annual rainfall varies across the region from approximately 900 mm in the south-west to 300 mm in the north-east. The annual average rainfall for the entire area is approximately 460 mm, with most rainfall occurring in winter and early spring (SAMDB NRM Board 2013c).

Land use in the EMLR is dominated by grazing and cropping which account for 77% of the total area. Other land uses include irrigated horticulture and pasture production (7%), conservation and natural environments including residual native cover (5%), intensive uses (including urban areas, mining, industrial and manufacturing land uses) (5%) and forestry (less than 2%) (SAMDB NRM Board 2013c). Farm development is significant, particularly in the hills with approximately 7,000 farm dams and an estimated combined storage capacity of 18,285 ML (SAMDB NRM Board 2013c).

Streams within the EMLR gain water from catchment runoff largely in the hills and from discharge of underground water into watercourses. Streams also lose water to underground water resources. Flow in streams is mostly seasonal or ephemeral, with the exception of Tookayerta Creek where underground water contribution to streamflow is sufficient to maintain permanent flow in most years.

The boundary of SS13 is consistent with the EMLR PWRA boundary, however for the purposes of this risk assessment the SS13 SDL resource unit was sub-divided into two sub-areas: SS13 North and SS13 South (Figure 5) due to the differences in climatic conditions, land use practices and presence of water dependent ecosystems between the northern and southern areas. The northern boundary of the Bremer River catchment was selected as the boundary between the two areas with the SS13 North sub-area being the area north of the Bremer River catchment boundary (up to the southern boundary of SS12) and the SS13 South sub-area being the area south of the Bremer River catchment boundary (Figure 5).

2.2.2.1 SS13 North – EMLR Northern Portion

The northern sub-area is contiguous with the Marne Saunders surface water sub-area (SS12) and includes the catchments of Reedy Creek, Bees Knees, Long Gully, Milendella Creek, Underwood Hill, Mannum Baseby, Salt Creek, Preamimma Creek and Rocky Gully Creek. Land use in this sub-area is dominated by grazing of modified pastures and cropping. There are no mining operations (including historic mining operations) located within the sub-area. The main townships in the sub-area include Murray Bridge, Monarto, Mannum, and Tungkillo.

Catchments in the SS13 North sub-area are drier than those of SS13 South. A few dry season pools that contain water of reasonable quality occur within Reedy Creek and support a range of water-dependent species, including six native fish species (Hammer 2004 and Whiterod and Hammer 2014). The wetland at the terminus of the Reedy Creek catchment where it meets the River Murray also supports a range of aquatic species. Water in this wetland is largely derived from flows from the River Murray with only minor, seasonal flows from Reedy Creek reaching the wetland. No species formally listed under state or national legislation are known from these pools.

2.2.2.2 SS13 South – EMLR Southern Portion

The SS13 South sub-areas includes the catchments of the Bremer River, Angas River, Angas Plains, Sandergrove Plains, Finniss River, Tookayerta, Currency Creek, Deep Creek and the south-western portion of Ferries-McDonald. Important townships in the sub-area include Mount Barker, Meadows, Macclesfield, Mount Compass, Goolwa and Strathalbyn. Two small operational mines (Kanmantoo and Angas) and one historic site (Brukunga) are located within the sub-area.

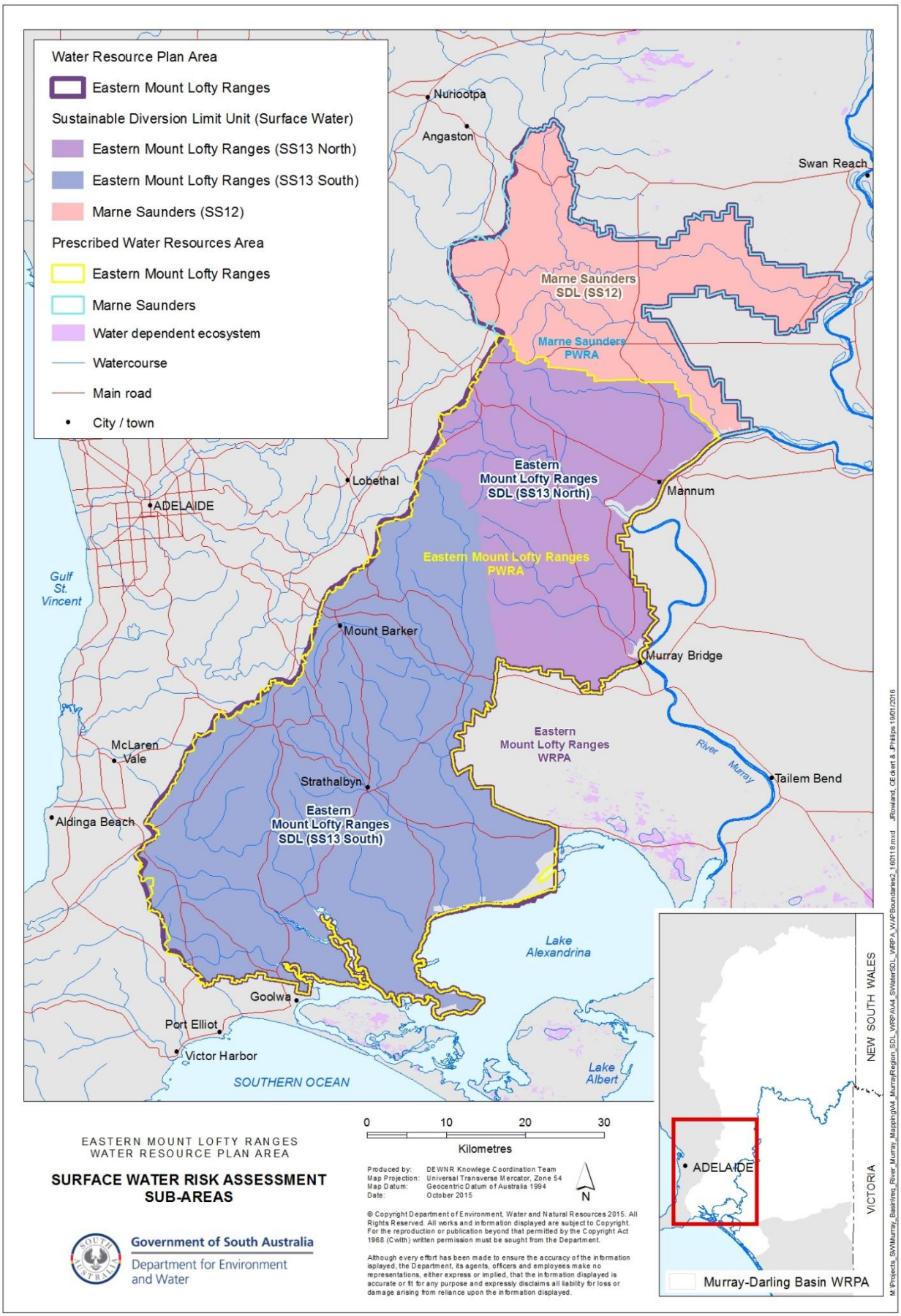

Figure 5. EMLR surface water risk assessment sub-areas (SS12, SS13 north and SS13 south)

The internationally listed Coorong, Lake Alexandrina and Lake Albert Ramsar wetland site is located south of and adjacent to the EMLR WRP area. As defined under the Basin Plan, the Coorong falls within the SA Murray Region WRP area while the Lower Lakes (Lake Alexandrina and Lake Albert) fall within the River Murray WRP area. The confluences of the Finniss River and Currency Creek with Lake Alexandrina also fall within the Ramsar wetland site, and consequently risks to these areas fall outside of the EMLR WRP area. Risks to these confluences (and their associated ecosystems) will be assessed as part of the River Murray WRP area risk assessment.

Although numerous rivers and streams drain from the ranges into Lake Alexandrina and the River Murray, there is no direct discharge to the Coorong from the EMLR.

The Fleurieu Peninsula Swamps are a subset of the Fleurieu Peninsula wetlands and are located within the Currency Creek, Tookayerta Creek and Finniss River catchments. The swamps are listed as a critically endangered ecological community under the EPBC Act and provide habitat for a number of listed endangered species such as the southern brown bandicoot and the southern emu wren (SAMDB NRM Board 2013c).

Overall the Fleurieu wetlands support a large number of species including 73 plant species listed under the state's *National Parks and Wildlife Act 1972* and six species under the EPBC Act. Some 22 fauna species listed under the *National Parks and Wildlife Act 1972* and three species listed under the EPBC Act are also known from the wetlands. In addition, three bird species listed under the Japan-Australia and China-Australia Migratory Bird Agreements (JAMBA and CAMBA) have been recorded from the wetlands (SAMDB NRM Board 2013c and Department for Water 2012b).

Watercourses within the EMLR surface water SDL resource unit are home to numerous native fish species, including species listed as protected under the State's *Fisheries Management Act 2007*, such as southern pygmy perch and river blackfish. Other environmental assets include the river red gum swamps located on the Angas and Bremer Plains (SAMDB NRM Board 2013c).

2.3 Groundwater sub-areas

The groundwater SDL resource units are shown in Figure 6 and a description of the groundwater sub-areas comprising these units is discussed in detail below.

In the EMLR WRP area, groundwater is sourced from two different types of aquifers; fractured rock aquifers, and sedimentary aquifers. Fractured rock aquifers occur in the ranges where groundwater is stored and moves through joints and fractures in the basement rocks. Sedimentary aquifers (where groundwater flows through the pore spaces within the sediments) occur to a limited extent in the valleys in the ranges, but have larger thicknesses in the Murray Basin (up to 100 m) (Barnett, 2016).

Groundwater moves from the higher points in the landscape (which are usually basement rocks around the catchment boundaries) towards the lowest areas where discharge normally occurs to the streams. This discharge constitutes baseflow of the streams, which dominates flow for most of the year, particularly over the summer and between rainfall events. Recharge to these aquifers occurs directly from rainfall that percolates down to the watertable through the soil profile (most rainfall runs off to streams or is used by vegetation). Some throughflow occurs from the fractured rock aquifers in the ranges to the sedimentary aquifers on the plains (Barnett, 2016).

2.3.1 GS1 Angas Bremer

2.3.1.1 GS1a – Angas Bremer Quaternary aquifer

The Quaternary aquifer system has developed within a 10 – 20 m thick sequence of Quaternary sediments that consist mainly of clays, silts, sands and occasional gravels (DEWNR, 2012c). The Angas

Bremer Quaternary aquifer is generally highly saline (ranging up to 20,000 mg/L total dissolved solids (TDS)) with low yields (<5 L/s) and has limited use (used for stock supply only). Good-quality groundwater is only found within narrow zones of rapid recharge, which occur along the Angas and Bremer Rivers during flood events (DEWNR, 2012c). This aquifer is mostly unconfined.

Within the Angas Bremer catchment, there are plants that depend on the groundwater, particularly river red gums (*Eucalyptus camaldulensis*) growing along watercourses. These trees may use groundwater from the shallow unconfined Quaternary aquifer, which is not used extensively by licensees or stock and domestic users because of low yields and high salinities (DEWNR, 2012c).

2.3.1.2 GS1b – Angas Bremer Murray Group Limestone and all other groundwater

The GS1b sub-area includes the Murray Group Limestone aquifer and all other groundwater not included in the sub-area GS1a, specifically, the Renmark Group confined aquifer. A description of both aquifers is provided below.

The confined Murray Group Limestone aquifer is up to 100 m thick and varies in composition from soft clayey limestone, hard sandy limestone to soft bryozoal limestone layers (DEWNR, 2015a). The general groundwater flow direction is in a south-easterly direction towards Lake Alexandrina. Irrigation supplies are generally obtained from the fossiliferous limestone member, which can be cavernous in some areas. Well yields vary from about 5 L/s in the north to over 15 L/s in the south, with occasional yields of up to 40 L/s (DEWNR, 2015a).

There is very little recharge of low salinity water to the aquifer. Existing fresh groundwater originated about 4,000 to 8,000 years ago when South Australia experienced a much wetter climate (Zulfic and Barnett, 2007). During this time, greater volumes of runoff flowing out of the ranges and onto the plains of the Murray Basin would have recharged the Murray Group Limestone aquifer via slow downward leakage from the overlying Quaternary aquifer forming the areas of low salinity. This process of ancient recharge is supported by the carbon-14 estimate of uncorrected age of the Murray Group Limestone groundwater of about 4,000 – 8,000 years (Cresswell and Herczeg, 2004). The low salinity areas within the Murray Group Limestone aquifer generally have salinities less than 1,500 mg/L and up to 3,000 mg/L, and are limited to relatively narrow zones near the Angas and Bremer Rivers. Towards the east and western margins of the aquifer, salinities can be as high as 10,000 mg/L.

The current primary recharge mechanisms are lateral throughflow from the adjoining fractured rock aquifers in the hills, and downward leakage from the overlying Quaternary aquifer. Downward leakage occurs when the water pressure level in the overlying aquifer is greater than the pressure level in the underlying aquifer. The greater the difference in pressure levels, the greater potential for leakage. The pressure level in the underlying Murray Group Limestone aquifer may be reduced by water extraction, which may induce or enhance downward leakage of saline water from the overlying Quaternary aquifer. Although the Murray Group Limestone aquifer is confined and does not receive direct recharge from rainfall, the intensity and timing of rainfall and subsequent irrigation practices can have an effect on groundwater levels and salinity of the aquifer (DEWNR, 2015a). For example during periods of above-average rainfall during typically dry summer months, less groundwater may be extracted from the aquifer for irrigation purposes resulting in smaller declines in groundwater levels. A smaller reduction in groundwater level (or pressure) means less downward leakage from the overlying saline Quaternary aquifer and hence stable or improving salinities in the Murray Group Limestone aquifer.

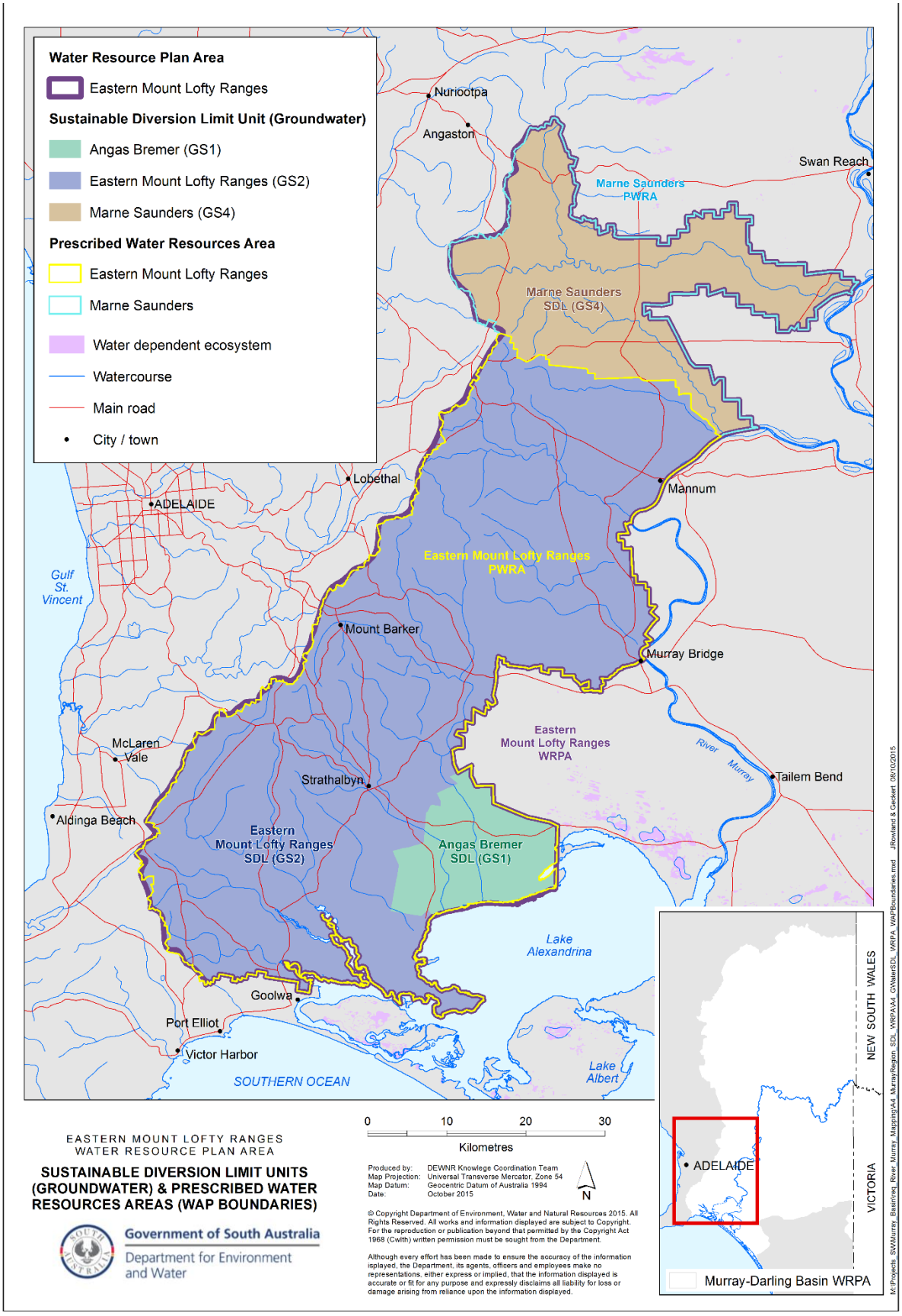

Figure 6. EMLR groundwater sub-areas (sustainable diversion limit unit)

The Renmark Group confined aquifer underlies the Murray Group Limestone aquifer and is separated from it by a low-permeability aquitard comprising the Ettrick Formation. The Renmark Group aquifer consists of interbedded sands, silt and carbonaceous clay. It is not used extensively for irrigation due to low yields, the discontinuous nature of the aquifer and the availability of much larger supplies in the overlying Murray Group Limestone aquifer (DEWNR, 2015a). There are no known extractions from this aquifer. The Murray Group Limestone and Renmark Group aquifers are considered too deep below the surface to support surface GDEs, including terrestrial vegetation and wetlands (DEWNR, 2012c).

2.3.2 GS1 and GS2 EMLR, including Angas Bremer

For the purposes of this risk assessment, SDL reporting units GS1a (Angas Bremer Quaternary) and GS1b (Angas Bremer Murray Group Limestone) were included as sub-areas. In addition, the SDL reporting unit GS2, which corresponds to aquifers within the EMLR PWRA excluding the Angas Bremer area, was subdivided into two sub-areas: GS2b – all confined aquifers within the EMLR PWRA (excluding Angas Bremer); and GS2c - all fractured rock and other unconfined aquifers (excluding Angas Bremer). A description of these sub-areas is provided below.

2.3.2.1 GS 1a and GS2b – EMLR confined aquifers

The confined aquifers within the EMLR, including the Angas Bremer area, include:

- Murray Group Limestone confined aquifer; and
- Renmark Group.

Confined Murray Group Limestone aquifer

The Murray Group Limestone aquifer is confined on the southwest margin of the Murray Basin aquifer where it is overlain by Quaternary clay sediments to the south-west of Murray Bridge. Groundwater is extracted mainly for the irrigation of vineyards in the Angas Bremer Limestone and Currency Creek Limestone groundwater management zones (Barnett, 2016). The confined aquifer does not receive direct recharge from rainfall. However, the intensity and timing of rainfall during the irrigation season can affect the volumes of water pumped from the aquifer which can in turn affect groundwater levels and salinity (DEWNR, 2015a).

Renmark Group

The Renmark Group is a confined aquifer comprising discontinuous deposits along the western margin of the Murray Basin due to the undulating nature of the basement rock. It consists of dark-brown, fine to medium-grained sands with interbedded carbonaceous clays and lignites. There is very little use from this aquifer due to the variable salinities, and the availability of better quality water with higher yields in the overlying limestone aquifer.

2.3.2.2 GS1a and GS2c – EMLR fractured rock and unconfined aquifers

The GS1a and GS2c sub-areas includes the fractured rock and other unconfined aquifers including the:

- Barossa Complex;
- Adelaidean sedimentary rocks;
- Normanville Group; and
- Kanmantoo group.

The unconfined sedimentary aquifers of this sub-area include the:

- Permian Sands aquifer;
- Murray Group Limestone aquifer; and
- Quaternary sediments.

Water in sedimentary aquifers flows through the pore spaces within the sediments while water movement in fractured rock aquifers is largely governed by the size and connection of the water-holding fractures within the rock. The quality of water held in fractures is influenced by the type of rock around it. Fracture size, connectivity and rock type is highly variable over the landscape, which makes behaviour of the aquifer highly variable.

Baseflow (discharge of groundwater into streams) is an important source of surface water in the EMLR. Average annual baseflow from the fractured rock and Permian Sands aquifers of this sub-area has been estimated at 31.8 GL/yr, using a standard baseflow separation calculation that distinguishes streamflow components derived from rainfall runoff and baseflow (SAMDB NRM Board 2013c).

Barossa Complex

The Barossa Complex consists of gneisses, schists and pegmatites, which were metamorphosed at high temperature and pressure deep in the earth's crust. They are the oldest rocks in the Mount Lofty Ranges and have been exposed by erosion as part of the Myponga Inlier in the southwest of the WRP area. This is also the highest topography reaching up to 440 m above sea level. The Barossa Complex is generally considered to be a poor aquifer from which irrigation supplies are usually not obtained. These basement rocks are, in general, tight and impermeable with few open systems of fractures and joints in which groundwater is stored and transmitted. Clayey weathered materials have in-filled joints and fractures. Soluble components of these materials can dissolve and raise the salinity of the groundwater. The clays can also restrict the infiltration of rainwater (Barnett, 2016).

Adelaidean sedimentary rocks

The Adelaidean sedimentary rocks, although strongly folded, have been relatively unaffected by heat and pressure. Consequently they provide a record of depositional and climatic conditions that occurred about 1,000 million years ago. These rock units consist mainly of siltstone, shale and slate with minor interbeds of sandstone and quartzite. Because the Adelaidean sediments have not been subjected to the heat and pressure of metamorphism, they are considered good aquifers because the joints and fractures are open and permeable, resulting in relatively high yields. In addition, these sediments occur to the west of the region where rainfall is higher, resulting in higher recharge and low salinities.

Normanville group

The Normanville group consists of calcareous shale, phosphatic phyllite and marble. The Macclesfield Marble unit is a white coarsely crystallized marble that occurs in the Macclesfield area and has developed secondary porosity (fissures), which can provide greater yields, and allows greater recharge and hence lower salinities than the surrounding rock units.

Kanmantoo group

The Kanmantoo group underlies the largest part of the eastern area. A large trough was formed by rapid subsidence in a broad arc around the eastern side of the present Mount Lofty Ranges during the Cambrian period, about 500 million years ago. The feldspathic sandstone that infilled this trough was later metamorphosed by heat and pressure into greywacke, schist and gneiss with a thickness of about 21 km. For similar reasons as the Barossa Complex, the Kanmantoo group aquifer is also generally considered to be a poor aquifer, with higher salinities evident due to lower rainfall in the east. This results in reduced flushing and recharge to the aquifer. However, isolated instances of low salinity and high yields still occur.

Permian Sands

Approximately 280 million years ago in the Permian era, large continental ice sheets moving from the south-east to the north-west carved out several large, U-shaped valleys from the older basement rocks in the south-west of the WRP area. These were later filled by glacial deposits. The sediments consist of unconsolidated sands, silts and clays with occasional gravel beds, and are known as the Cape Jervis Formation.

This Permian Sands aquifer is widely developed for irrigation and town water supply in the Mt Compass area (Barnett and Zulfic, 1999). The Permian Sands aquifer varies in productivity due to changes in the sedimentary deposition. This results in higher clay contents in some areas leading to low yields and high salinities.

Murray Group Limestone

The Murray Group Limestone consists predominantly of shallow marine fossiliferous limestone with minor clays, silt and sands, that were deposited about 50 million years ago in the Murray Basin. It underlies most of the plains between the ranges and the River Murray. The confined parts of the Murray Group Limestone aquifer (GS2b) (described earlier) are an important source of water where it contains groundwater of good quality. However, elsewhere in the WRP area, the aquifer is unconfined and has salinities over 3,000 mg/L resulting in very little use.

Quaternary sediments

At the lowest points in the catchments (in the ranges adjacent to the drainage lines), Quaternary alluvium has been deposited and usually consists of dark grey silts and clays with a high organic content and some reworked Permian sands. Significant thicknesses of peat occur in some places. On the plains, these sediments usually consist of red-brown clays and silts which overlie the Murray Group Limestone aquifer and contain brackish to saline groundwater (Barnett, 2016). On the Murray Plains, the regional Quaternary sediments contain an unconfined aquifer between Lake Alexandrina and the EMLR highlands. This aquifer is generally saline (salinities up to 10,000 mg/L total dissolved solids) and has low yields. Consequently use from this aquifer is limited (SAMDB NRM Board, 2013c).

2.3.3 GS4 Marne Saunders

2.3.3.1 GS4a - Marne Saunders fractured rock

The Marne Saunders fractured rock aquifer occurs within the hills zone and is comprised of hard, largely impermeable basement rocks where water is stored and moves through joints and fractures in the rock. Movement is largely governed by the size and connection of the water-holding fractures within the rock. The quality of water held in fractures is influenced by the type of rock around it. Salinity varies from 500 – 8,000 mg/L with a broad trend of increasing salinity from west to east, corresponding with decreasing rainfall and a consequent decrease in recharge. Fracture size, connectivity and rock type is highly variable over the landscape, which makes behaviour of the aquifer highly variable (SAMDB NRM Board, 2010). Well yields are generally low and below 2 L/s (Department for Water, 2012a).

Water is recharged into the Marne Saunders fractured rock aquifer by percolation of rainfall through the soil profile into the rock fractures. Water moves through the fractures from high points to the lowest points before discharging into watercourses as baseflow. Analysis of streamflow data for the Marne River and Saunders Creek shows that on average, approximately 28% and 22% of annual streamflow in the Upper Marne and Upper Saunders respectively is derived from baseflow. For the Marne catchment the average throughflow from the fractured rock aquifer to the sedimentary Murray Group Limestone aquifer has been estimated to be approximately 950 ML per year (based on modelling) (SAMDB NRM Board, 2010). An extrapolation of this volume indicates approximately

1,625 ML per year flows from the fractured rock aquifer to the Murray Group Limestone aquifer for the whole of the Marne Saunders PWRA.

2.3.3.2 GS4b – Marne Saunders Murray Group Limestone and Quaternary aquifers

The Murray Group Limestone aquifer is the main aquifer on the plains of the Marne Saunders PWRA and has been developed along the Marne River for the irrigation of crops including lucerne, turf and olives. The aquifer is confined to the west of Cambrai where it adjoins the hills area, and unconfined to the east. It is between 20 and 25 m thick.

Recharge to the confined part of the Murray Group Limestone aquifer comes from throughflow from the adjacent basement rocks in the hills zone. The unconfined section is recharged mainly through infiltration of streamflow from the rivers during flood periods as they flow out of the hills and onto the plains. Groundwater trends have shown a close correlation with streamflow and rainfall in the Mount Lofty Ranges (DEWNR, 2015b).

The Quaternary sediments overlie the Murray Group Limestone on the Marne Saunders plains. Within the Marne River and Saunders Creek floodplains, alluvial silts, sands, clays and gravels form the Quaternary aquifer. The aquifer is on average 10 m thick, and the primary source of recharge is likely to be streamflow and local rainfall. Well yields are low (generally less than 0.5 L/s), with salinities mostly in the range of 1,500 – 2,200 mg/L. There is little use of this aquifer as most users target the better yielding Murray Group Limestone aquifer beneath it (SAMDB NRM Board, 2010).

2.3.3.3 GS4c – Marne Saunders Renmark Group and all other ground waters

The GS4c sub-area includes the Renmark Group aquifer and all other ground waters not included in the GS4a and GS4b sub-areas.

The Renmark Group underlies the Murray Group Limestone aquifer but very little information is available for this confined aquifer. It is comprised of interbedded sands and lignitic (brown) clays and ranges in thickness from 10 m to greater than 50 m. There is no known use from this aquifer as yields are thought to be low and most users target the better yielding Murray Group Limestone aquifer above it. The Ettrick Formation is a confining layer that separates the Renmark Group from the overlying Murray Group Limestone aquifer. The Ettrick Formation (aquitard) is absent for most of the Marne Saunders PWRA and occurs primarily in the north-west.

2.4 South Australian Instruments for Water Resource Management

South Australia has a range of legislation, plans and policies addressing water planning and management issues within the state. Collectively, these interventions address risks to water resources arising from multiple sources and covering different scales.

Most importantly the *Natural Resources Management Act 2004* (NRM Act) provides the legislative framework for the sustainable management, planning and allocation of surface water and groundwater resources in South Australia. Under this legislation water resources can be prescribed by the Minister. Where a resource is prescribed, a water allocation plan (WAP) must be prepared and must outline the principles by which the water resources are managed. The purpose of the WAP is to provide for the sustainable use of the resources while achieving an equitable balance between environmental, social and economic needs for the water. The WAPs govern access entitlements and any other rules related to the use of water resources which are managed through a water licensing system.

In accordance with the NRM Act, water resources within the EMLR WRP area have been prescribed and as such the EMLR WAP and Marne Saunders WAP are the key South Australian instruments for managing the water resources in the EMLR WRP area. Other important instruments governing the management of water resources in the WRP area include the SA Murray-Darling Basin (SA MDB) regional NRM Plan, the South Australian *Environment Protection (Water Quality) Policy 2003* (SA Water Quality Policy), the *Development Act 1993* and the *River Murray Act 2003*. These instruments control activities affecting the quality and quantity of water resources in the WRP area or to adjacent resources.

In accordance with the directions of the Agreement on a National Water Initiative 2004 (the NWI), South Australia is moving towards risk based management of the State's water resources. DEWNR has developed and published the Risk Management Framework for Water Management and Planning (DEWNR, 2012a) and the Risk Management Policy and Guidelines for Water Allocation Plans (DEWNR, 2012b). These frameworks adopt the principles and processes of the AS/NZS 31000:2009 risk management standard for assessing and managing water resource risks in South Australia.

Table 1. EMLR WRP risk assessment sub-areas

Sub-area name	Sub-area abbreviation	Corresponding SDL resource unit	Resource type	Description
Marne-Saunders	SS12	SS12	Surface water	All surface waters located within the SDL resource unit identified in the Basin Plan as SS12
EMLR northern portion	SS13 North	SS13	Surface water	The northern portion of the SDL resource unit SS13 from the Bremer River Catchment up to the southern boundary of SS12
EMLR southern portion	SS13 South	SS13	Surface water	The southern portion of the SDL resource unit SS13 from the Bremer River Catchment south to the boundary of the SA Murray Region WRP area. The estuaries of the Coorong fall outside of the WRP area and were considered as part of the SA Murray Region WRP. The confluences of the Finniss River and Currency Creeks with Lake Alexandrina fall outside of the WRP area (these will be assessed as part of the River Murray WRP)
Angas Bremer quaternary sediments	GS1a	GS1a	Groundwater	Groundwater within Quaternary sediments
Angas Bremer Murray Group Limestone	GS1b	GS1b	Groundwater	Groundwater in the Murray Group Limestone, and all other groundwater excluding groundwater within GS1a
EMLR confined aquifers	GS2b	GS2	Groundwater	Groundwater within confined aquifers (Renmark Group and confined portion of Murray Group Limestone aquifer) of the EMLR (excluding Angas Bremer).
EMLR fractured rock and unconfined aquifers	GS2c	GS2	Groundwater	All groundwater in fractured rock (Barrossa Complex, Adelaidean sedimentary rocks, Normanville Group and Kanmantoo Group) and unconfined sedimentary aquifers (Permian Sands Murray Group Limestone and Quaternary sediments)
Marne Saunders fractured rock	GS4a	GS4a	Groundwater	All groundwater in fractured rock aquifers within Marne-Saunders

Sub-area name	Sub-area abbreviation	Corresponding SDL resource unit	Resource type	Description
Marne Saunders Murray Group Limestone	GS4b	GS4b	Groundwater	All groundwater within: Murray Group Limestone aquifer Quaternary sediments
Marne Saunders Renmark Group	GS4c	GS4c	Groundwater	All groundwater within the Renmark Group and all other groundwater, excluding that included in GS4a and GS4b

3 Risk Assessment Methodology

3.1 Overview

The risk assessment process utilised for the EMLR WRP area followed that established for the SA Murray Region WRP area (DEWNR, 2015c) to ensure a consistent approach to the identification and assessment of risks across the SA Murray–Darling Basin. As detailed in the SA Murray Region risk assessment report, the framework utilised was based on DEWNR's Risk Management Framework for Water Planning and Management (DEWNR, 2012a). Therefore, it implements the international standard ISO (AS/NZS) 31000:2009 (first edition), *Risk management – Principles and guidelines*. The accompanying handbook ((HB 203:2012) *Managing environment-related risk* (prepared by Standards Australia)) (Standards Australia, 2012), the AS/NZS 31000:2009 risk management standard (Joint Technical Committee OB-007, Risk Management, 2013) and the ISO guide 73 (73:2009) *Risk management – Vocabulary* were also used to guide the risk process.

The risk assessment process utilised can be summarised as:

1. *Establishing context*, which involves determining the internal and external parameters (purpose, scope, principles, scales and assessment criteria) to be taken into account when managing risk and setting the risk criteria
2. Assessing risks, involving:
   - *Risk identification*, whereby risks are identified, recognised and described;
   - *Risk analysis*, which involves risk prioritisation, participatory analysis of priority risks, and evaluation of uncertainty, and
   - *Risk evaluation*, whereby the results of the risk analysis (that is, probability distributions of likelihood and consequence) are compared with the risk matrix (Table 5) to produce the final risk rating.
3. *Risk treatment*, involving decisions regarding management response to medium and high risks (e.g. mitigation of likelihood or consequences, avoidance, transfer to another party, retain and accept).

The SA Murray Region risk assessment (DEWNR, 2015c) was conducted in two phases; phase one was a desktop analysis of inherent risks not accounting for existing controls to manage risk, while phase two was a participatory analysis that accounted for the effectiveness and implementation of existing controls.

For the present assessment it was decided to combine these steps into a single phase in which the effectiveness and evaluation of controls was integrated into the risk analysis process. The two-phased approach was considered less appropriate for the EMLR risk assessment due to i) the relatively small spatial area of the WRP area (compared with the SA Murray Region WRP area), and ii) all water resources within the EMLR WRP area are prescribed meaning that an analysis of existing controls is more important for determining risk levels.

The risk assessment process was developed and undertaken by a risk assessment team comprising staff from the Water and Climate Change (WCC) and Science Monitoring and Knowledge (SMK) Branches of DEWNR, with significant input from key experts from within the South Australian Government. Given that risk arises through a chain of circumstances, a multi-disciplinary approach was required to achieve a realistic determination of the risk level. To this end, engagement was structured

to bring together knowledge regarding sources of risk, water resource characteristics, water resource dependencies and the planning and policy environment affecting decision making within the EMLR WRP area. Experts making up the risk assessment team included DEWNR central and regional staff, the Environment Protection Authority of South Australia (EPA) and SA Water.

3.2 Risk assessment context

The context informing the scope of the risk assessment and risk evaluation criteria were developed through an initial context setting workshop involving the risk assessment team, water resource managers, policy officers and technical experts.

3.2.1 Purpose and scope

Section 10.41 of the Basin Plan states that "a water resource plan must be prepared having regard to current and future risks to the condition and continued availability of the water resources of the water resource plan area". In this context, condition is deemed to refer to the quality of the water resource, while continued availability is considered to be the quantity of water resources available.

The purpose of the risk assessment is to assess risks to water resources within and affected by the EMLR WRP area. As detailed under s. 3.07 of the Basin Plan, the WRP area for the EMLR incorporates all surface waters in the WRP area and all ground waters beneath the area. To facilitate the risk assessment the EMLR WRP area was divided into ten sub-areas (Risk Assessment sections 2.2 and 2.3).

As outlined in s. 22(1) of the Water Act (item 3), the risks dealt with by the Basin Plan must include risks to the availability of Basin water resources that arise from the following:

a) The taking and use of water (including through interception activities);
b) The effects of climate change;
c) Changes to land use; and
d) Limitations on the state of knowledge on the basis of which estimates about matters relating to Basin water resources are made.

The risks arising from these, as defined by s. 4.02 of the Basin Plan are:

- Insufficient water available for the environment (risks to the capacity to meet environmental water requirements); and
- Water being of a quality unsuitable for use (risks arising from elevated levels of salinity or other types of water quality degradation); and
- Poor health of water-dependent ecosystems.

Water Act section 22(1) (a) to (c) inclusive (as above) form the basis of the risk identification stage of the assessment process while (d) is addressed through the risk analysis and evaluation process which quantifies the uncertainty regarding the level of risk.

Water resources within the EMLR WRP area are already significantly developed. Under the NRM Act management of water resources must aim to achieve an equitable balance between environmental, social and economic outcomes. That is, management is not directed towards achieving pristine or pre-European conditions (although opportunities for restoration of environmental values are to be pursued as far as reasonably practicable). Given this, it was agreed that the requirements outlined by the NRM Act should inform the baseline or reference point for determining risk levels through the risk assessment process. Specifically, analysis of risk should consider:

- The current condition of water resources and water dependent environmental values in the EMLR WRP area, and
- The community's aspirations regarding the condition of water resources and water dependent environmental values as expressed in relevant policy and planning documents (e.g. EMLR WAP, Marne Saunders WAP).

3.2.2 General principles

The risk assessment team and experts agreed that the risk assessment method for the EMLR assessment would be similar to that followed for the SA Murray Region with the following general principles established:

- Where possible, risk identification and analysis to determine risk level would be a participatory process, involving representation from relevant experts
- Risks would be assessed according to quantitative criteria describing absolute rather than relative risk
- Criteria for rating the level of the risk would be configured such that they are relevant given the spatial and temporal scales addressed by the WRP, thus:
  - The time period over which risks are assessed and reported is the ten year timeframe of a WRP
  - Risk statements describe the potential for aggregate consequences at the scale of sub-areas
- The scope of the risks assessed covers:
  - All water resource events potentially impacting the availability, quality, quantity and timing of water
  - All potential sources of risk causing water resource events, including sources of risk outside the sub-area, or outside the WRP area (Basin and non-Basin areas)
  - Environmental, social and economic consequences consistent with Basin Plan requirements, state legislation and policy and regional planning
- The scope specifically excludes potential risks to Aboriginal cultural values. These risks have not been considered in this risk assessment as input from relevant Aboriginal nations is required to adequately identify and quantify these risks. These risks will be assessed in a separate, culturally appropriate process involving representation from relevant Aboriginal nations.
- The assessment is to draw on existing data and knowledge with no new investigations or monitoring programs initiated to inform the risk analysis.
- Risks were assessed with controls at the current level of implementation at the time of the assessment (2016). Where there were programs being developed to improve the control of risks, a conservative approach was taken and the projected, but not yet implemented, outcomes of those programs were not taken into consideration.

3.2.3 Risk statements

In accordance with definitions of AS/NZS ISO 31000:2009, risk statements have the following generic format:

'There is the potential that [RISK SOURCE] leads to [EVENT] which results in [CONSEQUENCE]'.

- Where a *risk source* is an element which alone or in combination has the intrinsic potential to give rise to risk
- An *event* is an occurrence or change of a particular set of circumstances
- A *consequence* is the outcome of an event affecting objectives and may be expressed quantitatively or qualitatively (ISO, 2009a and ISO, 2009b).

3.2.4 Spatial and temporal scales

The spatial scales for assessing, aggregating and reporting risk are defined by the WRP area sub-areas (Risk Assessment sections 2.2 and 2.3). Sub-areas were defined with the assistance of water planners and technical experts.

The EMLR surface water SDL resource unit (SS13) was subdivided on a geographical basis, where areas with similar characteristics (for example, rainfall, topography and availability of resources) were grouped together to produce two separate areas. The Marne Saunders surface water SDL resource unit (SS12) was determined to be appropriate for the risk assessment with no further subdivision required.

The groundwater SDL resource units, defined in Schedule 4 of the Basin Plan were used for Angas Bremer (GS1a and GS1b) and Marne Saunders (GS4a, GS4b and GS4c). The groundwater SDL resource unit for EMLR (GS2) was sub-divided into two separate sub-areas based on aquifer type to be consistent with the SDL reporting units for Angas Bremer and Marne Saunders. A summary of the sub-areas and maps showing the boundaries between the sub-areas is provided in Risk Assessment sections 2.2 and 2.3.

The temporal scale selected considers the potential for events and consequences occurring during the term of the WRP – that is, ten years. The risk criteria consider the environmental, social and economic values and uses of the water resources within the EMLR.

3.2.5 Risk criteria

Risk criteria are the terms of reference for determining the significance of risk. In accordance with the requirements of the Basin Plan, risk criteria for the EMLR risk assessment outline the criteria for assigning low, medium and high risks.

Level of risk is defined in ISO 31000:2009 as the "*Magnitude of a risk or combination of risks, expressed in terms of the combination of consequences and their likelihood*".

Likelihood is defined as "*the chance of something occurring*" and consequence is defined as "*the outcome of an event affecting objectives*". As required by the Basin Plan, this definition for level of risk and associated definitions for likelihood and consequence have been adopted for this risk assessment where:

- Likelihood was determined by considering the probability that a source of risk would cause an event (water quality or quantity) in the sub-area to occur over a period of ten years. Likelihood categories were expressed as percentages (Table 2) to represent the probability of a defined consequence category occurring; and
- Consequence was determined by considering the severity of the impact on social, economic, environmental or connected water resource values which could arise as a result of a water quality or quantity event (Table 3).

Table 2. Likelihood categories.

Likelihood Category	Likelihood as a percentage
Almost certain	81 – 100%
Likely	61 – 80%
Possible	41 – 60%
Unlikely	21 – 40%
Rare	0 – 20%

Table 3. Consequence categories

Category	Description	Key
Very high (5)	Significant loss of water dependent ecosystem values having international, national or state importance. Recovery of environmental values not feasible over timeframe of WRP (10 years).	WDE
	Interruption to primary source for reticulated town or community water supply.	HCD
	> 10,000ML of water intended for consumptive use for commercial purposes no longer available.	EUC
	> $10 million decline in gross value of production.	EUN
	Water quantity and/or quality effects on connected water resources having very high impact on the environmental and/or beneficial use vales of that resource.	CWR
High (4)	Significant loss of water dependent ecosystem values having regional or local importance. Recovery of environmental values not feasible over timeframe of WRP.	WDE
	Interruption to supplementary source for reticulated town or community water or interruption to a large number (>1000) domestic users.	HCD
	1,000 - 10,000ML of water intended for consumptive use for commercial purposes no longer available.	EUC
	$1 - $10 million decline in gross value of production.	EUN
	Water quantity and/or quality effects on connected water resources having high impact on the environmental and/or beneficial use vales of that resource.	CWR
Medium (3)	Some loss of water dependent ecosystem values having international, national or state importance. Recovery of environmental values is feasible over timeframe of WRP.	WDE
	Interruption to supplementary non-potable town water supply, or interruption to a medium number (100-1000) domestic users.	HCD
	100 - 1,000ML of water intended for consumptive use for commercial purposes no longer available.	EUC
	$100,000 - $1 million decline in gross value of production.	EUN
	Water quantity and/or quality effects on connected water resources having medium impact on the environmental and/or beneficial use vales of that resource.	CWR

Category	Description	Key
Minor (2)	Some loss of water dependent ecosystem values having regional or local importance. Recovery of environmental values is feasible over timeframe of WRP.	WDE
	Interruption to small number (<100) domestic users.	HCD
	10 - 100ML of water intended for consumptive use for commercial purposes no longer available.	EUC
	$10,000 - $100,000 decline in gross value of production.	EUN
	Water quantity and/or quality effects on connected water resources having minor or negligible impact on the environmental and/or beneficial use vales of that resource.	CWR
Insignificant (1)	Any loss of water dependent ecosystem values is minimal. Recovery possible without management intervention over timeframe of WRP.	WDE
	Negligible impacts observed.	HCD
	< 10ML of water intended for consumptive use for commercial purposes no longer available.	EUC
	<$10,000 decline in gross value of production.	EUN
	Insignificant effect on environmental and/or beneficial use values of connected water resources.	CWR

Risk Consequences

HCD	Human consumption/domestic needs not met
WDE	Water-dependent ecosystems impacted
EUN	Economic use of water impacted (non-consumptive)
EUC	Economic use of water impacted (consumptive)
CWR	Connected water resources impacted

3.3 Risk identification

The first stage of the risk assessment process is risk identification. This involves finding, recognising and describing risks relevant to the EMLR WRP area. The product of risk identification is a register of risk statements, which provide a description of the chain of circumstances giving rise to risk in each case.

Risks were identified through a series of workshops involving technical experts from relevant SA government departments (as described in Section 3.1). Consistent with the risk assessment context (Section 3.2), risk identification is concerned with two classes of water resource events:

- **Change in water quality –** a change in the quality of the resource attributes outside the bounds of current known qualities. Water quality attributes may include salinity, sediment load, temperature, pH, pollutants, toxicants, nutrients and dissolved oxygen
- **Change in water quantity –** a change in the amount of water available (including the pattern or regime of availability over time), outside that currently available, including either an increase or decrease in the amount available.

3.3.1 Bow-tie diagram for risk identification

A bow-tie diagram (Figure 7) was used as a tool for identifying and communicating risks consistent with the structure of risk statements. Bow-tie diagrams are visual representations of the potential chains of cause and effect in a timeline starting at risk sources progressing to the event and then consequences. The defining feature of a bow-tie model is that an event (the "knot") may be caused by multiple sources of risk and may in turn lead to multiple consequences independent of the source of risk. Thus:

- Sources of risk are listed on the left hand side of the bow-tie;
- Consequences on the right side of the bow-tie; and
- The event is represented in the centre of the bow-tie (that is, the 'knot' of the bow-tie).

Risk identification workshops used the bow-tie diagram developed for the SA Murray Region risk assessment (DEWNR, 2015c) as a starting point for risk identification. It was agreed that descriptions of events and consequences developed for the SA Murray Region were applicable to the overarching context driving the WRP risk assessments undertaken for SA and could therefore be adopted for the present assessment. Descriptions of the consequence categories used are set out in Table 3. Because of this, participants focused on identifying or modifying sources of risk based on their understanding of the context specific to the EMLR WRP area. Descriptions of the categories of risk source used are set out in Appendix C. The final bow-tie model was then used to populate the risk register through iterative combinations of all risk sources, events and consequences (Figure 7).

3.4 Risk analysis

The risk analysis process consisted of three stages:

1. Risk prioritisation
2. Participatory analysis of priority risks
3. Evaluation of uncertainty and further analysis

3.4.1 Risk prioritisation

The risk identification process has the potential to produce a large number of provisional risk statements. Risk prioritisation streamlines the assessment process by determining which risks can be classified as 'low' with a high level of confidence.

To undertake prioritisation, a set of principles (Section 4.2) was developed in consultation with relevant technical experts which were then applied to the risk register by the assessment team. The remaining risks were determined to be priority risks requiring further detailed analysis.

3.4.2 Participatory analysis of priority risks

Priority risks were analysed through a series of workshops involving the project team and key experts as described in Section 3.1. The workshops followed a structured format to ensure the following outcomes:

- The risk assessment context and criteria were understood by all participants
- There was a consistent understanding of the pathway described by each risk statement among participants
- The most relevant evidence was identified and discussed by participants
- Disagreements, differences or uncertainty regarding interpretation of risks or evidence were accounted for through the risk rating process.

To achieve these objectives, workshops commenced with a presentation of the context of the risk assessment including the purpose, scope, relevant spatial and temporal scales and criteria. In particular, participants were briefed on the criteria for consequence severity levels against which risks were to be analysed (Table 3).

For each risk statement, the following structure was followed during the workshops:

1. Discussion of the risk statement to ensure comprehension of the nature of the risk and the pathways of cause and effect relevant to the statement. This discussion allowed determination of whether the risk statement overlapped other risk statements, or where it would be advantageous to split a risk statement into multiple pathways to be assessed independently.
2. Identification and discussion of factors known to affect the level of risk. This included evidence regarding i) the source of risk (e.g. potential for overuse, inherent vulnerability of the resource to stressors), ii) the event (e.g. current condition of the resource), and iii) consequences (e.g. environmental, social and/or economic dependencies on the resource)
3. Identification of existing controls for managing risk, where controls are defined as policies, plans or programs developed and/or implemented by government (South Australia or

Commonwealth) to manage risk. For example, legislation, water allocation plans, land use policies, regulation of activities, infrastructure projects etc.

4. Discussion and qualitative evaluation of controls according to their inherent effectiveness at reducing the level of risk and the extent to which they had been successfully implemented.
5. Quantification of risk level. Judgements regarding the likelihood of each consequence severity level occurring as a result of the risk pathway in a ten year period over the scale of the sub-area were recorded individually by each participant.

Ratings and additional information regarding risks were captured in worksheets by each participant for each risk statement (an example worksheet is provided in Appendix A). Worksheets were structured according to the workshop process outlined above and included the following fields:

- Risk statement, including the source of risk, event and consequence
- Risk factors
- Existing controls for risk
- Evaluation of effectiveness and implementation of existing controls
- Likelihood for each level of consequence

Criteria for evaluating controls (step 4 of the participatory risk analysis process) were based on DEWNR's risk management framework for water planning and management (DEWNR, 2012a). Effectiveness describes the inherent efficacy of the control at reducing the level of risk in question if fully implemented:

- **Highly effective** – Total control or mitigation of risk (>95% effective)
- **Moderately effective** – Risk is controlled in most circumstances (75 – 95% effective)
- **Partially effective** – Risk controlled in some circumstances (30 – 75% effective)
- **Mostly ineffective** – Risk is mostly uncontrolled by measures (5 – 30% effective)
- **Ineffective** – Controls do not mitigate the impacts of the risk (<5% effective)

The existing level of implementation of the control was evaluated as follows:

- Fully implemented: >95% implemented
- Mostly implemented: 75 – 95% implemented
- Partially implemented: 30 – 75% implemented
- Mostly not implemented: 5 – 30% implemented
- Not implemented: <5% implemented

Unlike many risk assessments where the analysis assigns a single rating of likelihood and consequence, participants were required to rate the likelihood of all consequence categories occurring. Thus, similar to the SA Murray Region WRP risk assessment (DEWNR, 2015c), the analysis produces a probability distribution of consequences with the total likelihood summing to 100%. Low risks are therefore correlated with a greater likelihood of the lowest consequence severity level (that is insignificant impact), and high risks were correlated with greater likelihood of more severe consequences.

This approach allowed uncertainty for each risk to be quantified according to the properties of the probability distributions produced by the participatory analysis. Evaluation of uncertainty and determination for the need of further analysis then occurred following the workshop (see Section 3.4.3).

Finally, participants were requested to identify what they considered to be the most important factors and controls influencing their determination of likelihood and consequence.

Following each workshop, data collected on the worksheets was synthesised into the risk register.

3.4.3 Evaluation of uncertainty and further analysis

Following the participatory analysis of the priority risks, the level of uncertainty associated with likelihood and consequence ratings were analysed. Where uncertainty was found to be high (that is low confidence), the risk was subject to a further round of analysis.

Evaluation of uncertainty was based on analysis of the distribution of mean likelihood ratings (that is aggregated ratings from all participants), with a wider spread of likelihood values across the consequence categories correlating to higher uncertainty. Criteria for determining uncertainty are presented in Table 4. Uncertainty was evaluated for all risk statements.

Risk statements with a low level of confidence (that is high uncertainty) were then subject to a further analysis by relevant experts. Depending on the risk statement, this involved either inviting additional experts to participate in the analysis and/or accessing additional information. The reassessment also examined the extent to which differences in interpretation of the risk statement by participants was a source of uncertainty.

Table 4. Criteria for confidence according to uncertainty

Confidence	Criteria
High	Probabilities assigned to single category is >60%
Moderate	Probabilities assigned to 2 or 3 consequence levels AND probabilities assigned to a single category are ≤60%
Low	Probabilities assigned to >3 consequence levels AND probability assigned to a single category ≤30%

Following reanalysis, the additional risk ratings were aggregated with those from the previous assessments and the final risk levels and confidence ratings determined and reported for each risk statement. These additional ratings were further evaluated by the risk assessment team to ensure that the outcomes accurately reflected conditions and context relevant to the EMLR WRP area. No further analysis was conducted of risks even if the confidence level remained low after the reanalysis phase.

3.5 Risk evaluation

3.5.1 Assigning risk ratings from likelihood and consequence

In accordance with the requirements of the Basin Plan, risks were rated as low, medium or high with options for the treatment of medium and high risks to be considered by the EMLR WRP. Risk evaluation compares the results of the risk analysis (that is, probability distributions of likelihood and

consequence) with the risk matrix (Table 5) which encapsulates the risk criteria. This process produces the final risk rating.

For each risk statement, determination of the rating involved calculation of mean likelihood ratings for each of the five consequence levels. These were then individually compared with the risk matrix (Table 5) to produce a set of five ratings per risk statement. The highest rating from this distribution was then reported as the final risk rating in each case. Mean likelihood ratings were the aggregated ratings from all who participated in the risk analysis process.

Table 6 presents an example of the evaluation process. Following analysis involving multiple experts, the mean likelihoods for the very high, high and medium consequences were very unlikely (0%) while minor and insignificant consequences were rated 20% and 80% respectively. The final risk level for this assessment is therefore low, with a high level of confidence (low uncertainty).

Since risk is a combination of likelihood and consequence, the highest likelihood or consequence level does not necessarily correspond with the final level of risk. For example, if likelihoods are distributed as 0% insignificant, 50% minor, 20% medium, 25% high and 5% very high (total = 100%), comparison with the risk matrix produces a final risk rating of medium due to the 25% likelihood of high consequence.

3.6 Risk treatment and data management

Risk treatment describes the proposed management response(s) to medium and high risks. As required under the Basin Plan, actions to address the medium and high risks identified through the risk assessment process must be included in the EMLR WRP. To facilitate development of appropriate response measure(s) to medium and high risk(s), information regarding the effectiveness and level of implementation of controls produced through the assessment process was subject to further analysis. Controls identified as influencing ratings for a given risk statement were identified as priority controls. Analysis was then undertaken to determine whether additional controls (including response/recovery measures) were available or whether the risk was inherently difficult to control.

All risks, controls (including their degree of implementation and effectiveness) and factors from the workshops were entered into the database as a numbered list of agreed facts, data, references or other sources of information. These were combined with the outcomes of the likelihood and consequence probability analyses to compile a risk register for the EMLR WRP area. The register was structured as a relational database to support documentation of linkages between risks, controls and ratings.

Table 5. Risk matrix - risk level according to likelihood and consequence

Consequence					
Likelihood	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	**L**	**M**	**H**	**H**	**H**
Likely	**L**	**M**	**M**	**H**	**H**
Possible	**L**	**L**	**M**	**M**	**H**
Unlikely	**L**	**L**	**L**	**M**	**M**
Rare	**L**	**L**	**L**	**L**	**L**

Where L = low; M = medium; and H = high

Table 6. Example showing assignment of likelihoods to consequence categories

Consequence Level	Consequence definition	Likelihood Probability										
		Rare			Unlikely		Possible		Likely		Almost certain	
Very high	Loss of values for water dependent environmental assets having international, national or state significance. Recovery not feasible over planning timeframe	0	10	20	30	40	50	60	70	80	90	100
High	Loss of values for water dependent environmental assets having regional or local significance. Recovery not feasible over planning timeframe	0	10	20	30	40	50	60	70	80	90	100
Medium	Loss of values for water dependent environmental assets having international, national or state significance. Recovery feasible but may require management intervention	0	10	20	30	40	50	60	70	80	90	100
Minor	Loss of values for water dependent environmental assets having regional or local significance. Recovery feasible but may require management intervention	0	10	20	30	40	50	60	70	80	90	100
Insignificant	No loss or loss where recovery feasible without management intervention	0	10	20	30	40	50	60	70	80	90	100

4 Results

4.1 Risk identification

The risk identification process (Section 3.3) produced a bow-tie diagram consisting of seven risks sources, one event with two aspects and four consequence categories (Table 7 and Figure 7). Changes in the risk source categories defined in the SA Murray Region risk assessment (DEWNR 2015c) specific to the EMLR WRP area were:

- Managed aquifer recharge (MAR) was added as a new source of risk relevant for the EMLR WRP area
- Point source pollution was added as a new generic source of risk
- Acid sulphate soil potential was removed (replaced by point source pollution)
- Diffuse pollution and susceptibility to flooding were removed and replaced by land use (which includes both of these sources)
- Climate change was removed

It was noted that climate change potentially influences all risk pathways (e.g. through increased frequency and/or severity of climate extremes). Therefore it was agreed that it was more efficient to consider climate change as a factor affecting risk during the analysis process rather than as a separate source of risk. Data pertaining to climate change studies conducted for the SA Murray-Darling NRM region as a whole (Charles and Guobin, 2015) were made available to participants during the risk analysis process.

All risk sources were combined with each of the consequence categories for each of the ten sub-areas to produce a total of 280 theoretical risk statements.

Table 7. Categories of risk sources and consequences from bow-tie diagram

Risk Source	Event	Risk Consequence
Climate extremes	Change in water quality	Human consumption/domestic needs not met
Demand/take (incl. interception activities)		
Management of connected water resources	or	WDEs impacted
Infrastructure (affecting natural flow regimes)		Economic use impacted
Point source pollution	Change in water quantity (availability)	Connected water resources impacted
Land use		
Managed aquifer recharge		

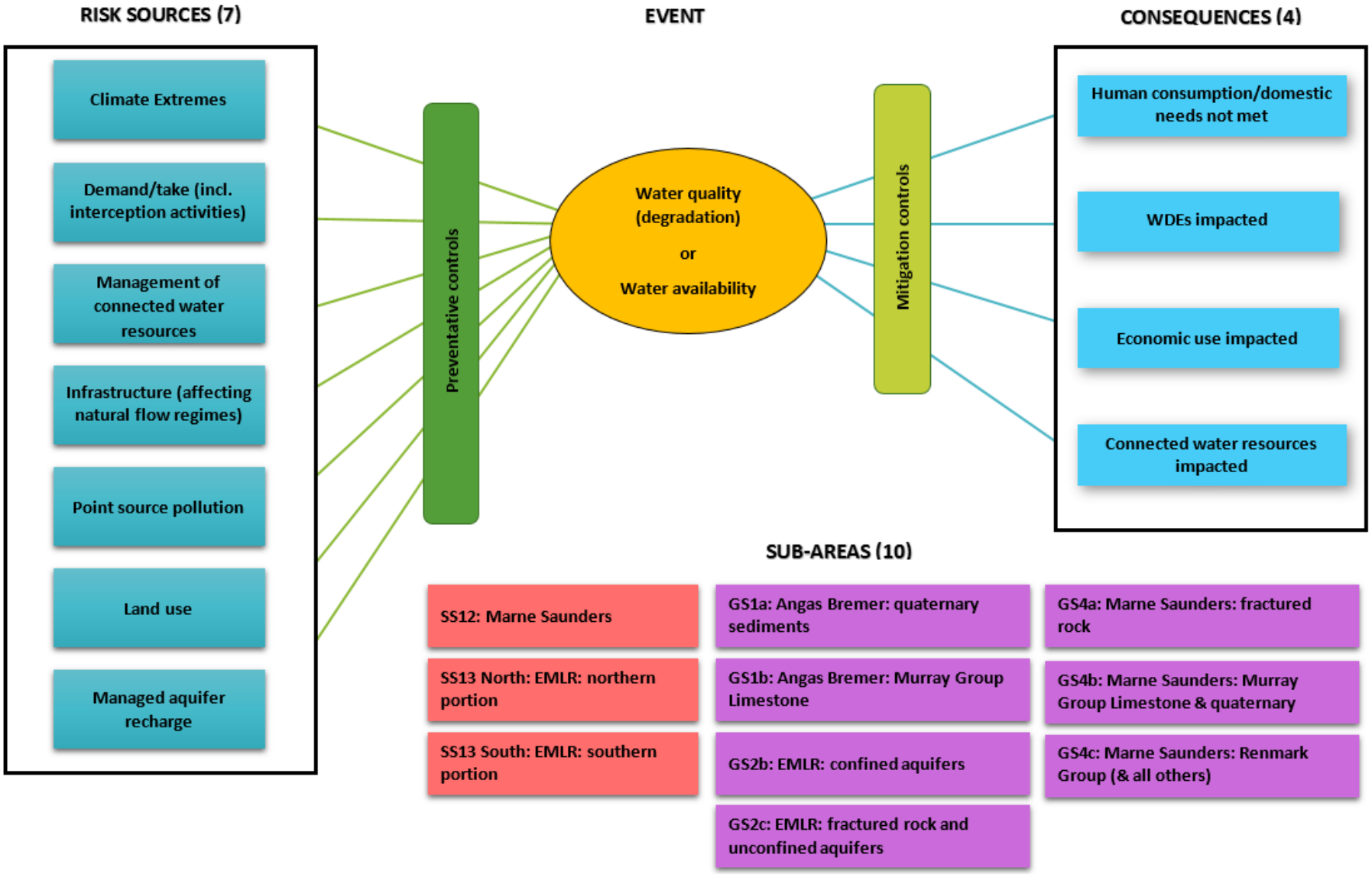

Figure 7. Bow-tie diagram for risk pathways in the EMLR WRP area

4.2 Risk analysis and evaluation

4.2.1 Priority risks

A review of each of the 280 theoretical risk statements generated by the bow-tie diagram was conducted to identify any risk sources or consequences that were not applicable for a particular sub-area. Risks flagged by this process were assigned a rating of 'low' with high certainty and subject to no further analysis. Criteria for identifying non-applicable risks, developed in consultation with relevant technical experts, included:

- Risks caused by 'infrastructure affecting flow regimes' do not apply to groundwater sub-areas. Impacts associated with infrastructure relevant to groundwater considered under the risk sources 'demand/take' and 'management of connected water resources'.
- There is negligible managed aquifer recharge in aquifers within the Marne Saunders or EMLR sub-areas. Therefore, this source of risk is only relevant for Angas Bremer Murray Group Limestone aquifer (i.e. sub-area GS1b).
- It was determined that there is insignificant impact to water dependent ecosystems caused by events in confined groundwater aquifers or unconfined aquifers having a depth to groundwater more than 10 metres (i.e. GS2b).
- There is minimal consumptive use of water from the Marne Saunders Renmark Group aquifer (sub-area GS4c) as the overlying Murray Group Limestone aquifer is more easily accessible and provides water of better quality and more reliable yields. Therefore risks to this resource are inherently low. Further assessment was therefore only warranted for risks associated with management of connected water resources.
- Risk statements where the risk source was 'management of connected water resources' and the consequence was 'connected water resources impacted' were not assessed. It was determined that risks are only assessed where the source of risk or consequence is identified within a given sub-area.

Analysis based on these criteria rated 115 risks as low with high confidence while the remaining 165 risks were prioritised for the participatory analysis process. The risk register (Appendix B) tabulates the output from risk prioritisation process.

4.2.2 Risk profile

165 priority risks were addressed through a series of structured risk analysis workshops (described by Section 3.4.2). The ratings produced by the analysis was collated and applied to the risk evaluation criteria to produce provisional risk ratings of 'low', 'medium' or 'high' (Section 3.5). The uncertainties were quantified to rate the confidence of the assessment for each risk (Section 3.4.3).

A provisional risk profile was generated and consisted of one high risk, 15 medium risks and 149 low risks (Table 8). Of these, a total of eight risk statements (six medium and two low) had a confidence rating of 'low' (Table 8) (four within SS13 south and four within GS2c).

Low confidence risks were subject to further analysis and were subsequently re-evaluated (as described in Section 3.4.3). This reassessment resulted in three medium risks being re-evaluated as low while the other risks retained their provisional ratings (Table 9).

The final risk profile for the EMLR WRP area constituted 1 high risk (in GS4b), 12 medium risks (3 in SS12, 2 in SS13 north, 4 in SS13 south, 2 in GS4b and 1 in GS2c) and 152 low risks.

Table 8. Provisional EMLR WRP Area risk profile (excluding risks rated low with high confidence)

Sub-area	Risk ID	Risk Source	Consequence Category	Likelihood	Consequence	Risk Level	Confidence
SS12	2	Climate extremes	Water dependent ecosystems impacted	Likely	Minor	Medium	High
SS12	3	Climate extremes	Economic use	Possible	Medium	Medium	Moderate
SS12	6	Demand/take	Water dependent ecosystems impacted	Unlikely	High	Medium	Moderate
SS13 North	30	Climate extremes	Water dependent ecosystems impacted	Likely	Minor	Medium	High
SS13 North	50	Land use	Water dependent ecosystems impacted	Likely	Minor	Medium	High
SS13 South	57	Climate extremes	Domestic needs not met	Unlikely	High	Medium	Moderate
SS13 South	59	Climate extremes	Economic use impacted	Unlikely	High	Medium	Moderate
SS13 South	62	Demand/take	Water dependent ecosystems impacted	Unlikely	Very high	Medium	Low
SS13 South	76	Point source pollution	Connected water resources impacted	Possible	Minor	Low	Low
SS13 South	78	Land use	Water dependent ecosystems impacted	Likely	Medium	Medium	Low
SS13 South	80	Land Use	Connected water resources impacted	Likely	Medium	Medium	Low
GS4b	114	Climate extremes	Water dependent ecosystems impacted	Likely	Very high	High	High
GS4b	115	Climate extremes	Economic use	Likely	Minor	Medium	High
GS4b	123	Management of connected water resources	Economic use	Likely	Minor	Medium	High
GS2c	226	Climate extremes	Water dependent ecosystems impacted	Unlikely	Very high	Medium	Low

Sub-area	Risk ID	Risk Source	Consequence Category	Likelihood	Consequence	Risk Level	Confidence
GS2c	227	Climate extremes	Economic uses impacted	Possible	Medium	Medium	Low
GS2c	230	Demand/take	Water dependent ecosystems impacted	Unlikely	High	Medium	Low
GS2c	242	Point sources pollution	Water dependent ecosystems impacted			Low	Low

Table 9. EMLR WRP Area risk profile - medium and high risks

Sub-area	Risk ID	Risk Source	Consequence description	Likelihood rating	Consequence category	Risk level
SS12	r2	Climate extremes	Water dependent ecosystems impacted	Likely	Minor	Medium
SS12	r3	Climate extremes	Economic use	Possible	Medium	Medium
SS12	r6	Demand/take	Water dependent ecosystems impacted	Unlikely	High	Medium
SS13 North	r30	Climate extremes	Water dependent ecosystems impacted	Likely	Minor	Medium
SS13 North	r50	Land Use	Water dependent ecosystems impacted	Likely	Minor	Medium
SS13 South	r57	Climate extremes	Domestic needs not met	Unlikely	High	Medium
SS13 South	r59	Climate extremes	Economic use	Unlikely	High	Medium
SS13 South	r62	Demand/take	Water dependent ecosystems impacted	Unlikely	Very high	Medium
SS13 South	r78	Land use	Water dependent ecosystems impacted	Possible	Medium	Medium
GS4b	r114	Climate extremes	Water dependent ecosystems impacted	Likely	Very High	High
GS4b	r115	Climate extremes	Economic use	Likely	Minor	Medium
GS4b	r123	Management of connected water resources	Economic use	Likely	Minor	Medium
GS2c	r226	Climate extremes	Water dependent ecosystems impacted	Unlikely	Very high	Medium

4.3 Summary of medium and high risks

This section presents information relating to the high and medium risks identified through the assessment process. Information presented is based on the output of workshops and the risk evaluation process as described in Section 3.

The likelihood and consequence ratings provided for each risk refer to the aggregated probability distributions of consequences that gave rise to the highest risk (as described by Section 3.5.1). The factors and controls provided is based on a synthesis of all information produced by the participatory analysis process. In many cases additional post-workshop verification of key factors and controls was undertaken with key experts and have been included in the final synthesis.

4.3.1 SUB-AREA: SS12 – Marne Saunders surface water

Risk r2: There is the potential that climate extremes leads to a decline in water quality and/or availability of water which results in WDEs being impacted.

Risk source: Climate extremes
Consequence: Water dependent ecosystems impacted

Likelihood	Consequence	Risk Rating	Confidence
Likely	Minor	Medium	High

Risk factors

- Risks caused by climate extremes are inherently difficult to control.
- WAP designed to build resilience but climate extremes (particularly drought) will still lead to consequences
- Low potential for erosion issues as a result of flood events
- Drought events affect the quantity and quality of surface water
- One stretch of pools containing river blackfish (protected under *Fisheries Management Act 2007*) occurs in sub-area. It is the last known population of this species in the sub-area therefore it will not recover if lost, as it is effectively disconnected from other populations. Impacts to this population are already considered under risk statement 114 (GDEs), therefore this statement is focused on other WDEs that may be impacted
- Mountain galaxias in this subarea are genetically different to those of the Mount Lofty Ranges. However their populations are deemed resilient given they survived the Millennium drought, although recolonisation and recovery has been slow. If there is a drought, these populations will be impacted but recovery is likely, if sufficient refuge populations are able to persist through the drought and there is sufficient recovery before the next drought. However, there may be direct loss of local populations, which together with other stressors is likely to reduce resilience in the long-term. Risk in the long term (e.g. greater than the 10 year timeframe for this risk assessment) may be higher, if the level of control implementation at the time of the risk assessment continues.

Existing controls for risk

Document	Effectiveness	Implementation	Notes
Drought action plan – in-situ watering and/or temporary relocation of populations to refuge areas	Unknown	Unknown	Likely to be effective at a local scale. There have been precedents for this response elsewhere in the EMLR WRP area. Implementation is resource intensive and therefore dependent on resources.
Securing Low Flows Program and Marne Saunders WAP - Section 4.3.2.2 – requirement to return low flows. Legal instrument is water licence conditions or water affecting activity permit conditions.	Moderately effective	Not implemented	Low flows at or below a threshold flow rate must be bypassed, returned or not captured, at sufficient existing in-scope dams and watercourse diversions to meet the environmental flow targets for each management zone. The requirement also applies to most permits for construction of new dams and watercourse diversions. The requirement to secure low flows for new dams and diversions is fully implemented. At the time that the risk assessment was carried out, the program to secure low flows at key existing dams and diversions had not yet commenced on-ground implementation, beyond a few trial sites.
Marne Saunders WAP. Consumptive use limits and dam capacity limits	Mostly ineffective	Fully implemented	These limits are an important complementary measure for environmental water provisions. They manage flows provided by dams filling and spilling, and are configured to operate over a range of climate conditions, consequently they are less effective during drought than directly returning low flows.
NRM Act 2004. s. 132 – Restrictions in case of inadequate supply or overuse of water	Mostly ineffective	Partially implemented	Section 132 grants the South Australian minister a broad power to place temporary restrictions on the take of water in the case of inadequate supply or overuse. This provision of the NRM Act is fully operational and available for the Minister to use, however no such restriction is currently in place in this area. Making a s. 132 restriction would require the appropriate process to be undertaken, consequently this

Document	Effectiveness	Implementation	Notes
			control is considered partially implemented. This control is unlikely to provide significant benefit to water-dependent ecosystems during a drought, as the majority of surface water capture is via interception by dams. Restricting the amount used from dams that are already at a low level due to drought is not likely to return water to downstream ecosystems, as dams need to fill first before they spill water downstream. Securing low flows directly to ecosystems when runoff occurs is expected to be substantially more effective.

SUB-AREA: SS12 – Marne Saunders surface water

Risk r3: There is the potential that climate extremes leads to a decline in water quality and/or availability of water which results in economic uses being impacted.

Risk source: Climate extremes
Consequence: Economic uses impacted

Likelihood	Consequence	Risk Rating	Confidence
Possible	Medium	Medium	Moderate

Risk factors

- Risks caused by climate extremes are inherently difficult to control.
- During drought, dams required for economic uses do not fill and there is less or no flow in watercourses
- Economic uses reliant on dams within the sub-area include viticulture, horticulture and stock.
- Flooding is unlikely to cause economic consequences (the mostly likely impact is siltation of dams).
- The Marne Saunders is fully developed. The water allocation plan aims to achieve sustainable use of the resource. However it is configured to average conditions rather than extreme events.
- Alternative water sources in the sub-area include groundwater (although often salty and low yielding), water from the mains supply pipeline (including off-peak River Murray allocations), and roof runoff (although generally insufficient volumes for most economic purposes).

Existing controls for risk

Document	Effectiveness	Implementation	Notes
Marne Saunders WAP. Surface water consumptive use limits and dam capacity limits	Mostly ineffective	Fully implemented	Provides for sustainable use of resource under normal circumstances, including some local-scale water sharing considerations. However the limits have been configured for average rather than drought conditions.
Marne Saunders WAP. Consumptive use limits and buffer zones for underground water.	Partially effective	Fully implemented	Limits support sustainable management of underground water, which provides an alternative source to surface water during drought.
Marne Saunders WAP. Rollover provisions for underground water.	Partially effective	Fully implemented	Many surface water users have a small allocation from a bore as a drought backup. The rollover provision provides users with flexibility to use more groundwater in some years – helpful when drought reduces surface water availability.

Document	Effectiveness	Implementation	Notes
SA MDB NRM Board irrigation efficiency program – including links to broader projects (e.g. On farm irrigation efficiency program and private irrigation infrastructure program).	Partially effective	Mostly not implemented	Supports more effective use of limited water resources. Only implemented in parts of region (mostly associated with River Murray)

SUB-AREA: SS12 – Marne Saunders surface water

Risk r6: There is the potential that demand/take (incl. interception activities) leads to a decline in water quality and/or availability of water which results in WDEs being impacted.

Risk source: Demand/take including interception activities
Consequence: Water dependent ecosystems impacted

Likelihood	Consequence	Risk Rating	Confidence
Unlikely	High	Medium	Moderate

Risk factors

- Surface water resources are highly developed. Dams are in chains along watercourses.
- Demand/take has already significantly impacted water dependent ecosystems (SAMDB NRM Board 2010). The risk assessment considers potential for impacts to worsen (over the WRP timeframe) from the existing baseline.
- Some examples of existing degradation include pools drying, poor condition of fish populations (Hammer 2004) and loss of aquatic species due to terrestrial encroachment.
- Ongoing encroachment of terrestrial ecosystems will not be halted or reversed under current levels of take
- No state or nationally important species are found in the upper Marne. River blackfish (protected under *Fisheries Management Act 2007*) are found in Lower Marne (Black Hill Springs). However the springs are primarily supported by groundwater, so the risks to these river blackfish are discussed in the groundwater risk assessment (risk 114).
- The Marne subspecies of mountain galaxias is genetically distinct and thus has regional significance.
- Risk in the long term (e.g. greater than the 10 year timeframe for this risk assessment) may be higher, if the level of control implementation at the time of the risk assessment continues.
- Controls are likely to be mostly effective, but the program to return low flows has not yet been implemented at the time the risk assessment was done. Implementation of low flow policy will reduce the level of risk.

Existing controls for risk

Document	Effectiveness	Implementation	Notes
Securing Low Flows Program and Marne Saunders WAP - Requirement to return low flows. Legal instrument is water licence conditions or water affecting activity permit conditions.	Moderately effective	Not implemented	Low flows at or below a threshold flow rate must be bypassed, returned or not captured, at sufficient existing in-scope dams and watercourse diversions to meet the environmental flow targets for each management zone. The requirement also applies to most permits for construction of new dams and

Document	Effectiveness	Implementation	Notes
			watercourse diversions. The requirement to secure low flows for new dams and diversions is fully implemented. At the time that the risk assessment was carried out, the program to secure low flows at key existing dams and diversions had not yet commenced on-ground implementation, beyond a few trial sites.
Marne Saunders WAP. Consumptive use and dam capacity limits.	Partially effective	Fully implemented	These limits are an important complementary measure for environmental water provisions. They manage medium to high flows provided by dams filling and spilling, however these flow components have been less affected by water resource development than low flows.

4.3.2 SUB-AREA: SS13 North – EMLR northern portion surface water

Risk r30: There is the potential that climate extremes lead to a decline in water quality and/or availability of water which results in WDEs being impacted.

Risk source: Climate extremes
Consequence: Water dependent ecosystems impacted

Likelihood	Consequence	Risk Rating	Confidence
Likely	Minor	Medium	High

Risk factors

- Risks caused by climate extremes are inherently difficult to control.
- WAP designed to build resilience but climate extremes (particularly drought) will still lead to consequences
- There are no known state-listed species reliant on EMLR surface water resources in this sub-area. The wetlands at the terminus of several catchments support state-listed fish species, but are dependent on River Murray flows and/or stormwater inflow, with EMLR surface water inflow being a minor contributor.
- Mountain galaxias are present, as are a range of other plants and animals that are locally important in creating functional water-dependent ecosystems
- Wetlands are less impacted but naturally more saline than in the Marne sub-area (SS12) in general
- During dry years water quality decreases (increase in salinity) and water availability is more limited

Existing controls for risk

Document	Effectiveness	Implementation	Notes
EMLR WAP Section 7 permits Requirements for permits for water affecting activities (wells, dams, forestry etc).	Mostly ineffective	Fully implemented	This control only applies to new activities, not existing dams, which limits its effectiveness (although this area is not heavily developed, so there are still opportunities to apply this control). The limits are based on long-term averages, thus are not completely effective for climate extremes.
EMLR WAP Section 5.2 Surface water and watercourse allocation criteria, including taking limits at the scale of significant environmental assets.	Mostly ineffective	Fully implemented	The limits are based on long-term averages, thus are not completely effective for climate extremes. These limits are an important complementary measure for environmental water provisions. They manage medium to high flows provided by dams filling and spilling,

Document	Effectiveness	Implementation	Notes
			however these flow components have been less affected by water resource development than low flows.
Securing Low Flows Program and EMLR WAP - Requirement to return low flows. Legal instrument is water licence conditions, water affecting activity permit conditions, or NRM (Eastern Mount Lofty Ranges—Longer-Term Water Conservation Measures) Regulations 2014.	Moderately effective	Not implemented	Low flows at or below a threshold flow rate must be bypassed, returned or not captured, at sufficient existing in-scope dams and watercourse diversions to meet the environmental flow targets for each management zone. The requirement also applies to most permits for construction of new dams and watercourse diversions. The requirement to secure low flows for new dams and diversions is fully implemented. At the time that the risk assessment was carried out, the program to secure low flows at key existing dams and diversions had not yet commenced on-ground implementation, beyond a few trial sites.
NRM Act 2004. s. 132 – Restrictions in case of inadequate supply or overuse of water	Mostly ineffective	Partially implemented	Section 132 grants the South Australian minister a broad power to place temporary restrictions on the take of water in the case of inadequate supply or overuse. This provision of the NRM Act is fully operational and available for the Minister to use, however no such restriction is currently in place in this area. Making a s. 132 restriction would require the appropriate process to be undertaken, consequently this control is considered partially implemented. This control is unlikely to provide significant benefit to water-dependent ecosystems during a drought, as the majority of surface water capture is via interception by dams. Restricting the amount used from dams that are already at a low level due to drought is not likely to return water to downstream ecosystems,

Document	Effectiveness	Implementation	Notes
			as dams need to fill first before they spill water downstream. Securing low flows directly to ecosystems when runoff occurs is expected to be substantially more effective.
Drought action plan – in-situ watering and/or temporary relocation of populations to refuge areas	Unknown	Unknown	This is a potential action that is likely to be effective at a local scale. There have been precedents for this response in the EMLR WRP area. Implementation is resource intensive and therefore dependent on resources.
EMLR WAP. Section 5.1. Principles 14-23. Allocations for purpose of environmental watering	Unknown	Partially implemented	The use of this provision to allocate water for environmental purposes during a dry period maybe effective at a local scale, if alternative water sources are available. There is a provision for this control in the WAP, but no such allocations have yet been made and would require work to grant such an allocation and implement environmental watering (hence partially implemented). Implementation is resource intensive and therefore dependent on resources.

SUB-AREA: SS13 North - EMLR northern portion surface water

Risk r50: There is the potential that land use leads to a decline in water quality and/or availability of water which results in WDEs being impacted.

Risk source: Land use
Consequence: Water dependent ecosystems impacted

Likelihood	Consequence	Risk Rating	Confidence
Likely	Minor	Medium	High

Risk factors

- There are no known state-listed species reliant on EMLR surface water resources in this sub-area. The wetlands at the terminus of several catchments support state-listed fish species, but are dependent on River Murray flows and/or stormwater inflow, with EMLR surface water inflow being a minor contributor.
- Mountain galaxias are present (Hammer 2004), as are a range of other plants and animals that are locally important in creating functional water-dependent ecosystems
- There are impacts of sedimentation, nutrients and salinity in Reedy Creek (EPA 2010). Sedimentation is a concern for permanent pools and may be irreversible.
- Historical clearing of deep-rooted native vegetation has led to dryland salinity, with impacts on surface water quality; and also reduced buffering of streams by riparian vegetation (e.g. reduction in pollutants washing into streams, shading and provision of resources by riparian vegetation). Further clearing is controlled through the *Native Vegetation Act 1991*.
- Wetlands are less impacted but naturally more saline than in the Marne sub-area (SS12) in general

Existing controls for risk

Document	Effectiveness	Implementation	Notes
Development Act	Mostly ineffective	Mostly implemented	This control could prevent more intensive land use from occurring. Applies to new development, not existing development (hence mostly ineffective).
SAMDB Regional NRM Plan – resource condition targets and management action targets in relation to land management	Partially effective	Partially implemented	Incentive programs to remove watering points from watercourses and fencing riparian areas (run through a range of organisations); Natural Resources SAMDB land management and sustainable agriculture programs. Programs are fully implemented to the extent that resources are available, but demand exceeds available resources.
NRM Act 2004 [s. 9(1)] Statutory duty to act responsibly in	Partially effective	Partially implemented	NRM Act General duty of care requires persons to act reasonably in relation to management of natural resources. The

Document	Effectiveness	Implementation	Notes
relation to the management of natural resources (duty of care provision); chapter 6 (provisions related to land management including action plans			NRM Act also contains provisions that potentially could be used to require a landholder to develop and implement action plans remediate poor land management practices, although this is a tool of last resort and the focus is on working with landholders, support and education. This provision of the NRM Act is fully operational and available for use, but work would be required to be implement case-by-case (hence considered partially implemented).
Environment Protection Act 1993 and Environment Protection (Water Quality) Policy 2015	Partially effective	Fully implemented	General environmental duty and schedule of prescribed activities; obligations to avoid discharge of waste to waters and not to cause certain environmental harm.
Native Vegetation Act 1991	Moderately effective	Fully implemented	The Act controls the clearance of native vegetation, e.g. within a catchment, along the banks of a water course or within a drainage line or watercourse. The presence of native vegetation helps to mitigate dryland salinity and sediment transport.
SA MDB NRM Board irrigation efficiency program – including links to broader projects (e.g. On farm irrigation efficiency program and private irrigation infrastructure program).	Partially effective	Mostly not implemented	Helps reduce impact of irrigation on water resources (e.g. reduces likelihood of nutrient runoff and irrigation-induced rising water tables). Only implemented in parts of EMLR region (mostly associated with River Murray)

4.3.3 SUB-AREA: SS13 South - EMLR southern portion surface water

Risk r57: There is the potential that climate extremes leads to a decline in water quality and/or availability of water which results in domestic needs not being met.

Risk source: Climate extremes
Consequence: Human consumption/domestic needs not met

Likelihood	Consequence	Risk Rating	Confidence
Unlikely	High	Medium	Moderate

Risk factors

- Risks caused by climate extremes are inherently difficult to control.
- Recent data indicates that there has been a shift in seasonality in the EMLR (Goyder Institute for Water Research, 2015). Therefore, the number of rural households affected would be linked to the severity of drought and the geographic extent of dry conditions
- The impact of another drought would lead to compounded effects of previous drought
- Generally a small amount of water, at a regional scale, is used for domestic purposes (SAMDB NRM 2013c)
- Relatively low reliance on surface water for human consumption, but used for other in-house use and garden (SAMDB NRM 2013c)
- Southern EMLR sub-area is more heavily developed than the north, so more likely to see impacts of drought on human domestic needs in the south, particularly in high demand management zones where total consumptive demand exceeds consumptive use limits

Existing controls for risk

Document	Effectiveness	Implementation	Notes
EMLR WAP. Section 5.2 Surface water and watercourse allocation criteria.	Mostly ineffective	Mostly implemented	Consumptive use limits are based on long-term averages, thus are not completely effective for climate extremes. Southern EMLR is more developed than the north. Water demand is higher than limits in some areas. A 'high demand' program is working with the community to bring total water demand to within sustainable limits in such areas, but had not commenced on-ground implementation at the time of the risk assessment (hence 'mostly implemented').
EMLR WAP. Section 7 permits - Requirements for	Mostly ineffective	Fully implemented	Permit rules include interception (dam capacity) limits. The limits are based on long-term averages,

Document	Effectiveness	Implementation	Notes
permits for water affecting activities (wells, dams, forestry etc).			thus are not completely effective for climate extremes. Permit rules also apply to well drilling, including buffer zones to minimise impact on adjoining wells. Permit rules apply to new activities, not existing infrastructure, so minimise future impacts but don't deal with existing impacts (hence mostly ineffective).
NRM Act 2004. s. 132 – Restrictions in case of inadequate supply or overuse of water	Mostly ineffective	Partially implemented	Section 132 grants the South Australian minister a broad power to place temporary restrictions on the take of water in the case of inadequate supply or overuse. This provision of the NRM Act is fully operational and available for the Minister to use, however no such restriction is currently in place in this area. Making a s. 132 restriction would require the appropriate process to be undertaken, consequently this control is considered partially implemented. Restricting the amount used from licensed dams that are already at a low level due to drought is not likely to return water to downstream domestic users soon, as dams need to fill first before they spill water downstream (hence considered mostly ineffective).

SUB-AREA: SS13 South - EMLR southern portion surface water

Risk r59: There is the potential that climate extremes lead to a decline in water quality and/or availability of water which results in economic uses being impacted.

Risk source: Climate extremes
Consequence: Economic uses impacted

Likelihood	Consequence	Risk Rating	Confidence
Unlikely	High	Medium	Moderate

Risk factors

- Risks caused by climate extremes are inherently difficult to control.
- Recent data indicates that there has been a shift in seasonality in the EMLR (Goyder Institute for Water Research, 2015).
- The impact of another drought would lead to compounded effects of previous drought
- Southern EMLR sub-area is more heavily developed than the north, so more likely to see impacts of drought on human domestic needs in the south, particularly in high demand management zones where total consumptive demand exceeds consumptive use limits
- River Murray supply pipelines, groundwater, urban runoff and roof runoff are alternative sources of water in this area – higher rainfall and more urban areas (e.g. Mt Barker) make urban and roof runoff a more viable alternative than elsewhere in the region.
- Regulatory mechanisms cap water use, but cannot fully mitigate the impacts of climate extremes
- There is high dam development for irrigated crops and pasture

Existing controls for risk

Document	Effectiveness	Implementation	Notes
EMLR WAP. Consumptive use limits and buffer zones for underground water.	Partially effective	Mostly implemented	Limits support sustainable management of underground water, which provides an alternative source to surface water during drought. Water demand is higher than limits in some areas. A 'high demand' program is working with the community to bring total water demand to within sustainable limits in such areas, but had not commenced onground implementation at the time of the risk assessment (hence 'mostly implemented').

Document	Effectiveness	Implementation	Notes
EMLR WAP Principles 113-123 – groundwater rollover provisions	Partially effective	Fully implemented	Some surface water users have a small groundwater allocation as a backup source in dry times. Groundwater rollover provisions allow flexibility to use more groundwater in some years.
EMLR WAP. Section 7 permits - Requirements for permits for water affecting activities (wells, dams, forestry etc)	Mostly ineffective	Fully implemented	Permit requirements aim to minimise impact of new development on other users. Permit rules include interception (dam capacity) limits. The limits are based on long-term averages, thus are not completely effective for climate extremes. Permit rules apply to new activities, not existing infrastructure, so they minimise future impacts but don't deal with existing impacts (hence mostly ineffective).
EMLR WAP Section 5.2 Surface water and watercourse allocation criteria.	Mostly ineffective	Mostly implemented	Limits in general are based on long term average climate conditions, so they may not be completely effective in extreme events. Water demand is higher than limits in some management zones. A 'high demand' program is working with the community to bring total water demand to within sustainable limits in such areas, but had not commenced on-ground implementation at the time of the risk assessment (hence 'mostly implemented').
EMLR WAP Section 5.2.3 and 5.2.4 – urban runoff and roof runoff allocation criteria.	Mostly ineffective (localised solution only)	Fully implemented	Allocation of urban runoff and roof runoff water as an alternative water source during droughts.
SA MDB NRM Board irrigation efficiency program – including links to broader projects (e.g. On farm irrigation efficiency program and private irrigation infrastructure program).	Partially effective	Mostly not implemented	Supports more effective use of limited water resources. Only implemented in parts of EMLR region (mostly associated with River Murray)

SUB-AREA: SS13 South - EMLR southern portion surface water

Risk r62: There is the potential that demand/take (incl. interception activities) leads to a decline in water quality and/or availability of water which results in WDEs being impacted.

Risk source: Demand/take including interception activities
Consequence: Water dependent ecosystems impacted

Likelihood	Consequence	Risk Rating	Confidence
Unlikely	Very high	Medium	Moderate

Risk factors

- Demand/take has already significantly impacted water dependent ecosystems (SAMDB NRM Board 2013c). The risk assessment considers potential for impacts to worsen (over the WRP timeframe) from the existing baseline.
- Fleurieu swamps are EPBC listed and are thus a matter of national environmental significance.
- There have been observed declines in fish populations including declines among listed species (e.g. Hammer, Wedderburn and van Weenan 2009)
- Water dependent ecosystems in the terminal wetlands of Finniss River and Currency Creek have not been considered as part of this assessment – instead they will be considered as part of the River Murray WRP risk assessment, as they are largely dependent on River Murray flows.
- There are high levels of development and in some management zones the total demand for water is higher than the limits defined within the WAP.
- Risk in the long term (e.g. greater than the 10 year timeframe for this risk assessment) may be higher, if the level of control implementation at the time of the risk assessment continues.
- Controls are likely to be mostly effective, but the program to return low flows has not yet been implemented at the time the risk assessment was done. Implementation of low flow policy will reduce the level of risk.

Existing controls for risk

Document	Effectiveness	Implementation	Notes
Securing Low Flows Program and EMLR WAP. Legal instruments are water licence conditions, water affecting activity permit conditions and NRM (Eastern Mount Lofty Ranges—Longer-Term Water Conservation Measures) Regulations 2014.	Moderately effective	Not implemented	Low flows at or below a threshold flow rate must be bypassed, returned or not captured, at sufficient existing in-scope dams and watercourse diversions to meet the environmental flow targets for each management zone. The requirement also applies to most permits for construction of new dams and watercourse diversions. The requirement to secure low flows for new dams and diversions is fully implemented. At the time that the risk assessment was carried out, the program to secure low flows at key existing dams and diversions had not yet commenced on-ground implementation, beyond a few trial sites.
EMLR WAP-Section 5.2 Surface water and watercourse allocation criteria, including taking limits at the scale of significant environmental assets	Partially effective	Mostly implemented	These limits are an important complementary measure for environmental water provisions. They manage medium to high flows provided by dams filling and spilling, however these flow components have been less affected by water resource development than low flows. Water demand is higher than limits in some areas. A 'high demand' program is working with the community to bring total water demand to within sustainable limits in such areas, but had not commenced on-ground implementation at the time of the risk assessment (hence 'mostly implemented').
EMLR WAP-Section 7 Permits - Requirements for permits for water affecting activities (wells, dams, forestry etc)	Mostly ineffective	Fully implemented	This control addresses new, but not existing, dams and forestry. Much of the area is close to fully developed, so limited opportunities to apply this control.

SUB-AREA: SS13 South - EMLR southern portion surface water

Risk r78: There is the potential that land use leads to a decline in water quality and/or availability of water which results in WDEs being impacted.

Risk source: Land use
Consequence: Water dependent ecosystems impacted

Likelihood	Consequence	Risk Rating	Confidence
Possible	Medium	Medium	Moderate

Risk factors

- Water dependent ecosystems in the terminal wetlands of Finniss River and Currency Creek have not been considered as part of this assessment – instead they will be considered as part of the River Murray region risk assessment, as they are largely dependent on River Murray flow.
- Water tables are observed to be rising
- Fleurieu swamps are EPBC listed and thus are a matter of national environmental significance.
- Declines in fish populations, including listed species, have been observed (e.g. Hammer, Wedderburn and van Weenan 2009)
- There are impacts associated with increased nutrient runoff, sedimentation and salinity (associated with dryland salinity arising from historical clearance of deep-rooted native vegetation)

Existing controls for risk

Document	Effectiveness	Implementation	Notes
SAMDB Regional NRM Plan – resource condition targets and management action targets in relation to land management	Partially effective	Partially implemented	Incentive programs to remove watering points from watercourses and fencing riparian areas (run through a range of organisations); Natural Resources SAMDB land management and sustainable agriculture programs. Programs are fully implemented to the extent that resources are available, but demand exceeds available resources.
NRM Act 2004 and River Murray Act Duty of Care provisions	Partially effective	Partially implemented	General duty of care requires persons to act reasonably in relation to management of natural resources. The NRM Act also contains provisions that potentially could be used to require a landholder to develop and implement action plans remediate poor land management practices, although this is a tool of last

Document	Effectiveness	Implementation	Notes
			resort and the focus is on working with landholders, support and education. This provision of the NRM Act is fully operational and available for use, but work would be required to be implement case-by-case (hence considered partially implemented).
Development Act	Mostly ineffective	Mostly implemented	This control could prevent more intensive land use from occurring. Applies to new applications, not existing land use (hence mostly ineffective).
Native Vegetation Act 1991, particularly Schedule 1 (1)(i)&(l)	Moderately effective	Fully implemented	The Act controls the clearance of native vegetation, e.g. within a catchment, along the banks of a water course or within a drainage line or watercourse. The presence of native vegetation helps to mitigate dryland salinity and sediment transport.
SA MDB NRM Board irrigation efficiency program – including links to broader projects (e.g. On farm irrigation efficiency program and private irrigation infrastructure program).	Partially effective	Mostly not implemented	Helps reduce impact of irrigation on water resources (e.g. reduces likelihood of nutrient runoff and irrigation-induced rising water tables). Only implemented in parts of EMLR region (mostly associated with River Murray)
Environment Protection Act 1993 and Environmental Protection (Water Quality) Policy 2015	Partially effective	Fully implemented	General environmental duty and schedule of prescribed activities; obligations to avoid discharge of waste to waters and not to cause certain environmental harm.
Mining Act 1971 Part 10A and 10B: Environmental protection and rehabilitation requirements for mining developments	Partially effective	Fully implemented	Environmental protection and rehabilitation requirements for mining developments. Expected to be effective for this type of land use, but only deals with one specific type of land use with limited extent - hence considered partially effective.

4.3.4 SUB-AREA: GS4b - Marne Saunders Murray Group Limestone

Risk r114: There is the potential that climate extremes lead to a decline in water quality and/or availability of water which results in WDEs being impacted.

Risk source: Climate extremes
Consequence: Water dependent ecosystems impacted

Likelihood	Consequence	Risk Rating	Confidence
Likely	Very high	High	High

Risk factors

- Risks caused by climate extremes are inherently difficult to control.
- WAP designed to build resilience but climate extremes (particularly drought) will still lead to consequences
- Black Hill Springs is a groundwater dependent system with a river blackfish population (SAMDB NRM 2010). River blackfish are protected under the *Fisheries Management Act 2007* (SA).
- It was determined that the river blackfish population in Black Hill Springs are unlikely to be naturally repopulated should they become extinct in that location as there are no other connected populations.
- The aquifer that flows into Black Hill Springs is known to be primarily recharged by large surface water flows from higher in the catchment caused by unusually wet conditions. Prolonged dry periods may reduce the incidence of these events causing discharge from the aquifer to be insufficient to support the environmental values of Black Hill Springs (Harrington 2004).
- Groundwater extraction on the plains is unlikely to affect discharge at Black Hill Springs.
- Existing conditions in Black Hill Springs are poor and the small population of river blackfish are at a high risk of becoming locally extinct. The presence of river blackfish was recorded during an annual fish survey in 2016 after not being recorded for several years. River blackfish were not recorded during the 2017 survey.
- There is little opportunity to control the source of risk, which in this case is largely climate driven. Controls over surface water use were deemed to have little influence of the likelihood of significant recharge events.
- There is very little groundwater extraction in the vicinity of the springs.
- Existing controls are configured to prevent further degradation, but do not aim to achieve a recovery to a pristine state. WAP rules for buffer zones around new wells will help to minimise future additional local scale impacts.
- Existing controls, such as take limits and dam capacity limits, are configured for average climatic conditions and may be less effective during climate extremes.

Existing controls for risk

Document	Effectiveness	Implementation	Notes
Marne Saunders WAP. Management zone limits, and, buffer zones for underground water	Partially effective	Fully implemented	The WAP places an exclusion zone around the springs preventing new local extractions from having a direct impact – minimises risk of new direct impacts from local groundwater extraction
Marne Saunders WAP. Surface water consumptive use limits and dam capacity limits	Mostly ineffective	Fully implemented	Recharge of the Black Hill Springs thought to be primarily from very large runoff events, and modelling shows current dam development has little impact on these events.
Drought action plan – in-situ watering and/or temporary relocation of populations to refuge areas	Unknown	Unknown	This is a potential action that is likely to be effective at a local scale. There have been precedents for this response elsewhere in the EMLR WRP area. Implementation is resource intensive.
NRM Act 2004. s. 132 – Restrictions in case of inadequate supply or overuse of water	Mostly ineffective	Partially implemented	Section 132 grants the South Australian minister a broad power to place temporary restrictions on the take of water in the case of inadequate supply or overuse. This provision of the NRM Act is fully operational and available for the Minister to use, however no such restriction is currently in place in this area. Making a s. 132 restriction would require the appropriate process to be undertaken, consequently this control is considered partially implemented. A s. 132 restriction on take, implemented during an extended dry period, is not likely to be effective in managing this risk.

SUB-AREA: GS4b - Marne Saunders Murray Group Limestone

Risk r115: There is the potential that climate extremes lead to a decline in water quality and/or availability of water which results in economic uses being impacted.

Risk source: Climate extremes
Consequence: Economic uses impacted

Likelihood	Consequence	Risk Rating	Confidence
Likely	Minor	Medium	High

Risk factors

- Risks caused by climate extremes are inherently difficult to control.
- Drought impacts access to groundwater for irrigation.
- Droughts are likely to occur over the WRP timeframe (Goyder Institute for Water Research, 2015)
- Increases in salinity are expected to cause more significant impacts to economic use than declining water level
- Some crops dependent on groundwater for irrigation are relatively salt tolerant (e.g. olives and lucerne), however turf farms require relatively fresh water. Some of the turf farms' water is obtained from the confined limestone aquifer which is relatively insensitive to climate extremes
- Total use from this sub-area is approximately 2,000 ML/year. Not all of this would be affected by a drought.
- Recovery of the resource to an event is expected to occur within one to two years.
- Risks caused by climate extremes are inherently difficult to control.
- Roof runoff and mains water are alternative sources of water in this area. These sources are likely to be too limited in quantity or too expensive to be a viable alternative for economic use.

Existing controls for risk

Document	Effectiveness	Implementation	Notes
Marne Saunders WAP Management zone limits, regional scale limits and buffer zones for groundwater.	Mostly ineffective	Fully implemented	These controls provide for sustainable use of the resource, but are configured for average climate conditions, not extremes.
SA MDB NRM Board irrigation efficiency program – including links to broader projects (e.g. On farm irrigation efficiency program and private irrigation infrastructure program).	Partially effective	Mostly not implemented	Supports more effective use of limited water resources. Only implemented in parts of region (mostly associated with River Murray)

4.3.5 SUB-AREA: GS4b - Marne Saunders Murray Group Limestone

Risk r123: There is the potential that management of connected water resources leads to a decline in water quality and/or availability of water which results in economic uses being impacted.

Risk source: Management of connected water resources
Consequence: Economic uses impacted

Likelihood	Consequence	Risk Rating	Confidence
Likely	Minor	Medium	High

Risk factors

- Recharge occurs by infiltration of stream flow. Use of the upstream surface water resource impacts recharge which in turn affects the availability of the groundwater resource for economic use
- The level of water allocation and dam development in the surface water resource (upper catchments) is at the WAP consumptive use limits and dam capacity limits, consequently new surface water allocations and dam construction is not permitted.
- Total use from this sub-area is approximately 2,000 ML/year
- Crops that could be impacted are mostly olives, lucerne and turf

Existing controls for risk

Document	Effectiveness	Implementation	Notes
Marne Saunders WAP. Rollover provisions for underground water.	Mostly ineffective	Fully implemented	This provision provides users with flexibility during climate extremes. In this case having a rollover unlikely to be effective due to less water being available during drought.
Marne Saunders WAP. Surface water consumptive use and dam capacity limits.	Partially effective	Fully implemented	These limits provide for the sustainable use of the surface water (connected) resource. Take limits for surface water in the hills and groundwater on the plains were set in the Marne Saunders WAP were set based on resource capacity, environmental water provisions and balancing water user needs, including consideration of upstream vs downstream needs. Existing water users in both areas were allocated less than their maximum theoretical requirements to keep demand within sustainable limits,

Document	Effectiveness	Implementation	Notes
			with users in both areas receiving a similar proportion of their theoretical requirements and hence were considered to be treated equivalently. Reducing water take in the hills to increase recharge on the plains (and hence reduce economic impacts on the plains) would increase economic impacts for surface water users in the hills.
SA MDB NRM Board irrigation efficiency program – including links to broader projects (e.g. On farm irrigation efficiency program and private irrigation infrastructure program).	Partially effective	Mostly not implemented	Supports more effective use of limited water resources. Only implemented in parts of region (mostly associated with River Murray)

4.3.6 SUB-AREA: GS2c – EMLR fractured rock and unconfined aquifers

Risk r226: There is the potential that climate extremes leads to a decline in water quality and/or availability of water which results in WDEs being impacted.

Risk source: Climate extremes
Consequence: Water dependent ecosystems impacted

Likelihood	Consequence	Risk Rating	Confidence
Unlikely	Very high	Medium	Low

Risk factors

- Risks caused by climate extremes are inherently difficult to control.
- WAP designed to build resilience but climate extremes (particularly drought) will still lead to consequences
- Development has significantly impacted water dependent ecosystems in this sub-area. Recent data and knowledge indicate that the condition of permanent pools and the fish populations they support is declining.
- Local scale regulatory controls in WAPs such as buffer zones around water-dependent ecosystems generally only apply to new activities (new wells, transfer, new allocations), not existing activities. Hence WAP regulatory controls are effective to minimise future impacts, but don't address existing impacts.
- Existing WAP regulatory controls are configured to minimise further degradation from new activities, but do not aim to achieve a recovery to a pristine state. WAP rules for buffer zones around new wells will help to address additional local scale impacts.
- Existing WAP controls, such as limits, are configured for average climatic conditions and may be less effective during climate extremes.
- Large storage volumes in aquifers buffer the impact of demand and variable recharge on a year to year basis.
- The Fleurieu swamps are an EPBC Act listed threatened ecological community and depend on groundwater in this area (SAMDB NRM Board, 2013c).
- There are other water dependent environmental values that have local or regional significance in the sub-area. These assets are increasingly dependent on groundwater due to development of surface water resources in this sub-area.

Existing controls for risk

Document	Effectiveness	Implementation	Notes
NRM Act 2004. s. 132 – Restrictions in case of inadequate supply or overuse	Mostly ineffective	Partially implemented	Section 132 grants the South Australian minister a broad power to place temporary restrictions on the take of water in the case of inadequate supply or overuse. This provision of the NRM Act is fully

Document	Effectiveness	Implementation	Notes
of underground water			operational and available for the Minister to use, however no such restriction is currently in place in this area. Making a s. 132 restriction would require the appropriate process to be undertaken, consequently this control is considered partially implemented. The likely impact of taking water from specific bores on aquatic ecosystems is very hard to predict in fractured rock aquifers where connectivity is highly variable across space, so it is difficult to be confident that restricting groundwater take will reduce impacts on water-dependent ecosystems during drought. More likely to be locally effective in sedimentary aquifers.
Drought action plan – in-situ watering and/or temporary relocation of populations to refuge areas	Unknown	Unknown	This is a potential action that is likely to be effective at a local scale. There have been precedents for this response in the EMLR WRP area. Implementation is resource intensive and therefore dependent on resources.
EMLR WAP. Section 5.1. Principles 14-23. Allocations for purpose of environmental watering	Unknown	Partially implemented	The use of this provision to allocate water for environmental purposes during a dry period maybe effective at a local scale, if alternative water sources are available. There is a provision for this control in the WAP, but no such allocations have yet been made and would require the appropriate process to be undertaken to grant such an allocation and implement environmental watering (hence partially implemented). Implementation is resource intensive and therefore dependent on resources.
EMLR WAP. Section 5.3. Management zone limits,	Mostly ineffective	Mostly implemented	Buffer zones apply to new activities but not existing infrastructure. Much of the area is developed so limited opportunity

Document	Effectiveness	Implementation	Notes
regional scale limits and buffer zones for underground water.			to apply this control. Limits configured for average rather than drought conditions. Total demand exceeds limits for some management zones. A 'high demand' program is working with the community to bring total water demand to within sustainable limits in such areas, but had not commenced on-ground implementation at the time of the risk assessment (hence 'mostly implemented').
EMLR WAP. Section 7. Requirements for permits for water affecting activities (wells, dams, forestry etc).	Mostly ineffective	Fully implemented	Addresses new activities, not existing infrastructure. Permit requirements for new wells and forestry include buffer distances from environmental assets to minimise impacts.
Securing Low Flows Program and EMLR WAP - Requirement to return low flows. Legal instrument is water licence conditions, water affecting activity permit conditions, or NRM (Eastern Mount Lofty Ranges—Longer-Term Water Conservation Measures) Regulations 2014.	Partially effective	Not implemented	Low flows at or below a threshold flow rate must be bypassed, returned or not captured, at sufficient existing in-scope dams and watercourse diversions to meet the environmental flow targets for each management zone. The requirement also applies to most permits for construction of new dams and watercourse diversions. The requirement to secure low flows for new dams and diversions is fully implemented. At the time that the risk assessment was carried out, the program to secure low flows at key existing dams and diversions had not yet commenced on-ground implementation, beyond a few trial sites. Drought impacts on baseflow from groundwater into streams may have a long recovery time. Returning low surface water flows when rainfall occurs helps to support refuge pools in the meanwhile.

5 Discussion and conclusions

5.1 Risk profile – sub-areas, risk sources and consequence categories

A total of 280 theoretical risks were assessed for the EMLR WRP area across ten sub-areas. The final risk profile identified 13 significant risks consisting of one high risk and 12 medium risks. The remaining risks were rated as low or not applicable. The significant risks[1] affect five of the ten sub-areas (Table 10).

Table 10. EMLR WRP Area risk profile - significant risks by sub-area

Sub-area	Sub-area name	Med risks	High risks
SS12	Marne Saunders	3	0
SS13 North	EMLR northern portion	2	0
SS13 South	EMLR southern portion	4	0
GS4b	Marne Saunders Murray Group Limestone and quaternary aquifers	2	1
GS2c	EMLR fractured rock and unconfined	1	0

A review of risks by risk source categories (Table 11) indicated that one high risk and seven medium risks are caused by climate extremes. The analysis found that climate extremes are both inherently uncontrollable and their effects are characterised by uncertainty. Climate change may also affect the frequency and intensity of climate extremes, although it is generally recognised that the impact of climate change may be limited over the ten year timeframe of the present assessment.

Other sources of risk causing medium risk are land use (two risks), demand/take (two risks) and management of connected water resources (one risk). Infrastructure affecting natural flow regimes was not found to be a significant source of risk since the impacts of farm dams are largely covered through assessment of risks caused by demand/take including interception activities. This means that no other regulating structures exist which cause significant risk in the EMLR WRP area. Similarly, point source pollution does not cause significant risk in the EMLR WRP area in the context of the present assessment.

A review of the risk profile according to consequence categories (Table 12) identified one high risk and seven medium risks to WDEs (Table 12). There was also significant risk affecting economic use (four medium risks) and human consumption and domestic use of the resource (one medium risk). There is no significant risk identified for connected water resources.

[1] Significant risks refer to any risks assessed as being medium or high

Table 11. EMLR WRP Area risk profile - significant risks by source of risk

Source of risk	Med risks	High risks
Climate extremes	7	1
Demand/take (incl. interception activities)	2	0
Management of connected water resources	1	0
Infrastructure (affecting natural flow regimes)	0	0
Point source pollution	0	0
Land use	2	0

Table 12. EMLR WRP Area risk profile - significant risks by consequence category

Consequence category	Med risks	High risks
Human consumption/domestic needs not met	1	0
WDEs impacted	7	1
Economic use impacted	4	0
Connected water resources impacted	0	0

5.2 Opportunities to address significant risks

5.2.1 Implementation and effectiveness of controls

The risk assessment team undertook a high level analysis to identify treatment opportunities for the significant (high and medium) risks. This analysis was based on the outputs of the risk assessment workshops regarding the effectiveness and implementation of existing controls.

Risks were classified as having:

a) Opportunities for reducing the risk by addressing the level of implementation of existing controls;
b) Limited opportunity for cost-effective control.

These risks are summarised in tables 13 and 14 respectively. Note that the analysis represents a preliminary assessment of opportunities based on existing information. Further assessment of treatment options could be considered as part of EMLR water resource planning processes.

It was concluded that the most important existing controls for risks to water dependent ecosystems are the return of low flows and take limits. Together these controls restore aspects of the flow regime

which are ecologically important. Since the medium and low flow segments of the flow patterns have been most affected by development in the EMLR, implementation of controls to restore these flows have been judged as having higher priority with respect to reducing ecological risk. At the time of the risk assessment, requirements to pass low flows around new dams and diversions were in place for new applications for these activities. A program to secure low flows at key existing dams and diversions has been partially funded but as of October 2017 has not yet started on-ground implementation, beyond a few trial sites. Full implementation of this control is expected to reduce the identified risks to water dependent ecosystems.

It was noted through the assessment that total demand for water exceeds management zone limits imposed by WAPs in some areas[2] ('high demand zones'). The excess demand at the management zone level is being addressed through a 'high demand' program that is working with the community to bring total water demand to within sustainable limits in such areas. However this program had not commenced on-ground implementation at the time of the risk assessment. In some high demand zones (but not all), it is likely that current water use does not exceed the sustainable taking limits, despite high theoretical demand for water. This is because existing user allocations[3] are based on maximum theoretical crop requirements which in other water resources, have been found to be higher than actual use. Water metering will confirm the extent to which water use relates to allocations.

Table 13. Risk treatment opportunities - implementation of existing controls

Risk id	Sub-area	Risk source	Consequence	Notes
r2	SS12	Climate extremes	WDEs impacted	Return of low flows is potentially effective but not currently implemented.
r6	SS12	Demand/take	WDEs impacted	Return of low flows is potentially effective but not currently implemented.
r30	SS13 North	Climate extremes	WDEs impacted	Return of low flows is potentially effective but not currently implemented.
r62	SS13 South	Demand/take	WDEs impacted	Return of low flows is potentially effective but not currently implemented.
r226	GS2c	Climate extremes	WDEs impacted	Return of low flows is potentially effective but not currently implemented.

[2] While management zone limits are exceeded in some areas, demand limits at the whole of resource scale for all resources prescribed under the NRM Act within the EMLR WRP area are not exceeded

[3] Existing user allocations are the allocations made when a water resource is first comes under a water licensing regime under the NRM Act.

Table 14. Risks having limited opportunities for treatment

Id	Sub-area	Risk source	Consequence	Notes
r3	SS12	Climate extremes	Economic use	Climate extremes inherently uncontrollable. Much risk is managed by landholders (large dams, water conservation).
r50	SS13 North	Land use	WDEs impacted	Existing controls are ineffective to partially effective and implemented to varying degrees
r57	SS13 South	Climate extremes	Domestic needs not met	Climate extremes inherently uncontrollable. Users largely manage their own risks.
r59	SS13 South	Climate extremes	Economic use	Climate extremes are inherently uncontrollable. Many controls are fully implemented but partially effective.
r78	SS13 South	Land use	WDEs impacted	Existing controls are ineffective to partially effective and implemented to varying degrees.
r114	GS4b	Climate extremes	WDEs impacted	Climate extremes inherently uncontrollable. Potential recovery based controls may be resource intensive.
r115	GS4b	Climate extremes	Economic use	Climate extremes inherently uncontrollable. Existing controls to deal with impact are partially effective
r123	GS4b	Management of connected resources	Economic use	Existing controls are partially effective to mostly ineffective.

5.2.2 Uncertainty affecting risk ratings

In some cases, significant risks are associated with high uncertainty regarding likelihood and consequence. The risk analysis process quantified uncertainty in the distribution of likelihoods against the consequence categories (see Section 3.4.3). Higher uncertainty is correlated with a greater spread of likelihoods and thus higher risk ratings. Therefore, one approach to addressing significant risks caused by high uncertainty is additional investigations. Reduced uncertainty may cause risk ratings to be revised downwards in these cases.

Seven of the medium and high risks (Table 16) were rated as having low or moderate confidence. These risks could be the subject of further analysis to reduce uncertainty and increase confidence in the ratings. This analysis could involve more intensive assessments of existing data, collection of new data or additional modelling (which was outside the scope of the present assessment).

It should be noted that response/recovery measures, such as drought action plans, were identified as a control for some of the significant risks (with unknown ascribed to the implementation and effectiveness categories). In general there is some uncertainty regarding the costs versus benefits of these measures and the degree to which they may be implemented in future. Addressing uncertainties regarding treatments could be considered as part of developing the WRP for the EMLR.

Table 15. Risk treatment opportunities – addressing uncertainty

Id	Sub-area	Risk source	Consequence	Confidence
r226	GS2c	Climate extremes	WDEs impacted	Low
r3	SS12	Climate extremes	Economic use	Moderate
r6	SS12	Demand/take	WDEs impacted	Moderate
r57	SS13 south	Climate extremes	Domestic needs not met	Moderate
r59	SS13 south	Climate extremes	Economic use	Moderate
r62	SS13 south	Demand/take	WDEs impacted	Moderate
r78	SS13 south	Land use	WDEs impacted	Moderate

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Appendices

A. Example of worksheet used for assessing priority risks

Name:_____

Risk Number: **«Risk_Statement_Number»**

Sub-area number: «Subarea_Number» Sub-area: «Subarea»

Risk Statement:

Factors

Controls	Effectiveness	Implementation

Probability of each consequence level (assigned probabilities should add up to 100)

Level	**Percent chance of consequence in 10 years**										
Very high	0	10	20	30	40	50	60	70	80	90	100
High	0	10	20	30	40	50	60	70	80	90	100
Medium	0	10	20	30	40	50	60	70	80	90	100
Minor	0	10	20	30	40	50	60	70	80	90	100
Insignificant	0	10	20	30	40	50	60	70	80	90	100

Main Factor

Main Control

B. Eastern Mount Lofty Ranges WRP Area Risk Register

SS12 – Marne Saunders surface water

Table 1. Risk statements assessed as medium or high (SS12)

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Risk Level	Key factors
Sub-area SS12 - Marne Saunders surface water						
2	Climate extremes	Water dependent ecosystems impacted	Likely	Minor	Medium	Risks caused by climate extremes inherently difficult to control. No state or nationally listed fish species in upper catchment. River blackfish in lower catchment are dependent on groundwater and are addressed by risk r114. Mountain galaxias in this subarea genetically distinct and thus have regional significance. Drought will affect these populations but recovery is likely. Key control to reduce risk (returning low flows) not yet implemented.
3	Climate extremes	Economic use	Possible	Medium	Medium	Risks caused by climate extremes inherently difficult to control. During drought, dams required for economic uses will not fill. Economic uses reliant on dams within the sub-area include viticulture, horticulture and stock.
6	Demand/take	Water dependent ecosystems impacted	Unlikely	High	Medium	No state or nationally listed fish species in upper catchment. River blackfish in lower catchment are dependent on groundwater and are addressed by risk r114. Mountain galaxias in this subarea genetically distinct and thus have regional significance. High level of surface water resource development. Key control to reduce risk (returning low flows) not yet implemented.

Table 2. Risk statements assessed as low (SS12)

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Summary of key factors leading to rating
Sub-area SS12 - Marne Saunders surface water					
1	Climate extremes	Human consumption/domestic needs not met	Possible	Minor	There is some domestic use, but low dependency. Properties are mostly large (sparse population).
4	Climate extremes	Connected water resources impacted	Rare	Minor	Negligible connection with River Murray. Effect on connection with groundwater assessed separately (r88 and r144)
5	Demand/take including interception activities	Human consumption/domestic needs not met	Possible	Minor	Minimal reliance on surface water for domestic use. Major towns have reticulated supplies
7	Demand/take including interception activities	Economic uses impacted	Possible	Minor	Stock water derived from groundwater in lower catchment. Cropping on plains does not rely on surface water.
9	Management of connected water resources	Human consumption/domestic needs not met	Rare	Minor	Minimal reliance on surface water for domestic use. Major towns have reticulated supplies
10	Management of connected water resources	Water dependent ecosystems impacted	Almost certain	Insignificant	Pathway considered to be a duplication of the pathway of r14 with the management of water resources upstream predominantly related to infrastructure that controls flow regimes.
11	Management of connected water resources	Economic uses impacted	Rare	Minor	Only relevant connection is with underground water in the Marne Saunders. Movement of underground water is very slow meaning any groundwater impact unlikely to affect baseflow.
14	Infrastructure affecting natural flow regimes	Water dependent ecosystems impacted	Rare	Minor	

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Summary of key factors leading to rating
Sub-area SS12 - Marne Saunders surface water					
18	Point source pollution	Water dependent ecosystems impacted	Unlikely	Minor	Few point source pollution source. No nationally or internationally listed species. WDEs are widespread with potential to recover.
19	Point source pollution	Economic uses impacted	Unlikely	Minor	Point source event unlikely and, if occurring, would be highly localised. Any impacts are unlikely to affect economic uses of the resources.
20	Point source pollution	Connected water resources impacted	Almost certain	Insignificant	The River Murray is the only connected surface water resource with flows reaching the river only in exceptionally wet years. It is therefore deemed very unlikely that a point source pollution event big enough to impact the River Murray will occur
22	Land use	Water dependent ecosystems impacted	Rare	High	There are no nationally or internationally listed species likely to be impacted in this sub-area. WDEs are widespread with potential to recover. Unlikely land use activities would cause an event significant enough to impact WDEs
23	Land use	Economic uses impacted	Unlikely	Minor	Stock water is derived from groundwater in lower catchment. Cropping on plains does not rely on surface water.
24	Land use	Connected water resources impacted	Possible	Minor	River Murray is the only connected surface water resource. Flows only reach the river in exceptionally wet years.

Table 3. Risk statements not further assessed (SS12)

Risk ID	Risk Source	Risk Consequence	Rationale for not proceeding with analysis
Sub-area SS12 - Marne Saunders surface water			
8	Demand/take including interception activities	Connected water resources impacted	Groundwater is the only significantly connected resource. This risk assessed under sub-area GS4a (r 92)
12	Management of connected water resources	Connected water resources impacted	Circular logic.
13	Infrastructure affecting natural flow regimes	Human consumption/domestic needs not met	Very little reliance on surface water for human consumption/domestic needs. Infrastructure deemed unlikely to impact on the minor surface water use for this purpose.
15	Infrastructure affecting natural flow regimes	Economic uses impacted	Flow regimes not considered to impact on economic uses (quantity would, however this is considered under the take/demand risk source)
16	Infrastructure affecting natural flow regimes	Connected water resources impacted	River Murray is the only connected surface water resource. Flows only reach the river in exceptionally wet years.
17	Point source pollution	Human consumption/domestic needs not met	Low dependency of surface water for human consumption/domestic needs. It was deemed unlikely that a large enough point source pollution event that could impact supplies obtained through farm dams for human consumption/domestic needs.
21	Land use	Human consumption/domestic needs not met	Low dependency of surface water for human consumption/domestic needs. It was deemed unlikely that a large enough diffuse pollution event that could impact

Risk ID	Risk Source	Risk Consequence	Rationale for not proceeding with analysis
Sub-area SS12 - Marne Saunders surface water			
			supplies obtained through farm dams for human consumption/domestic needs
25	Managed aquifer recharge	Human consumption/domestic needs not met	Risk source not relevant to sub-area
26	Managed aquifer recharge	Water dependent ecosystems impacted	Risk source not relevant to sub-area
27	Managed aquifer recharge	Economic uses impacted	Risk source not relevant to sub-area
28	Managed aquifer recharge	Connected water resources impacted	Risk source not relevant to sub-area

SS13 – EMLR north surface water

Table 4. Risk statements assessed as medium or high (SS13 north)

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Risk Level	Key factors leading to outcome
Sub-area SS13 – EMLR north surface water						
30	Climate extremes	Water dependent ecosystems impacted	Likely	Minor	Medium	Risks caused by climate extremes inherently difficult to control. Regionally significant species present (EPA 2010). During dry years water quality decreases (increases in salinity)
50	Land use	Water dependent ecosystems impacted	Likely	Minor	Medium	Regionally significant species present (EPA 2010). Sedimentation is a concern for permanent pools and may be irreversible

Table 5. Risk statements assessed as low (SS13 north)

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area SS13 – EMLR north surface water					
29	Climate extremes	Human consumption/domestic needs not met	Possible	Minor	There is some domestic use, but low dependency (SAMDB NRM 2013c). Properties are mostly large (sparse population).
31	Climate extremes	Economic uses impacted	Unlikely	Medium	Mostly stock use. Low level of development of surface water.
32	Climate extremes	Connected water resources impacted	Rare	Minor	Limited connectivity with other water resources. Some recharge of low value groundwater resources on plains.

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area SS13 – EMLR north surface water					
33	Demand/take including interception activities	Human consumption/domestic needs not met	Unlikely	Minor	Mostly large properties meaning low dependency on the resource for domestic use.
34	Demand/take including interception activities	Water dependent ecosystems impacted	Rare	High	Presence of ecosystem values having state or national importance deemed unlikely. Relatively low level of development.
35	Demand/take including interception activities	Economic uses impacted	Unlikely	Minor	Limited development of surface water resources in this subarea.
36	Demand/take including interception activities	Connected water resources impacted	Unlikely	Minor	Minimal connection to groundwater or River Murray. Limited development of the surface water resource.
37	Management of connected water resources	Human consumption/domestic needs not met	Rare	Minor	Mostly large properties meaning low dependency on the resource for domestic use. Minor connectivity with other water resources.
38	Management of connected water resources	Water dependent ecosystems impacted	Unlikely	Minor	Minor connectivity with other water resources (SAMDB NRM 2013c). Presence of ecosystem values having state or national importance deemed unlikely.
39	Management of connected water resources	Economic uses impacted	Rare	Minor	Limited development of the water resources meaning low dependency. Limited connectivity with other water resources.
42	Infrastructure affecting natural flow regimes	Water dependent ecosystems impacted	Unlikely	Minor	Low level of development. Impacts at local scales possible. Presence of ecosystem values having state or national importance deemed unlikely
46	Point source pollution	Water dependent ecosystems impacted	Unlikely	Minor	Few point sources of pollution. Presence of ecosystem values having state or national importance deemed unlikely.

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area SS13 – EMLR north surface water					
47	Point source pollution	Economic uses impacted	Rare	Minor	Few point sources of pollution. Limited development of surface water resource.
48	Point source pollution	Connected water resources impacted	Unlikely	Minor	Few point sources of pollution. Limited connectivity with other water resources.
51	Land use	Economic uses impacted	Unlikely	Minor	There are existing land use impacts (sedimentation, nutrification, salinity). However dependency on water resources for economic use is low.

Table 6. Risk statements not further assessed (SS13 north)

Risk ID	Risk Source	Risk Consequence	Reason statement not further assessed
Sub-area SS13 north – EMLR north surface water			
40	Management of connected water resources	Connected water resources impacted	Circular logic
41	Infrastructure affecting natural flow regimes	Human consumption/domestic needs not met	Low dependency of surface water for human consumption/domestic needs (SAMDB NRM 2013c). Flows unlikely to impact on human consumption needs or domestic needs (the amount available could have an impact and is considered under the take/demand risk source)
43	Infrastructure affecting natural flow regimes	Economic uses impacted	Flow regimes not considered to impact on economic uses (the amount available could have an impact and is considered under the take/demand risk source)

Risk ID	Risk Source	Risk Consequence	Reason statement not further assessed
44	Infrastructure affecting natural flow regimes	Connected water resources impacted	Limited connectivity with other water resources (SAMDB NRM 2013c). Flow regimes considered unlikely to impact on connected water resources
45	Point source pollution	Human consumption/domestic needs not met	Low dependency of surface water for human consumption/domestic needs (SAMDB NRM 2013c). Unlikely that a large enough point source pollution event that could impact supplies obtained through farm dams for human consumption/domestic needs
49	Land use	Human consumption/domestic needs not met	Low dependency of surface water for human consumption/domestic needs (SAMDB NRM 2013c). Unlikely that a large enough diffuse pollution event that could impact supplies obtained through farm dams for human consumption/domestic needs
52	Land use	Connected water resources impacted	Unlikely that a large enough diffuse pollution event would occur such that connected water resources are impacted. Limited connectivity with other water resources.
53	Managed aquifer recharge	Human consumption/domestic needs not met	Risk source not relevant to sub-area
54	Managed aquifer recharge	Water dependent ecosystems impacted	Risk source not relevant to sub-area
55	Managed aquifer recharge	Economic uses impacted	Risk source not relevant to sub-area
56	Managed aquifer recharge	Connected water resources impacted	Risk source not relevant to sub-area

SS13 – EMLR south surface water

Table 7. Risk statements assessed as medium or high (SS13 south)

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Risk Level	Key factors leading to outcome
Sub-area SS13 – EMLR south surface water						
57	Climate extremes	Domestic needs not met	Unlikely	High	Medium	Risks caused by climate extremes are inherently difficult to control. More heavily developed than EMLR north sub-area and there are areas of high demand. Number of affected households dependent on severity and geographic extent of dry conditions.
59	Climate extremes	Economic use	Unlikely	High	Medium	Risks caused by climate extremes are inherently difficult to control. High dam development for irrigated crops and pasture. Regulatory mechanisms cap water use but cannot fully mitigate climate extreme impacts.
62	Demand/take	Water dependent ecosystems impacted	Unlikely	Very high	Medium	Fleurieu swamps are present (matter of national environmental significance. High level of surface water demand. Securing low flows has not been implemented but are considered to help minimise this risk. Some declines in fish populations (including of listed species) has been observed.
78	Land use	Water dependent ecosystems impacted	Possible	Medium	Medium	Impacts associated with increased nutrient runoff. Fleurieu swamps are present (matter of national environmental significance. Some declines in fish populations (including of listed species) has been observed.

Table 8. Risk statements assessed as low (SS13 south)

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area SS13 south – EMLR south surface water					
58	Climate extremes	Water dependent ecosystems impacted	Unlikely	Medium	Recent data indicates long term change in seasonality (Goyder Institute for water research 2015). Significant environmental values exist. Observed declines in fish populations. WAP designed to build resilience.
60	Climate extremes	Connected water resources impacted	Unlikely	Minor	Considers connection with groundwater and River Murray/Lake Alexandrina. During drought, people may increase use of groundwater resources. Flows into terminal wetlands however, a drought would result in reduced flows from the River Murray as well which are more important than those of the EMLR. Controls considered to adequately manage risks
61	Demand/take including interception activities	Human consumption/domestic needs not met	Unlikely	Minor	Limited use of surface water for human consumption (SAMDB NRM 2013c). Most households have alternate options (or domestic use) if farm dams become dry (e.g. sacrifice garden, cart water in for domestic use).
63	Demand/take including interception activities	Economic uses impacted	Unlikely	Medium	Some zones of overallocation (implementation of high demand policy will reduce this). High dam development for irrigated crops/pasture. Alternative water sources available for economic uses
64	Demand/take including interception activities	Connected water resources impacted	Unlikely	Minor	Connections considered are with shallow groundwater aquifers on the plains (salty and not commonly used) and River Murray/Lake Alexandrina. Impacts are likely to be minor and on a local scale. River Murray flows are more important for terminal wetlands than EMLR flows.

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area SS13 south – EMLR south surface water					
65	Management of connected water resources	Human consumption/domestic needs not met	Unlikely	Minor	Only upstream connected resource is groundwater. Very high usage of groundwater over a long period of time may impact baseflows into watercourses and permanent pools. However causal pathway is unlikely and if impacts were to occur only a small number could potentially be affected. Limited if any use of surface water for human consumption
66	Management of connected water resources	Water dependent ecosystems impacted	Rare	Very high	Limited connectivity between River Murray and EMLR wetlands. Groundwater provides baseflows to watercourses and permanent pools and these support WDEs (incl. Fleurieu swamps). If groundwater is not appropriately managed, baseflow that supports the WDEs may be impacted. However impacts are likely to be on a local scale. Impacts associated with demand/take considered more of a risk (see r62)
67	Management of connected water resources	Economic uses impacted	Possible	Minor	Causal pathway is unlikely (i.e. issues with groundwater resulting in a change to surface water extraction for economic purposes). Alternative water sources are available. WAP limits protect productive use of the resource
69	Infrastructure affecting natural flow regimes	Human consumption/domestic needs not met	Rare	Minor	Dams may interrupt flow patterns downstream (i.e. cause the filling of downstream dams to be delayed). Impacts would be on a local scale during dry periods. Households tend to have alternative water supplies in case dam is dry or water unusable. Little use of surface water for human consumption, some use in households for toilet flushing and gardens.
70	Infrastructure affecting natural flow regimes	Water dependent ecosystems impacted	Rare	Very high	Existing farm dams are a barrier to dispersal for some species (legacy issue from time prior to WAA policy). Current controls

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area SS13 south – EMLR south surface water					
					minimise further risks. Demand/take considered to the more important pathway for this risk (see r62)
71	Infrastructure affecting natural flow regimes	Economic uses impacted	Unlikely	Minor	Main infrastructure relates to dams altering flow patterns (not volumes held i.e. demand/take). Culverts, bridges, road crossings etc not likely to have major impact to flow patterns. Likely to be local-scale impacts during dry years. Broad-scale impacts unlikely. There may be delays in water getting to the bottom of the catchment which could affect some economic uses but demand/take likely to be the more important risk source
72	Infrastructure affecting natural flow regimes	Connected water resources impacted	Possible	Minor	Connected resources considered includes downstream surface water (River Murray/Lake Alexandrina) and groundwater aquifers (under losing streams). Infrastructure includes dams (that alter flow patterns and not take (see r62)), weirs etc. Possible localised impacts only.
73	Point source pollution	Human consumption/domestic needs not met	Unlikely	Minor	Minimal reliance on surface water for human consumption. Point source pollution sources considered includes Brukunga (ongoing but unlikely to get worse), intensive animal keeping, waste water treatment plants, industrial areas etc. There have been incidents of illegal/accidental discharges but not a major concern (i.e. not intended). Causal pathway unlikely.
74	Point source pollution	Water dependent ecosystems impacted	Rare	High	Point source pollution sources considered includes Brukunga (ongoing but unlikely to get worse), intensive animal keeping, waste water treatment plants, industrial areas etc. Localised impacts may occur, but unlikely to impact WDEs to a point where recovery is not feasible or species eliminated

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area SS13 south – EMLR south surface water					
75	Point source pollution	Economic uses impacted	Unlikely	Minor	Use (volume) of resource for economic purposes greater than for human consumption. Some localised impacts may occur from a spill, however broad-scale impacts unlikely
76	Point source pollution	Connected water resources impacted	Possible	Minor	Connected resources include Lake Alexandrina (however main driver for water quality and quantity in the lower lakes and Coorong is flows from the River Murray). Any impacts likely to be localised. Impact may include localised freshening of estuaries
77	Land use	Human consumption/domestic needs not met	Rare	Minor	Minimal reliance on surface water for human consumption. Impacts to water quality/quantity from land use possible however to an extent that the domestic use is affected is very unlikely. New impacts are generally well controlled
79	Land use	Economic uses impacted	Rare	Medium	Impacts to water quality/quantity from land use possible however to an extent that the economic uses are affected is very unlikely. New impacts are generally well controlled
80	Land use	Connected water resources impacted	Likely	Minor	Relatively limited recharge of groundwater from surface water in this area. Main driver of water quality and quantity in Lower Lakes and Coorong is flows from the River Murray

Table 9. Risk statements not further assessed (SS13 south)

Risk ID	Risk Source	Risk Consequence	Reason statement not further assessed
Sub-area SS13 south – EMLR south surface water			
68	Management of connected water resources	Connected water resources impacted	Circular logic
81	Managed aquifer recharge	Human consumption/domestic needs not met	Risk source not relevant to sub-area
82	Managed aquifer recharge	Water dependent ecosystems impacted	Risk source not relevant to sub-area
83	Managed aquifer recharge	Economic uses impacted	Risk source not relevant to sub-area
84	Managed aquifer recharge	Connected water resources impacted	Risk source not relevant to sub-area

GS4a – Marne Saunders Fractured rock

Table 10. Risk statements assessed as low (GS4a)

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area GS4a – Marne Saunders fractured rock					
85	Climate extremes	Human consumption/domestic needs not met	Rare	Minor	Recharge of aquifer is low, therefore drought would not impact recharge greatly. Only some domestic use (toilet flushing and gardens)
86	Climate extremes	Water dependent ecosystems impacted	Unlikely	Minor	No nationally or internationally listed species. Would require a long-term drought for impact to occur
87	Climate extremes	Economic uses impacted	Rare	Medium	Recharge of aquifer is low, therefore drought would not impact recharge greatly. More reliance on groundwater during a drought which may lead to some users potentially dewatering their bore. Use potentially impacted is approx. 500 to 1,000ML.
88	Climate extremes	Connected water resources impacted	Unlikely	Minor	Connected resources to surface water streams. Severe/extreme drought would be required for an impact to occur
89	Demand/take including interception activities	Human consumption/domestic needs not met	Rare	Minor	Low connectivity between fractures therefore only local scale impacts. Yields are generally low and therefore relatively low demand.
90	Demand/take including interception activities	Water dependent ecosystems impacted	Unlikely	Minor	Any impacts would only be localised. Buffer zones control impacts. WDEs widespread and therefore recovery is possible. No nationally or internationally listed species.
91	Demand/take including interception activities	Economic uses impacted	Rare	Minor	Low connectivity between aquifers therefore any impacts would be high localised (i.e. extraction for irrigation of one bore results in a neighbour's well drying up).

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area GS4a – Marne Saunders fractured rock					
92	Demand/take including interception activities	Connected water resources impacted	Unlikely	Minor	There is the potential for a bore near a permanent pool to take water from the permanent pool. However impacts would be highly localised.
93	Management of connected water resources	Human consumption/domestic needs not met	Almost certain	Insignificant	Top of system, therefore negligible connection that discharges into this resource
94	Management of connected water resources	Water dependent ecosystems impacted	Almost certain	Insignificant	Top of system, therefore negligible connection that discharges into this resource
95	Management of connected water resources	Economic uses impacted	Almost certain	Insignificant	Top of system, therefore negligible connection that discharges into this resource
101	Point source pollution	Human consumption/domestic needs not met	Rare	Minor	Low likelihood that domestic supply would be interrupted. Few point source emitters in sub-area
102	Point source pollution	Water dependent ecosystems impacted	Rare	Minor	Low likelihood that WDEs would be impacted. Few point source emitters in sub-area
103	Point source pollution	Economic uses impacted	Rare	Minor	Few point source emitters in sub-area, low likelihood that economic uses would be impacted
104	Point source pollution	Connected water resources impacted	Rare	Minor	Low likelihood that connected water resources would be impacted. Few point source emitters in sub-area
105	Land use	Human consumption/domestic needs not met	Rare	Minor	Land use in area mostly grazing. May have impacts associated with vegetation clearing (i.e. salinity) however long-term impacts are not getting worse. Controls effectively manage vegetation clearing activities.

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area GS4a – Marne Saunders fractured rock					
106	Land use	Water dependent ecosystems impacted	Rare	Minor	Land use in area mostly grazing. May have impacts associated with vegetation clearing (i.e. salinity) however long-term impacts are not getting worse. Controls effectively manage vegetation clearing activities. Low likelihood that WDEs would be impacted
107	Land use	Economic uses impacted	Rare	Minor	Less sensitive to pesticide runoff, but more sensitive to salinity associated with vegetation clearing. Controls effectively manage vegetation clearing activities. Low likelihood that economic uses impacted
108	Land use	Connected water resources impacted	Rare	Minor	Extraction volumes from the fractured rock aquifers are considered too low and dispersed to affect regional water levels.

Table 11. Risk statements not further assessed (GS4a)

Risk ID	Risk Source	Risk Consequence	Reason statement not further assessed
Sub-area GS4a - Marne Saunders fractured rock			
96	Management of connected water resources	Connected water resources impacted	Circular logic
97	Infrastructure affecting natural flow regimes	Human consumption/domestic needs not met	Risk source not relevant to sub-area
98	Infrastructure affecting natural flow regimes	Water dependent ecosystems impacted	Risk source not relevant to sub-area
99	Infrastructure affecting natural flow regimes	Economic uses impacted	Risk source not relevant to sub-area

Risk ID	Risk Source	Risk Consequence	Reason statement not further assessed
100	Infrastructure affecting natural flow regimes	Connected water resources impacted	Risk source not relevant to sub-area
109	Managed aquifer recharge	Human consumption/domestic needs not met	Risk source not relevant to sub-area
110	Managed aquifer recharge	Water dependent ecosystems impacted	Risk source not relevant to sub-area
111	Managed aquifer recharge	Economic uses impacted	Risk source not relevant to sub-area
112	Managed aquifer recharge	Connected water resources impacted	Risk source not relevant to sub-area

GS4b – Marne Saunders Murray Group Limestone

Table 12. Risk statements assessed as medium or high (GS4b)

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Risk Level	Key factors leading to outcome
Sub-area GS4b – Marne Saunders Murray Group Limestone						
114	Climate extremes	Water dependent ecosystems impacted	Likely	Very high	High	Risks caused by climate extremes are inherently difficult to control. WAP designed to build resilience but extended drought will still lead to consequences. Black Hill springs is groundwater fed with the state-listed river blackfish reliant on these springs. It is the only remaining population in the sub-area and therefore would not recover if lost.
115	Climate extremes	Economic use	Likely	Minor	Medium	Risks caused by climate extremes are inherently difficult to control. Drought likely to occur during the WRP timeframe and would impact on people's ability to access groundwater for irrigation. Increases in salinity would be bigger impact than drop in water levels. Not all use would be affected as some crops relatively salt tolerant.
123	Management of connected water resources	Economic use	Likely	Minor	Medium	Upstream capture of surface water could impact recharge to the aquifer which may then lead to security of supply issues for groundwater users. Crops that could be impacted are olives, and Lucerne.

Table 13. Risk statements assessed as low (GS4b)

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area GS4b – Marne Saunders Murray Group Limestone					
113	Climate extremes	Human consumption/domestic needs not met	Rare	Minor	Less than 100 households would be dependent or resource, most have rainwater as alternate supply source.
116	Climate extremes	Connected water resources impacted	Almost certain	Insignificant	Negligible connection with other water resources. Fracture immediately before connection with River Murray, therefore no discharge to the River Murray
117	Demand/take including interception activities	Human consumption/domestic needs not met	Rare	Minor	Less than 100 households would be dependent or resource, most have rainwater as alternate supply source. Any part of resource worth using is fully allocated (no increase in demand likely)
118	Demand/take including interception activities	Water dependent ecosystems impacted	Rare	Minor	Strongest drawdown occurs in confined areas of aquifer where no WDEs exist. Recovery is possible.
119	Demand/take including interception activities	Economic uses impacted	Rare	Minor	Salinity greater impact than drop in water levels. May impact on ability to irrigate, however some crops are salt-tolerant therefore not all economic uses impacted. Recovery possible.
120	Demand/take including interception activities	Connected water resources impacted	Almost certain	Insignificant	Negligible connection with other water resources. Slow travel times for underground water limits impacts to baseflow.
121	Management of connected water resources	Human consumption/domestic needs not met	Rare	Minor	Negligible connection with other water resources.
122	Management of connected water resources	Water dependent ecosystems impacted	Almost certain	Insignificant	Negligible connection with other water resources.

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area GS4b – Marne Saunders Murray Group Limestone					
129	Point source pollution	Human consumption/domestic needs not met	Almost certain	Insignificant	Very few sources of point source pollution. Low likelihood that domestic supplies would be interrupted.
130	Point source pollution	Water dependent ecosystems impacted	Almost certain	Insignificant	Very few sources of point source pollution. Low likelihood that WDEs would be impacted.
131	Point source pollution	Economic uses impacted	Almost certain	Insignificant	Very few sources of point source pollution. Low likelihood that economic supplies would be interrupted.
132	Point source pollution	Connected water resources impacted	Almost certain	Insignificant	Very few sources of point source pollution. Low likelihood that impacts to connected water resources would occur. Slow travel times for underground water limits impacts to baseflow.
133	Land use	Human consumption/domestic needs not met	Rare	Minor	Likelihood of land use chemicals getting into water table are very low. Low recharge rates.
134	Land use	Water dependent ecosystems impacted	Almost certain	Insignificant	Very slow travel times. River blackfish are state listed, but very low likelihood of impact.
135	Land use	Economic uses impacted	Almost certain	Insignificant	Pollution travels slowly through groundwater and is subject to dilution. Economic use is not as sensitive to water quality as other values.
136	Land use	Connected water resources impacted	Almost certain	Insignificant	Negligible discharge into other resources. Slow travel times for underground water limits impacts to baseflow.

Table 14. Risk statements not further assessed (GS4b)

Risk ID	Risk Source	Risk Consequence	Reason statement not further assessed
Sub-area GS4b - Marne Saunders Murray Group Limestone			
124	Management of connected water resources	Connected water resources impacted	Circular logic
125	Infrastructure affecting natural flow regimes	Human consumption/domestic needs not met	Risk source not relevant to sub-area
126	Infrastructure affecting natural flow regimes	Water dependent ecosystems impacted	Risk source not relevant to sub-area
127	Infrastructure affecting natural flow regimes	Economic uses impacted	Risk source not relevant to sub-area
128	Infrastructure affecting natural flow regimes	Connected water resources impacted	Risk source not relevant to sub-area
137	Managed aquifer recharge	Human consumption/domestic needs not met	Risk source not relevant to sub-area
138	Managed aquifer recharge	Water dependent ecosystems impacted	Risk source not relevant to sub-area
139	Managed aquifer recharge	Economic uses impacted	Risk source not relevant to sub-area
140	Managed aquifer recharge	Connected water resources impacted	Risk source not relevant to sub-area

GS4c – Marne Saunders Renmark Group

Table 15. Risk statements assessed as low (GS4c)

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area GS4c Marne Saunders Renmark Group					

144	Climate extremes	Connected water resources impacted	Almost certain	insignificant	Aquifer receives water from other sources (slow lateral recharge from hills) but otherwise is not connected to other sources. Therefore impacts to connected water resources unlikely
148	Demand/take including interception activities	Connected water resources impacted	Almost certain	insignificant	Negligible to no current use from aquifer. Therefore impacts unlikely. A nominal 200ML has been allocated for future use but impacts associated with this take (if used) unlikely.
160	Point source pollution	Connected water resources impacted	Almost certain	insignificant	Confined aquifer therefore impacts associated with point source pollution events to connected water resources unlikely.
164	Land use	Connected water resources impacted	Almost certain	insignificant	Confined aquifer therefore impacts associated with land use activities to connected water resources unlikely.

Table 16. Risk statements not further assessed (GS4c)

Risk ID	Risk Source	Risk Consequence	Reason statement not further assessed
Sub-area GS4c - Marne Saunders Renmark Group			
141	Climate extremes	Human consumption/domestic needs not met	Little to no consumptive use from this aquifer
142	Climate extremes	Water dependent ecosystems impacted	Aquifer is deep (>20m) therefore no dependency by WDEs
143	Climate extremes	Economic uses impacted	Little to no consumptive use from this aquifer
162	Land use	Water dependent ecosystems impacted	Aquifer is deep (>20m) therefore no dependency by WDEs
163	Land use	Economic uses impacted	Little to no consumptive use from this aquifer
165	Managed aquifer recharge	Human consumption/domestic needs not met	Risk source not relevant to sub-area
166	Managed aquifer recharge	Water dependent ecosystems impacted	Risk source not relevant to sub-area

Risk ID	Risk Source	Risk Consequence	Reason statement not further assessed
Sub-area GS4c - Marne Saunders Renmark Group			
167	Managed aquifer recharge	Economic uses impacted	Risk source not relevant to sub-area
168	Managed aquifer recharge	Connected water resources impacted	Risk source not relevant to sub-area
145	Demand/take including interception activities	Human consumption/domestic needs not met	Little to no consumptive use from this aquifer
146	Demand/take including interception activities	Water dependent ecosystems impacted	Aquifer is deep (>20m) therefore no dependency by WDEs
147	Demand/take including interception activities	Economic uses impacted	Little to no consumptive use from this aquifer
149	Management of connected water resources	Human consumption/domestic needs not met	Little to no consumptive use from this aquifer
150	Management of connected water resources	Water dependent ecosystems impacted	Aquifer is deep (>20m) therefore no dependency by WDEs
151	Management of connected water resources	Economic uses impacted	Little to no consumptive use from this aquifer
152	Management of connected water resources	Connected water resources impacted	Circular logic
153	Infrastructure affecting natural flow regimes	Human consumption/domestic needs not met	Risk source not relevant to sub-area
154	Infrastructure affecting natural flow regimes	Water dependent ecosystems impacted	Risk source not relevant to sub-area
155	Infrastructure affecting natural flow regimes	Economic uses impacted	Risk source not relevant to sub-area
156	Infrastructure affecting natural flow regimes	Connected water resources impacted	Risk source not relevant to sub-area
157	Point source pollution	Human consumption/domestic needs not met	Little to no consumptive use from this aquifer
158	Point source pollution	Water dependent ecosystems impacted	Aquifer is deep (>20m) therefore no dependency by WDEs
159	Point source pollution	Economic uses impacted	Little to no consumptive use from this aquifer
161	Land use	Human consumption/domestic needs not met	Little to no consumptive use from this aquifer

GS2b – EMLR confined aquifers

Table 17. Risk statements assessed as low (GS2b)

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area GS2b EMLR confined aquifers					
197	Climate extremes	Human consumption/domestic needs not met	Almost certain	Insignificant	Very little (if any) human consumption/domestic needs from confined aquifer
199	Climate extremes	Economic uses impacted	Unlikely	Medium	Considers increased demand on confined aquifer during drought (surface water unavailable). Virtually no use from Renmark Group aquifer. Economic use associated with confined Murray Group Limestone includes irrigation. Alternative water sources available to minimise impacts to economic uses
200	Climate extremes	Connected water resources impacted	Almost certain	Insignificant	Confined aquifers not significantly connected
201	Demand/take including interception activities	Human consumption/domestic needs not met	Almost certain	Insignificant	Very little human consumption/domestic needs
203	Demand/take including interception activities	Economic uses impacted	Unlikely	Medium	Current overallocation in some zones of Murray Group Limestone confined aquifer (existing users) however actual use is likely to be less than allocation. WAP manages future allocations. Alternative water sources available to minimise impacts to economic uses
204	Demand/take including interception activities	Connected water resources impacted	Almost certain	Insignificant	Confined aquifers not significantly connected

Table 18. Risk statements not further assessed (GS2b)

Risk ID	Risk Source	Risk Consequence	Reason statement not further assessed
Sub-area GS2b – EMLR Confined Aquifers			
198	Climate extremes	Water dependent ecosystems impacted	Confined aquifer, no WDEs dependent on aquifer
202	Demand/take including interception activities	Water dependent ecosystems impacted	Confined aquifer, no WDEs dependent on aquifer
205	Management of connected water resources	Human consumption/domestic needs not met	Confined aquifer, limited to no connection
206	Management of connected water resources	Water dependent ecosystems impacted	Confined aquifer, limited to no connection
207	Management of connected water resources	Economic uses impacted	Confined aquifer, limited to no connection
208	Management of connected water resources	Connected water resources impacted	Circular logic
209	Infrastructure affecting natural flow regimes	Human consumption/domestic needs not met	Risk source not relevant to sub-area
210	Infrastructure affecting natural flow regimes	Water dependent ecosystems impacted	Risk source not relevant to sub-area
211	Infrastructure affecting natural flow regimes	Economic uses impacted	Risk source not relevant to sub-area
212	Infrastructure affecting natural flow regimes	Connected water resources impacted	Risk source not relevant to sub-area
213	Point source pollution	Human consumption/domestic needs not met	Confined aquifer, not used for human consumption or domestic supply
214	Point source pollution	Water dependent ecosystems impacted	Confined aquifer, no WDEs dependent on aquifer
215	Point source pollution	Economic uses impacted	Confined aquifer, risk arising from point source pollution considered to be inherently low
216	Point source pollution	Connected water resources impacted	Confined aquifer, limited to no connection

217	Land use	Human consumption/domestic needs not met	Confined aquifer, not used for human consumption or domestic supply
218	Land use	Water dependent ecosystems impacted	Confined aquifer, no WDEs dependent on aquifer
219	Land use	Economic uses impacted	Confined aquifer, risk arising from land use considered to be inherently low
220	Land use	Connected water resources impacted	Confined aquifer, no WDEs dependent on aquifer
221	Managed aquifer recharge	Human consumption/domestic needs not met	Risk source not relevant to sub-area
222	Managed aquifer recharge	Water dependent ecosystems impacted	Risk source not relevant to sub-area
223	Managed aquifer recharge	Economic uses impacted	Risk source not relevant to sub-area
224	Managed aquifer recharge	Connected water resources impacted	Risk source not relevant to sub-area

GS2c – EMLR fractured rock and unconfined aquifers

Table 19. Risk statements assessed as medium or high (GS2c)

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Risk Level	Key factors leading to outcome
Sub-area GS2c – ELMR fractured rock and unconfined aquifers						
226	Climate extremes	Water dependent ecosystems impacted	Unlikely	Very high	Medium	Risks caused by climate extremes are inherently difficult to control. Fleurieu swamps are a matter of national environmental significance. Existing regulatory controls to minimise further degradations caused by new activities, but don't apply to existing infrastructure and may not be effective during extreme climatic events.

Table 20. Risk statements assessed as low (GS2c)

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
GS2c – EMLR fractured rock and unconfined aquifers					
225	Climate extremes	Human consumption/domestic needs not met	Rare	Very high	Considers both interruption to town water supply, as well as individual users (private supply bores). Supply arrangements well managed, bores can be deepened during drought to access dropping levels, therefore impacts considered to be low. Some localised impacts where insufficient domestic supply results from drought, however most households have multiple domestic supply sources
227	Climate extremes	Economic uses impacted	Unlikely	Medium	During Millennium drought some minor impacts occurred (some bores ran dry) however WAP allows wells to be

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
GS2c – EMLR fractured rock and unconfined aquifers					
					deepened (Principle 46) therefore impacts to economic uses reduced
229	Demand/take including interception activities	Human consumption/domestic needs not met	Rare	Very high	Only small area affected (Mt Compass and potentially Macclesfield). One town water supply and some domestic bores. Controls manage risks associated with demand/take (licensing)
230	Demand/take including interception activities	Water dependent ecosystems impacted	Rare	High	Considers WDEs dependent on baseflow. Rules in WAP prevent risk getting worse, however more important to this risk pathway is climate extremes as controls may not manage extreme conditions (see r226)
231	Demand/take including interception activities	Economic uses impacted	Unlikely	Medium	Current controls (WAP, NRM Plan) manages take therefore impacts to economic use as a result of take are unlikely.
232	Demand/take including interception activities	Connected water resources impacted	Almost certain	Insignificant	
233	Management of connected water resources	Human consumption/domestic needs not met	Rare	Very high	Main pathway would be associated with poor management of surface water within EMLR which impacts on the unconfined aquifers. Domestic supplies using EMLR groundwater (unconfined aquifers) is reticulated supply to Mount Compass and some supply in Meadows and some domestic supply to private bores. Mt Compass is high up in the catchment therefore unlike to be affected by management of EMLR surface water. Groundwater in Mt Compass area is preferred water source therefore conjunctive use related issues unlikely. For private domestic users, any impacts would be highly localised and very unlikely to occur

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
GS2c – EMLR fractured rock and unconfined aquifers					
234	Management of connected water resources	Water dependent ecosystems impacted	Rare	Minor	
235	Management of connected water resources	Economic uses impacted	Rare	Minor	
241	Point source pollution	Human consumption/domestic needs not met	Rare	Very high	A point source of pollution would need to be located in close proximity of a domestic supply bore (not likely) and if so, impacts would be very localised (individual bore scale). Bigger consequence would be if point source pollution impacted on a reticulated town water supply (Mt Compass groundwater) however carefully managed and therefore very unlikely to occur
242	Point source pollution	Water dependent ecosystems impacted	Rare	Very high	High consequences (Fleurieu swamps and many groundwater fed pools that support a number of species) however likelihood of occurrence is low. Limited point sources of pollution. Point source would need to be located near groundwater fed pool or WDE. Very unlikely that any are located within vicinity of Fleurieu swamps. Groundwater movement is very slow
243	Point source pollution	Economic uses impacted	Unlikely	Minor	Limited point sources of pollution (waste water treatment plants, septics, dairies, Brukunga mine site). Pollution events unlikely to impact on the economic use of the water
244	Point source pollution	Connected water resources impacted	Rare	High	Limited point sources of pollution. Unlikely that a pollution event significant enough could impact on groundwater connected resources. Groundwater movement is very slow
245	Land use	Human consumption/domestic needs not met	Rare	Medium	Considers increased urbanisation resulting in faster runoff and less infiltration. However focus on water sensitive urban design

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
GS2c – EMLR fractured rock and unconfined aquifers					
					means that these negative impacts less likely. Land use impacts (including nitrification, sedimentation etc) that would impact human consumption/domestic needs considered to be very unlikely on a broad scale
246	Land use	Water dependent ecosystems impacted	Rare	Minor	Considers increased urbanisation resulting in faster runoff and less infiltration. However focus on water sensitive urban design means that these negative impacts less likely. Land use impacts (including nitrification, sedimentation etc) that would impact WDEs (including Fleurieu swamps) considered very unlikely.
247	Land use	Economic uses impacted	Rare	Medium	Considers increased urbanisation resulting in faster runoff and less infiltration. However focus on water sensitive urban design means that these negative impacts less likely. Land use impacts (including nitrification, sedimentation etc) that would impact economic uses considered to be very unlikely
248	Land use	Connected water resources impacted	Possible	Minor	Considers increased urbanisation resulting in faster runoff and less infiltration. However focus on water sensitive urban design means that these negative impacts less likely. Land use impacts (including nitrification, sedimentation etc) that would impact on groundwater connected resources may occur however overall consequence to these connected resources considered to be minor

Table 21. Risk statements not further assessed (GS2c)

Risk ID	Risk Source	Risk Consequence	Reason statement not further assessed
Sub-area GS2c - EMLR fractured rock and unconfined aquifers			
236	Management of connected water resources	Connected water resources impacted	Circular logic
237	Infrastructure affecting natural flow regimes	Human consumption/domestic needs not met	Risk source not relevant to sub-area
238	Infrastructure affecting natural flow regimes	Water dependent ecosystems impacted	Risk source not relevant to sub-area
239	Infrastructure affecting natural flow regimes	Economic uses impacted	Risk source not relevant to sub-area
240	Infrastructure affecting natural flow regimes	Connected water resources impacted	Risk source not relevant to sub-area
249	Managed aquifer recharge	Human consumption/domestic needs not met	Risk source not relevant to sub-area
250	Managed aquifer recharge	Water dependent ecosystems impacted	Risk source not relevant to sub-area
251	Managed aquifer recharge	Economic uses impacted	Risk source not relevant to sub-area
252	Managed aquifer recharge	Connected water resources impacted	Risk source not relevant to sub-area

GS1a – Angas Bremer quaternary sediments

Table 22. Risk statements assessed as low (GS1a)

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area GS1a – Angas Bremer quaternary sediments					
253	Climate extremes	Human consumption/domestic needs not met	Almost certain	Insignificant	No licenced extraction. Brackish to saline water. No human consumption (too saline for human consumption)
254	Climate extremes	Water dependent ecosystems impacted	Unlikely	Minor	Brackish water. Drought would result in water levels dropping (surface water management) however no nationally or internationally listed species. Species can recolonise after drought event
255	Climate extremes	Economic uses impacted	Rare	Minor	No economic use of aquifer
256	Climate extremes	Connected water resources impacted	Rare	Minor	Small discharge into Lake Alexandrina. Downward leakage into confined aquifer but limited effect due to drought.
257	Demand/take including interception activities	Human consumption/domestic needs not met	Almost certain	Insignificant	No human consumption (too saline for human consumption)
258	Demand/take including interception activities	Water dependent ecosystems impacted	Rare	Minor	Negligible use
259	Demand/take including interception activities	Economic uses impacted	Rare	Minor	Negligible use
260	Demand/take including interception activities	Connected water resources impacted	Almost certain	Insignificant	Negligible use

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area GS1a – Angas Bremer quaternary sediments					
261	Management of connected water resources	Human consumption/domestic needs not met	Almost certain	Insignificant	No human consumption (too saline for human consumption)
262	Management of connected water resources	Water dependent ecosystems impacted	Unlikely	Minor	Brackish water. Drought would result in water levels dropping (surface water management) however no nationally or internationally listed species. Species can recolonise after drought event
263	Management of connected water resources	Economic uses impacted	Rare	Minor	Very limited economic use (<10ML)
269	Point source pollution	Human consumption/domestic needs not met	Almost certain	Insignificant	No human consumption (too saline for human consumption)
270	Point source pollution	Water dependent ecosystems impacted	Almost certain	Insignificant	No nationally or internationally listed species
271	Point source pollution	Economic uses impacted	Almost certain	Insignificant	Very limited economic use (<10ML)
272	Point source pollution	Connected water resources impacted	Almost certain	Insignificant	Slow moving groundwater, low permeability
273	Land use	Human consumption/domestic needs not met	Almost certain	Insignificant	No human consumption (too saline for human consumption)
274	Land use	Water dependent ecosystems impacted	Almost certain	Insignificant	Negligible due to localised nature of WDEs, low permeability of aquifer. Source would need to get into aquifer (low likelihood)
275	Land use	Economic uses impacted	Almost certain	Insignificant	Very limited economic use (<10ML)

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area GS1a – Angas Bremer quaternary sediments					
276	Land use	Connected water resources impacted	Rare	Minor	Very slow moving (time scale of hundreds of years).

Table 23. Risk statements not further assessed (GS1a)

Risk ID	Risk Source	Risk Consequence	Reason statement not further assessed
Sub-area GS1a - Angas Bremer quaternary sediments			
264	Management of connected water resources	Connected water resources impacted	Circular logic
265	Infrastructure affecting natural flow regimes	Human consumption/domestic needs not met	Risk source not relevant to sub-area
266	Infrastructure affecting natural flow regimes	Water dependent ecosystems impacted	Risk source not relevant to sub-area
267	Infrastructure affecting natural flow regimes	Economic uses impacted	Risk source not relevant to sub-area
268	Infrastructure affecting natural flow regimes	Connected water resources impacted	Risk source not relevant to sub-area
277	Managed aquifer recharge	Human consumption/domestic needs not met	Risk source not relevant to sub-area
278	Managed aquifer recharge	Water dependent ecosystems impacted	Risk source not relevant to sub-area
279	Managed aquifer recharge	Economic uses impacted	Risk source not relevant to sub-area
280	Managed aquifer recharge	Connected water resources impacted	Risk source not relevant to sub-area

GS1b – Angas Bremer Murray Group Limestone

Table 24. Risk statements assessed as low (GS1b)

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area GS1b – Angas Bremer Murray Group Limestone					
281	Climate extremes	Human consumption/domestic needs not met	Almost certain	insignificant	No current natural recharge, therefore climate extremes not a relevant risk source. Some domestic use of resource
282	Climate extremes	Water dependent ecosystems impacted	Almost certain	insignificant	No known stygofauna and unlikely to be affected by pumping of the resource. No current natural recharge
283	Climate extremes	Economic uses impacted	Possible	Minor	No current natural recharge. Likelihood of consequence reduced as alternate supplies available
284	Climate extremes	Connected water resources impacted	Almost certain	insignificant	No current natural recharge. Negligible diffuse discharge into the middle of Lake Alexandrina
285	Demand/take including interception activities	Human consumption/domestic needs not met	Rare	Minor	Very few users of resource. Rainwater tanks provide alternate supply source. Any impacts would be very localised
286	Demand/take including interception activities	Water dependent ecosystems impacted	Rare	Minor	Negligible. Very few users of resources. No known stygofauna and any impacts would be localised
287	Demand/take including interception activities	Economic uses impacted	Possible	Minor	No current natural recharge. Likelihood of consequence reduced as alternate supplies available
288	Demand/take including interception activities	Connected water resources impacted	Almost certain	insignificant	Negligible connection
289	Management of connected water resources	Human consumption/domestic needs not met	Almost certain	insignificant	Negligible connection

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area GS1b – Angas Bremer Murray Group Limestone					
290	Management of connected water resources	Water dependent ecosystems impacted	Almost certain	insignificant	Negligible connection
291	Management of connected water resources	Economic uses impacted	Almost certain	insignificant	Negligible connection
297	Point source pollution	Human consumption/domestic needs not met	Rare	Minor	Would require direct dumping into well, therefore very unlikely. Discharge to surface water (for human consumption/domestic supplies) would need to pass through quaternary sediments, therefore very unlikely. Controlled via EPA permits
298	Point source pollution	Water dependent ecosystems impacted	Rare	Minor	Would require direct dumping into well, therefore very unlikely. Discharge to surface water would need to pass through quaternary sediments, therefore very unlikely. Controlled via EPA permits
299	Point source pollution	Economic uses impacted	Rare	Minor	Would require direct dumping into well, therefore very unlikely. Discharge to surface water would need to pass through quaternary sediments, therefore very unlikely. Controlled via EPA permits
300	Point source pollution	Connected water resources impacted	Almost certain	Insignificant	Negligible connection to other water resources
301	Land use	Human consumption/domestic needs not met	Almost certain	Insignificant	Confined aquifer therefore no connection that would be impacted by land use practices
302	Land use	Water dependent ecosystems impacted	Almost certain	Insignificant	Confined aquifer therefore no connection that would be impacted by land use practices

Risk ID	Risk Source	Risk Consequence	Likelihood rating	Consequence rating	Key factors leading to outcome
Sub-area GS1b – Angas Bremer Murray Group Limestone					
303	Land use	Economic uses impacted	Almost certain	Insignificant	Confined aquifer therefore no connection that would be impacted by land use practices
304	Land use	Connected water resources impacted	Almost certain	Insignificant	Confined aquifer therefore no connection that would be impacted by land use practices
305	Managed aquifer recharge	Human consumption/domestic needs not met	Rare	Minor	Permits required and prevent worse quality water being injected. Controls manage injection pressures (NRM and EP Act)
306	Managed aquifer recharge	Water dependent ecosystems impacted	Almost certain	Insignificant	Permits required and prevent worse quality water being injected. Controls manage injection pressures (NRM and EP Act). No known stygofauna.
307	Managed aquifer recharge	Economic uses impacted	Rare	Minor	Potential impact only if somebody accidentally puts poorer quality water in well (accidental). Only local impact if it were to occur.
308	Managed aquifer recharge	Connected water resources impacted	Almost certain	Insignificant	Minimal connection. Only potential would be with the quaternary sediments which would become fresher

Table 25. Risk statements not further assessed (GS1b)

Risk ID	Risk Source	Risk Consequence	Reason statement not further assessed
Sub-area GS1b - Angas Bremer Murray Group Limestone			
292	Management of connected water resources	Connected water resources impacted	Circular logic

Risk ID	Risk Source	Risk Consequence	Reason statement not further assessed
293	Infrastructure affecting natural flow regimes	Human consumption/domestic needs not met	Risk source not relevant to sub-area
294	Infrastructure affecting natural flow regimes	Water dependent ecosystems impacted	Risk source not relevant to sub-area
295	Infrastructure affecting natural flow regimes	Economic uses impacted	Risk source not relevant to sub-area
296	Infrastructure affecting natural flow regimes	Connected water resources impacted	Risk source not relevant to sub-area

C. Sources of risk

Climate extremes:

Climate extremes and climate change are addressed separately in this risk assessment.

Climate extremes are considered to be natural variations in climatic conditions that include, but are not limited to, drought and flood events (and conditions following these extreme events) while climate change is considered to be in the increase in intensity, duration and/or frequency of these events.

In the context of this assessment climate change is not assessed as a risk source due to the temporal scale of this assessment (10 years) and the limited controls that can be put in place within the water resource plan area to mitigate the impacts of climate change during the 10 year assessment period. Climate change has instead been included as a factor that will influence the derivation of risk level for each risk statement.

Demand/take (including interception activities):

Demand includes the following:

- Extraction from aquifers via wells;
- Storage and extraction of surface water through:
  - Run-off dams
  - On-stream dams
  - Off-stream dams
- Plantation forestry
  - extracting underground water in areas where plantation forestry overlies shallow water tables
  - intercepting rainfall at closed canopy thereby
    - reducing surface water runoff;
    - changing the volume, timing and duration of flow: and
    - reducing underground water recharge
- Interception by mining (e.g. dewatering of an aquifer to gain access to mineral resources)
- Interception activities that alter the natural water regime
  - Run-off dams
  - Commercial plantations (other than forestry)
  - Mining activities (including CSG)
  - Floodplain harvesting
- Long-term changes in land use (that may increase demand)

Intensification of land uses away from relatively low intensity agriculture such as grazing, towards more intensive uses such as viticulture, horticulture and residential development places greater pressure on water resources (EPA, 2008).

Determination of existing take considers measured or estimated water extraction or diversion, presence of forestry plantations and current mining production tenements. Potential future take considers trends in water extraction or diversion, suitability of water quality to support development, coverage of mining exploration licences, changes in forestry plantation coverage and changes in land use associated with an increase in water use (excl. forestry)

Infrastructure (affecting natural flow regimes):

For this assessment, infrastructure includes water control structures. The presence of infrastructure such as weirs and regulators is considered a risk to the natural flow regimes of surface water (and not groundwater). Other types of infrastructure that may affect natural flow regimes considered include:

- Crossings and culverts
- Levee banks

The influence on dams on demand/take is considered in risks related to demand/take. In the context of infrastructure, dams are only considered by way of their impacts to modifying natural flow regimes. Infrastructure is only relevant to surface water sub-areas. Impacts associated with infrastructure to groundwater sub-areas is considered under the risk sources 'demand/take' and 'management of connected water resources'.

Management of connected water resources:

The management of water from significant hydrologically connected water resources and the management of infrastructure that controls the flow of connected water resources can be a potential source of risk to water quantity and quality. "Significant hydrological connection" is defined as: *a hydrological connection that is of consequence to the effective management of a Basin resource*. This assessment deals with connections of resources within and outside the water resource plan area as follows:

- Resources connected between sub-areas *within* the water resource plan area
  - Groundwater ⇔ surface water
  - Surface water ⇔ surface water
  - Groundwater ⇔ groundwater
- Resources (surface and groundwater) connected with Basin or non-basin resources *outside* the water resource plan area
  - SA Murray Region (Coorong, Lower Lakes)
  - River Murray
  - WMLR
  - Barossa

(Connections include between groundwater aquifers, between groundwater and surface water resources and from one surface water resource to another).

The likelihood of there being an impact to water resources is based on three key considerations:

- Whether there is hydrological connection;
- The degree of connectivity; and
- Whether the resource is being managed to prevent an impact from occurring.

Point source pollution:

Considers point sources of pollution that may impact on the quality of water resources (both ground and surface waters). Point sources considered in this assessment include:

- Disposal of brine from desalination plants
- Tailings storage facilities and waste rock dumps at mine sites
- Chemical spills from industry and/or transport accidents
- Disposal of septic/sewage
- Municipal waste facilities
- Industrial waste (e.g. dairies, wineries)
- Other waste treatment facilities

There are a number of projects within the EMLR that provide for re-use of wastewater from community wastewater management systems and industries (e.g. re-use of recycled wastewater after treatment in the Laratinga wetlands at Mount Barker, the upgrade of the Bird in Hand wastewater treatment system in Woodside that enables recycled water to be used for irrigation purposes (SA Water 2013 in EMLR WAP p. 42)).

Land use:

Considers the impacts of using the land for a particular purpose and how this may result in changes to the quality or availability of water resources. Land use practices may result in increased vegetation clearing and/or compaction of soils resulting in increased runoff (sedimentation, agricultural runoff, increased nutrients etc). Practices may also result in the water table to rise and in turn resulting in increased salinity. The timing and intensity of flows may also be affected as a result of land use activities. Land use does not consider the potential for contamination of water resources as a result of point source pollution. These are considered as a separate risk source. Land uses considered (current and future potential) for this risk assessment include:

- Urban
- Grazing
- Cropping
- Industrial
- Natural vegetation

Managed aquifer recharge:

Defined as the intentional, artificial recharge of water to aquifers for subsequent recovery or environmental benefit. For this risk assessment, managed aquifer recharge also considers other water imported to the region for consumptive uses. Domestic water needs that are not supplied via the SA Water mains network includes:

- Mt Compass is supplied with underground water by SA Water and a private water supply scheme
- Meadows is supplied with underground water by a private water supply scheme and by a non-potable supply to approximately 40 households maintained by the District council of Mt Barker
- A pipeline to supply potable water to Langhorne Creek exists
- Macclesfield is not connected to the SA Water mains network or council-managed schemes

Based on calculations provided in the EMLR WAP (p.33), domestic water requirements outside of the townships supplied by the SA Water mains network, is 503 ML/yr consisting of 262ML/yr of surface waters and 241 ML/yr of groundwater. Water imported to the region as detailed in the above dot points is for human consumption/domestic needs and therefore is not relevant to other consequence categories.

The use of imported water and effluent is controlled under Section 127 (5)(i) and (j) of the NRM Act.

Draining or discharging water into a well (artificial recharge) is controlled under Section 127 (3)(c) of the NRM Act

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Department for Environment and Water