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Sustainable Extraction Limits Derived from the Recharge Risk Assessment Method – New South Wales (part 1)

CSIRO and SKM

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Report to Murray-Darling Basin Authority

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Abbreviations

CSIRO	Commonwealth Scientific and Industrial Research Organisation
DECCW	Department of Environment, Climate Change and Water
GL	Gigalitre
GMA	Groundwater Management Area
GMU	Groundwater Management Unit
GS1*	Groundwater SDL area 1
km^2	kilometres squared
m	metres
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
mg/L	Milligrams per Litre
mm	Millimetres
N/A	Not Applicable
NSW	New South Wales
RRAM	Recharge Risk Assessment Method
SDL	Sustainable Diversion Limit
SF	Sustainability Factor
SKM	Sinclair Knight Merz
TDS	Total Dissolved Solids
WAVES	Water Atmosphere Vegetation Energy Soil

*The number at the end of the GS code is unique for each groundwater SDL area

Executive Summary

The Murray-Darling Basin Authority has responsibility for development of the Basin Plan for the Murray-Darling Basin (MDB) as specified under the *Water Act 2007*. The Basin Plan must include a number of mandatory conditions, including the development of a sustainable diversion limit (SDL) for the MDB's water resources. SDLs must encompass both surface water and groundwater. The SDL will limit the take of water for consumptive uses and is expressed as a volume.

The Recharge Risk Assessment Method (RRAM) was developed to derive preliminary SDLs to inform the Basin Plan development process.

The RRAM is based on the requirements of the *Water Act 2007* and the expectation that SDLs will reflect an environmentally sustainable level of take. According to the RRAM, the level of take must not compromise the following characteristics of the resource; key environmental assets, key ecosystem functions, the productive base and key environmental outcomes. In general terms, the RRAM is based on setting an extraction limit by applying a sustainability factor to groundwater recharge. For more information regarding the methodology, refer to CSIRO (2010).

For the New South Wales (part 1) SDL areas, the preliminary RRAM extraction limits were generally superseded by extraction limits determined via more rigorous numerical modelling results.

1 Sustainable extraction limits derived from the RRAM for New South Wales (part 1)

1.1 Lower Lachlan Alluvium (GS39)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the recharge risk assessment method (RRAM) for the Lower Lachlan Alluvium sustainable diversion limit (SDL) area.

1.1.1 Background

The Lower Lachlan Alluvium SDL area is equivalent to the Lower Lachlan Alluvium GMU and corresponds closely to the boundary of the Lower Lachlan Alluvium numerical model boundary. The long-term average extraction limit (LTAEL) and supplementary licences defined in the Water Sharing Plan for the Lower Lachlan Groundwater Sources are 108 GL/year and 21 GL/year respectively. The supplementary licences are expected to be reduced to 0 by the year 2018. The volume of current use for this unit is 129 GL/year (Table 1). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010k).

The aquifers in this SDL area comprise unconsolidated alluvial sediments that fill the river valley. The unconsolidated sediments are subdivided into two systems; the broad and highly heterogeneous shallow unconfined Shepparton Formation aquifer and the underlying leaky confined aquifers of the Calivil Formation and Renmark Group.

Table 1. Groundwater take summary for the Lower Lachlan Alluvium SDL area

Lower Lachlan Alluvium SDL area	GL/year
Entitlement*	**108**
Current use for entitlement bores**	118
Estimated use for stock & domestic bores***	11
Total use	**129**

*Entitlement volume is equal to the LTAEL, which will be achieved by 30 June 2018
**Current Use is the average annual metered use volume from 2003/2004 to 2007/2008
**Estimated use for stock and domestic bores was provided by DECCW

1.1.2 Salinity zoning

Groundwater salinity is characterised by four salinity zones in the Lower Lachlan Alluvium SDL area, with groundwater ranging from 0 to greater than 14,000 mg/L total dissolved solids (TDS). The groundwater salinity distribution can be seen in Figure 1 and is summarised in Table 2.

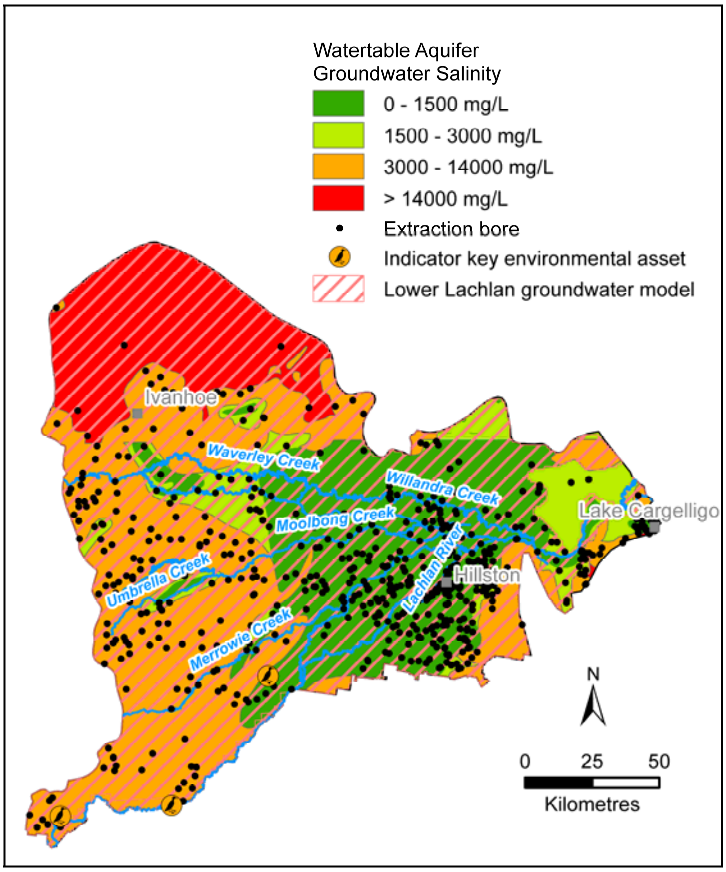

Figure 1. Lower Lachlan Alluvium watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 2. Summary of salinity zones in the Lower Lachlan Alluvium SDL area

Watertable salinity zone	Portion of area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	32	8270
Zone 2 (1500–3000 mg/L TDS)	10	2628
Zone 3 (3000–14,000 mg/L TDS)	41	10,788
Zone 4 (>14,000 mg/L TDS)	17	4382
Water bodies	0	7
Total	**100**	**26,074**

1.1.3 Key environmental assets

The *Water Act 2007* requires that assessment of environmental water needs of the Murray-Darling Basin (MDB) must encompass key environmental assets, including water-dependent ecosystems, ecosystem services, and sites with ecological significance.

The Murray-Darling Basin Authority has identified 18 key environmental assets – hydrologic indicator sites that drive the environmental hydrology of the MDB (MDBA, 2010). These 18 sites have been assessed to determine the objectives, targets and flow regimes required to sustain them. This information was input to the generation of an estimate of the long-term average sustainable diversion limits that will not compromise the water requirements for the rivers, wetlands and floodplains of the Basin.

The Lower Lachlan SDL area encompasses the Lachlan Swamps, Booligal Wetlands and the Great Cumbung Swamp, which are three of the 18 key environmental asset – hydrologic indicator sites identified by the Murray-Darling Basin Authority.

The Booligal Wetlands cover approximately 5000 ha on the lower Lachlan River near the township of Booligal. The wetlands are low-gradient braided channels situated on the Muggabah-Merrimajeel Creek, a distributary creek system which leaves the Lachlan River. The wetlands include the Booligal Swamp, and Little Gum Swamp, and are also associated with Lake Merrimajeel and Murrumbidgil swamps which are downstream on the same creek system. Flood flows into the system are infrequent and the area drains rapidly once floods in the river recede (CSIRO, 2008a).

The Great Cumbung Swamp is around 16,000 ha located at the terminus of the Lachlan River and is adjacent to the Murrumbidgee River and the Lowbidgee Wetlands. The swamp is dependent on flood flows in the Lachlan River (CSIRO, 2008a).

The Booligal Wetlands and Great Cumbung Swamp are considered to be dominantly surface water fed and discharge to the surrounding aquifers. Although the assets are hydraulically linked to groundwater, they are associated with the Shepparton Formation aquifer, which has a low level of development relative to the deeper aquifer.

Therefore this unit is considered to be at medium risk in terms of the key environmental assets, given there is only a moderate level of groundwater dependency and a high sensitivity to take.

1.1.4 Key ecosystem function

The Lower Lachlan River is considered to be under maximum losing conditions (CSIRO, 2008a). This means that the watertable is at a significant depth below the river, such that any fluctuations in groundwater elevation cannot induce additional stream leakage.

The key ecosystem function of the Lower Lachlan Alluvium SDL area is at low risk, given that the connectivity between the groundwater and surface water is low.

The impact of groundwater pumping on river flow in the Lower Lachlan numerical model was assessed by comparing river flow in the no-development scenario and the scenario that incorporated a historical climate and 2004/2005 groundwater extraction (96 GL/year). Figure 2 shows this impact and indicates that the impact of groundwater development (as indicated by river loss) does not reach a dynamic equilibrium over the model run. The stream impacts rise to 3.5 GL/year after 222 years, which is less than 5 percent of the extracted groundwater volume. The stream impact within a typical planning period (i.e. 50 years) would be even less.

The key ecosystem function of the Lower Lachlan Alluvium SDL area is at low risk, given that the connectivity between the groundwater and surface water is low.

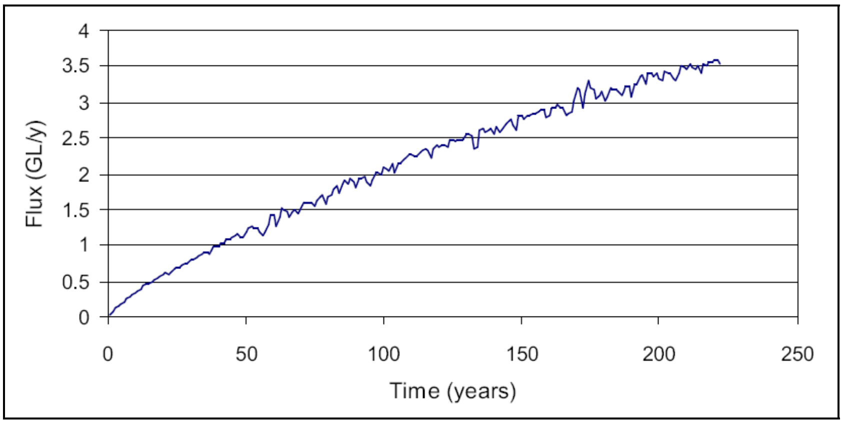

Figure 2. Change in river leakage from the no-development to the 2004/2005 groundwater development scenario; from the Lower Lachlan groundwater model

1.1.5 Productive base

Recharge

The results of the Lower Lachlan Alluvium numerical modelling that occurred for the Murray-Darling Basin Sustainable Yields Project study (CSIRO, 2008a) have been used to estimate recharge in this unit. The Lower Lachlan Alluvium numerical model incorporates recharge via rainfall, irrigation accessions and lateral flow. The mass-balance for management zones 1 and 2 was used as input to the RRAM (Table 3), as opposed to the mass-balance for the entire Lower Lachlan Alluvium model domain. The reason for this is based on the fact that the mass-balance for management zones 1 and 2 focuses on the area of good quality groundwater.

The recharge volume to zones 1 and 2 (148 GL/year) has been apportioned to salinity zones 1 and 2, based on their relative size. This is summarised in Table 4.

Table 3. Modelled average annual general water balances for the Lower Lachlan Alluvium groundwater management zones 1 and 2 for 2004/2005 groundwater development

	GL/year
Recharge - gains	
Rainfall & irrigation	88
River system	48
Lateral flow	13
Total	**148**
	Discharge – Losses
Extraction	94
Rivers	3
Lateral flow	95
Total	**192**

Table 4. Recharge calculation – from the numerical groundwater model

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km2)	8270	2628	10,788	4382
Recharge derived from the Lower Lachlan Numerical Model (GL/yr)	**112**	**36**	**0**	**0**

Storage

The specific yield of the Shepparton Formation aquifer is 0.05 and for the Calivil/Renmark aquifers is 0.15 (CSIRO, 2008a). An average specific yield of 0.10 has been used for the purpose of the storage calculation.

The average thickness of the Calivil/Renmark aquifer is 186 m. This thickness has been adopted for the storage calculation.

Total storage of the Lower Lachlan Alluvium is 202, 703 GL (Table 5).

Table 5. Storage calculation

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km2)	8270	2628	N/A	N/A
Saturated thickness (m)	186	186	N/A	N/A
Specific yield	0.10	0.10	N/A	N/A
Total storage (GL)	**153,822**	**48,881**	**N/A**	**N/A**

Storage relative to recharge

The ratio of storage to recharge ranges from 1,358 to 1,373 for each of the salinity classes. This indicates that there is a low risk of the productive base of the aquifer being jeopardised by factors such as climate change and the short-term over extraction of the groundwater resource.

1.1.6 The risk matrix

Table 6 provides a summary of the risk ranking associated with: key environmental assets, key ecosystem function, the productive base and key environmental outcome. An allowance for uncertainty is also made via the matrix. Where a high level of uncertainty is associated with the risk ranking, the sustainability factor is reduced by between 25 percent and 50 percent. In summary:

- the SDL area is ranked medium risk in terms of key environmental assets
- the SDL area is ranked low risk in terms of key ecosystem function, given that the lower reaches of the Lachlan River are under maximum losing conditions
- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio far exceeds 40
- there is a risk to the key environmental outcome (i.e. groundwater salinity)
- there is a low uncertainty associated with this unit, given that the recharge calculation was based on numerical modelling for the Lower Lachlan Alluvium.

Table 6. Risk matrix

Risk ranking	Environmental assets (EAs)	OR	Ecosystem function	OR	Productive base	Sustainability factor (SF)	Key environmental outcome	Degree of uncertainty
High	EA that is highly groundwater dependent and highly sensitive to take		In the current state, groundwater discharge provides baseflow to the unregulated river reach. Groundwater extraction is likely to result in streamflow depletion		Storage/ recharge <20	0.10	Where there is no risk to the key environmental outcome (i.e. groundwater salinity) there is no reduction to the SF for any of the salinity classes. Where there is a risk to the key environmental outcome, as a measure to reduce risk to groundwater quality, the following reductions are made: Salinity class 1: reduce SF by 20% Salinity class 2: reduce SF by 10% Salinity classes 3 & 4: no reduction	Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 50%
Medium	EA that is highly groundwater dependent and is moderately sensitive to take EA that is moderately groundwater dependent and is highly sensitive to take		The rivers in the SDL unit are regulated and they are highly connected to the groundwater system (i.e. >50% impact of pumping on streamflow)		Storage/ recharge 20–40	0.50		
Low	EA that has a low groundwater dependence and low sensitivity to take EAs do not exist in the SDL unit		The rivers in the SDL unit are regulated or unregulated and they have low–moderate connection with the groundwater system (i.e. <50% impact of pumping on streamflow)		Storage/ recharge >40	0.70		Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 25%

1.1.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Lower Lachlan SDL area is 61 GL/year (Table 7). It should be noted that this only includes an extraction limit for the area of salinity class 1 and 2 groundwater (i.e. 0 mg/L TDS to 3000 mg/L TDS). The RRAM extraction limit was based on the Murray-Darling Basin Sustainable Yields Project Lower Lachlan Alluvium numerical modelling results (CSIRO, 2008a) as these provided the best available information at the time of the RRAM analysis.

The preliminary RRAM extraction limit for the Lower Lachlan SDL area has been superseded by more recent modelling results (CSIRO, 2010a).

Table 7. Extraction limit summary

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	112	36	0	0
Sustainability factor	0.40	0.45	N/A	N/A
Extraction limit (GL/yr)	45	16	N/A	N/A

1.2 Lower Gwydir Alluvium (GS38)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the RRAM for the Lower Gwydir Alluvium SDL area.

1.2.1 Background

The Lower Gwydir Alluvium SDL area corresponds to the Lower Gwydir Alluvium GMU boundary. The Lower Gwydir numerical model covers the majority of the SDL area and a larger area to the west of it. The LTAEL for the Lower Gwydir Alluvium is 32.3 GL/year and the supplementary water access licences that will be reduced to 0 by June 2017, total 14 GL/year.

The Lower Gwydir Alluvium numerical model comprises two layers (CSIRO, 2007a). The upper layer represents the unconfined Narrabri Formation aquifer, comprised of shallow alluvial fan sediments. The lower layer represents the Gunnedah Formation. The numerical model indicates that approximately 40 percent of extraction occurs from the shallow aquifer and the remaining 60 percent occurs from the deeper aquifer. A preliminary extraction limit has been calculated for the entire area, based on the results of the Murray-Darling Basin Sustainable Yields Project Lower Gwydir Alluvium numerical modelling (CSIRO, 2007a).

1.2.2 Salinity zoning

The groundwater salinity map for the watertable aquifer has been used to define SDLs for each of the salinity classes.

Groundwater salinity is characterised by two salinity zones in the Lower Gwydir Alluvium SDL area, ranging from 0 – 3000 mg/L TDS. The portion of groundwater characterised by salinity zone 2 is small (i.e. less than 2 percent) and hence has been combined with the area characterised by salinity zone 1 groundwater. The groundwater salinity distribution can be seen in Figure 3 and is summarised in Table 8.

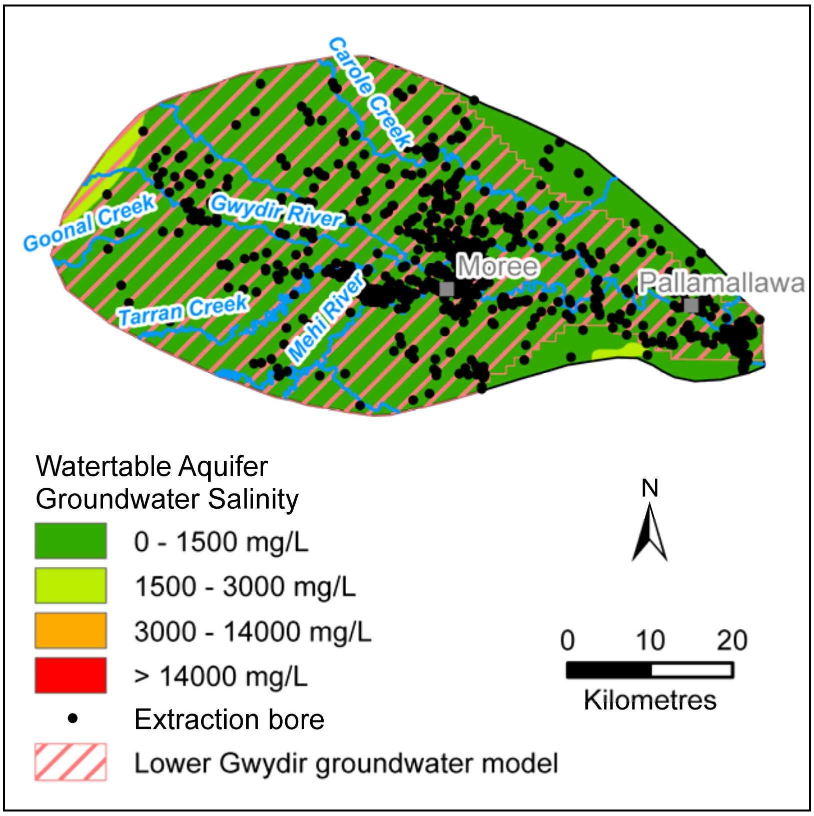

Figure 3. Lower Gwydir Alluvium watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 8. Summary of salinity zones in the Lower Gwydir Alluvium SDL area

Watertable salinity zone	Portion of area	Area)
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	98	2463
Zone 2 (1500–3000 mg/L TDS)	2	50
Zone 3 (3000–14,000 mg/L TDS)	0	0
Zone 4 (>14,000 mg/L TDS)	0	0
Water bodies	0	0
Total	**100**	**2513**

1.2.3 Key environmental assets

There are no groundwater dependent ecosystems sensitive to take in the Lower Gwydir SDL area and therefore there is a low risk to the key environmental asset.

1.2.4 Key ecosystem function

Figure 4 shows the annual net river loss due to groundwater pumping in the Lower Gwydir numerical model. Approximately 25 GL/year groundwater extraction is derived from the river, under the scenario of 2004/2005 development and historical climate. This indicates that there is approximately 75 percent connectivity between the groundwater and surface water systems.

The key ecosystem function of the Lower Gwydir Alluvium SDL area is at medium risk, given that the connectivity between the groundwater and surface water is high and the river is regulated.

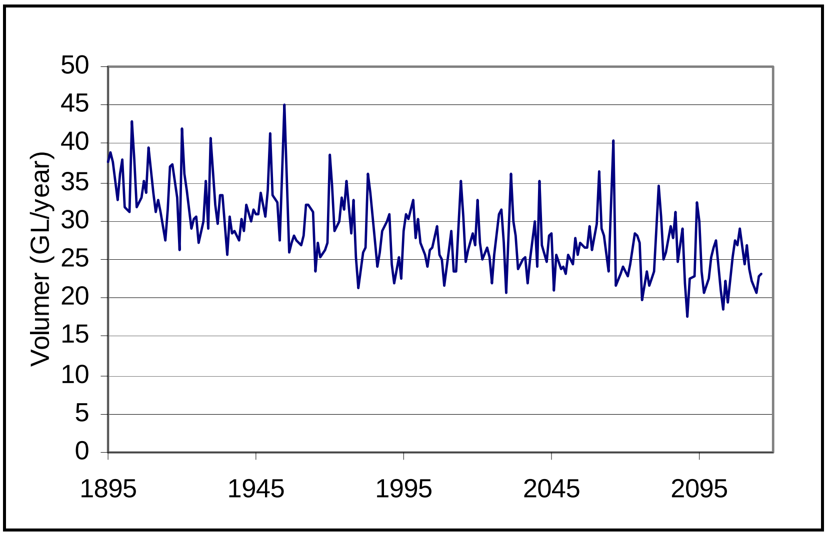

Figure 4. Annual net river loss due to groundwater extraction in the Lower Gwydir numerical model, under the 2004/2005 groundwater development scenario

1.2.5 Productive base

Recharge

Given that 90 percent of the SDL area is represented by the Lower Gwydir numerical model, the recharge derived from the model has been used for the entire SDL area.

The results of the Lower Gwydir Alluvium numerical modelling that occurred for the Murray-Darling Basin Sustainable Yields Project study (CSIRO, 2007a) have been used to estimate recharge in this unit. The numerical model includes the following recharge components; rainfall infiltration, irrigation, river losses and lateral flow. Average annual recharge under the 2004/2005 groundwater development scenario was 51 GL/year (Table 9).

The entire Lower Gwydir Alluvium SDL area is classified as salinity zone 1 and therefore this volume is entirely assigned to this salinity zone.

Table 9. Modelled average annual groundwater balance for the Lower Gwydir Alluvium GMU under the second 111-year period und the 2004/2005 groundwater development scenario

	GL/year
Recharge - gains	
Rainfall	15
Irrigation	6.5
River system	22
Lateral flow	7.7
Total	**51**
Discharge – losses	
Extraction	32
Rivers	5.3
Lateral flow	11
Total	**48**

Storage

The sedimentary sequence, including the Narrabri and Gunnedah Formation aquifers, range in thickness from approximately 30 m to 90 m each, across the model domain. An average thickness of 30 m has been assumed for each aquifer for the purpose of the storage calculation. The specific yield of the unconfined Narrabri Formation aquifer ranges from 0.05 to 0.35 across the model domain. An average specific yield of 0.20 has been assumed for the purpose of the storage calculation.

Total storage estimated for the alluvial aquifers, is approximately 15,000 GL per aquifer (Table 10).

Table 10. Storage calculation

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km2)	2513	0	0	0
Saturated thickness (m)	30	N/A	N/A	N/A
Specific yield	0.20	N/A	N/A	N/A
Total storage (GL)	**15,076**	**N/A**	**N/A**	**N/A**

Storage relative to recharge

The ratio of storage to recharge is 296. This indicates that there is a low risk of the productive base of the aquifer being jeopardised by factors such as climate change and the short-term over extraction of the groundwater resource.

1.2.6 The risk matrix

Table 11 provides a summary of the risk ranking associated with: key environmental assets, key ecosystem function, the productive base, the key environmental outcome and the uncertainty inherent in the RRAM calculation. In summary:

- the SDL area is ranked low risk in terms of key environmental assets, given none have been identified that are groundwater dependent in this area
- the SDL area is ranked medium risk in terms of ecosystem function, given that there is approximately 75 percent groundwater and surface water connectivity and the rivers are regulated

- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio far exceeds 40
- there is a risk to the key environmental outcomes (i.e. groundwater salinity)
- there is a low uncertainty given that groundwater recharge was derived from a numerical model for the area.

Table 11. Risk matrix

Risk ranking	Environmental assets (EAs)	OR	Ecosystem function	OR	Productive base	Sustainability factor (SF)	Key environmental outcome	Degree of uncertainty
High	EA that is highly groundwater dependent and highly sensitive to take		In the current state, groundwater discharge provides baseflow to the unregulated river reach. Groundwater extraction is likely to result in streamflow depletion		Storage/ recharge <20	0.10	Where there is no risk to the key environmental outcome (i.e. groundwater salinity) there is no reduction to the SF for any of the salinity classes. Where there is a risk to the key environmental outcome, as a measure to reduce risk to groundwater quality, the following reductions are made: Salinity class 1: reduce SF by 20% Salinity class 2: reduce SF by 10% Salinity classes 3 & 4: no reduction	Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 50%
Medium	EA that is highly groundwater dependent and is moderately sensitive to take EA that is moderately groundwater dependent and is highly sensitive to take		The rivers in the SDL unit are regulated and they are highly connected to the groundwater system (i.e. >50% impact of pumping on streamflow)		Storage/ recharge 20–40	0.50		
Low	EA that has a low groundwater dependence and low sensitivity to take EAs do not exist in the SDL unit		The rivers in the SDL unit are regulated or unregulated and they have low–moderate connection with the groundwater system (i.e. <50% impact of pumping on streamflow)		Storage/ recharge >40	0.70		Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 25%

1.2.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Lower Gwydir SDL area is 20 GL/year. The RRAM extraction limit was based on the Murray-Darling Basin Sustainable Yields Project Lower Gwydir Alluvium numerical modelling results (CSIRO, 2007a) as these provided the best available information at the time of the RRAM analysis.

This preliminary RRAM extraction limit has been superseded by more recent modelling results (CSIRO, 2010b).

Table 12. Extraction limit summary

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	51	0	0	0
Sustainability factor	0.40	N/A	N/A	N/A
Extraction limit (GL/yr)	**20**	**N/A**	**N/A**	**N/A**

1.3 Lower Namoi Alluvium (GS43)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the RRAM for the Lower Namoi Alluvium SDL area.

1.3.1 Background

The Lower Namoi Alluvium SDL area corresponds to the area of the Lower Namoi Alluvium GMU. The Lower Namoi numerical model covers 70 percent of the SDL area. The model boundary is similar to the SDL area boundary in the north, east and south; however the western boundary of the model falls short of the western edge of the SDL area by about 45 km. (CSIRO, 2007b). The LTAEL defined for the Water Sharing Plan for the Lower Namoi Groundwater Sources 2003 includes an extraction limit of 86 GL/year plus 21 GL/year available to supplementary water access licences, which are to reduce to 0 GL/yr by June 2017, plus basic landholder rights.

Current groundwater use in the non-modelled part of the Lower Namoi Alluvium SDL area is 2.2 GL/year (Table 13). Total groundwater use for the entire SDL area is 102 GL/yr. For more information regarding the source of the entitlement and use information, refer to CSIRO (2010k).

The Lower Namoi Alluvium SDL area contains three main aquifers, the unconfined Narrabri Formation, the semi-confined Gunnedah Formation and the confined Cubbaroo Formation. The upper aquifers are laterally extensive, whereas the Cubbaroo Formation is a palaeochannel facies with limited extent. Each of these aquifers is represented by a discrete layer in the numerical model (CSIRO, 2007b). These unconsolidated sediment layers overlie sandstone of the Great Artesian Basin (GAB).

A preliminary RRAM extraction limit has been determined for the modelled part and the non-modelled part of the Lower Namoi Alluvium, based on the results of the CSIRO (2007b) Lower Namoi numerical model.

Table 13. Groundwater take summary for the non modelled part of the Lower Namoi Alluvium SDL area

Lower Namoi Alluvium SDL area (non modelled area)	GL/year
Entitlement*	**7.7**
Current use for entitlement bores**	2.0
Estimated use for stock & domestic bores***	0.18
Total 2007/2008 use	**2.2**

*2007/2008 entitlement data was provided by DECCW
**Current Use is the average annual metered use volume from 2003/2004 to 2007/2008
***Estimated use for stock and domestic bores was provided by DECCW

1.3.2 Salinity zoning

The groundwater salinity map for the watertable aquifer has been used to define the SDL for the Lower Namoi Alluvium SLD Unit. There is no groundwater salinity map available for the Gunnedah Formation aquifer (i.e. the deeper aquifer).

Groundwater salinity is characterised by four salinity zones in the Lower Namoi Alluvium SDL area, ranging from 0 – > 14,000 mg/L TDS. The groundwater salinity distribution can be seen in Figure 5 and is summarised in Table 14.

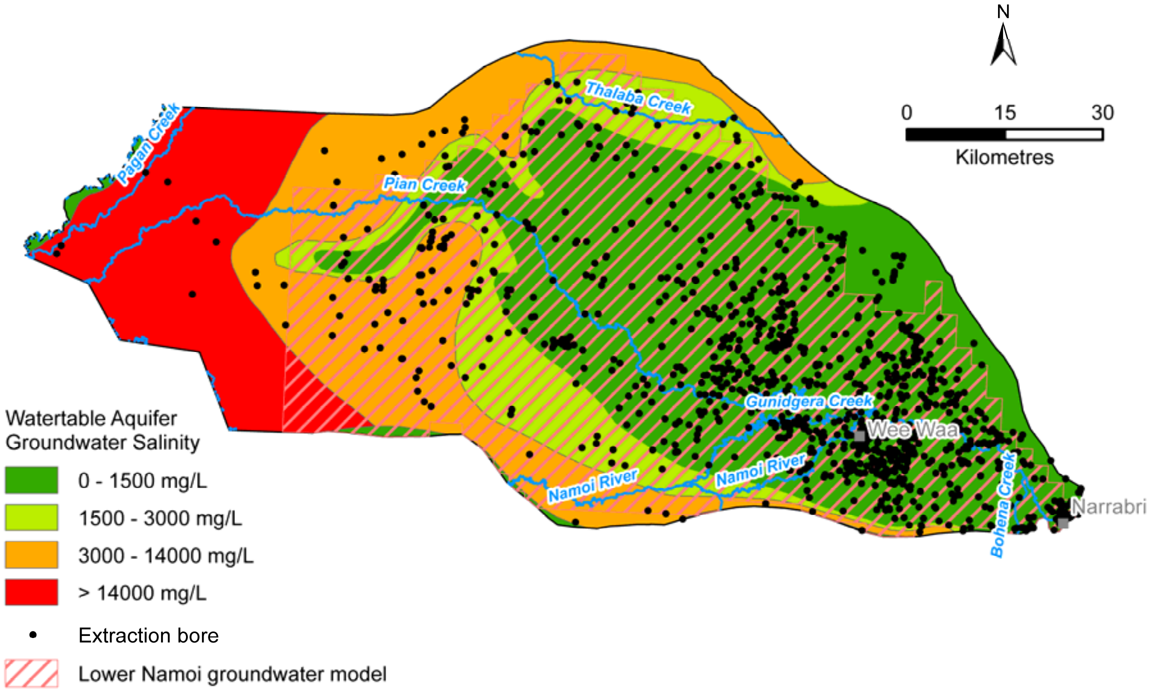

Figure 5. Lower Namoi Alluvium watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 14. Summary of salinity zones in the Lower Namoi Alluvium SDL area

Watertable salinity zone	Portion of area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	48	3648
Zone 2 (1500–3000 mg/L TDS)	14	1028
Zone 3 (3000–14,000 mg/L TDS)	23	1744
Zone 4 (>14,000 mg/L TDS)	15	1171
Water bodies	0	0
Total	100	7592

1.3.3 Key environmental assets

There are no key environmental assets that are groundwater dependent and sensitive to take in the Lower Namoi Alluvium SDL area.

1.3.4 Key ecosystem function

The impact of groundwater pumping on river flow in the Lower Namoi numerical model was assessed by comparing river flow in the no-development scenario and the scenario that incorporated a historical climate and 2004/2005 groundwater extraction (i.e. 87 GL/year). Figure 6 shows this impact and indicates that within a typical planning time-frame of approximately 50 years, the annual river flow reduction is approximately 40 GL/year.

The Key Ecosystem Function of the Lower Namoi Alluvium SDL area is at low risk, given that the connectivity between the groundwater and surface water is approximately 45 percent.

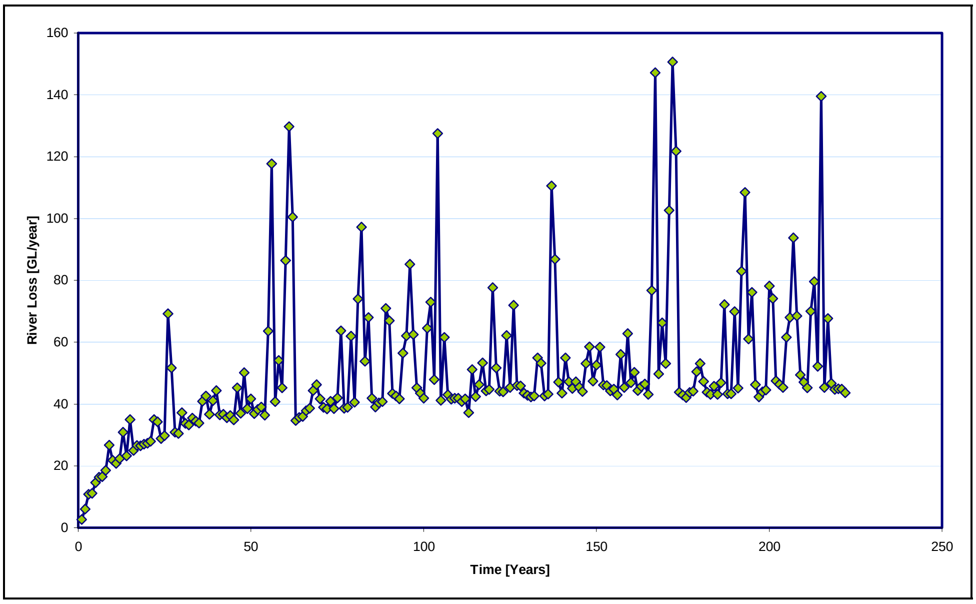

Figure 6. Change in river loss between the no-development and the 2004/2005 groundwater development scenario; from the Lower Namoi numerical model

1.3.5 Productive base

Recharge

The numerical model mass balance results have been used to calculate the preliminary extraction limit for the portion of the unit that is represented by the model domain (i.e. 70 percent of the total area). Recharge to the Lower Namoi Alluvial aquifers occurs via; rainfall infiltration, seepage from irrigation, rivers, creeks and floods and via lateral flow (CSIRO, 2007b). Average annual recharge under the 2004/2005 groundwater development scenario was 81 GL/year (Table 15). This recharge volume has been apportioned to each of the salinity zones within the part of the unit represented by the numerical model (Table 16).

For the remaining non-modelled part of the unit (i.e. 30 percent of the total area), the rainfall recharge value derived from the numerical model was used to calculate the preliminary extraction limit. It was not considered reasonable to extrapolate the mass balance results for the numerical model, as a major component of the inflows is river leakage and this is not expected to occur to such a high degree outside of the model domain. The average rainfall recharge rate for the numerical model is 3.0 mm/year. This rate was applied to each of the salinity zones within the non-modelled part of the numerical model and total recharge to the area equates to 6.9 GL/year (Table 17).

Table 15. Average annual fluxes into and out of the groundwater system (second 111 years) in the Lower Namoi, under 2004/2005 groundwater development (CSIRO, 2007b)

	GL/year
Recharge – gains	
Rainfall and irrigation	41
River system	32
Lateral flow	8
Total	**81**
Discharge – losses	
Extraction	83
Rivers	6
Lateral flow	9
Total	**98**

Table 16. Recharge apportioned to the salinity zones in the numerical model

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km2)	3245	904	1046	90
Recharge (GL/yr)	**50**	**14**	**16**	**1**

Table 17. Recharge in the non-modelled part of the SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km2)	402	124	698	1081
Recharge rate (mm/yr)	3.0	3.0	3.0	3.0
Recharge (GL/yr)	**1.2**	**0.37**	**2.1**	**3.2**

Storage

The Narrabri Formation ranges in thickness from 10 m to 40 m. The Gunnedah Formation reaches a thickness of 80 m and the Cubbaroo Formation is up to 60 m thick (CSIRO, 2007b). An average thickness of 100 m has been estimated for the alluvial sequence within the Lower Namoi. The specific yield was set to 0.10 for all cells in all layers. Based on these parameters, a total storage volume of 76,000 GL has been estimated for the Lower Namoi Alluvium (Table 18).

Table 18. Storage calculation

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km2)	3648	1028	1744	1171
Saturated thickness (m)	100	100	100	100
Specific yield	0.1	0.1	0.1	0.1
Total storage (GL)	36,480	10,280	17,440	11,710

Storage relative to recharge

The ratio of storage to recharge ranges from 713 to 2,788 for each of the salinity zones. This indicates that there is a low risk of the productive base of the aquifer being jeopardised by factors such as climate change and the short-term over extraction of the groundwater resource.

1.3.6 The risk matrix

Table 19 provides a summary of the risk ranking associated with: key environmental assets, key ecosystem function, the productive base, the key environmental outcome and the uncertainty inherent in the RRAM calculation. In summary:

- the SDL area is ranked low risk in terms of key environmental assets, given none have been identified that are groundwater dependent in this area
- the SDL area in the modelled area is ranked low risk in terms of ecosystem function, given that there is approximately 45 percent groundwater and surface water connectivity. The SDL area in the non-modelled area is also ranked low risk in terms of ecosystem function, given that the river leakage component of recharge was not included in the extrapolation of recharge in the non-modelled area, given the conceptualisation is that there is poor connection with surface water in this area
- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio far exceeds 40
- there is a risk to the key environmental outcome (i.e. groundwater salinity)
- there is a low uncertainty for both the modelled and non-modelled parts of the SDL area, given that recharge estimates were derived from numerical modelling and also because there is an annual groundwater status report for the entire area.

Table 19 .Risk matrix

Risk ranking	Environmental assets (EAs)	OR	Ecosystem function	OR	Productive base	Sustainability factor (SF)	Key environmental outcome	Degree of uncertainty
High	EA that is highly groundwater dependent and highly sensitive to take		In the current state, groundwater discharge provides baseflow to the unregulated river reach. Groundwater extraction is likely to result in streamflow depletion		Storage/ recharge <20	0.10	Where there is no risk to the key environmental outcome (i.e. groundwater salinity) there is no reduction to the SF for any of the salinity classes. Where there is a risk to the key environmental outcome, as a measure to reduce risk to groundwater quality, the following reductions are made: Salinity class 1: reduce SF by 20% Salinity class 2: reduce SF by 10% Salinity classes 3 & 4: no reduction	Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 50%
Medium	EA that is highly groundwater dependent and is moderately sensitive to take EA that is moderately groundwater dependent and is highly sensitive to take		The rivers in the SDL unit are regulated and they are highly connected to the groundwater system (i.e. >50% impact of pumping on streamflow)		Storage/ recharge 20–40	0.50		
Low	EA that has a low groundwater dependence and low sensitivity to take EAs do not exist in the SDL unit		The rivers in the SDL unit are regulated or unregulated and they have low–moderate connection with the groundwater system (i.e. <50% impact of pumping on streamflow)		Storage/ recharge >40	0.70		Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 25%

1.3.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the modelled part of the Lower Namoi SDL area is 49 GL/year (Table 20). The RRAM extraction limit was based on the Murray-Darling Basin Sustainable Yields Project Lower Namoi Alluvium numerical modelling results (CSIRO, 2007b) as these provided the best available information at the time of the RRAM analysis.

The preliminary RRAM extraction limit for the modelled part of the Lower Namoi SDL area has been superseded by more recent modelling results (CSIRO, 2010c).

The RRAM extraction limit for the non modelled part of the Lower Namoi SDL area is 4.6 GL/year (Table 21).

Table 20. Summary for the modelled part of the Lower Namoi Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	50	14	16	1.0
Sustainability factor	0.56	0.63	0.7	0.7
Extraction limit (GL/yr)	**28**	**8.8**	**11**	**0.70**

Table 21. Summary for the non-modelled part of the Lower Namoi Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	1.2	0.37	2.1	3.2
Sustainability factor	0.56	0.63	0.7	0.7
Extraction limit (GL/yr)	**0.68**	**0.23**	**1.5**	**2.3**

1.4 Upper Namoi Alluvium (GS60)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the RRAM for the Upper Namoi Alluvium SDL area.

1.4.1 Background

The Upper Namoi Alluvium SDL area corresponds to the area of the Upper Namoi Alluvium GMU. The Upper Namoi Alluvium GMU is subdivided into 12 zones (numbered 1 to 12). The Upper Namoi Alluvium numerical model represents zones 2, 3, 4, 5, 11 and 12. The non modelled part of the unit includes the remaining zones; 1, 6, 7, 8, 9 and 10. A summary of the LTAEL for each zone is provided in Table 22. The total LTAEL for the Upper Namoi Alluvium is 122 GL/year. The total volume of supplementary water access licences is 38 GL/year (these will be reduced to 0 by June 2017).

The sum of current use in the non-modelled part of the unit is 22 GL/year (Table 23). Total groundwater use for the entire SDL area is 99 GL/y. For more information regarding the source of the entitlement and use information, refer to CSIRO (2010k).

The Upper Namoi numerical model covers 63 percent of the SDL area, including the north and central zones of the SDL area. This model represents the two main alluvial aquifers; the unconfined Narrabri Formation and the basal Gunnedah Formation, as separate layers (CSIRO, 2007b).

Two extraction limits have been determined for the Upper Namoi Alluvium, one for the modelled and the other for the non-modelled part of the unit.

Table 22. Summary of long-term average extraction limits in the Upper Namoi Alluvium

Zone	LTAEL (GL/yr)	Zone representation
2	7.2	Modelled
3	17	Modelled
4	26	Modelled
5	16	Modelled
11	2.2	Modelled
12	2.0	Modelled
Modelled total		**70**
1	2.1	Non Modelled
6	14	Non Modelled
7	3.7	Non Modelled
8	16	Non Modelled
9	11	Non Modelled
10	4.5	Non Modelled
Non modelled total		**51**
Upper Namoi Alluvium total		**122**

Table 23. Groundwater take summary for the non modelled part of the Upper Namoi Alluvium SDL area

Upper Namoi Alluvium SDL area – non-modelled area	GL/year
Entitlement*	**52**
Current use for entitlement bores**	22
Estimated use for stock & domestic bores***	0.30
Total Current Use	**22**

*Entitlement is equivalent to the LTAEL for each of the non-modelled zones
**Current use is the average annual metered use volume over the period 2003/2004 to 2007/2008
***Estimated use for stock and domestic bores was provided by DECCW

1.4.2 Salinity zoning

The groundwater salinity map for the watertable aquifer has been used to define extraction limits for each of the salinity classes.

Groundwater salinity is characterised by three salinity zones in the Upper Namoi Alluvium SDL area, ranging from 0 – 14,000 mg/L TDS. The portion of groundwater characterised by salinity zones 2 and 3 are small, accounting for approximately 4 percent of the total area and hence, the entire area has been classified as salinity zone 1, for the purpose of the RRAM assessment. Groundwater salinity distribution can be seen in Figure 7 and is summarised in Table 24.

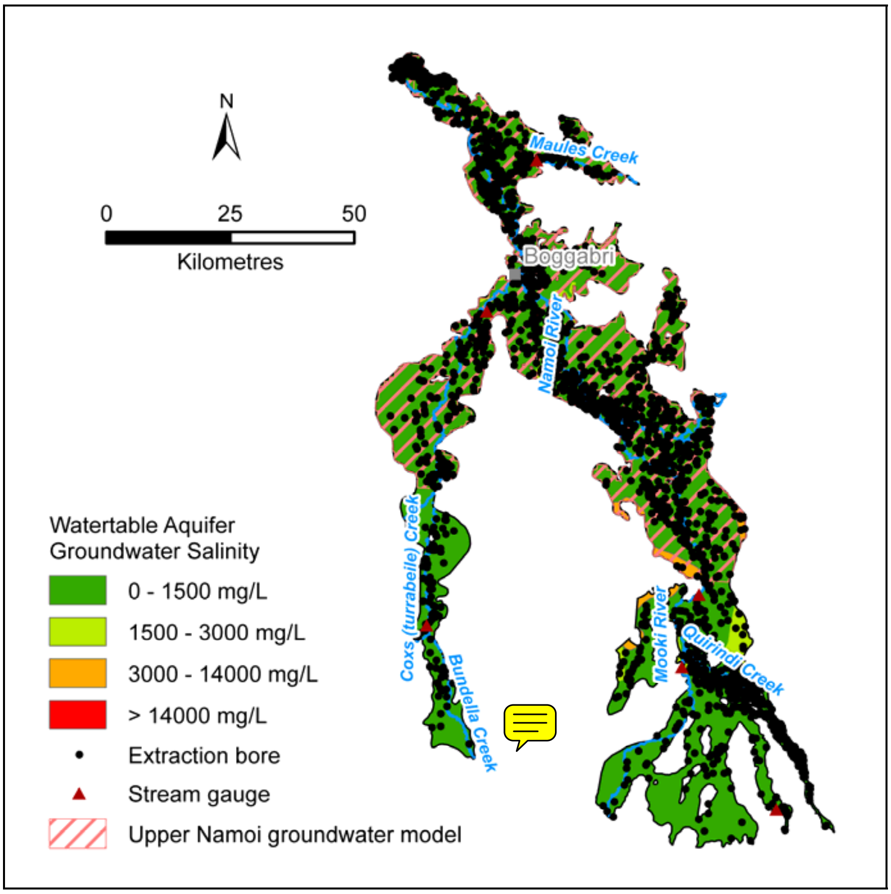

Figure 7. Upper Namoi Alluvium watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 24. Summary of salinity zones in the Upper Namoi Alluvium SDL area

Watertable salinity zone	Modelled area	Modelled area	Non modelled area	Non modelled area
	km^2	percent	km^2	percent
Zone 1 (0–1500 mg/L TDS)	2296	97	1316	94
Zone 2 (1500–3000 mg/L TDS)	22	1	69	5
Zone 3 (3000–14,000 mg/L TDS)	47	2	21	1
Zone 4 (>14,000 mg/L TDS)	0	0	0	0
Total	**2365**	**100**	**1406**	**100**

1.4.3 Key environmental assets

There are no key environmental assets in the Upper Namoi Alluvium SDL area that are groundwater dependent and sensitive to take.

1.4.4 Key ecosystem function

A no-development scenario does not exist for the Upper Namoi modelled area and hence there was no ability to determine groundwater – surface water connectivity by comparing river loss in a no-development and 2004/2005 development scenario.

The Upper Namoi model indicates good connection to the river and that any change in flux is offset by changes in fluxes from the river with about 85 percent connectivity.

The upper river reaches in the non modelled part of the unit are also unregulated. The risk ranking for key ecosystem function is high. A lower risk ranking may be achieved via prudent water resource planning according to the requirements of the Basin Plan. Local management rules will be difficult to define in this system because the system is narrow and time-lags are short. It will be up to New South Wales to define these rules and the Murray-Darling Basin Authority to endorse them.

1.4.5 Productive base

Recharge

The results of the Upper Namoi Alluvium numerical modelling that occurred for the Murray-Darling Basin Sustainable Yields Project study (CSIRO, 2007b) have been used to estimate recharge in this unit. The Upper Namoi numerical model includes recharge via; dryland rainfall, flooding, irrigation, river leakage, hillslope runoff and lateral flow. Average annual recharge under the 2004/2005 groundwater development scenario was 73 GL/year (Table 25). This entire recharge volume has been assigned to salinity zone 1 of the modelled part of the SDL area.

For the non modelled part of the SDL area, the hydrogeological understandings gained from the numerical modelling results have been used to derive an extraction limit for groundwater management Zone 1 and Zone 8. The hydrogeological setting present in these zones is similar to that of the modelled management zones and hence the modelling outcome (namely that the current levels of extraction are sustainable due to the influence of groundwater surface water interaction) is assumed to hold for these management zones (LTAEL for zone 1 = 2.1 GL/year and LTAEL for zone 8 = 16 GL/year).

For the remaining non modelled management zones, recharge rates consistent with the Upper Namoi numerical model (including natural recharge, lateral fluxes and river leakage) was assessed as applicable. A recharge rate of 18 mm/year was applied to the area of these zones, equating to a recharge volume of 18 GL/year (Table 26).

Table 25. Average annual fluxes into and out of the groundwater system (second 111 years) in the Upper Namoi, under 2004/2005 groundwater development (CSIRO, 2007b)

	GL/year
Recharge - gains	
Dryland rainfall recharge	21
Flood recharge	4.5
Irrigation recharge	17
River system	24
Lateral flow	3.9
Hillslope run-on	2.5
Total	**73**
Discharge – losses	
Extraction	70
Rivers	2.4
Lateral flow	1.7
Total	**74**

Table 26. Recharge calculation for non modelled Zones 6, 7, 9, and 10

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km2)	981	0	0	0
Recharge to zones 6,7,9,10 (GL/yr)	18	N/A	N/A	N/A
Total recharge (GL/yr)	**18**	**N/A**	**N/A**	**N/A**

Storage

The Gunnedah Formation reaches a maximum thickness of 115 m and the overlying Narrabri Formation reaches a maximum thickness of 70 m (CSIRO, 2007b). An average thickness of 120 m has been used for the purpose of this storage estimate. The average specific yield for the Narrabri Formation aquifer (0.04) has been adopted for the storage calculation (McNeilage, 2006).

The total storage estimated for the Upper Namoi Alluvium SDL area is 18,101 GL (Table 27).

Table 27. Storage calculation

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km2)	3771	0	0	0
Saturated thickness (m)	120	N/A	N/A	N/A
Specific yield	0.04	N/A	N/A	N/A
Total storage (GL)	**18,101**	**N/A**	**N/A**	**N/A**

Storage relative to recharge

The ratio of storage to recharge is 199 for the entire alluvial sequence. This indicates that there is a low risk of the productive base of the aquifer being jeopardised by factors such as climate change and the short-term over extraction of the groundwater resource.

1.4.6 The risk matrix

Table 28 provides a summary of the risk ranking associated with: key environmental assets, key ecosystem function, the productive base, the key environmental outcome and the uncertainty inherent in the RRAM calculation. In summary:

- the SDL area is ranked low risk in terms of key environmental assets, given none have been identified that are groundwater dependent in this area
- the SDL area is ranked medium risk in terms of ecosystem function, however water resource plan requirements will be required to mitigate the risks to the unregulated gaining river reaches
- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio exceeds 40
- there is a risk to the key environmental outcome (i.e. groundwater salinity)
- there is a low level of uncertainty given that the modelled and non modelled extraction limits are based on numerical modelling results.

Table 28. Risk matrix

Risk ranking	Environmental assets (EAs)	OR	Ecosystem function	OR	Productive base	Sustainability factor (SF)	Key environmental outcome	Degree of uncertainty
High	EA that is highly groundwater dependent and highly sensitive to take		In the current state, groundwater discharge provides baseflow to the unregulated river reach. Groundwater extraction is likely to result in streamflow depletion		Storage/ recharge <20	0.10	Where there is no risk to the key environmental outcome (i.e. groundwater salinity) there is no reduction to the SF for any of the salinity classes. Where there is a risk to the key environmental outcome, as a measure to reduce risk to groundwater quality, the following reductions are made: Salinity class 1: reduce SF by 20% Salinity class 2: reduce SF by 10% Salinity classes 3 & 4: no reduction	Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 50%
Medium	EA that is highly groundwater dependent and is moderately sensitive to take EA that is moderately groundwater dependent and is highly sensitive to take		The rivers in the SDL unit are regulated and they are highly connected to the groundwater system (i.e. >50% impact of pumping on streamflow)		Storage/ recharge 20–40	0.50		
Low	EA that has a low groundwater dependence and low sensitivity to take EAs do not exist in the SDL unit		The rivers in the SDL unit are regulated or unregulated and they have low–moderate connection with the groundwater system (i.e. <50% impact of pumping on streamflow)		Storage/ recharge >40	0.70		Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 25%

1.4.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the modelled part of the Upper Namoi SDL area is 29 GL/year (Table 29). The RRAM extraction limit was based on the Murray-Darling Basin Sustainable Yields Project Upper Namoi Alluvium numerical modelling results (CSIRO, 2007b) as these provided the best available information at the time of the RRAM analysis.

The preliminary RRAM extraction limit for the Upper Namoi Alluvium SDL area has been superseded by more recent modelling results (CSIRO, 2010d).

For the non-modelled part of the Upper Namoi SDL area, the extraction limit is 25 GL/year (Table 30).

Table 29. Preliminary extraction limit summary for the part of the Upper Namoi SDL area represented by the Upper Namoi Alluvium numerical model

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge to modelled zones (GL/yr)	73	0	0	0
Sustainability factor	0.40	N/A	N/A	N/A
Extraction limit for modelled zones (GL/yr)	**29**	**N/A**	**N/A**	**N/A**

Table 30. Preliminary extraction limit summary for the non-modelled part of the Upper Namoi SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge to non modelled zones 6, 7, 9 & 10 (GL/yr)	18	0	0	0
Sustainability factor	0.40	N/A	N/A	N/A
Extraction limit for Zones 6, 7, 9 & 10 (GL/yr)	7.2	N/A	N/A	N/A
Extraction limit for Zone 1 + Zone 8 (GL/yr)*	18	N/A	N/A	N/A
Total extraction limit (Zones 1, 6, 1, 8, 9 & 10) (GL/yr)	**25**	**N/A**	**N/A**	**N/A**

*Extraction limits for zones 1 and 8 equates to the LTAELs for these zones

1.5 Upper Macquarie Alluvium (GS58)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the RRAM for the Upper Macquarie Alluvium SDL area.

1.5.1 Background

The Upper Macquarie Alluvium SDL area corresponds to the Upper Macquarie Alluvium GMU boundary. 96 percent of the SDL area is covered by the Upper Macquarie Alluvium numerical model. The numerical model is larger than the SDL area, extending further downstream to its convergence with the Lower Macquarie SDL area and is also wider than the SDL area. There is no water sharing plan specific to the groundwater sources of the Upper Macquarie Alluvium SDL area. Current groundwater use is 14.3 GL/year, which includes an estimate for stock and domestic use. For more information regarding the source of the entitlement and use information, refer to CSIRO (2010k).

1.5.2 Salinity zoning

The groundwater salinity map for the watertable aquifer has been used to define extraction limits for each of the salinity classes.

Groundwater salinity is characterised by three salinity zones in the Upper Macquarie Alluvium SDL area, ranging from 0 – 14,000 mg/L TDS. Most of the area is characterised by salinity zone 2. The groundwater salinity distribution can be seen in Figure 8 and is summarised in Table 31.

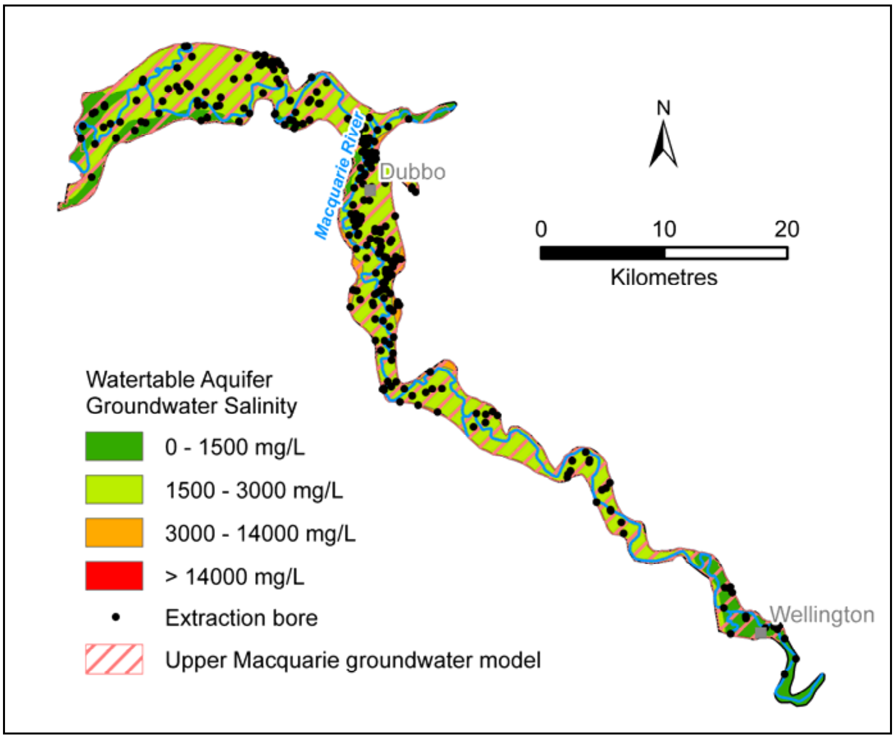

Figure 8. Upper Macquarie Alluvium watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 31. Summary of salinity zones in the Upper Macquarie Alluvium SDL area

Watertable salinity zone	Portion of area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	19	55
Zone 2 (1500–3000 mg/L TDS)	78	226
Zone 3 (3000–14,000 mg/L TDS)	3	9
Zone 4 (>14,000 mg/L TDS)	0	0
Water bodies	0	0
Total	100	290

1.5.3 Key environmental assets

There are no key environmental assets that are groundwater dependent and sensitive to take in this SDL area.

1.5.4 Key ecosystem function

Given that the Upper Macquarie River is regulated and that connectivity between the narrow alluvial aquifer and the river is high, the key ecosystem function is at medium risk.

1.5.5 Productive base

Recharge

Given that 96 percent of the SDL area is represented by the Upper Macquarie numerical model, the recharge derived from the model has been used for the entire SDL area (SKM, 2010). Table 32 summarises the mass balance for the calibration model. The mass balance was derived from a zone budget for the SDL area boundary. The total recharge to the system over the calibration period (1980 to 2008) averages 13 GL/year.

This recharge volume has been apportioned to each of the salinity zones in the Upper Macquarie SDL area, according to the relative size of each of the salinity zone areas (Table 33).

Table 32. Water balance for the Upper Macquarie SDL area

	GL/year
Recharge - gains	
Recharge	5.4
River system	6.7
Lateral flow	1.0
Total	**13**
Discharge – losses	
Extraction	10
Rivers	7.7
Lateral flow	0.40
Evapotranspiration	0.50
Total	**19**

Table 33. Recharge calculation – from the numerical groundwater model

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km2)	55	236	9	0
Recharge (GL/yr)	2.5	10	0.42	N/A
Total recharge to SDL area (GL/yr)		**13**		

Storage

The average thickness of the alluvial sequence in the Upper Macquarie is 50 m. The average specific yield was 0.15 (SKM, 2010)

Total storage estimated for the Upper Macquarie Alluvium SDL area is 2252 GL (Table 34).

Table 34. Storage calculation

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km2)	55	236	9	0
Saturated thickness (m)	50	50	50	0
Specific yield	0.15	0.15	0.15	0
Total storage (GL)	414	1767	71	0

Storage relative to recharge

The ratio of storage to recharge ranges from 166 to 177 for each of the salinity zones. This indicates that there is a low risk of the productive base of the aquifer being jeopardised by factors such as climate change and the short-term over extraction of the groundwater resource.

1.5.6 The risk matrix

Table 35 provides a summary of the risk ranking associated with: key environmental assets, key ecosystem function, the productive base, the key environmental outcome and the uncertainty inherent in the RRAM calculation. In summary:

- the SDL area is ranked low risk in terms of key environmental assets, given none have been identified that are groundwater dependent in this area
- the SDL area is ranked medium risk in terms of ecosystem function, given that the river is regulated and there is a strong connection between groundwater and surface water
- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio far exceeds 40
- there is no risk to the key environmental outcomes (i.e. groundwater salinity)
- there is a low uncertainty associated with this RRAM calculation given that a numerical model exists for the area.

Table 35. Risk matrix

<table>
<tr><th>Risk ranking</th><th>Environmental assets (EAs)</th><th>OR</th><th>Ecosystem function</th><th>OR</th><th>Productive base</th><th>Sustainability factor (SF)</th><th>Key environmental outcome</th><th>Degree of uncertainty</th></tr>
<tr><td>High</td><td>EA that is highly groundwater dependent and highly sensitive to take</td><td rowspan="3"></td><td>In the current state, groundwater discharge provides baseflow to the unregulated river reach. Groundwater extraction is likely to result in streamflow depletion</td><td rowspan="3"></td><td>Storage/ recharge <20</td><td>0.10</td><td rowspan="3">Where there is no risk to the key environmental outcome (i.e. groundwater salinity) there is no reduction to the SF for any of the salinity classes.

Where there is a risk to the key environmental outcome, as a measure to reduce risk to groundwater quality, the following reductions are made:

Salinity class 1: reduce SF by 20%

Salinity class 2: reduce SF by 10%

Salinity classes 3 & 4: no reduction</td><td rowspan="2">Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF

Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 50%</td></tr>
<tr><td>Medium</td><td>EA that is highly groundwater dependent and is moderately sensitive to take

EA that is moderately groundwater dependent and is highly sensitive to take</td><td>The rivers in the SDL unit are regulated and they are highly connected to the groundwater system (i.e. >50% impact of pumping on streamflow)</td><td>Storage/ recharge 20–40</td><td>0.50</td></tr>
<tr><td>Low</td><td>EA that has a low groundwater dependence and low sensitivity to take

EAs do not exist in the SDL unit</td><td>The rivers in the SDL unit are regulated or unregulated and they have low–moderate connection with the groundwater system (i.e. <50% impact of pumping on streamflow)</td><td>Storage/ recharge >40</td><td>0.70</td><td>Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF

Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 25%</td></tr>
</table>

1.5.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Upper Macquarie Alluvium SDL area is 6.6 GL/year. The RRAM extraction limit was based on the Upper Macquarie Alluvium numerical modelling results (SKM, 2010) as these provided the best available information at the time of the RRAM analysis.

The preliminary RRAM extraction limit for the Upper Macquarie Alluvium SDL area has been superseded by more recent modelling results (CSIRO, 2010e).

Table 36. Extraction limit summary for the Upper Macquarie Alluvium

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	2.5	10	0.42	N/A
Sustainability factor	0.50	0.50	0.50	N/A
Extraction limit (GL/yr)	**1.2**	**5.1**	**0.21**	**N/A**

1.6 Upper Lachlan Alluvium (GS57)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the RRAM for the Upper Lachlan SDL area.

1.6.1 Background

The Upper Lachlan Alluvium SDL area correlates to the area of the Upper Lachlan Alluvium GMU. The Upper Lachlan numerical model covers 41 percent of the SDL area. The model boundaries are similar to the SDL area bounds in the north and east, but the southern and western portions of the SDL area are not covered by the model. There is no water sharing plan specific to the groundwater sources of the Upper Lachlan Alluvium SDL area.

Current use in the Upper Lachlan Alluvium model domain is 48.4 GL/year. For the non-modelled part of the unit, current use is 7.5 GL/year (Table 37). Total groundwater use for the entire SDL area is 56 GL/yr. For more information regarding the source of the entitlement and use information, refer to CSIRO (2010k).

The Upper Lachlan Alluvium SDL area contains two main aquifers: the unconfined Cowra Formation and the semi-confined Lachlan Formation, which is a palaeochannel facies with limited extent. The two aquifers are represented by discrete layers in the numerical model, with the Cowra Formation being represented by two layers: an upper unconfined layer and a lower semi-confined layer (CSIRO, 2008a).

An extraction limit has been determined for the Lachlan Formation of the Upper Lachlan Alluvium SDL area.

Table 37. Groundwater take summary for the non modelled part of the Upper Lachlan Alluvium SDL area

Upper Lachlan Alluvium SDL area (non modelled)	GL/year
Total 2007/2008 entitlement*	21
Current Use for entitlement bores**	4.3
Estimated use for stock & domestic bores***	3.2
Total Current Use	7.5

*2007/2008 Entitlement information was provided by DECCW
**Current use is equivalent to the annual average metered use volume over the period 2002/2003 to 2007/2008
***Stock and domestic use estimates were provided by DECCW

1.6.2 Salinity zoning

The groundwater salinity map for the watertable aquifer has been used to define extraction limits for each of the salinity classes.

Groundwater salinity is characterised by four salinity zones in the Upper Lachlan Alluvium SDL area, ranging from 0 – > 14,000 mg/L TDS. Most of the area is characterised by salinity zone 2 groundwater. The groundwater salinity distribution can be seen in Figure 9 and is summarised in Table 38.

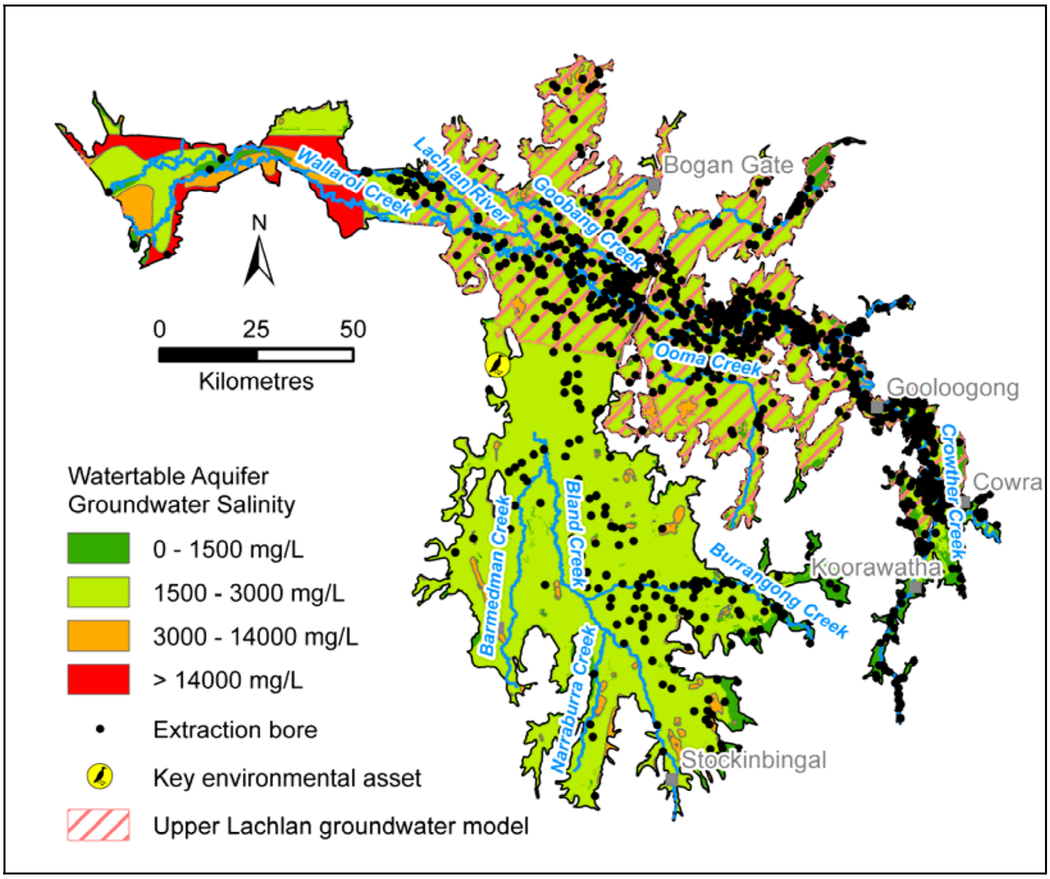

Figure 9. Upper Lachlan Alluvium watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 38. Summary of salinity zones in the Upper Lachlan Alluvium SDL area

Watertable salinity zone	Portion of area	Area
Zone 1 (0–1500 mg/L TDS)	9	1224
Zone 2 (1500–3000 mg/L TDS)	82	10,912
Zone 3 (3000–14,000 mg/L TDS)	6	752
Zone 4 (>14,000 mg/L TDS)	3	432
Total	**100**	**13,323**

1.6.3 Key environmental assets

Lake Cowal is on the Register of the National Estate and in the Directory of Important Wetlands, and it is listed as a Landscape Conservation Area by the National Trust of Australia. It is situated 47 km north-east of West Wyalong in central New South Wales and is the state's largest natural inland lake. It is part of the Wilbertroy-Cowal Wetlands within a large flood plain, the Jemalong Plain.

Flows to the Lake are restricted unless the Lachlan River floods and overflows its banks. The major tributaries that flow into the creek – Bland and Sandy Creeks – have been blocked where they enter the lake for about 12 years. Lake Cowal is an ephemeral lake and wetland and has been dry for up to 30 years at a time. It has been largely dry since October 2001 (Williams, 2009).

Lake Cowal is considered to have a low dependency on groundwater. The Lake is primarily fed by flood water from the Lachlan River and resides on a 7 m to 10 m thick laterally continuous clay layer with very low hydraulic conductivity (0.00077 to 0.000027 m/day) (Lampayan and Ghassemi, 1998).

Groundwater use near the asset is limited by the groundwater salinity. Although Figure 9 indicates that groundwater salinity is low in this area, more site specific information indicates that it is much more saline and on the order of ~22,000

– 48,000 mg/L TDS (Lampayan and Ghassemi, 1998). Lake Cowal has therefore been ranked a low risk environmental asset.

1.6.4 Key ecosystem function

The impact of groundwater pumping on river flow in the Upper Lachlan numerical model was assessed by comparing river flow in the no-development scenario and the scenario that incorporated a historical climate and 2004/2005 groundwater extraction (65 GL/year). Figure 10 shows this impact and indicates that after a typical planning timeframe of approximately 50 years, the annual river flow reduction is around 16 GL/year. This indicates that there is approximately 25 percent connectivity between the groundwater and surface water systems.

The key ecosystem function of the Upper Lachlan Alluvium SDL area is at low risk, given that the connectivity between the groundwater and surface water is less than 50 percent.

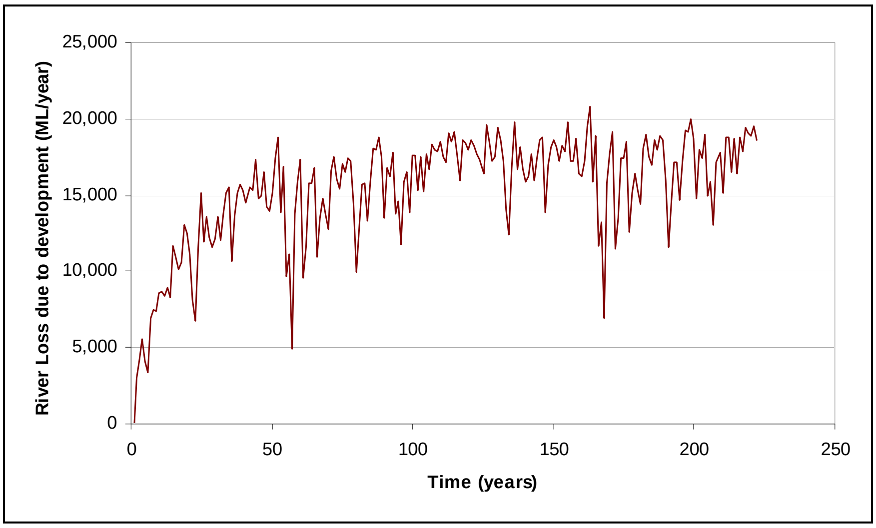

Figure 10. Change in river loss between the no-development and the 2004/2005 groundwater development scenario; from the Upper Lachlan groundwater model

1.6.5 Productive base

Recharge

Recharge inputs in the Upper Lachlan numerical model include; rainfall infiltration, irrigation accessions, river leakage and throughflow. The Lachlan Formation receives inflow via vertical leakage through the Cowra Formation and discharges mainly via extraction and vertical leakage.

The total area of the Upper Lachlan Alluvium SDL area is 13,320 km^2. The Lachlan Formation palaeochannel is expected to be restricted to approximately 2200 km^2 within the SDL area. This equates to one sixth of the total SDL area, which was informed via interrogation of the layers within the numerical model.

The long term average leakage rate from the Cowra Formation to the Lachlan Formation, derived from the proposed SDL scenario model (CSIRO, 2010f) indicated a leakage rate of 34 GL/year (equivalent to 37 mm/year over the model domain).

When the net vertical leakage rate derived from the model (i.e. 37 mm/year) is applied to the area of the palaeochannel within the SDL area (i.e. 2200 km^2), the total recharge to the Lachlan Formation within the SDL boundary equates to 83 GL/year (Table 39).

The Upper Lachlan Alluvium numerical model covers 41 percent of the Upper Lachlan Alluvium SDL area. This percentage was used to separate the leakage rate for each of the salinity classes within the SDL area (which totalled 83 GL/year), to the modelled and non modelled areas. This resulted in 34 GL/year of recharge to the Lachlan Formation in the model domain (Table 40) and 49 GL/year recharge to the Lachlan Formation in the non-modelled part of the SDL area (Table 41).

Table 39. Recharge calculation for the entire Upper Lachlan SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area of Cowra Formation (km2)	1224	10,912	752	432
Approximate area of Lachlan Formation (km^2)*	204	1821	126	72
Leakage from Cowra to Lachlan (mm/yr)	37	37	37	37
Leakage from Cowra to Lachlan (GL/yr)	**7.6**	**68**	**4.7**	**2.7**

*based on a 1:6 ratio of Lachlan Formation to Cowra Formation

Table 40. Recharge in the model area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Leakage from Cowra to Lachlan (GL/yr)	7.6	68	4.7	2.7
Portion of SDL area covered by model	41 %	41 %	41 %	41 %
Leakage from Cowra to Lachlan in the model area (GL/yr)	**3.1**	**28**	**1.9**	**1.1**

Table 41. Recharge in the non-model area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Leakage from Cowra to Lachlan (GL/yr)	7.6	68	4.7	2.7
Portion of non modelled SDL area	59 %	59 %	59 %	59 %
Leakage from Cowra to Lachlan in the non-model area (GL/yr)	**4.5**	**40**	**2.7**	**1.6**

Storage

The numerical model set the specific yield at 0.10 for the Lachlan aquifer. The maximum thickness of the Lachlan Formation in the paleochannel is 70 m. An average thickness of 40 m has been used for the storage estimate.

Total storage estimated for the Lachlan Formation is approximately 9000 GL (Table 42).

Table 42. Storage calculation

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area of Lachlan Formation (km2)	204	1821	126	72
Saturated thickness (m)	40	40	40	40
Specific yield	0.10	0.10	0.10	0.10
Total storage (GL)	817	7283	502	288

Storage relative to recharge

The ratio of storage to recharge is approximately 100 for each of the salinity classes. This indicates that there is a low risk of the productive base of the aquifer being jeopardised by factors such as climate change and the short-term over extraction of the groundwater resource.

1.6.6 The risk matrix

Table 43 provides a summary of the risk ranking associated with: key environmental assets, key ecosystem function, the productive base, the key environmental outcome and the uncertainty inherent in the RRAM calculation. In summary:

- the SDL area is ranked low risk in terms of key environmental assets, given none have been identified that are groundwater dependent in this area
- the SDL area is ranked low risk in terms of ecosystem function, given that there is approximately 25 percent groundwater and surface water connectivity
- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio exceeds 40
- there is a risk to the key environmental outcomes (i.e. groundwater salinity)
- a low uncertainty is associated with the modelled part of the unit and a high uncertainty is associated with the non-modelled part, given the assumptions inherent in the calculations for this part of the unit (i.e. that the extent of the palaeochannel is similar to that in the modelled part of the unit).

Table 43. Risk matrix

Risk ranking	Environmental assets (EAs)	OR	Ecosystem function	OR	Productive base	Sustainability factor (SF)	Key environmental outcome	Degree of uncertainty
High	EA that is highly groundwater dependent and highly sensitive to take		In the current state, groundwater discharge provides baseflow to the unregulated river reach. Groundwater extraction is likely to result in streamflow depletion		Storage/ recharge <20	0.10	Where there is no risk to the key environmental outcome (i.e. groundwater salinity) there is no reduction to the SF for any of the salinity classes. Where there is a risk to the key environmental outcome, as a measure to reduce risk to groundwater quality, the following reductions are made: Salinity class 1: reduce SF by 20% Salinity class 2: reduce SF by 10% Salinity classes 3 & 4: no reduction	Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 50%
Medium	EA that is highly groundwater dependent and is moderately sensitive to take EA that is moderately groundwater dependent and is highly sensitive to take		The rivers in the SDL unit are regulated and they are highly connected to the groundwater system (i.e. >50% impact of pumping on streamflow)		Storage/ recharge 20–40	0.50		
Low	EA that has a low groundwater dependence and low sensitivity to take EAs do not exist in the SDL unit		The rivers in the SDL unit are regulated or unregulated and they have low–moderate connection with the groundwater system (i.e. <50% impact of pumping on streamflow)		Storage/ recharge >40	0.70		Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 25%

1.6.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the modelled part of the Upper Lachlan SDL area is 22 GL/year (Table 44). The RRAM extraction limit was based on leakage rates derived from the Upper Lachlan Alluvium SDL scenario model results (CSIRO, 2010f) as these provided the best available information at the time of the RRAM analysis. The preliminary RRAM extraction limit for the modelled part of the Upper Lachlan SDL area has been superseded by more recent modelling results (CSIRO, 2010f).

For the non-modelled part of the unit, the RRAM extraction limit is 23 GL/year (Table 45).

Table 44. Summary for the area represented by the numerical model in the Upper Lachlan SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	3.1	28	1.9	1.1
Sustainability factor	0.56	0.63	0.7	0.7
Extraction limit (GL/yr)	**1.7**	**18**	**1.3**	**0.77**

Table 45. Summary for the non-modelled portion of the Upper Lachlan SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	4.5	40	2.7	1.6
Sustainability factor	0.42	0.47	0.53	0.53
Extraction limit (GL/yr)	**1.9**	**19**	**1.5**	**0.77**

1.7 Lower Macquarie Alluvium (GS40)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the RRAM for the Lower Macquarie Alluvium SDL area.

1.7.1 Background

The Lower Macquarie Alluvium SDL area corresponds closely to the boundary of the Lower Macquarie GMU and the numerical model boundary. The Lower Macquarie Alluvium numerical model consists of four layers, including two layers that represent GAB aquifers and confining layers, the Gunnedah Formation and the Narrabri Formation aquifers. The results of the numerical model have been used to determine the extraction limit for this unit.

The Lower Macquarie Alluvium SDL area incorporates a Palaeozoic basement comprised of folded metasediments. Unconformably overlying the eroded surface of the Palaeozoic rocks, are Mesozoic rocks that form the GAB intake-beds. The top of the now buried GAB sequence is a deeply weathered erosion surface that was dissected by ancient river systems (likely the predecessor of today's Macquarie River system). The erosion period lasted almost 40 million years and resulted in several deep incised valley and ridge profiles. Following the weathering period, was a period of sedimentation. This sedimentation period completely buried the valleys and ridges of the older GAB sequence with Cainozoic unconsolidated sediments. The Cainozoic alluvial sequence of the Gunnedah and Narrabri Formation comprise interbedded clay, silt, gravel and sand and form the present alluvial plains of the area (Bilge, 2007).

The Lower Macquarie groundwater source is subject to a water sharing plan (Water Sharing Plan for the Lower Macquarie Groundwater Sources 2003). The water source covered by the plan includes all water contained in the unconsolidated alluvial aquifers and the sandstone aquifers of the GAB within the area to which this plan applies. The Plan for the Water Source has been signed into law by the Minister and is therefore a Transitional Plan under the Water Act. The Water Act, though, does not explicitly exclude these GAB sediments and their contained groundwater from the definition of GAB water resources or include them as part of the MDB water resources. However, given that the jurisdiction has included the groundwater contained in the GAB sediments in this area in the water source for the Lower Macquarie, rather than into the GAB water source (as part of the Water Sharing plan for the GAB), it would be consistent to continue to treat these GAB groundwater resources as part of the MDB water resources.

If the groundwater contained in the GAB sediments in the Lower Macquarie water source area were excluded from the Basin Plan, New South Wales would be responsible for reporting (under Section 21 (4) (c) vii and viii) on the impacts of usage of the groundwater in the GAB sediments on the groundwater in the unconsolidated sediments directly overlying, and conversely, the impact of usage of groundwater in the unconsolidated sediments on the groundwater in the GAB sediments. The result of this requirement would be the same as if the groundwater in the GAB was included in the MDB water resources.

Therefore, it is proposed that groundwater contained in the GAB sediments in the Lower Macquarie water source area (and the SDL area) be counted as part of the MDB water resources. Legal advice on this matter should also be sought.

The LTAEL for the Lower Macquarie is 69 GL/year, plus an additional 2.4 GL/year for supplementary water access licences and requirements for basic landholder rights. The groundwater take summary for the Lower Macquarie Alluvium SDL area (Table 46) includes entitlement volumes and use volumes associated with the GAB aquifer. The GAB aquifer and the overlying alluvium are intrinsically linked, with bores often screened against both the alluvium and the GAB sandstone. The sum of current use for the Lower Macquarie Alluvium SDL area is 49 GL/year (Table 46). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010k).

Table 46. Groundwater take summary for the Lower Macquarie Alluvium SDL area

Lower Macquarie Alluvium SDL area	GL/year
Entitlement*	**69**
Current use for entitlement bores**	44
Estimated use for stock & domestic bores***	4.6
Total current use	**49**

*Entitlement volume is equal to the LTAEL, which will be achieved by 30 June 2017.
**Current use is the average annual metered groundwater use over the period 2003/2004 to 2007/2008
***Stock and domestic use was based on estimates provided by DECCW

1.7.2 Salinity zoning

The watertable groundwater salinity is characterised by four salinity zones in the Lower Macquarie Alluvium SDL area, however the portion of groundwater characterised by salinity zone 4 is small (i.e. less than 2%) and hence has been combined with the area characterised by salinity zone 3 groundwater, for the purpose of this assessment. Groundwater salinity therefore ranges from 0 to 14,000 mg/L TDS. The groundwater salinity distribution can be seen in Figure 11 and is summarised in Table 47.

Although the watertable aquifer is often not the productive aquifer in this unit, no other salinity mapping data was available at the time of this assessment and so is considered the most appropriate dataset to use for the purpose of the RRAM assessment for this unit.

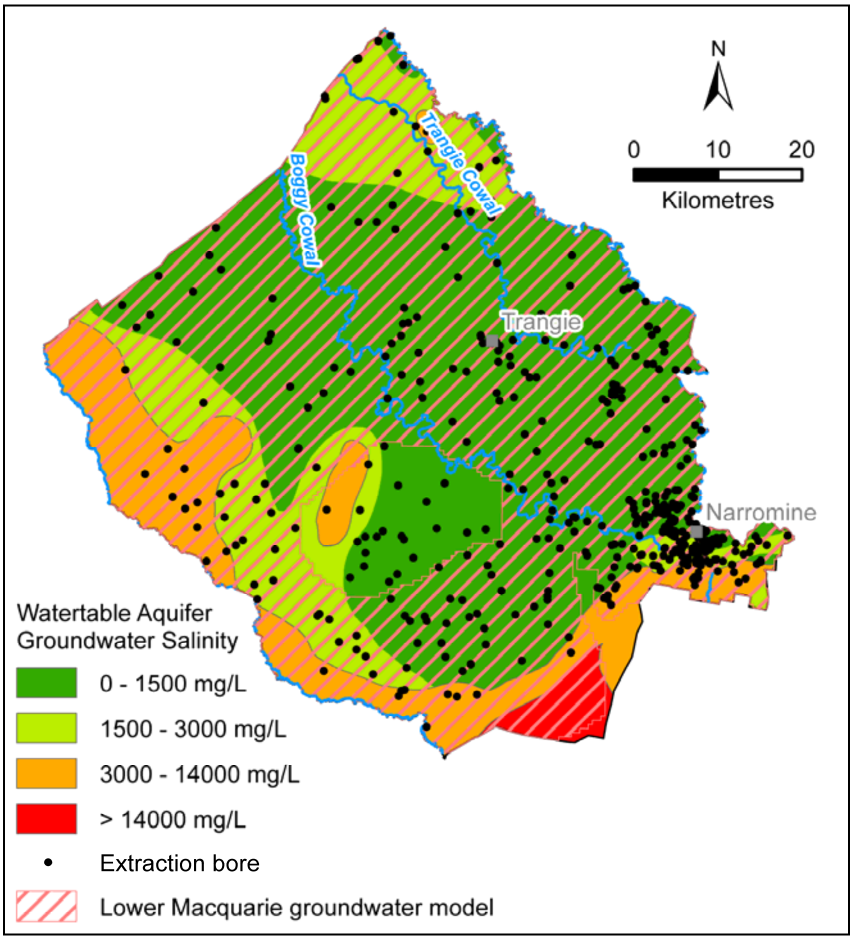

Figure 11. Lower Macquarie Alluvium watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 47. Summary of salinity zones in the Lower Macquarie Alluvium SDL area

Watertable salinity zone	Portion of area	Area
	percent	km²
Zone 1 (0–1500 mg/L TDS)	63	2615
Zone 2 (1500–3000 mg/L TDS)	19	779
Zone 3 (3000–14,000 mg/L TDS)	18	740
Zone 4 (>14,000 mg/L TDS)	0	0
Water bodies	0	0
Total	**100**	**4134**

1.7.3 Key environmental assets

There are no environmental assets that are groundwater dependent and sensitive to take in the Lower Macquarie SDL area.

1.7.4 Key ecosystem function

The risk to the key ecosystem function in the Lower Macquarie Alluvium SDL area was assessed via the results of the numerical modelling (CSIRO, 2008b). The impacts of groundwater pumping on river flow in the Lower Macquarie were determined by comparing river flow in the no-development scenario and the scenario that incorporated a historical climate and 2004/2005 groundwater extraction (approximately 48 GL/year). Figure 12 shows this impact and indicates that after a typical planning timeframe of approximately 50 years, the annual river flow reduction is approximately 5 GL/year. This equates to approximately 10 percent connectivity and hence the key ecosystem function is considered to be at low risk in this SDL area.

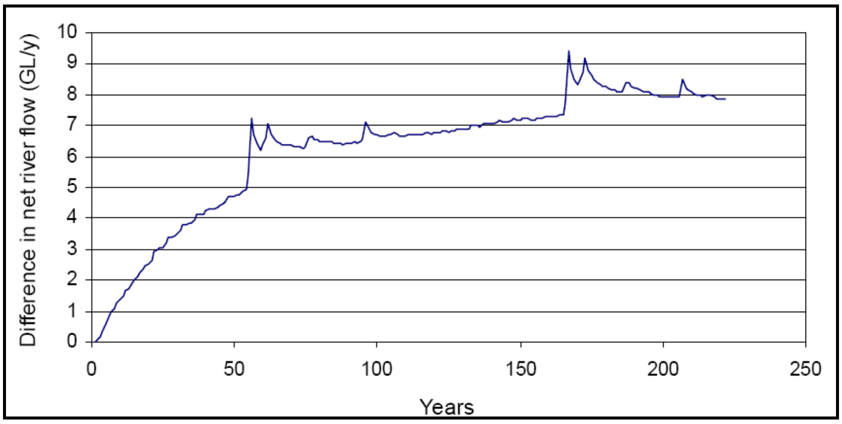

Figure 12. Change in river loss between the no-development and the 2004/2005 groundwater development scenario; from the Lower Macquarie groundwater model

1.7.5 Productive base

Recharge

The results of the Lower Macquarie Alluvium numerical modelling that occurred for the Murray-Darling Basin Sustainable Yields Project study (CSIRO, 2008b) have been used to estimate recharge in this unit. Recharge components for the model include: rainfall infiltration, irrigation, river leakage and lateral flow (Table 48). Total recharge to the system is 74 GL/year and this volume has been apportioned to each of the salinity zones, based on area (Table 49).

Table 48. Modelled average annual groundwater balance over the second 111 years of simulation within the Lower Macquarie Alluvium GMU under the 2004/2005 level of groundwater development scenario

	GL/year
Recharge – gains	
Rainfall	27
Irrigation	19
River system	16
Lateral flow	12
Total	**74**
Discharge – Losses	
Extraction	48
Rivers	10
Lateral Flow	14
Total	**72**

Table 49. Recharge calculation

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (%)	63	19	18	0
Recharge derived from numerical model (GL/yr)	47	14	13	N/A
Total recharge to SDL area (GL/yr)	**74**			

Storage

The younger shallow alluvial sediments have a maximum thickness of 60 m and are the most extensive across the model area. The deeper alluvium is confined to a palaeochannel and underlies the upper alluvium and may overly the Mesozoic sandstone or Palaeozoic bedrock. The thickness of the deep alluvial sediments varies from 20 to 80 m (Bilge, 2007). A thickness of 50 m has been estimated for the purpose of the storage calculation. The specific yield of the shallow alluvial sediments ranged from 0.05 and 0.25. A specific yield of 0.15 has been used for the purpose of the storage calculation.

Total storage of the alluvial sequence in the Lower Macquarie, is approximately 31,000 GL (Table 50).

Table 50. Storage calculation

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km2)	2615	779	740	0
Saturated thickness (m)	50	50	50	N/A
Specific yield	0.15	0.15	0.15	N/A
Total storage (GL)	**19,613**	**5843**	**5550**	**N/A**

Storage relative to recharge

The ratio of storage to recharge ranges from 417 to 427 for each of the salinity zones. This indicates that there is a low risk of the productive base of the aquifer being jeopardised by factors such as climate change and the short-term over extraction of the groundwater resource.

1.7.6 The risk matrix

Table 51 provides a summary of the risk ranking associated with: key environmental assets, key ecosystem function, the productive base, the key environmental outcome and the uncertainty inherent in the RRAM calculation. In summary:

- the SDL area is ranked low risk in terms of key environmental assets, given none have been identified that are groundwater dependent in this area
- the SDL area is ranked low risk in terms of ecosystem function, given that the groundwater and surface water connectivity is approximately 10 percent

- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio far exceeds 40
- there is a risk to the key environmental outcomes (i.e. groundwater salinity)
- there is a low uncertainty associated with this unit, given that recharge was derived from the Lower Macquarie Alluvium numerical model.

Table 51. Risk matrix

Risk ranking	Environmental assets (EAs)	OR	Ecosystem function	OR	Productive base	Sustainability factor (SF)	Key environmental outcome	Degree of uncertainty
High	EA that is highly groundwater dependent and highly sensitive to take		In the current state, groundwater discharge provides baseflow to the unregulated river reach. Groundwater extraction is likely to result in streamflow depletion		Storage/ recharge <20	0.10	Where there is no risk to the key environmental outcome (i.e. groundwater salinity) there is no reduction to the SF for any of the salinity classes. Where there is a risk to the key environmental outcome, as a measure to reduce risk to groundwater quality, the following reductions are made: Salinity class 1: reduce SF by 20% Salinity class 2: reduce SF by 10% Salinity classes 3 & 4: no reduction	Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 50%
Medium	EA that is highly groundwater dependent and is moderately sensitive to take EA that is moderately groundwater dependent and is highly sensitive to take		The rivers in the SDL unit are regulated and they are highly connected to the groundwater system (i.e. >50% impact of pumping on streamflow)		Storage/ recharge 20–40	0.50		
Low	EA that has a low groundwater dependence and low sensitivity to take EAs do not exist in the SDL unit		The rivers in the SDL unit are regulated or unregulated and they have low–moderate connection with the groundwater system (i.e. <50% impact of pumping on streamflow)		Storage/ recharge >40	0.70		Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 25%

1.7.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Lower Macquarie Alluvium SDL area is 44 GL/year (Table 52). The RRAM extraction limit was based on the Murray-Darling Basin Sustainable Yields Project Lower Macquarie Alluvium numerical modelling results (CSIRO, 2008b) as these provided the best available information at the time of the RRAM analysis.

The preliminary RRAM extraction limit for the Lower Macquarie Alluvium SDL area has been superseded by more recent modelling results (CSIRO, 2010g).

Table 52. Extraction limit summary

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	47	14	13	0
Sustainability factor	0.56	0.63	0.70	N/A
Extraction limit (GL/yr)	26	8.7	9.2	N/A

1.8 Mid-Murrumbidgee Alluvium (GS45)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the RRAM for the Mid-Murrumbidgee Alluvium SDL area.

1.8.1 Background

The Mid-Murrumbidgee Alluvium SDL area correlates to the area of the Mid-Murrumbidgee Alluvium GMU. The Mid-Murrumbidgee numerical model covers 86 percent of the SDL area. The most eastern portion of the SDL area is not within the model bounds. The Mid-Murrumbidgee Alluvium SDL area contains two main aquifers, the Cowra Formation and the basal Lachlan Formation, which overlie a palaeo-valley of weathered bedrock. They are represented by two separate layers in the numerical model (CSIRO, 2008c). Groundwater extraction is mainly from the deeper Lachlan Formation, which has a higher hydraulic conductivity than the Cowra Formation.

In the non modelled part of the unit, current use is 0.43 GL/year (Table 53). Total groundwater use for the entire SDL area is 43 GL/yr. For more information regarding the source of the entitlement and use information, refer to CSIRO (2010k).

Table 53. Groundwater take summary for the non-modelled part of the Mid-Murrumbidgee Alluvium SDL area

Mid-Murrumbidgee Alluvium SDL area (non-modelled)	GL/year
Total 2007/2008 entitlement	0.82
Current use for entitlement bores	0.17
Estimated use for stock & domestic bores	0.26
Total current use	**0.43**

*2007/2008 entitlement volumes were provided by DECCW
**Current use for entitlement bores is equal to the average annual metered use volume over the period 2002/2003 to 2007/2008.
***Stock and domestic use estimate was provided by DECCW

1.8.2 Salinity zoning

The groundwater salinity map for the watertable aquifer has been used to define extraction limits for each of the salinity classes.

Groundwater salinity is characterised by three salinity zones in the Mid-Murrumbidgee Alluvium SDL area, ranging from 0 to 14,000 mg/L TDS. The groundwater salinity distribution can be seen in Figure 13 and is summarised in Table 54.

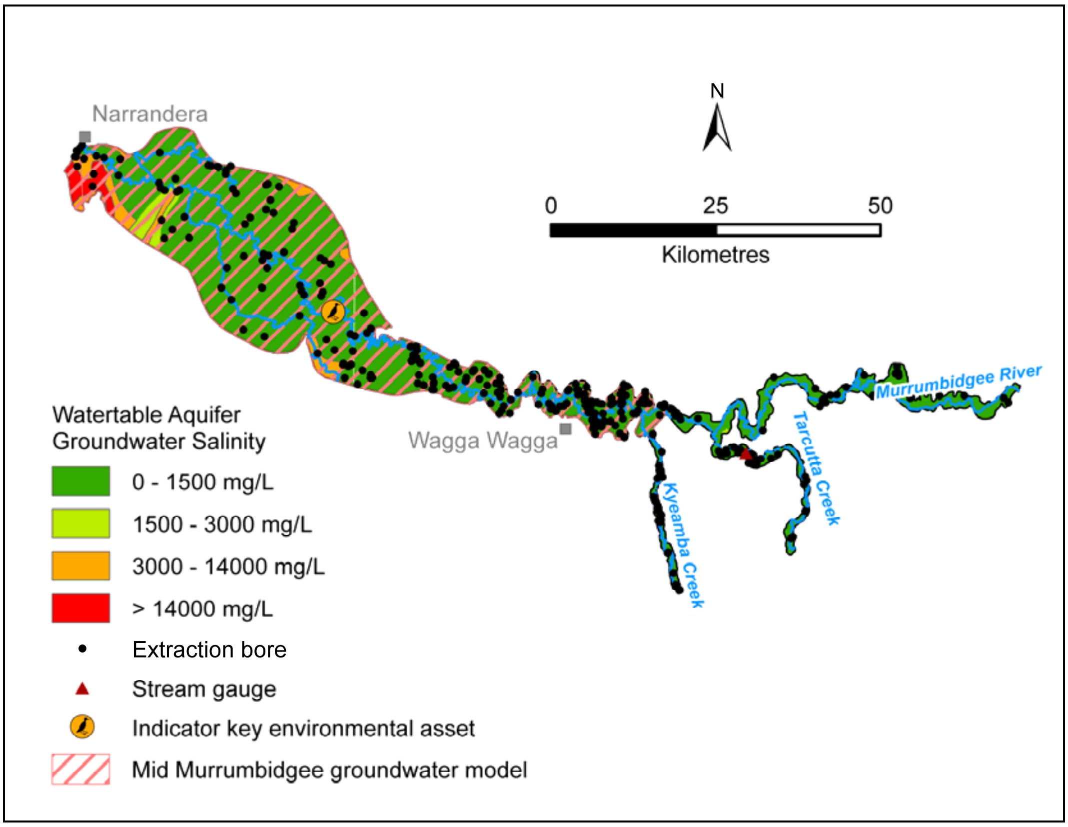

Figure 13. Mid-Murrumbidgee Alluvium watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 54. Summary of Salinity Zones in the Mid-Murrumbidgee Alluvium SDL area

Watertable salinity zone	Portion of area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	91	1240
Zone 2 (1500–3000 mg/L TDS)	2	28
Zone 3 (3000–14,000 mg/L TDS)	5	63
Zone 4 (>14,000 mg/L TDS)	2	27
Water bodies	0	0
Total	**100**	**1359**

1.8.3 Key environmental assets

The *Water Act 2007* requires that assessment of environmental water needs of the Basin must encompass key environmental assets, including water-dependent ecosystems, ecosystem services, and sites with ecological significance.

The Murray-Darling Basin Authority has identified 18 key environmental asset – hydrologic indicator sites that drive the environmental hydrology of the MDB (MDBA, 2010). These 18 sites have been assessed to determine the objectives, targets and flow regimes required to sustain them. This information was input to the generation of an estimate of the long-term average sustainable diversion limits that will not compromise the water requirements for the rivers, wetlands and floodplains of the Basin.

The Mid-Murrumbidgee Alluvium SDL area encompasses the Mid-Murrumbidgee River Wetlands, which is one of the 18 key environmental asset – hydrologic indicator sites identified by the Murray-Darling Basin Authority.

The nationally important Mid-Murrumbidgee Wetlands are located along the Murrumbidgee River between Narrandera and Carrathool. The wetlands are considered to be significant because they support a wide variety of plants and animals, including numerous endangered species. The main threat to wetland health is river regulation and significant areas of the Mid-Murrumbidgee Wetlands have been affected by changes in the hydrological regime. Reduced frequency of floods (particularly since the mid-1990s) presents a major threat to river and wetland health (Graham, 2006).

A watertable aquifer observation bore resides near the Mid-Murrumbidgee Wetlands (GW030164) and the water levels recorded for this bore from 1972 to 2008 are shown in Figure 14. This indicates that up to 1996, the watertable was within approximately 4 to 6 m of the land surface. However, from 1996 to 2008 there has been a steady decline in groundwater levels, such that they now reside at approximately 11 m below the surface.

In the absence of other information, the Mid-Murrumbidgee River Wetlands are assumed to be groundwater dependent and sensitive to take and therefore there is a high risk to the key environmental asset.

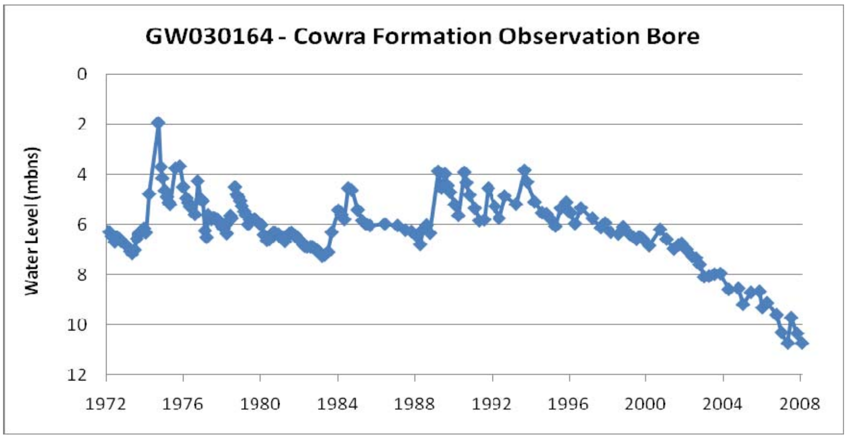

Figure 14. Monitored water levels for GW030164

1.8.4 Key ecosystem function

The risk to the key ecosystem function in the Mid-Murrumbidgee Alluvium SDL area was assessed via the results of the numerical modelling (CSIRO, 2008c). The impacts of groundwater pumping on river flow in the Mid-Murrumbidgee were determined by comparing river flow in the no-development scenario and the scenario that incorporated a historical climate and 2004/2005 groundwater extraction (40 GL/year). The purple line (called 'increase' in Figure 15) shows the difference between the river loss due to pumping at 2004/2005 levels and the river loss when there is no pumping. This indicates that when 40 GL/year is pumped, approximately 31 GL/year of this water is derived from the Murrumbidgee River. This equates to a connectivity of 79percent.

The risk to the key ecosystem function for the Mid-Murrumbidgee Alluvium is therefore high, given that the upstream tributaries are unregulated.

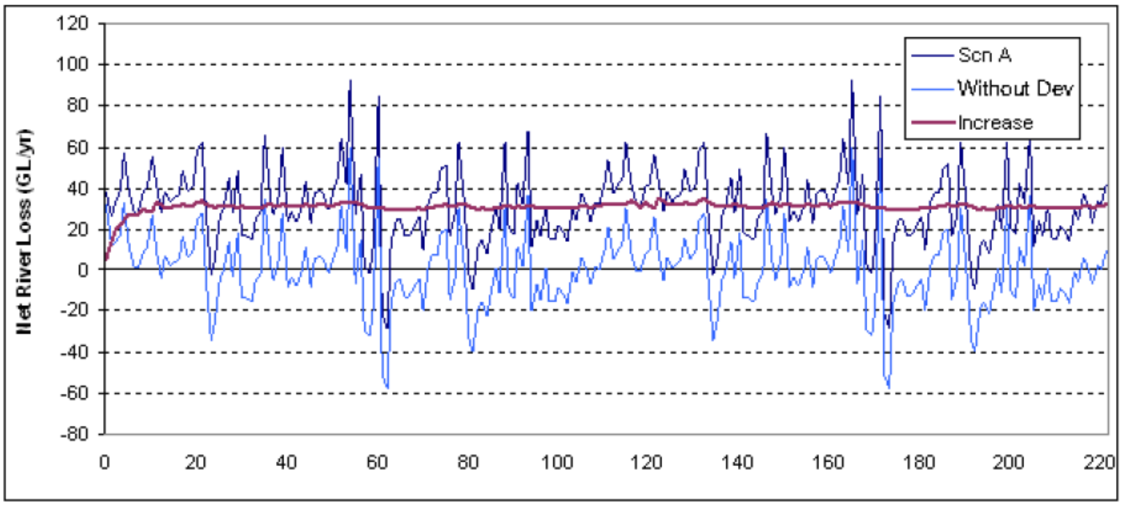

Figure 15. Comparison of net river loss under a no-development scenario and a 2004/2005 groundwater development scenario

1.8.5 Productive base

Recharge

The results of the Mid-Murrumbidgee Alluvium numerical modelling for the SDL scenario (CSIRO, 2010h) have been used to estimate recharge in this unit. Within the portion of the SDL area represented by the model (i.e. 86 percent of the total area), the model mass balance was used as input to the RRAM calculation. The model results indicated that total inflow to the system was 65 GL/year (Table 55). Groundwater recharge has been apportioned to each of the salinity zones within the modelled part of the SDL area, based on the relative size of the salinity zone (Table 56).

For the remaining non-modelled part of the unit (i.e. 14 percent of the total area) rainfall recharge, irrigation recharge and river leakage from the SDL model scenario (CSIRO, 2010h) was used to derive the RRAM extraction limit. These recharge components equated to 65 GL/yr within the model domain and given that the area of the model domain is 1582 km^2, the recharge rate corresponds to 41 mm/year.

When this recharge rate is applied to the non-modelled area, the total recharge volume is 8.2 GL (Table 57).

Table 55. Water budget for the Mid-Murrumbidgee, under the 2004/2005 groundwater development scenario

Groundwater balance	Volume (GL/yr)
Rainfall and irrigation recharge	24
River recharge	9.9
Flooding	31
Total inflows	**65**

Table 56. Recharge calculation for the modelled part of the SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km2)	1040	27	63	27
Recharge (GL/yr)	58	1.5	3.5	1.5
Total (GL/yr)	**65**			

Table 57. Recharge calculation for the non-modelled part of the unit

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km2)	200	1	0	0
Recharge (mm/yr)	41	41	N/A	N/A
Recharge (GL/yr)	8.2	0.041	N/A	N/A
Total recharge (GL/yr)	**8.2**			

Storage

The thickness of the Cowra sands varies from 15 m near Gundagai to 35 m near Narrandera and has a maximum thickness in the order of 80 m. The Lachlan Formation also has a maximum thickness of approximately 80 m and is made up of well sorted, clean quartz sand and gravel. An average thickness of 60 m has been used for the purpose of the storage calculation. The specific yield of the Cowra Formation is 0.2 and 0.041 for the Lachlan Formation (Goode and Daamen, 2008). A specific yield of 0.10 has been used for the purpose of this storage estimation.

Storage of the Mid-Murrumbidgee Alluvium is approximately 8000 GL (Table 58).

Table 58. Storage calculation

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km2)	1240	28	63	27
Saturated thickness (m)	60	60	60	60
Specific yield	0.10	0.10	0.10	0.10
Total storage (GL)	**7440**	**168**	**378**	**162**

Storage relative to recharge

The ratio of storage to recharge ranges from 108 to 112 for each of the salinity zones. This indicates that there is a low risk of the productive base of the aquifer being jeopardised by factors such as climate change and the short-term over extraction of the groundwater resource.

1.8.6 The risk matrix

Table 59 provides a summary of the risk ranking associated with: key environmental assets, key ecosystem function, the productive base, the key environmental outcome and the uncertainty inherent in the RRAM calculation. In summary:

- the SDL area is ranked high risk in terms of environmental assets, due to the presence of the Mid-Murrumbidgee River Wetlands
- the SDL area is ranked high risk in terms of ecosystem function, given that there is approximately 79 percent groundwater and surface water connectivity and unregulated creeks exist in the unit with an alluvial aquifer
- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio is approximately 80
- there is no risk to the key environmental outcomes (i.e. groundwater salinity)
- there is a low uncertainty given the recharge input to the RRAM calculation was derived from a numerical model for the area.

Table 59. Risk matrix

Risk ranking	Environmental assets (EAs)	OR	Ecosystem function	OR	Productive base	Sustainability factor (SF)	Key environmental outcome	Degree of uncertainty
High	EA that is highly groundwater dependent and highly sensitive to take		In the current state, groundwater discharge provides baseflow to the unregulated river reach. Groundwater extraction is likely to result in streamflow depletion		Storage/ recharge <20	0.10	Where there is no risk to the key environmental outcome (i.e. groundwater salinity) there is no reduction to the SF for any of the salinity classes. Where there is a risk to the key environmental outcome, as a measure to reduce risk to groundwater quality, the following reductions are made: Salinity class 1: reduce SF by 20% Salinity class 2: reduce SF by 10% Salinity classes 3 & 4: no reduction	Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 50%
Medium	EA that is highly groundwater dependent and is moderately sensitive to take EA that is moderately groundwater dependent and is highly sensitive to take		The rivers in the SDL unit are regulated and they are highly connected to the groundwater system (i.e. >50% impact of pumping on streamflow)		Storage/ recharge 20–40	0.50		
Low	EA that has a low groundwater dependence and low sensitivity to take EAs do not exist in the SDL unit		The rivers in the SDL unit are regulated or unregulated and they have low–moderate connection with the groundwater system (i.e. <50% impact of pumping on streamflow)		Storage/ recharge >40	0.70		Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 25%

1.8.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the modelled part of the Mid-Murrumbidgee Alluvium SDL area is 6.5 GL/year. The RRAM extraction limit was based on the Murray-Darling Basin Sustainable Yields Project Mid-Murrumbidgee Alluvium numerical modelling results (CSIRO, 2008c) as these provided the best available information at the time of the RRAM analysis. The preliminary RRAM extraction limit for the Mid-Murrumbidgee Alluvium SDL area has been superseded by more recent modelling results (CSIRO, 2010h).

For the non-modelled part of the SDL area, the RRAM extraction limit is 0.82 GL/year.

Table 60. Extraction limit summary for the modelled part of the Mid-Murrumbidgee Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	58	1.5	3.5	1.5
Sustainability factor	0.1	0.1	0.1	0.1
Extraction limit (GL/yr)	**5.8**	**0.15**	**0.35**	**0.15**

Table 61. Summary for the non-modelled part of the Mid-Murrumbidgee Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	8.2	0.041	0.0	0.0
Sustainability factor	0.1	0.1	0	0
Extraction limit (GL/yr)	**0.82**	**0.0041**	**0.0**	**0.0**

1.9 Lower Murrumbidgee Alluvium (GS42)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the RRAM for the Lower Murrumbidgee Alluvium SDL area.

1.9.1 Background

The Lower Murrumbidgee Alluvium SDL area corresponds to the Lower Murrumbidgee Alluvium GMU boundary. The Lower Murrumbidgee numerical model boundary largely coincides with the SDL area, with 99 percent of the area covered by the model area. The water sharing plan for the Lower Murrumbidgee Groundwater Sources indicates the LTAEL for the shallow aquifer is 10 GL/year and for the deep aquifer is 270 GL/year. The volume of supplementary water access licences is 40 GL/year for the deep aquifer and 0 GL/year for the shallow. Current groundwater use in this SDL area is 318 GL/year (Table 62). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010k).

The Lower Murrumbidgee Alluvium SDL area contains three main aquifers, the Shepparton Formation, Calivil Formation and the Renmark Group, overlying a relatively impermeable basement. Each of these aquifers is represented by a discrete layer in the Lower Murrumbidgee Alluvium numerical model (CSIRO, 2008c). The numerical model included 96 percent of the extraction from the Calivil Formation aquifer and the remaining 4 percent from the overlying Shepparton Formation aquifer.

Table 62. Groundwater take summary for the Lower Murrumbidgee Alluvium SDL area

Lower Murrumbidgee Alluvium SDL area	GL/year
Entitlement*	**280**
Current use for entitlement bores**	303
Estimated use for stock & domestic bores***	15
Total current use	**318**

*Entitlement volume is equal to the LTAEL, which will be achieved by 30 June 2017
**Current use is the average annual metered use over the 5 year period 2003/2004 to 2007/2008
***Stock and Domestic use was estimated from data provided by DECCW

1.9.2 Salinity zoning

Groundwater salinity has been characterised based on the Calivil Formation aquifer salinity.

Groundwater salinity is characterised by four salinity zones in the Lower Murrumbidgee Alluvium SDL area, ranging from 0 to > 14,000 mg/L TDS. A small portion of the area was not represented by the groundwater salinity coverage (approximately 2 percent of the total area) and this area has therefore been combined with the adjacent salinity zone 3 groundwater. The groundwater salinity distribution can be seen in Figure 16 and is summarised in Table 63.

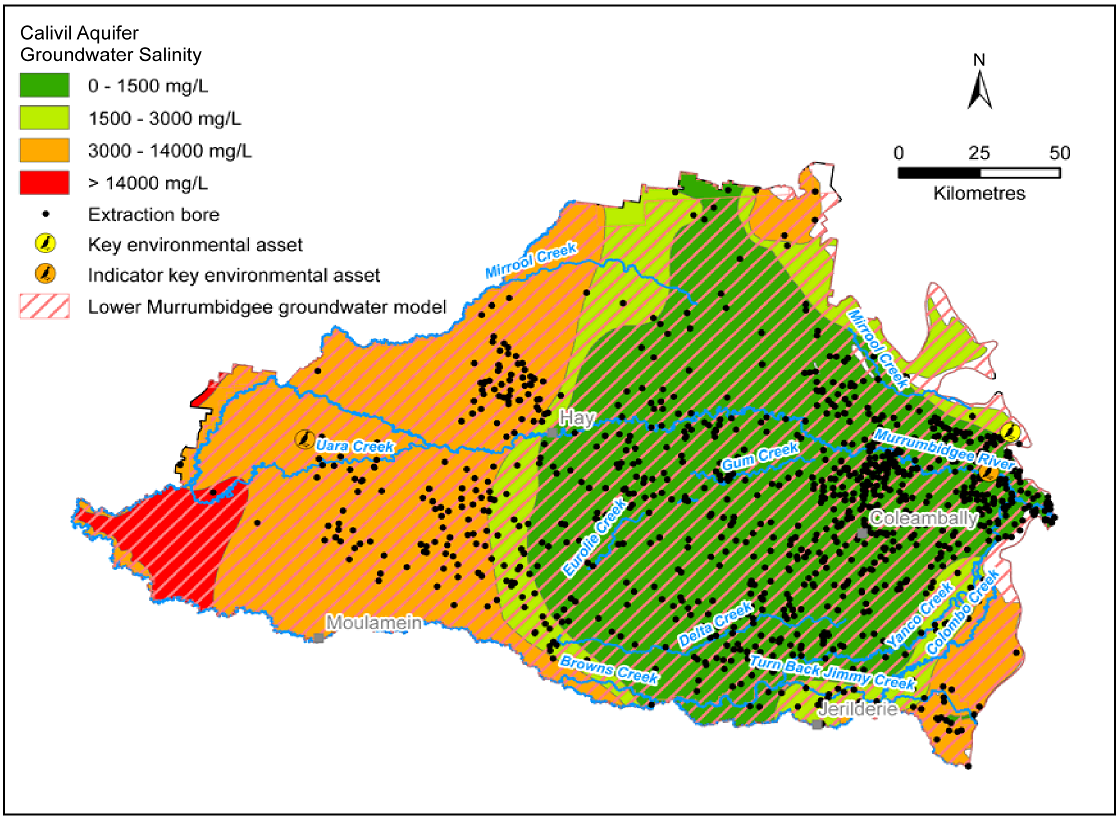

Figure 16. Lower Murrumbidgee Alluvium Calivil Formation aquifer salinity distribution, from the Pliocene Sands salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 63. Summary of salinity zones in the Lower Murrumbidgee Alluvium SDL area

Calivil Formation Aquifer salinity zone	Portion of area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	48	15,818
Zone 2 (1500–3000 mg/L TDS)	13	4201
Zone 3 (3000–14,000 mg/L TDS)	36	11,803
Zone 4 (>14,000 mg/L TDS)	3	1,181
Water bodies	0	0
Total	**100**	**33,003**

1.9.3 Key environmental assets

The *Water Act 2007* requires that assessment of environmental water needs of the Basin must encompass key environmental assets, including water-dependent ecosystems, ecosystem services, and sites with ecological significance.

The Murray-Darling Basin Authority has identified 18 key environmental asset – hydrologic indicator sites assets that drive the environmental hydrology of the Basin (MDBA, 2010). These 18 sites have been assessed to determine the objectives, targets and flow regimes required to sustain them. This information was input to the generation of an estimate of the long-term average sustainable diversion limits that will not compromise the water requirements for the rivers, wetlands and floodplains of the MDB.

The Lower Murrumbidgee SDL area encompasses the Lower Murrumbidgee River Floodplain and the Great Cumbung Swamp, which are two of the 18 key environmental asset – hydrologic indicator sites identified by the MDBA. These sites are not considered groundwater dependent or sensitive to take.

The Fivebough and Tuckerbill Swamps also occur in this SDL area and are located near Leeton in the New South Wales Riverina and are recognised as being a valuable habitat for a large number and a wide diversity of waterbirds. This site is now considered of national and international importance because of the diversity of waterbird species and the abundance of certain species that occur at the swamps.

The Fivebough Swamp basin is underlain by at least 10 m of extensive, impermeable clays. Prior to irrigation, the regional shallow groundwater levels were approximately 20 m below the surface. Groundwater information now indicates that the watertable is within 2.5 m of the basin surface. Due to the heavy nature of soils beneath the lunette formation, rainfall and irrigation water has caused the development of a perched saline water table at a depth of 1 to 2 m below the surface. Groundwater levels beneath the Tuckerbill swamp are also considered to be rising and currently within 2 m of the surface. There are some areas within the swamp that show signs of being salt affected. Patches of bare ground and the presence of salt tolerant species indicate that these areas may be salt affected.

Re-establishment of a cover of local native vegetation is currently underway, which will assist in the reduction of groundwater levels in the area (Fivebough and Tuckerbil Wetlands Management Trust Inc, 2002).

Given that measures are in place to reduce groundwater levels to prevent further salinisation of these swamps, this asset is considered at low risk to the impact of groundwater pumping.

1.9.4 Key ecosystem function

The risk to the key ecosystem function in the Lower Murrumbidgee Alluvium SDL area was assessed via the results of the numerical modelling (CSIRO, 2008c).

River flow in the numerical model no-development scenario and the scenario that incorporated a historical climate and 2004/2005 groundwater extraction (280 GL/year) was compared in order to quantify the impact of extraction on streamflow. Figure 17 shows this impact and indicates that within a typical planning timeframe of 50 years, the annual river flow reduction is approximately 20 GL/year. This indicates that there is less than 10 percent connectivity between the groundwater and surface water systems.

It should be noted that the no-development scenario included irrigation accessions that caused the modelled aquifers to fill up with water. Groundwater levels rose close to the river causing the modelled river losses to decrease and the river gains to increase. This means that the modelled connectivity is likely to be an underestimate of the actual connectivity.

The key ecosystem function of the Lower Murrumbidgee Alluvium SDL area is considered to be at low risk given that the connectivity between the groundwater and surface water is less than 50 percent. Even though the stream impact derived from the numerical model results are considered an underestimate, given that large sections of the Murrumbidgee River and Yanco Creek are under maximum losing conditions within the SDL area, a low risk to the key ecosystem function is consistent with the hydrogeological conceptualisation of this area.

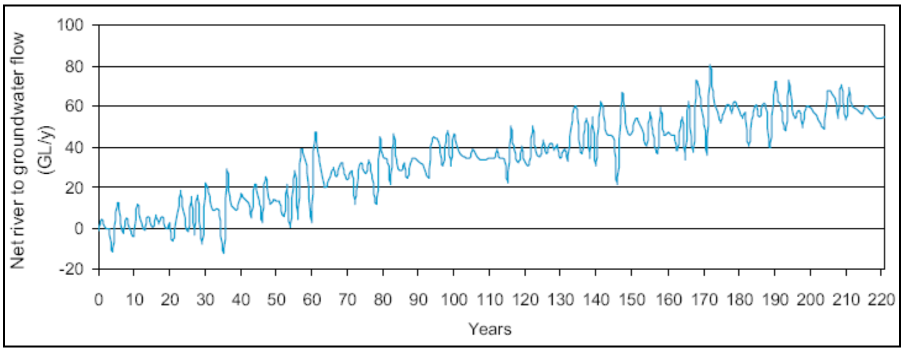

Figure 17. Change in river leakage between the no-development and 2005/2005 groundwater development scenario; for the Lower Murrumbidgee Alluvium model

1.9.5 Productive base

Recharge

The results of the Lower Murrumbidgee Alluvium numerical modelling that occurred for the Murray-Darling Basin Sustainable Yields Project study (CSIRO, 2008c) have been used to estimate recharge in this unit.

The water balance from the Lower Murrumbidgee Alluvium numerical modelling is summarised in Table 64 and indicates that total recharge to the alluvium is 479 GL/year. It can be seen that a significant portion of the inflows are attributed to irrigation recharge (i.e. approximately 51 percent). The numerical model assumed 9.6 percent of irrigation water that is applied to the ground surface becomes groundwater recharge. Surface water irrigation was applied to an area of 649 000 ha, which was determined by the NSW DECCW by analysing satellite imagery and annual rice mapping records. The area of primary surface water irrigation is shown in Figure 18. Irrigation from groundwater sources was assumed to be applied to where the water was extracted and the location of the extraction bores are shown in Figure 19.

It is evident from these two figures that the majority of surface water derived irrigation (particularly that for rice) occurs in the area characterised by groundwater of salinity zone 1, as too does the areas of groundwater derived irrigation. For this reason, the entire volume of irrigation derived groundwater recharge (245 GL/year; refer to Table 64) has been assigned to salinity zone 1. The remaining volume of recharge (234 GL/year) has been apportioned to each of the salinity zones within the SDL area, based on the area of the salinity zone (Table 65).

This results in a total volume of recharge of 357 GL/year for salinity zone 1, 30 GL/year for salinity zone 2, 84 GL/year for salinity zone 3 and 7 GL/year for salinity zone 4.

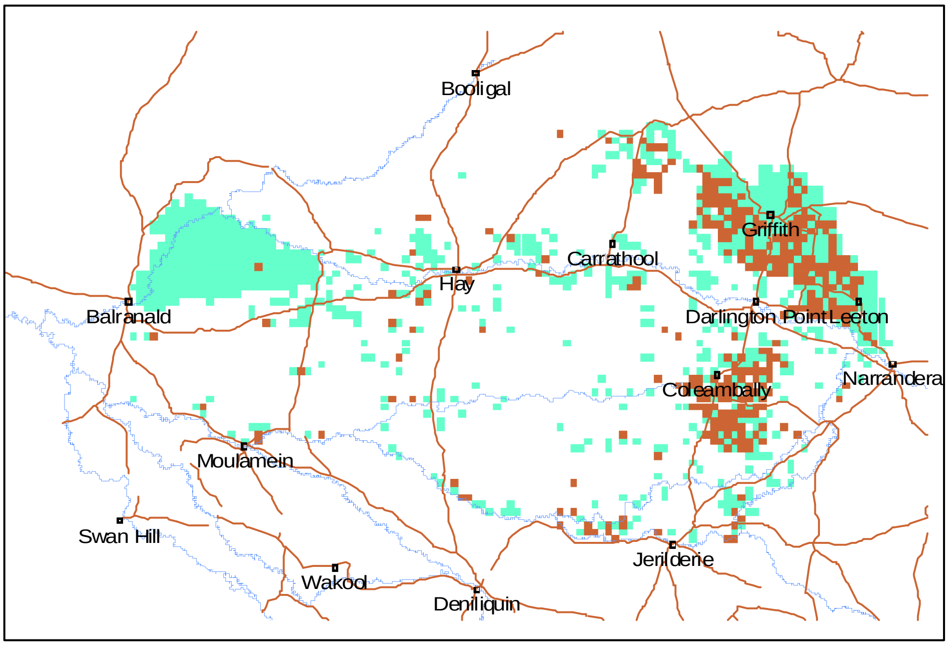

Figure 18. Lower Murrumbidgee Model - areas of surface water derived irrigation (rice irrigated areas shown in brown and non-rice irrigated areas shown in green)

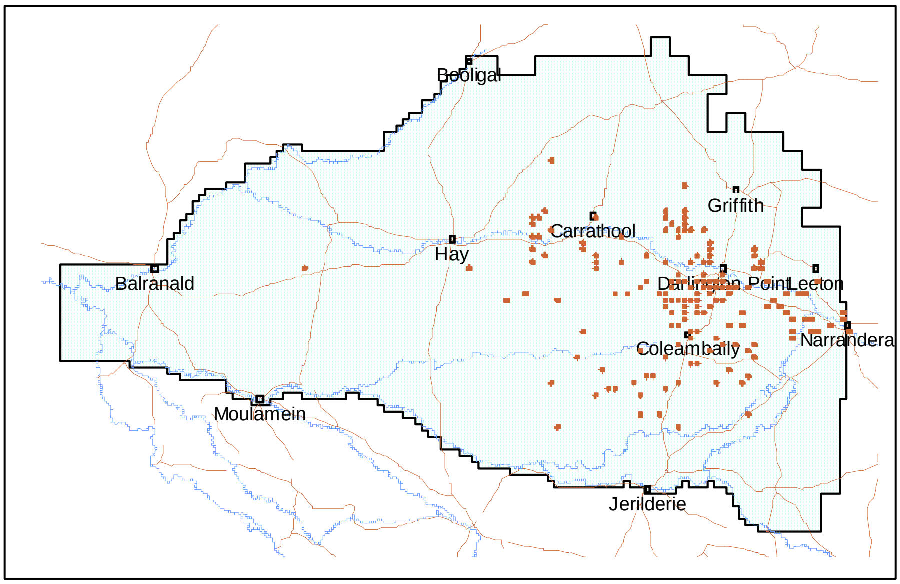

Figure 19. Lower Murrumbidgee Model – location of groundwater extraction bores

Table 64. Average annual water balance for the Lower Murrumbidgee Alluvium GMU for the 2004/2005 groundwater development scenario

Groundwater balance	Volume (GL/yr)
Rainfall	102
Irrigation	245
River recharge	8.6
Lateral groundwater flow in	123
Total inflows	**479**
Groundwater pumping	280
Later groundwater flow out	101
Evapotranspiration	48
River discharge	7.0
Total outflows	**436**

Table 65. Recharge calculation – from the numerical groundwater model

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (%)	48	13	36	3.0
Irrigation component of numerical model recharge (GL/yr)	245	0	0	0
Remaining components of numerical model recharge (GL/yr)	112	30	84	7.0
Total recharge (GL/yr)	**479**			

Storage

The thickness of the alluvial sequence ranges from 170 m at Narrandera to 400 m near Balranald (Kumar, 2002). An average thickness of 200 m has been assumed for the purpose of the storage estimate. The specific yield for the Shepparton Formation aquifer is 0.20 and has been adopted for the purpose of this storage estimate (CSIRO, 2008c).

Total storage for the alluvial sequence is approximately 1,320,000 GL (Table 66). This roughly agrees with the storage estimate of *Kumar* (2002) of 1,960,000 GL.

Table 66. Storage calculation

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km2)	15,818	4201	11,803	1181
Saturated thickness (m)	200	200	200	200
Specific yield	0.20	0.20	0.20	0.20
Total storage (GL)	**632,720**	**168,040**	**472,120**	**47,240**

Storage relative to recharge

The ratio of storage to recharge ranges from 1,772 to 6,749 for each of the salinity zones. This indicates that there is a low risk of the productive base of the aquifer being jeopardised by factors such as climate change and the short-term over extraction of the groundwater resource.

1.9.6 The risk matrix

Table 67 provides a summary of the risk ranking associated with: key environmental assets, key ecosystem function, the productive base, the key environmental outcome and the uncertainty inherent in the RRAM calculation. In summary:

- the SDL area is ranked low risk in terms of environmental assets, given that measures are in place to reduce groundwater levels around the Fivebough-Tuckerbill Ramsar sites and hence it is not sensitive to take

- the SDL area is ranked low risk in terms of ecosystem function, given that there is less than 10 percent connectivity within a 50-year planning timeframe
- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio far exceeds 40
- there is a risk to the key environmental outcomes (i.e. groundwater salinity)
- there is a low uncertainty associated with this unit given that the RRAM incorporates recharge derived from a numerical model.

Table 67. Risk matrix

Risk ranking	Environmental assets (EAs)	OR	Ecosystem function	OR	Productive base	Sustainability factor (SF)	Key environmental outcome	Degree of uncertainty
High	EA that is highly groundwater dependent and highly sensitive to take		In the current state, groundwater discharge provides baseflow to the unregulated river reach. Groundwater extraction is likely to result in streamflow depletion		Storage/ recharge <20	0.10	Where there is no risk to the key environmental outcome (i.e. groundwater salinity) there is no reduction to the SF for any of the salinity classes. Where there is a risk to the key environmental outcome, as a measure to reduce risk to groundwater quality, the following reductions are made: Salinity class 1: reduce SF by 20% Salinity class 2: reduce SF by 10% Salinity classes 3 & 4: no reduction	Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 50%
Medium	EA that is highly groundwater dependent and is moderately sensitive to take EA that is moderately groundwater dependent and is highly sensitive to take		The rivers in the SDL unit are regulated and they are highly connected to the groundwater system (i.e. >50% impact of pumping on streamflow)		Storage/ recharge 20–40	0.50		
Low	EA that has a low groundwater dependence and low sensitivity to take EAs do not exist in the SDL unit		The rivers in the SDL unit are regulated or unregulated and they have low–moderate connection with the groundwater system (i.e. <50% impact of pumping on streamflow)		Storage/ recharge >40	0.70		Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 25%

1.9.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Lower Murrumbidgee Alluvium SDL area is 283 GL/year. The RRAM extraction limit was based on the Murray-Darling Basin Sustainable Yields Project Lower Murrumbidgee Alluvium numerical modelling results (CSIRO, 2008c) as these provided the best available information at the time of the RRAM analysis.

The preliminary RRAM extraction limit for the Lower Murrumbidgee SDL area has been superseded by more recent modelling results (CSIRO, 2010i).

Table 68. Extraction limit summary for the Lower Murrumbidgee Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	357	30	84	7.0
Sustainability factor	0.56	0.63	0.7	0.7
Extraction limit (GL/yr)	200	19	59	5.0

1.10 Lower Murray Alluvium (GS41)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the RRAM for the Lower Murray Alluvium SDL area.

1.10.1 Background

The Lower Murray Alluvium SDL area corresponds to the Lower Murray GMU. The water sharing plan for the Lower Murray Groundwater Source represents the groundwater sources contained in the Calivil, Renmark and Lower Shepparton unconsolidated alluvial aquifers, deeper than 12 m below the ground surface. The LTAEL for the Lower Murray Groundwater Source is 84 GL/year, plus 49 GL/year supplementary water access licences, which will be reduced to 0 by June 2017.

Table 69 provides a summary of groundwater take for the groundwater sources represented by the water sharing plan. This means that it does not incorporate use from the top 12 m of Shepparton Formation aquifer. Table 69 does not include use from the Shepparton Formation for salinity control or water level control. For more information regarding the source of the entitlement and use information, refer to CSIRO (2010k).

The Lower Murray Alluvium SDL area is located between the Murray River and Billabong Creek and includes the deeper aquifers of the Calivil Formation and Renmark Group and also the Shepparton Formation sediments. The Calivil Formation has a high hydraulic conductivity, especially near the basin margins where alluvial fan deposits are thickest. In the west this unit fines and becomes thinner, and consequently the transmissivity decreases. The Calivil Formation outcrops in the east near Jerilderie. The Calivil Formation aquifer has the highest yields due to its transmissivity, whereas the Renmark Group is the thicker unit. Most water comes from the Calivil Formation.

Most of the SDL area is covered by a portion of the Southern Riverine Plains groundwater model (CSIRO, 2008d). In the area of the Lower Murray Alluvium SDL area, groundwater balances are provided for two aquifer systems:

1. The 'shallow aquifer' which includes the Shepparton Formation aquifer at depths less than 25 m
2. The 'deep aquifer' which includes the lower part of the Shepparton Formation and also the Calivil Formation and the Renmark Group aquifer, at depths greater than 25 m.

Two separate extraction limits have been determined for this unit, one for the shallow aquifer, and one for the deep aquifer.

Table 69. Groundwater take summary for the Lower Murray Alluvium SDL area

Lower Murray Alluvium SDL area	Shallow aquifer	Deep aquifer
	GL/yr	GL/yr
Entitlement*	**30**	**84**
Current use for entitlement bores**	34	78
Estimated use for stock & domestic bores***	5.5	8.3
Total current use	**40**	**86**

*Entitlement for the deep aquifer is equal to the LTAEL which is to be achieved by 30 June 2017. The entitlement volume for the shallow aquifer, was provided by DECCW
**Current use volumes are equal to the average annual metered use over the 5-year period 2003/2004 to 2007/2008
***Stock and domestic use was calculated based on information provided by DECCW

1.10.2 Salinity zoning

The groundwater salinity map for the Shepparton Formation aquifer and Calivil Formation aquifer (Figure 20 and Figure 21 respectively) have been used to define extraction limits for the shallow and deep aquifer.

For the shallow aquifer, the groundwater salinity is characterised by four salinity zones ranging from 0 to > 14,000 mg/L TDS. More than half of the shallow aquifer is characterised by groundwater classified as the two higher salinity zones (Table 70).

For the deeper aquifer, the groundwater salinity is also characterised by four salinity zones, however more than half of the groundwater source is characterised by groundwater classified as the two lower salinity zones

Table 71).

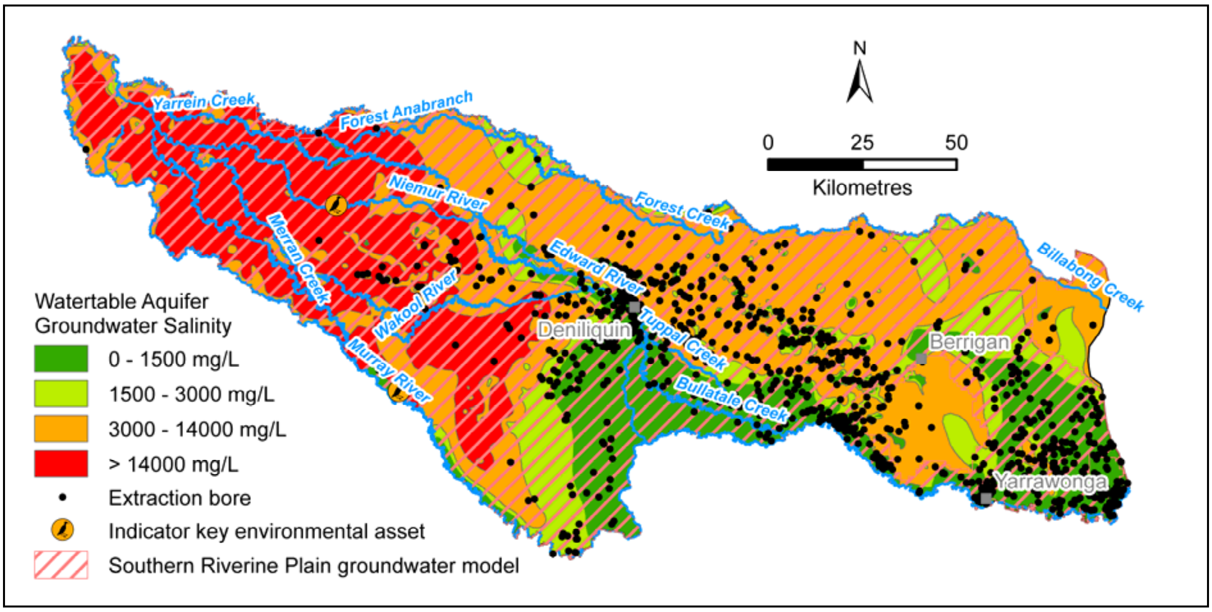

Figure 20. Lower Murray Alluvium Shepparton Formation aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

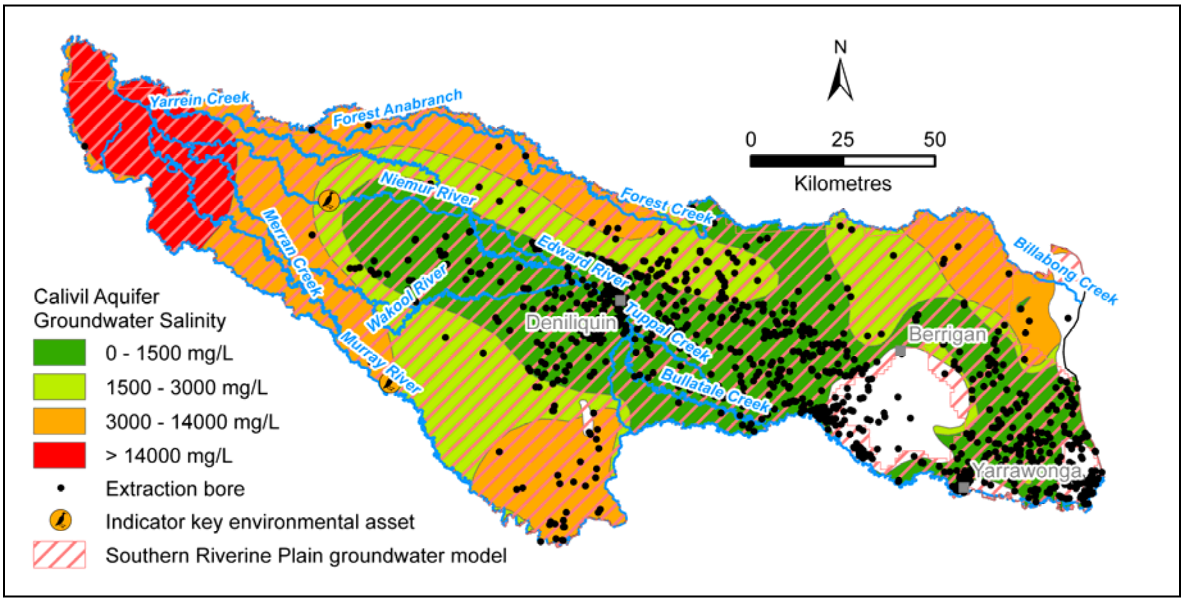

Figure 21. Lower Murray Alluvium Calivil Formation aquifer salinity distribution, from the Pliocene Sands salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 70. Summary of salinity zones in the Lower Murray Alluvium SDL area – shallow aquifer

Watertable salinity zone	Portion of area)	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	20	3538
Zone 2 (1500–3000 mg/L TDS)	14	2500
Zone 3 (3000–14,000 mg/L TDS)	42	7570
Zone 4 (>14,000 mg/L TDS)	24	4473
Total	**100**	**18080**

Table 71. Summary of salinity zone in the Lower Murray Alluvium SDL area – deep aquifer

Deep aquifer salinity zone	Portion of area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	40	6621
Zone 2 (1500–3000 mg/L TDS)	24	4035
Zone 3 (3000–14,000 mg/L TDS)	28	4576
Zone 4 (>14,000 mg/L TDS)	8	1402
Total	**100**	**16,634***

*The Calivil Formation Aquifer is absent in some area in the SDL area. It covers 92 percent of the SDL area.

1.10.3 Key environmental assets

The *Water Act 2007* requires that assessment of environmental water needs of the MDB must encompass key environmental assets, including water-dependent ecosystems, ecosystem services, and sites with ecological significance.

The Murray-Darling Basin Authority has identified 18 'key environmental asset – hydrologic indicator sites that drive the environmental hydrology of the Basin (MDBA, 2010). These 18 sites have been assessed to determine the objectives, targets and flow regimes required to sustain them. This information was input to the generation of an estimate of the long-term average sustainable diversion limits that will not compromise the water requirements for the rivers, wetlands and floodplains of the MDB.

The Lower Murray Alluvium SDL area encompasses the Edward-Wakool River system and the Koondrook-Perricoota Forest, which are two of the 18 key environmental asset – hydrologic indicator sites identified by the Murray-Darling Basin Authority.

The Edward-Wakool River system is considered at low risk given that the watertable aquifer is saline and provides a threat to the key environmental asset. Furthermore the key environmental asset is mainly surface-water fed (DECCW, pers. comm. 4/2/2010).

The Koondrook-Perricoota forest is recognised by Ramsar listing. It is rich in flora and fauna – including threatened species – and also contains significant social, cultural and economic resources. In the absence of information to the contrary, the Koondrook-Perricoota Forest is considered a high risk key environmental asset.

1.10.4 Key ecosystem function

The risk to the key ecosystem function in the Lower Murray Alluvium SDL area was assessed via the results of the numerical modelling (CSIRO, 2008d).

Figure 22 is for the entire Southern Riverine Plain groundwater model. It shows the river loss due to pumping at 2004/2005 levels (244 GL/year) and the river loss when there is no-pumping. The purple line shows the difference between the two and indicates that when 244 GL/year is pumped, approximately 56 GL/year of this water is derived from the river. This equates to a connectivity of 23 percent. Therefore the Lower Murray Alluvium is considered at low risk in terms of the key ecosystem function.

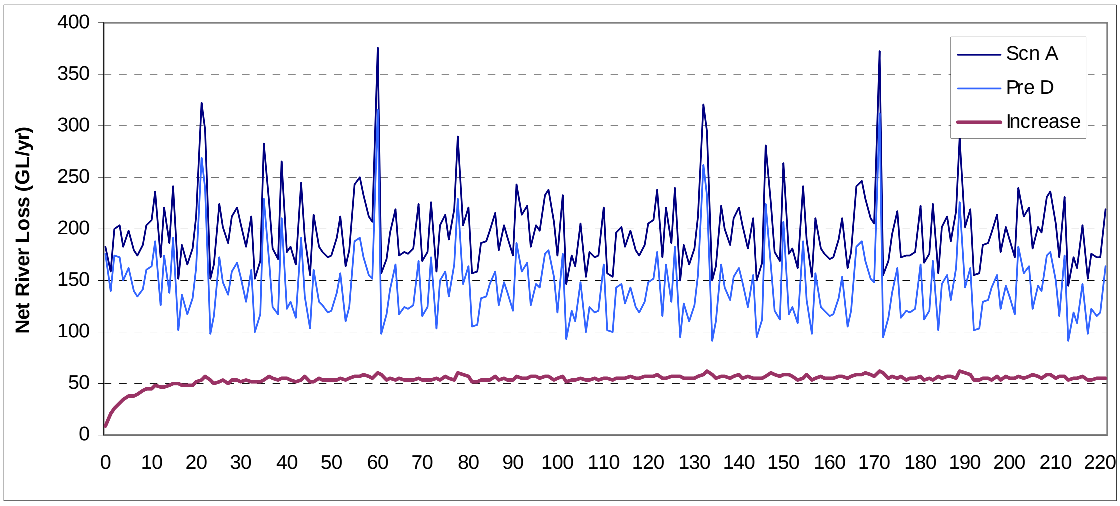

Figure 22. Change in river leakage from the no-development and the 2004/2005 groundwater development scenario; for the Southern Riverine Plains model

1.10.5 Productive base

Recharge

Recharge across the riverine plain is conceptualised to take place via the following mechanisms; leakage from the major river systems, dryland rainfall recharge, infiltration from irrigated areas, leakage from supply/drainage works and some run off from surrounding bedrock areas via small streams. Recharge through the Shepparton Formation to the deeper aquifers is restricted due to the clay rich nature of the Shepparton Formation. However, recharge via rainfall infiltration where the more permeable Calivil Formation outcrops is considered significant (CSIRO, 2008d).

Approximately half of the water extracted from the deeper aquifers is sourced from increased leakage from the overlying Shepparton Formation and the other half from changes in flux across lateral boundaries. The increased leakage from the Shepparton to the Calivil Formation leads to increased river losses.

The Southern Riverine Plain calibration model groundwater balance results were provided for the New South Wales portion of the model, for the shallow and deep aquifers. The mass balance for the shallow aquifer is summarised in Table 72 and indicates total recharge of 337 GL/year. The mass balance for the deeper aquifer is summarised in Table 73 and indicates total recharge of 271 GL/year.

These recharge volumes have been apportioned to the salinity classes, based on the relative size of the salinity class area (Table 74).

Table 72. Inflows for the shallow aquifer, from the 2004/2005 groundwater development model scenario

Groundwater balance for the Shepparton Formation aquifer	Volume
	GL/yr
Diffuse recharge	197
River recharge	87
GW flow from adjacent zone	6.0
Upward leakage from underlying aquifer	47
Total inflows	**337**

Table 73. Inflows for the deep aquifer, from the 2004/2005 groundwater development model scenario

Groundwater balance for the deep aquifers	Volume
	GL/yr
Diffuse recharge	2.0
River recharge	0.20
Downward leakge from overlying aquifer	108
GW flow from adjacent zone	118
Head dependent boundary	43
Total inflows	**271**

Table 74. Recharge calculation for the shallow and deep aquifers of the Lower Murray Alluvium

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Shallow aquifer % area covered by salinity zone	20	14	42	25
Recharge to the shallow aquifer (GL/yr)	66	47	141	83
Total recharge to shallow aquifer (GL/yr)	**337**			
Deep aquifer % area covered by salinity zone	40	24	28	8
Recharge to the deep aquifers (GL/yr)	108	66	75	23
Total recharge to deep aquifer(GL/yr)	**271**			

Storage

The specific yield used for the purpose of this storage calculation is 0.10. An average total thickness of 200 m was estimated for the entire sequence of shallow and deep sediments. Total storage to the Lower Murray Alluvium is approximately 36,000 GL (Table 75).

Table 75. Storage calculation for the Lower Murray Alluvium

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km2)	3538	2500	7570	4473
Saturated thickness (m)	200	200	200	200
Specific yield	0.10	0.10	0.10	0.10
Total storage (GL)	**70,760**	**50,000**	**151,400**	**89,460**

Storage relative to recharge

The ratio of storage to recharge ranges from 407 to 844 for the different salinity zones. This indicates that there is a low risk of the productive base of the aquifer being jeopardised by factors such as climate change and the short-term over extraction of the groundwater resource.

1.10.6 The risk matrix

Table 76 provides a summary of the risk ranking associated with: key environmental assets, key ecosystem function, the productive base, the key environmental outcome and the uncertainty inherent in the RRAM calculation. In summary:

- the SDL area is ranked high risk in terms of environmental assets, due to the presence of the Koondrook-Perricoota forest key environmental asset – hydrologic indicator sites, which has been assumed to be groundwater dependent and sensitive to take
- the SDL area is ranked low risk in terms of ecosystem function, given the connectivity is approximately 25 percent
- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio is approximately 600
- there is a risk to the key environmental outcomes (i.e. groundwater salinity)

- there is a low uncertainty associated with this unit given that the recharge component of the RRAM was derived from numerical modelling.

Table 76. Risk matrix

Risk ranking	Environmental assets (EAs)	OR	Ecosystem function	OR	Productive base	Sustainability factor (SF)	Key environmental outcome	Degree of uncertainty
High	EA that is highly groundwater dependent and highly sensitive to take		In the current state, groundwater discharge provides baseflow to the unregulated river reach. Groundwater extraction is likely to result in streamflow depletion		Storage/ recharge <20	0.10	Where there is no risk to the key environmental outcome (i.e. groundwater salinity) there is no reduction to the SF for any of the salinity classes. Where there is a risk to the key environmental outcome, as a measure to reduce risk to groundwater quality, the following reductions are made: Salinity class 1: reduce SF by 20% Salinity class 2: reduce SF by 10% Salinity classes 3 & 4: no reduction	Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 50%
Medium	EA that is highly groundwater dependent and is moderately sensitive to take EA that is moderately groundwater dependent and is highly sensitive to take		The rivers in the SDL unit are regulated and they are highly connected to the groundwater system (i.e. >50% impact of pumping on streamflow)		Storage/ recharge 20–40	0.50		
Low	EA that has a low groundwater dependence and low sensitivity to take EAs do not exist in the SDL unit		The rivers in the SDL unit are regulated or unregulated and they have low–moderate connection with the groundwater system (i.e. <50% impact of pumping on streamflow)		Storage/ recharge >40	0.70		Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 25%

1.10.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Lower Murray Alluvium SDL area is 56 GL/year. The RRAM extraction limit was based on the Murray-Darling Basin Sustainable Yields Project Southern Riverine Plain numerical modelling results (CSIRO, 2008d) as these provided the best available information at the time of the RRAM analysis.

The preliminary RRAM extraction limit for the Lower Murray Alluvium SDL area has been superseded by more recent modelling results (CSIRO, 2010j)

Table 77. Extraction limit summary for the shallow aquifer in the Lower Murray Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	66	47	141	83
Sustainability factor	0.08	0.09	0.10	0.10
Extraction limit (GL/yr)	**5.3**	**4.2**	**14**	**8.3**

Table 78. Extraction limit summary for the deep aquifer in the Lower Murray Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	108	66	75	23
Sustainability factor	0.08	0.09	0.10	0.10
Extraction limit (GL/yr)	**8.6**	**5.9**	**7.5**	**2.3**

1.11 Cudgegong Alluvium (GS25)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the RRAM for the Cudgegong Alluvium SDL area.

1.11.1 Background

The Cudgegong Alluvium SDL area comprises sand and gravel lenses scattered through an alluvial body that is dominated by silt and clay. Current groundwater use in this SDL area is 1.6 GL/year (Table 79). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010k).

Table 79. Groundwater take summary for the Cudgegong Alluvium SDL area

Cudgegong Alluvium SDL area	GL/year
Total 2007/2008 entitlement*	**15**
Current use for entitlement bores**	1.6
Estimated use for stock & domestic bores***	0.040
Total current use	**1.6**

*Entitlement volumes provided by DECCW
**Current Use is the average annual metered use volume over the 5-year period from 2003/2004 to 2007/2008
***Estimated stock and domestic use is based on information provided by DECCW

1.11.2 Salinity Zoning

Groundwater salinity is characterised by two salinity zones that range from 0 to 14,000 mg/L TDS. The majority of the unit is characterised by the lowest groundwater salinity zone (i.e. 97 percent of the area) and hence the entire area has been classified as salinity zone 1 groundwater, for the purpose of the RRAM. The groundwater salinity distribution can be seen in Figure 23 and is summarised in Table 80.

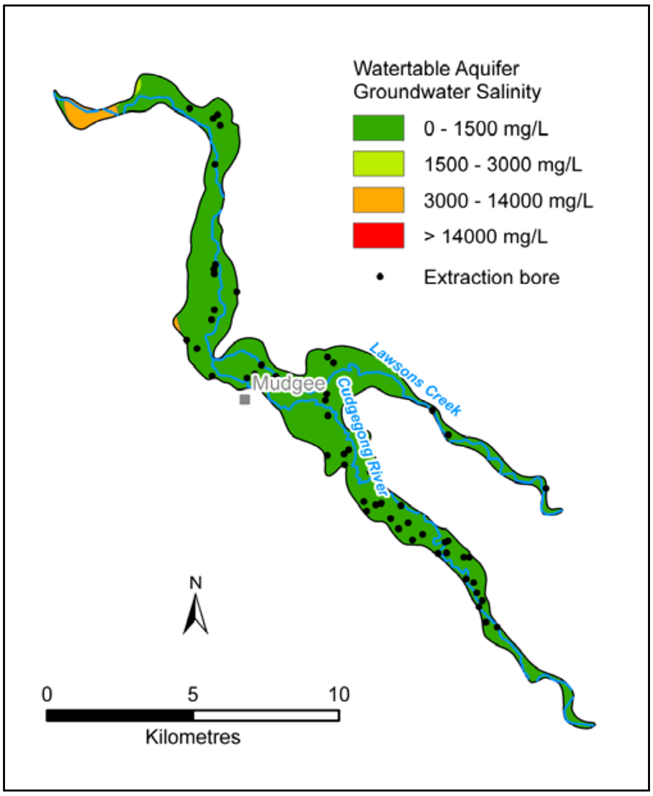

Figure 23. Cudgegong Alluvium watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 80. Summary of salinity zones in the Cudgegong Alluvium SDL area

Watertable salinity zone	Portion of area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	97	37
Zone 2 (1500–3000 mg/L TDS)	0	0
Zone 3 (3000–14,000 mg/L TDS)	3	1.1
Zone 4 (>14,000 mg/L TDS)	0	0
Water bodies	0	0
Total	**100**	**38**

1.11.3 Key environmental assets

There are no key environmental assets that are groundwater dependent and sensitive to take in the Cudgegong Alluvium SDL area.

1.11.4 Key ecosystem function

The alluvial aquifer is considered highly connected to the Cudgegong River, with 96 percent connectivity (CSIRO, 2008e). Lawsons Creek is unregulated and hence there is a high risk to the key ecosystem function.

1.11.5 Productive base

Recharge

Recharge to the Cudgegong Alluvium SDL area has been calculated at 1.4 GL/year via WAVES modelling and is reported per salinity zone in Table 81 . The area is not extensively irrigated and hence no allowance has been made for irrigation derived recharge.

Table 81. Recharge calculation

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km2)	38	0.0	0	0
Diffuse recharge (mm/yr)	36	N/A	N/A	N/A
Total recharge (GL/yr)	**1.4**	**N/A**	**N/A**	**N/A**

Storage

The maximum saturated thickness of the unconfined aquifer is approximately 10 m (ANRA, 2010). A specific yield of 0.1 has been adopted for the purposes of the storage calculation, based on a typical specific yield of an unconfined

Total storage estimated for the Cudgegong Alluvium aquifer is 38.3 GL (Table 82).

Table 82. Storage calculation

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km2)	38	0.0	0.0	0.0
Saturated thickness (m)	10	N/A	N/A	N/A
Specific yield	0.10	N/A	N/A	N/A
Total storage (GL)	**38**	**N/A**	**N/A**	**N/A**

Storage relative to recharge

The ratio of storage to recharge is 27. This indicates that there is a medium risk of the productive base of the aquifer being jeopardised by factors such as climate change and the short-term over extraction of the groundwater resource.

1.11.6 The risk matrix

Table 83 provides a summary of the risk ranking associated with: key environmental assets, key ecosystem function, the productive base, the key environmental outcome and the uncertainty inherent in the RRAM calculation. In summary:

- the SDL area is ranked low risk in terms of key environmental assets, given none have been identified that are groundwater dependent in this area
- the SDL area is ranked high risk in terms of ecosystem function, given that there is approximately 96 percent groundwater and surface water connectivity and there are unregulated river reaches
- the SDL area is ranked medium risk in terms of the productive base, given that the storage/recharge ratio is between 20 and 40
- there is no risk to the key environmental outcomes (i.e. groundwater salinity)
- there is a low uncertainty associated with this unit given that an extensive monitoring network exists and the recharge processes are well understood.

Table 83. Risk matrix

Risk ranking	Environmental assets (EAs)	OR	Ecosystem function	OR	Productive base	Sustainability factor (SF)	Key environmental outcome	Degree of uncertainty
High	EA that is highly groundwater dependent and highly sensitive to take		In the current state, groundwater discharge provides baseflow to the unregulated river reach. Groundwater extraction is likely to result in streamflow depletion		Storage/ recharge <20	0.10	Where there is no risk to the key environmental outcome (i.e. groundwater salinity) there is no reduction to the SF for any of the salinity classes. Where there is a risk to the key environmental outcome, as a measure to reduce risk to groundwater quality, the following reductions are made: Salinity class 1: reduce SF by 20% Salinity class 2: reduce SF by 10% Salinity classes 3 & 4: no reduction	Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 50%
Medium	EA that is highly groundwater dependent and is moderately sensitive to take EA that is moderately groundwater dependent and is highly sensitive to take		The rivers in the SDL unit are regulated and they are highly connected to the groundwater system (i.e. >50% impact of pumping on streamflow)		Storage/ recharge 20–40	0.50		
Low	EA that has a low groundwater dependence and low sensitivity to take EAs do not exist in the SDL unit		The rivers in the SDL unit are regulated or unregulated and they have low–moderate connection with the groundwater system (i.e. <50% impact of pumping on streamflow)		Storage/ recharge >40	0.70		Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 25%

1.11.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Cudgegong Alluvium SDL area is 0.14 GL/year (Table 84). This extraction limit can be increased to equal current use (i.e. 1.6 GL/year) given the highly connected nature of the system. The extraction limit for this unit for groundwater and surface water should be set taking into account the connectivity and to eliminate double accounting.

Table 84. Extraction limit summary for the Cudgegong Alluvium Aquifer

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	1.4	0	0	0
Sustainability factor	0.10	N/A	N/A	N/A
Extraction limit volume (GL/yr)	**0.14**	**N/A**	**N/A**	**N/A**

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Contact Us

Phone: 1300 363 400
+61 3 9545 2176

Email: enquiries@csiro.au

Web: www.csiro.au

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