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Sustainable Extraction Limits Derived from the Recharge Risk Assessment Method – New South Wales (part 2)

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).

In summary, for the New South Wales (part 2) SDL areas, the preliminary RRAM extraction limits that were calculated to inform the Basin Plan mainly included extraction limits set to equal current groundwater use.

1 Sustainable extraction limits derived from the RRAM – New South Wales (part 2)

1.1 Belubula Alluvium (GS21)

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

1.1.1 Background

The Belubula Alluvium SDL area is located in the upper Lachlan Catchment in Central New South Wales and incorporates the Belubula Valley Alluvium groundwater management unit (GMU). The Belubula River is a tributary to the Lachlan River.

The alluvial sediments in the valley contain basal gravels and sands overlain and interbedded with silty and sandy clays along the valley floor and terraced floodplains. Recharge to the alluvial aquifer is thought to occur via two main processes; direct diffuse rainfall recharge and river recharge during high river flows. The river and the alluvial aquifer are considered to be in good connection, with groundwater extraction from near river bores likely to result in stream depletion. A groundwater impact assessment for the Belubula Alluvium is currently being undertaken by the National Water Commission. This impact assessment indicates a strong connection between the groundwater and surfacewater sources.

Total current use in this SDL area is 1.9 GL/year (Table 1). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

Table 1. Groundwater take summary for the Belubula Alluvium SDL area

Belubula Valley Alluvium SDL area	GL/year
Total 2007/2008 entitlement*	**8.3**
Current use for entitlement bores**	1.9
Estimated use for stock & domestic bores***	0.040
Total current use	**1.9**

*2007/2008 entitlement information provided by New South Wales Department of Environment, Climate Change and Water (DECCW)
**Current Use is the average annual metered use over the 5-year period 2003/2004 to 2007/2008
***S&D estimates were based on data provided by DECCW

1.1.2 Salinity Zoning

Groundwater is characterised by two salinity zones in the Belubula Alluvium SDL area. The groundwater salinity distribution is shown in Figure 1 and is summarised in Table 2.

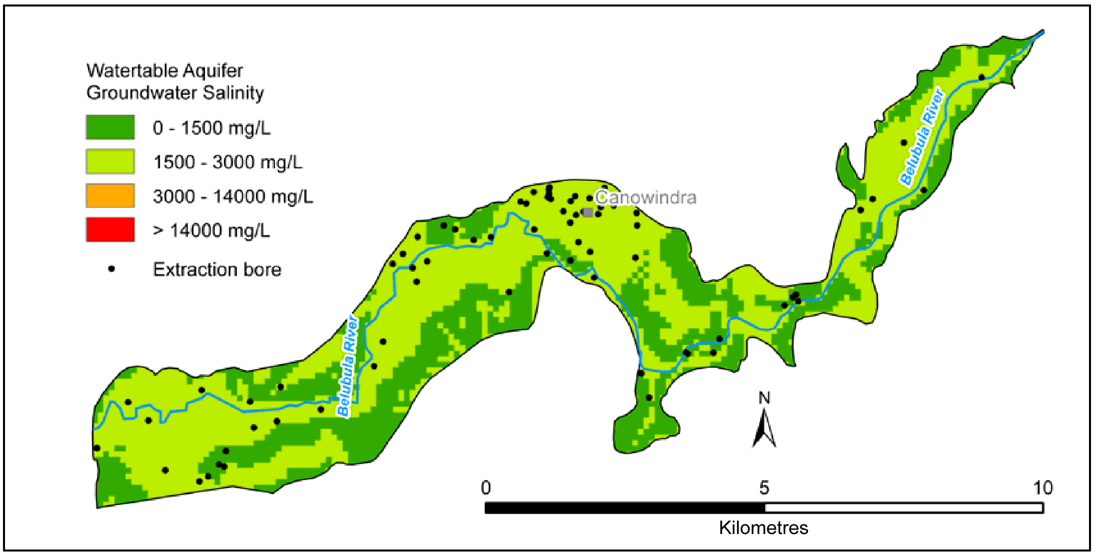

Figure 1. Belubula Alluvium watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

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

Watertable salinity zone	Portion of total area (%)	Area (km^2)
Zone 1 (0–1,500 mg/L TDS)	36	13
Zone 2 (1,500–3,000 mg/L TDS)	64	23
Zone 3 (3,000–14,000 mg/L TDS)	0	0
Zone 4 (> 14,000–mg/L TDS)	0	0
Water bodies	0	0
Total	**100**	**36**

1.1.3 Key environmental assets

There are no groundwater dependent key environmental assets that are sensitive to groundwater extraction, associated with the Belubula Alluvium SDL area.

1.1.4 Key ecosystem function

There is strong connection between surface water and groundwater in the Belubula Alluvium SDL area, both in the unregulated and regulated parts of the SDL area. The Belubula River is thought to be gaining groundwater along its upper reaches and variably gaining and losing seasonally along the lower reaches (CSIRO, 2008a).

A reduction in baseflow to the river is therefore likely to occur in response to any groundwater pumping in the SDL. The lag between groundwater extraction and stream depletion is likely to be short since the majority of groundwater extraction occurs in the high permeability sediments of the alluvial aquifer and the bores are located very close to the river as shown in Figure 1.

Therefore, there is a high risk to the key ecosystem function in the Belubula Alluvium SDL area.

1.1.5 Productive Base

Recharge

Modelled dryland diffuse groundwater recharge derived from WAVES modelling (Crosbie et al., 2010) has been used to calculate recharge to the alluvial aquifer. The historical climate scenario for a median 15- year period, results in a recharge rate of 107 mm/year for salinity zone 1 and 110 mm/year in salinity zone 2. This results in a total recharge of 4 GL/year within the SDL area as shown in Table 3. River recharge and recharge due to throughflow have not been accounted for here.

Table 3. Recharge calculation for the Belubula Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	13	23	0	0
Diffuse recharge (mm/yr)	107	110	N/A	N/A
Total recharge (GL/yr)	**1.4**	**2.6**	**N/A**	**N/A**

Storage

The alluvial aquifer has an average thickness of 24 m (based on an analysis of drillers logs for 31 bores in the area). Given that there is no hydrogeological data specific to the Belubula Alluvium, a specific yield value of 10 percent has been used, as it is typical of an alluvial aquifer with variable grain size (Johnson, 1967). Based on these assumptions, groundwater storage for the two salinity zones in the Belubula Alluvium SDL are 31 GL and 56 GL (Table 4).

Table 4 Storage calculation for the Belubula Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	13	23	0	0
Saturated thickness (m)	24	24	N/A	N/A
Specific yield	0.1	0.1	N/A	N/A
Total storage (GL)	**31**	**56**	**N/A**	**N/A**

Storage relative to recharge

The ratio of storage to recharge is 22 for each of the salinity zones. This indicates that there is a medium risk to the Productive Base and 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 5 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 that none have been identified that are groundwater dependenent
- The SDL area is ranked high risk in terms of Ecosystem Function, given that the Belubula River is unregulated in parts and is in good connection with the alluvial aquifer
- 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 high level of uncertainty given that the RRAM is derived from diffuse groundwater recharge derived from WAVES modelling only. It does not include other potential components of groundwater recharge, including river leakage, irrigation returns, throughflow etc

Table 5. Risk matrix

Risk ranking	Environmental assets (EAs)	OR	Ecosystem function	OR	Productive base	Sustainability factor	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 stream flow depletion.		Storage / recharge < 20	0.10	Where there is no risk to the Key Environmental Outcome (i.e. uniform 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 Class 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 area are regulated and they are highly connected to the groundwater system (i.e. > 50 % impact of pumping on stream flow within 50 years)		Storage / Recharge between 20-40	0.50		
Low	EA that has a low groundwater dependence and low sensitivity to take EAs do not exist in the SDL area		The rivers in the SDL area are regulated or unregulated and they have low—moderate connection with the groundwater system (i.e. < 50 % impact of pumping on stream flow within 50 years)		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 Belubula Alluvium SDL area is 0.20 GL/year (Table 6). This extraction limit can be increased to equal current use (i.e. 1.9 GL/year) given the highly connected nature of the system. The extraction limit for this SDL area for groundwater and surface water should be set taking into account the connectivity and to eliminate double accounting.

Table 6. Extraction limit summary for the Belubula Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	1.4	2.6	0	0
Sustainability factor	0.05	0.05	N/A	N/A
Extraction limit (GL/yr)	0.07	0.13	N/A	N/A

1.2 Upper Murray Alluvium (GS59)

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

1.2.1 Background

The Upper Murray SDL area corresponds to the Upper Murray GMU which is located on the New South Wales side of the River Murray between Hume Dam and Corowa. A water sharing plan does not exist for the groundwater sources associated with the Upper Murray SDL area. The GMU was embargoed in 2000 to prevent the growth in groundwater entitlements. Current use in this SDL area is 11 GL/year (Table 7). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

The River Murray and rainfall have been identified as the major recharge sources for the aquifers while irrigation leakage was identified as a minor recharge source as well. Annual groundwater recharge as determined by the groundwater model is 15.3 GL/year (Kulatunga, 2009).

The Lachlan Formation (equivalent to the Calivil Formation in the Murray Geological Basin to the west) is up to 80 m thick in the area (Kulatunga, 2009). The Shepparton Formation overlies the Lachlan Formation and is also up to about 80m thick in the area and varies between clay and gravel. The lower part of the Shepparton Formation has thick zones of sand and gravel.

The main aquifers are the quartz sand and gravel of the Lachlan Formation which have aquifer transmissivities up to 2000 m^2/day (Williams, 1989). Some of the irrigation bores, which are tapping this aquifer, have the capacity to yield up to 10 ML/day.

The Shepparton Formation generally has much lower aquifer transmissivities up to about 250 m^2/day. Some irrigation bores which obtain groundwater from the gravel and coarse sand in this formation have the capacity to yield up to about 3 ML/day. Aquifers in this formation provide water to the majority of stock and domestic bores in the management area. There is an estimated 500 stock and domestic bores in this SDL area (Kulatunga, 2009).

Table 7. Groundwater take summary for the Upper Murray Alluvium SDL area

Upper Murray Alluvium SDL area	GL/year
2007/2008 entitlement*	41
Current use for entitlement bores**	11
Estimated use for stock & domestic bores***	0.4
Total current use	**11**

*Entitlement data was provided by DECCW
**Current Use is the average annual metered use volume over the 5 year period 2003/2004 to 2007/2008
***Stock and domestic use was estimated based on volumes provided by DECCW

1.2.2 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 Murray Alluvium SDL area, ranging from 0 to 14,000 mg/L TDS. The groundwater salinity distribution can be seen in Figure 3 and is summarised in Table 8.

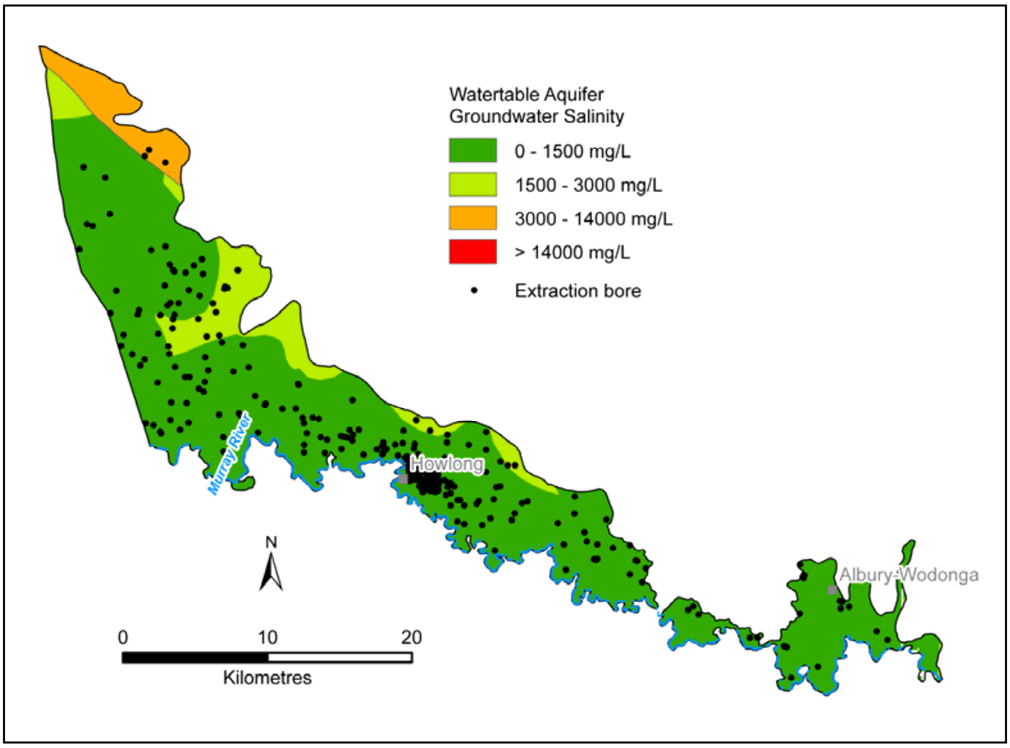

Figure 2. Upper Murray Alluvium watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 8. Summary of salinity zones in the Upper Murray Alluvium SDL area

Watertable salinity zone	Portion of area (%)	Area (km^2)
Zone 1 (0–1,500 mg/L TDS)	84	410
Zone 2 (1,500–3,000 mg/L TDS)	11	53
Zone 3 (3,000–14,000 mg/L TDS)	5	25
Zone 4 (> 14,000 mg/L TDS)	0	0
Total	100	489

1.2.3 Key environmental assets

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

1.2.4 Key ecosystem function

The Murray River is highly regulated. The connectivity between the groundwater and surface water of the Upper Murray Alluvium is believed to be approximately 80 % (DECCW, pers. comm. 4/2/2010) and therefore the key ecosystem function is at medium risk.

1.2.5 Productive base

Recharge

Recharge to the Upper Murray Alluvium has been determined from WAVES modelling, using the historical climate, median scenario.

Recharge rates vary from 14.9 mm/year to 43.0 mm/year between each of the salinity classes. The total volume of recharge to the alluvium is 19.7 GL/year (Table 9).

Table 9. WAVES recharge to the Upper Murray Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	410	53	25	0
WAVES recharge (mm/yr)	43.0	30.9	14.9	N/A
Total recharge (GL/yr)	17.6	1.7	0.4	N/A

Storage

The Lachlan Formation and the Shepparton Formation are up to 160 m thick. An average thickness of 100 m has been used for the purpose of the storage calculation. A specific yield of 0.10 has been used for the purpose of the storage calculation.

The total storage estimated for the alluvial sequence is approximately 7,800 GL (Table 10).

Table 10. Storage calculation for the Upper Murray Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	410	53	25	0
Saturated thickness (m)	160	160	160	0
Specific yield	0.1	0.1	0.1	0
Total storage (GL)	6560	848	400	0

Storage Relative to Recharge

The ratio of storage to recharge ranges from 373 to 1,000 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.

1.2.6 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 that none have been identified that are groundwater dependenent
- the SDL area is ranked medium risk in terms of Ecosystem Function, given that there is greater than 50 % connectivity 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 a risk to the Key Environmental Outcomes (i.e. groundwater salinity)
- there is a low level of uncertainty given that the SDL area is represented by an extensive groundwater monitoring program and a Groundwater Resource Status Report (Kulatunga, 2009) which means recharge processes are considered well understood and represented here

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 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	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%	
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	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 25%

1.2.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Upper Murray Alluvium SDL area is 8.0 GL/yr (Table 12). This extraction limit can be increased to equal current use (i.e. 11 GL/yr) given the highly connected nature of the system. The extraction limit for this SDL area for groundwater and surface water should be set taking into account the connectivity and to eliminate double accounting.

Table 12. Preliminary extraction limit summary for the Upper Murray Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	17.6	1.7	0.4	0
Sustainability factor	0.4	0.45	0.5	N/A
Extraction limit volume (GL/yr)	7.1	0.7	0.2	N/A

1.3 Bell Valley Alluvium (GS20)

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

1.3.1 Background

The Bell Valley Alluvium SDL area includes the Bell Valley Alluvium GMU which is located in Central NSW to the south of Wellington. The Bell River is a tributary to the Macquarie River and flows generally from south to north within a relatively narrow alluvial plain.

The alluvial aquifer consists of basal gravels and sands overlain and interbedded with finer grained sediments of silty and sandy clays. Recharge to the alluvial aquifer is thought to occur via two main processes, direct diffuse rainfall recharge and river recharge during high river flows. The river and the alluvial aquifer are considered to be in good connection, with groundwater extraction from near-river bores likely to result in stream depletion. Current groundwater use is 2.2 GL/yr (Table 13). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

Table 13. Groundwater take summary for the Bell Valley Alluvium SDL area

Bell Valley Alluvium SDL area	GL/year
Total 2007/2008 entitlement*	3.7
Current use for entitlement bores**	2.2
Estimated use for stock & domestic bores***	0.01
Total Current Use	2.2

*2007/2008 groundwater entitlement data was provided by DECCW
**Current use is equal to 60 % of the entitlement volume
***Stock and domestic use was provided by DECCW

1.3.2 Salinity zoning

The majority of the SDL area is characterised by zone 1 quality groundwater with a small proportion being zone 2 (Table 14). It can be seen in Figure 3 that the majority of extraction bores are very near the river and are likely to be in good connection through the alluvial sediments.

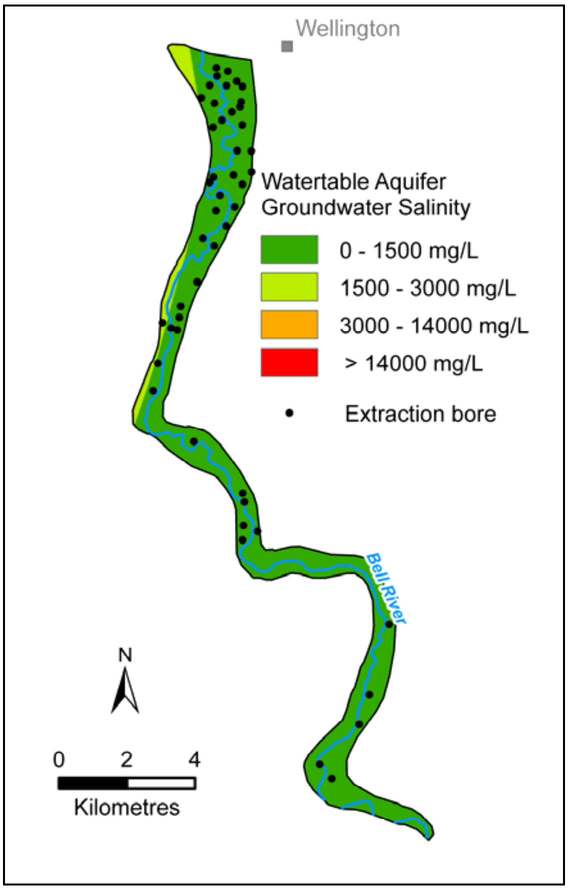

Figure 3. Bell Valley Alluvium watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 14. Summary of salinity zones in the Bell Valley Alluvium SDL area

Watertable salinity zone	Portion of total area (%)	Area (km^2)
Zone 1 (0–1500 mg/L TDS)	94	25
Zone 2 (1500–3000 mg/L TDS)	6	2
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**	**27**

1.3.3 Key environmental assets

There are no groundwater dependent key environmental assets that are sensitive to groundwater extraction, associated with the Bell Valley Alluvium SDL area.

1.3.4 Key ecosystem function

There is a high risk to key ecosystem function in the Bell Valley SDL area since there is a good connection between the unregulated Bell Creek and the alluvial aquifer. It is thought that the Bell Creek is gaining in nature, with river recharge occurring to some degree when creek elevations are high.

Stream depletion is therefore likely to occur in response to any groundwater pumping in the SDL area. The lag between groundwater extraction and stream depletion is likely to be short since the majority of groundwater extraction occurs in the high permeability sediments of the alluvial aquifer and the bores are located very close to the river as shown in Figure 3.

1.3.5 Productive base

Recharge

Dryland diffuse groundwater recharge derived from WAVES modelling (Crosbie et al., 2010) has been used to calculate recharge to the alluvial aquifer. The historical climate scenario for a median 15 year period, results in a recharge rate of 89 mm/year for salinity zone 1 and 84 mm/year in salinity zone 2. This results in a total recharge of 2.3 GL/year within the SDL area as shown in Table 15.

Table 15. Recharge calculation for the Bell Valley Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	25.2	1.5	0	0
Diffuse recharge (mm/yr)	88.7	84.4	N/A	N/A
Total recharge (GL/yr)	**2.24**	**0.13**	**N/A**	**N/A**

Storage

The alluvial aquifer has an average thickness of 15 m (based upon review of drill logs in the area). Given that there is no hydrogeological data specific to the Bell Valley Alluvium, a specific yield value of 10 percent has been used (Johnson, 1967), as it is typical of an alluvial aquifer with variable grain size. Based on these assumptions, the total groundwater storage for the alluvial aquifer is 40 GL (Table 16).

Table 16. Storage calculation for the Bell Valley Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	25.2	1.5	0	0
Saturated thickness (m)	15	15	N/A	N/A
Specific yield	0.1	0.1	N/A	N/A
Total storage (GL)	**37.8**	**2.3**	**N/A**	**N/A**

Storage Relative to Recharge

The ratio of storage to recharge ranges from 17 to 18 for each of the salinity zones. This indicates that there is a high 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 17 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 that none have been identified that are groundwater dependenent
- the SDL area is ranked high risk in terms of Ecosystem Function, given that the Bell River is unregulated and is well connected with the alluvial aquifer
- the SDL area is ranked high risk in terms of the Productive Base, given that the storage/recharge ratio is less than 20
- there is no risk to the Key Environmental Outcomes (i.e. groundwater salinity)
- there is a high level of uncertainty given that the RRAM is derived from diffuse groundwater recharge derived from WAVES modelling only. It does not include other potential components of groundwater recharge, including river leakage, irrigation returns, throughflow etc

Table 17. 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 Bell Valley Alluvium SDL area is 0.12 GL/year (Table 18). This extraction limit can be increased to equal current use (i.e. 2.2 GL/year) given the highly connected nature of the system. The extraction limit for this SDL area for groundwater and surface water should be set taking into account the connectivity and to eliminate double accounting.

Table 18. Preliminary extraction limit for the Bell Valley Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	2.24	0.13	0	0
Sustainability ractor	0.05	0.05	NA	NA
Extraction limit (GL/yr)	**0.11**	**0.01**	**NA**	**NA**

1.4 Lake George Alluvium (GS35)

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

1.4.1 Background

The Lake George Alluvium SDL area is located adjacent to Lake George in southeast NSW roughly along the Turallo and Butmaroo Creek drainage lines. The alluvial deposit consists of basal sands and gravels which are overlain by and are interbedded with, clayey sediments which occur in two separate palaeochannels (Hydroilex, 2005). The aquifer is used for town water supply and irrigation and current groundwater use is 0.23 GL/year (Table 19). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

Table 19 Groundwater Take Summary for the Lake George Alluvium SDL area

Lake George Alluvium SDL area	GL/year
Total 2007/2008 Entitlement*	1.2
Current Use for Entitlement Bores**	0.20
Estimated Use for Stock & Domestic Bores***	0.028
Total Current Use	0.23

*2007/2008 groundwater entitlement data supplied by DECCW
**Current use is the avearge annual metered use volume over the 5 year period 2003/2004 to 2007/2008
***Stock and domestic use was based on estimates provided by DECCW

1.4.2 Salinity zoning

The Lake George Alluvium SDL area contains salinity zone 1 salinty groundwater as shown in Figure 4 and is summarised in Table 20.

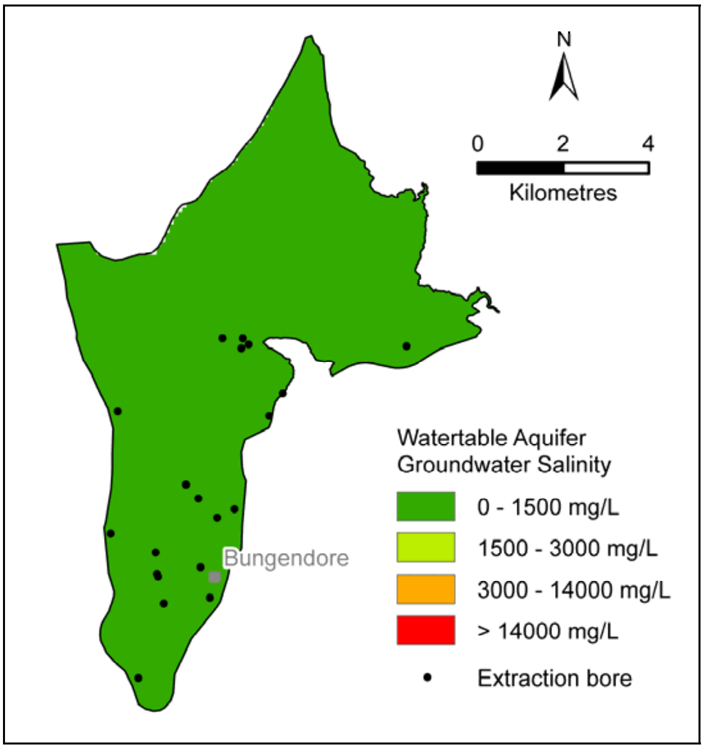

Figure 4 Lake George Alluvium watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 20. Summary of salinity zones in the Lake George Alluvium SDL area

Watertable salinity zone	Portion of total area (%)	Area (km^2)
Zone 1 (0–1500 mg/L TDS)	100	60
Zone 2 (1500–3000 mg/L TDS)	0	0
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**	60

1.4.3 Key environmental assets

There are no groundwater dependent key environmental assets that are sensitive to groundwater extraction, associated with the Lake George Alluvium SDL area.

1.4.4 Key ecosystem function

Groundwater and surface water are not considered to be highly connected in this SDL area (DECCW, February 2010, pers. comm.).

Tullaroo and Butmaroo Creeks are unregulated and are considered to be gaining streams in the fractured rock area upstream (and outside) of the SDL area. Inside the SDL area however, the creeks are ephemeral and are thought to be losing to the shallow groundwater when they are flowing. Therefore the key ecosystem function is at medium risk.

1.4.5 Productive base

Recharge

Modelled dryland diffuse groundwater recharge derived from WAVES modelling (Crosbie et al., 2010) has been used to calculate recharge to the alluvial aquifer. The historical climate scenario for a median 15-year period, results in a recharge rate of 34 mm/year for salinity class 1. This results in a total recharge of 2.1 GL/year within the SDL area.

Table 21. Recharge calculation for the Lake George Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	60	0	0	0
Diffuse recharge (mm/yr)	34	N/A	N/A	N/A
Total recharge (GL/yr)	**2.1**	**N/A**	**N/A**	**N/A**

Storage

The saturated thickness of the Lake George SDL area was estimated at 30 m based on an assessment of a number of drillers logs for bores drilled in the SDL area. Given that there is no hydrogeological data specific to the Lake George Alluvium, a specific yield value of 10 percent has been used (Johnson, 1967), as it is typical of an alluvial aquifer with variable grain size. Based on these assumptions, the total groundwater storage estimate for salinity zone 1 is 176 GL (Table 22).

Table 22. Storage calculation for the Lake George Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	60	0	0	0
Saturated thickness (m)	30	N/A	N/A	N/A
Specific yield	0.1	N/A	N/A	N/A
Total storage (GL)	**176**	**N/A**	**N/A**	**N/A**

Storage Relative to Recharge

The ratio of storage to recharge is 84 for salinity zone 1. 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 23 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 that none have been identified that are groundwater dependent
- the SDL area is ranked medium risk in terms of ecosystem function, given that losing streams exist with fractured rock in this SDL area
- the SDL area is ranked low risk in terms of the Productive Base, given that the storage/recharge ratio is greater than 40
- there is no risk to the key environmental outcomes (i.e. groundwater salinity)
- there is a high level of uncertainty given that the RRAM is derived from diffuse groundwater recharge derived from WAVES modelling only. It does not include other potential components of groundwater recharge, including river leakage, irrigation returns, throughflow etc

Table 23. 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 extraction limit resulting from the RRAM for the Lake George Alluvium is 0.51 GL/yr (Table 24).

Table 24. Extraction limit summary for the Lake George Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	2.1	0	0	0
Sustainability factor	0.25	N/A	N/A	N/A
Extraction limit (GL/yr)	0.51	N/A	N/A	N/A

1.5 Castlereagh Alluvium (GS23)

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

1.5.1 Background

The Castlereagh Alluvium SDL area incorporates the Castlereagh Alluvium GMU and is located along the Castlereagh River in north-eastern New South Wales. The alluvial aquifer contains basal gravels and sands and is interbedded and overlain by finer clayey sediments. Recharge is thought to occur through diffuse rainfall recharge and river recharge when higher flows occur.

Many of the bores in the SDL area are located in close proximity to the Castlereagh River and are likely to induce stream depletion as a result of pumping, as the river is considered to be in good connection with the alluvial aquifer. Current groundwater use is 0.44 GL/year (Table 25). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

Table 25. Groundwater take summary for the Castlereagh Alluvium SDL area

Castlereagh Alluvium SDL area	GL/year
Total 2007/2008 entitlement*	0.58
Current use for entitlement bores**	0.35
Estimated use for stock & domestic bores***	0.085
Total Current Use	0.44

*2007/2008 groundwater entitlement data was provided by DECCW
**Current use is equal to 60% of the entitlement volume
***Stock and domestic use was provided by DECCW

1.5.2 Salinity zoning

The Castlereagh Alluvium SDL area is predominantly characterised by salinity zone 1 groundwater salinity with a small area of salinity zone 2. This is shown in Figure 5 and is summarised in Table 26.

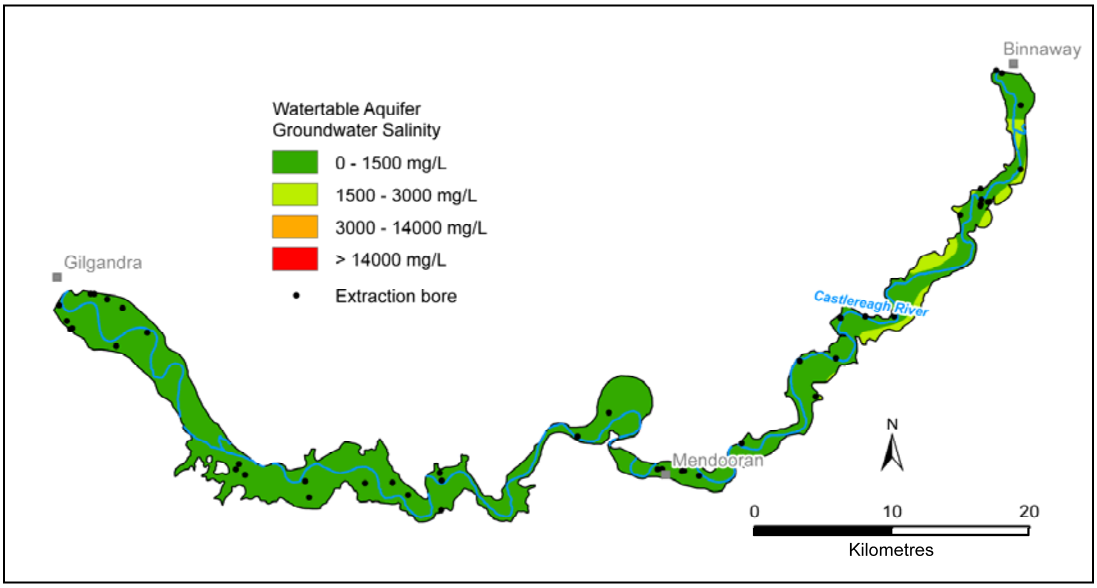

Figure 5 Castlereagh Alluvium watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 26. Summary of salinity zones in the Castlereagh Alluvium SDL area

Watertable Salinity Zone	Portion of Total Area (%)	Area (km^2)
Zone 1 (0– 1500 mg/L TDS)	94	200
Zone 2 (1500–3000 mg/L TDS)	6	12
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**	212

1.5.3 Key environmental assets

There are no groundwater dependent key environmental assets that are sensitive to groundwater extraction, associated with the Castlereagh Alluvium SDL area. Therefore there is a low risk of impact on key environmental assets.

1.5.4 Key ecosystem function

The Castlereagh River is unregulated and is considered to be medium gaining in its upper reaches and medium losing in the lower section (CSIRO, 2008b). The key ecosystem function is therefore considered to be at high risk of impact from groundwater pumping.

1.5.5 Productive base

Recharge

Modelled dryland diffuse groundwater recharge derived from WAVES modelling (Crosbie et al., 2010) has been used to calculate recharge to the alluvial aquifer. The historical dry climate scenario, results in a recharge rate of 42 mm/year for salinity zone 1 and 67 mm/yr in salinity zone 2. This results in a total recharge of 9.2 GL/year within the SDL area (Table 27).

Table 27 Recharge calculation for the Castlereagh Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	200	12	0.0	0.0
Diffuse recharge (mm/yr)	42	67	N/A	N/A
Total recharge (GL/yr)	**8.4**	**0.79**	**N/A**	**N/A**

Storage

The saturated thickness of the alluvial aquifer was estimated to be 50 m based on an analysis of a selection of drill logs for bores in the SDL area. Given that there is no hydrogeological data specific to the Castlereagh Alluvium, a specific yield value of 10 percent has been used (Johnson, 1967), as it is typical of an alluvial aquifer with variable grain size. Based on these assumptions, the total groundwater storage estimates for the two salinity zones in the Castlereagh Alluvium SDL area are 998 GL and 59 GL (Table 28).

Table 28. Storage calculation for the Castlereagh Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	200	12	0.0	0.0
Saturated thickness (m)	50	50	N/A	N/A
Specific yield	0.1	0.1	N/A	N/A
Total storage (GL)	**998**	**59**	**N/A**	**N/A**

Storage relative to recharge

The ratio of storage to recharge ranges from 75 to 119 for salinity zones 1 and 2. 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 29 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 that none have been identified that are groundwater depenendent
- the SDL area is ranked high risk in terms of ecosystem function, given that the Castlereagh River is unregulated and is well connected with the alluvial aquifer
- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio is greater than 40 for both salinity classes
- there is no risk to the key environmental outcomes (i.e. groundwater salinity)
- there is a high level of uncertainty given that the RRAM is derived from diffuse groundwater recharge derived from WAVES modelling only. It does not include other potential components of groundwater recharge, including river leakage, irrigation returns, throughflow etc

Table 29. 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%

1.5.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Castlereagh Alluvium SDL area is 0.37 GL/yr (Table 30). This extraction limit can be increased to equal current use (i.e. 0.44 GL/yr) given the highly connected nature of the system. The extraction limit for this SDL area for groundwater and surface water should be set taking into account the connectivity and to eliminate double accounting.

Table 30. Preliminary extraction limit summary for the Castlereagh Alluvium SDL

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	8.4	0.79	0	0
Sustainability factor	0.04	0.045	N/A	N/A
Extraction limit volume (GL/yr)	0.34	0.036	N/A	N/A

1.6 Collaburragundry – Talbragar Alluvium (GS24)

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

1.6.1 Background

The Collaburragundry – Talbragar Alluvium SDL area is located along the Talbragar and Coolaburragundy Rivers to the west of Dunedoo in eastern New South Wales. The alluvial sediments contain gravels and sands with finer grained clays overlying and interbedded with the more productive zones. The alluvial aquifer is thought to be in good connection with the rivers.

Many of the bores in the SDL area are located in close proximity to the rivers and are likely to induce stream depletion as a result of pumping. Recharge is thought to occur through diffuse rainfall recharge and river recharge when higher flows occur.

Groundwater from this aquifer is used for town supply, irrigation, stock and domestic purposes. Current groundwater use is 3.7 GL/year (Table 31). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

Table 31. Groundwater take summary for the Collaburragundry – Talbragar Alluvium SDL area

Collaburragundry – Talbragar Alluvium SDL area	GL/year
Total 2007/2008 entitlement*	6.0
Current use for entitlement bores*	3.6
Estimated use for stock & domestic bores*	0.079
Total current use	3.7

*2007/2008 groundwater entitlement data was provided by DECCW
**Current use is equal to 60 % of the entitlement volume
***Stock and domestic use was provided by DECCW

1.6.2 Salinity zoning

There are three salinity zones in the Collaburragundry – Talbragar Alluvium SDL area, with most of the area characterised by groundwater salinity classified as salinity zone 1. The area characterised by salinity zone 3 is small (i.e. less than 1 percent of the total area) and therefore was lumped with salinity zone 2 for the purpose of the RRAM. The salinity distribution can be seen in Figure 6 and is summarised in Table 32.

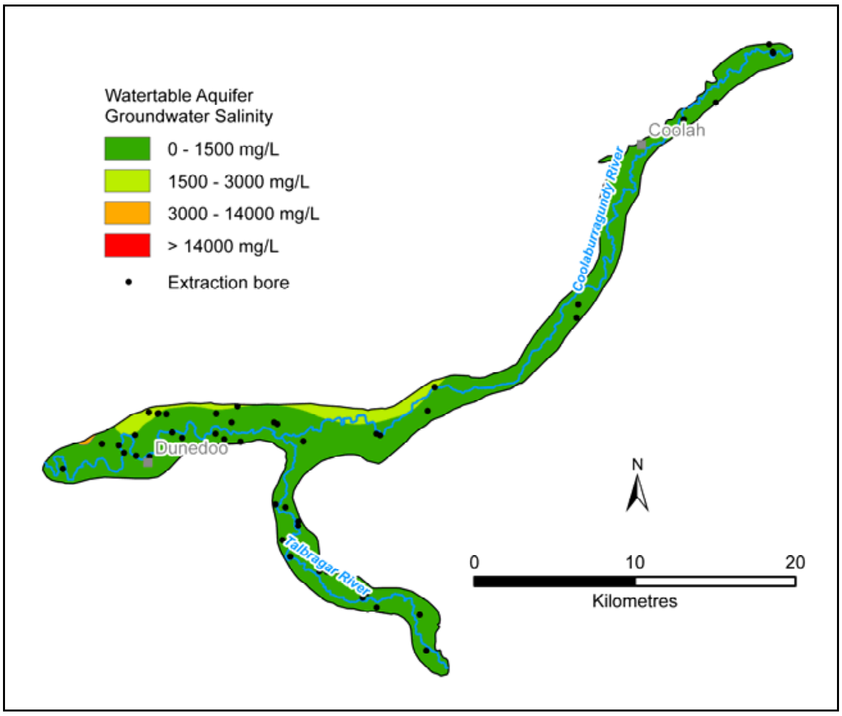

Figure 6. Collaburragundry – Talbragar Alluvium watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 32. Summary of salinity zones in the Collaburragundry – Talbragar Alluvium SDL area

Watertable salinity zone	Portion of total area (%)	Area (km^2)
Zone 1 (0–1500 mg/L TDS)	92	140
Zone 2 (1500–3000 mg/L TDS)	8	12
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	152

1.6.3 Key environmental assets

There are no groundwater dependent key environmental assets that are sensitive to groundwater extraction, associated with the Collaburragundry – Talbragar Alluvium SDL area. Therefore there is a low risk of impact on key environmental assetss.

1.6.4 Key ecosystem function

The Coolaburragundy and Talbragar Rivers are unregulated. The Talbragar River was described as low gaining within this SDL area (CSIRO, 2008b) and both rivers are considered to be in good connection with the alluvial aquifer. Therefore the key ecosystem function is considered to be at high risk in this SDL area.

1.6.5 Productive base

Recharge

Modelled dryland diffuse groundwater recharge derived from WAVES modelling (Crosbie et al., 2010) has been used to calculate recharge to the alluvial aquifer. The historical climate scenario for a median 15-year period, results in a recharge rate of 30 mm/year for salinity zone 1 and 7.3 mm/year in salinity zone 2. This results in a total recharge of 4.3 GL/year (Table 33).

Table 33. Recharge calculation for the Collaburragundry – Talbragar Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	140	12	0	0
Diffuse recharge (mm/yr)	30	7.3	N/A	N/A
Total recharge (GL/yr)	**4.2**	**0.088**	**N/A**	**N/A**

Storage

A saturated thickness of 40 m for the alluvial aquifer was estimated after the inspection of a selection of drillers logs associated with bores within the SDL area. Given that there is no hydrogeological data specific to the Collaburragundry – Talbragar Alluvium, a specific yield value of 10 percent has been used (Johnson, 1967), as it is typical of an alluvial aquifer with variable grain size. Based on these assumptions, the total groundwater storage volume for the alluvial aquifer is 608 GL (Table 34).

Table 34. Storage calculation for the Collaburragundry – Talbragar Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	140	12	0	0
Saturated thickness (m)	40	40	N/A	N/A
Specific yield	0.1	0.1	N/A	N/A
Total storage (GL)	**560**	**48**	**N/A**	**N/A**

Storage relative to recharge

The ratio of storage to recharge is 133 for salinity zone 1 and 545 for salinity zone 2. 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 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 that none have been identified that are groundwater dependent
- the SDL area is ranked high risk in terms of ecosystem function, given that the rivers are unregulated gaining rivers and have a good connection with the alluvial aquifer
- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio is greater than 40
- there is no risk to the key environmental outcomes (i.e. groundwater salinity)
- there is a high level of uncertainty given that the RRAM is derived from diffuse groundwater recharge derived from WAVES modelling only. It does not include other potential components of groundwater recharge, including river leakage, irrigation returns, throughflow etc

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></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></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></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></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></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></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>

1.6.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Collaburragundry – Talbragar Alluvium SDL area is 0.21 GL/year (Table 36). This extraction limit can be increased to equal current use (i.e. 3.7 GL/year) given the highly connected nature of the system. The extraction limit for this SDL area for groundwater and surface water should be set taking into account the connectivity and to eliminate double accounting.

Table 36. Preliminary extraction limit summary for the Collaburragundry – Talbragar Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	4.1	0.083	0	0
Sustainability factor	0.05	0.05	N/A	N/A
Extraction limit volume (GL/yr)	**0.21**	**0.0042**	**N/A**	**N/A**

1.7 Peel Valley Alluvium (GS54)

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

1.7.1 Background

The Peel Valley Alluvium SDL area is located in north-eastern New South Wales near Tamworth and incorporates the Peel Valley Alluvium GMU. The Peel River flows northwest and has a number of tributaries, including Goonoo – Goonoo Creek. The alluvial sediments of this valley consist of basal gravels and sands which are overlain and interbedded with finer grained sediments such as silty or sandy clays. The sediments are relatively shallow and thin within the narrow valleys.

The alluvial aquifer is used for mostly horticultural purpose, though it has historically been used for water supply. Current groundwater use is 7.3 GL/year (Table 37). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

Recharge to the alluvial aquifer is thought to occur via two main processes, with direct diffuse rainfall recharge being thought a lesser mechanism than river recharge during high river flows. The river and the alluvial aquifer are considered to be in good connection, with groundwater extraction from near river bores likely to result in stream depletion.

Table 37. Groundwater take summary for the Peel Valley Alluvium SDL area

Peel Valley Alluvium SDL area	GL/year
Total 2007/2008 entitlement*	**49**
Current use for entitlement bores*	7.1
Estimated use for stock & domestic bores*	0.24
Total current use	**7.3**

*2007/2008 groundwater entitlement data was provided by DECCW
**Current use is equal to average annual metered groundwater use from 2003/2004 to 2007/2008 that was provided by DECCW
***Stock and domestic use was provided by DECCW

1.7.2 Salinity zoning

The Peel Valley Alluvium SDL area is dominantly characterised by groundwater of salinity zone 1. Groundwater salinity distribution can be seen in Figure 7 and is summarised in Table 38.

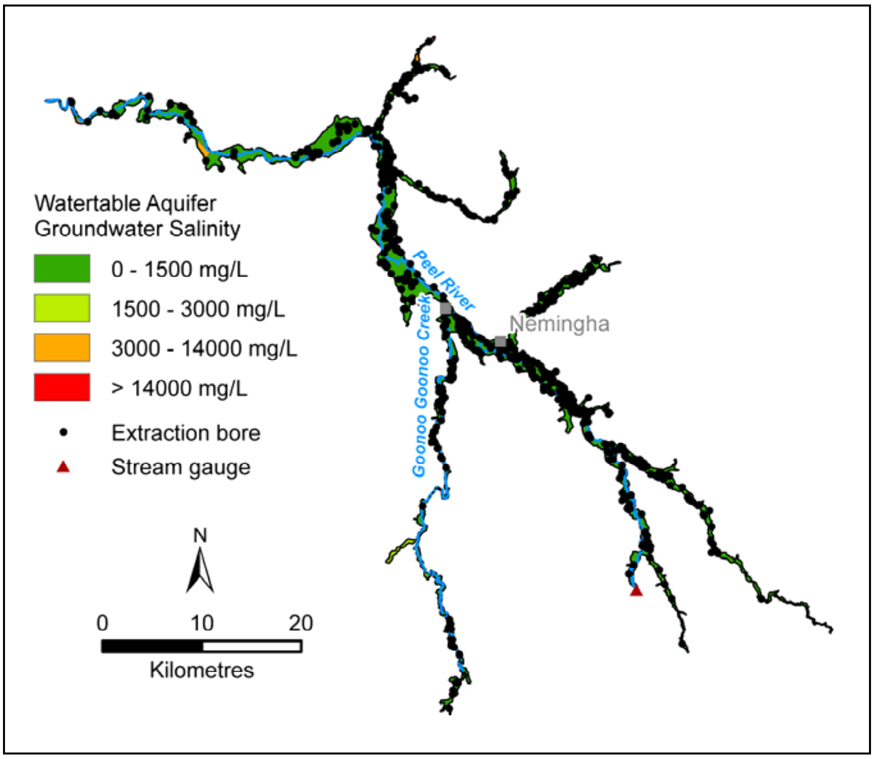

Figure 7. Peel Valley Alluvium watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 38. Summary of salinity zones in the Peel Valley Alluvium SDL area

Watertable salinity zone	Portion of total area (%)	Area (km^2)
Zone 1 (0–1500 mg/L TDS)	97	179
Zone 2 (1500–3000 mg/L TDS)	1	2.6
Zone 3 (3000–14,000 mg/L TDS)	2	3.2
Zone 4 (>14,000 mg/L TDS)	0	0
Water bodies	0	0
Total	**100**	**185**

1.7.3 Key environmental assets

There are no groundwater dependent key environmental assets that are sensitive to groundwater extraction, associated with the Peel Valley Alluvium SDL area. Therefore there is a low risk of impact on key environmental assets.

1.7.4 Key ecosystem function

The Peel River and tributaries are largely unregulated. The river is considered to be medium to high gaining in its upper reaches and medium losing in the lower section (CSIRO, 2007) and is likely to recharge the alluvial aquifer during flood events or high river flows. The key ecosystem function is therefore considered at high risk in this SDL area.

1.7.5 Productive base

Recharge

Modelled dryland diffuse groundwater recharge derived from WAVES modelling (Crosbie et al., 2010) has been used to calculate recharge to the alluvial aquifer. The historical climate scenario for a median 15-year period, results in a recharge rates ranging between 124 and 152 mm/year. This results in a total recharge of 23 GL/year within the SDL area (Table 39).

Table 39. Recharge calculation for the Peel Valley Alluvium SDL Unit

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	179	2.6	3.2	0
Diffuse recharge (mm/yr)	124	152	127	N/A
Total recharge (GL/yr)	**22**	**0.39**	**0.40**	**N/A**

Storage

The alluvial aquifer has an approximate average saturated thickness of 15 m (based on an analysis of drill logs in the area). Given that there is no hydrogeological data specific to the Peel Valley Alluvium, a specific yield value of 10 percent has been used (Johnson, 1967), as it is typical of an alluvial aquifer with variable grain size. Based on these assumptions, the total groundwater storage estimate for the Peel Valley Alluvium SDL is 277 GL (Table 40).

Table 40. Storage calculation for the Peel Valley Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	179	3	3	0
Saturated thickness (m)	15	15	15	N/A
Specific yield	0.1	0.1	0.1	N/A
Total storage (GL)	**269**	**3.9**	**4.7**	**N/A**

Storage relative to recharge

The ratio of storage to recharge ranges from 10 to 12 for each of the salinity zones. This indicates that there is a high 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 41 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 that none have been identified that are groundwater dependent
- the SDL area is ranked high risk in terms of ecosystem function, given that the Peel River is unregulated and is well connected with the alluvial aquifer
- the SDL area is ranked high risk in terms of the productive base, given that the storage/recharge ratio is less than 20
- there is no risk to the key environmental outcomes (i.e. groundwater salinity)
- there is a high level of uncertainty given that the RRAM is derived from diffuse groundwater recharge derived from WAVES modelling only. It does not include other potential components of groundwater recharge, including river leakage, irrigation returns, throughflow etc.

Table 41. 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></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></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></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></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></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></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>

1.7.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Peel Valley Alluvium SDL area is 1.1 GL/year (Table 42). This extraction limit can be increased to equal current use (i.e. 7.3 GL/year) given the highly connected nature of the system. The extraction limit for this SDL area for groundwater and surface water should be set taking into account the connectivity and to eliminate double accounting.

Table 42. Preliminary extraction limit summary for the Peel Valley Alluvium area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	22	0.39	0.40	0
Sustainability factor	0.05	0.05	0.05	N/A
Extraction limit (GL/yr)	**1.1**	**0.020**	**0.020**	**N/A**

1.8 Young Granite (GS64)

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

1.8.1 Background

The Young Granite SDL is centred on the town of Young in south eastern NSW and includes most of the outcropping Young Granite. Some of the Young Granite is overlain by thin alluvial sediments or weathered granite. The aquifer has been developed for irrigation purposes and current groundwater use is 4.6 GL/year (Table 43). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

Table 43 Groundwater Take Summary for the Young Granite SDL area

Young Granite SDL area	GL/year
Total 2007/2008 Entitlement*	6.3
Current Use for Entitlement Bores*	3.8
Estimated Use for Stock & Domestic Bores*	0.76
Total Current Use	4.6

*2007/2008 groundwater entitlement data was provided by DECCW
**Current use is equal to 60 % of the entitlement volume
***Stock and domestic use was provided by DECCW

1.8.2 Salinity zoning

Groundwater is dominantly characterised by salinity zone 1 groundwater in this SDL area. Less than 1 km^2 of the SDL area is characterised by salinity zone 3 groundwater and therefore for the purpose of this assessment, this area has been combined with salinity zone 2. Groundwater salinity distribution can be seen in Figure 8 and is summarised in Table 44.

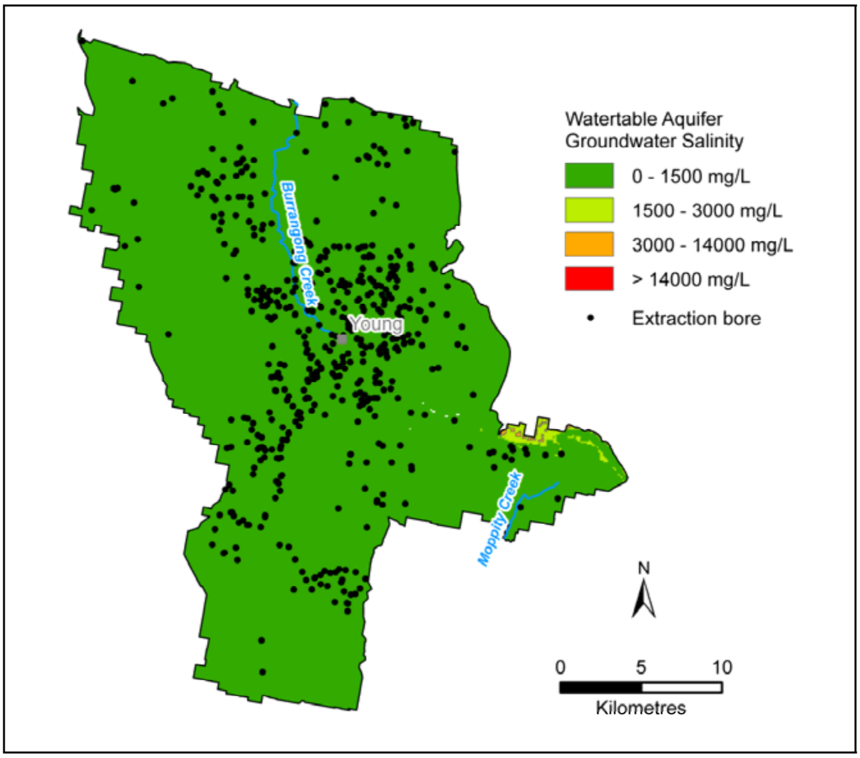

Figure 8 Young Granite watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 44. Summary of salinity zones in the Young Granite SDL area

Watertable salinity zone	Portion of total area (%)	Area (km^2)
Zone 1 (0–1500 mg/L TDS)	99	710
Zone 2 (1500–3000 mg/L TDS)	1	4.8
Zone 3 (3000–14,000 mg/L TDS)	0	0.0
Zone 4 (>14,000 mg/L TDS)	0	0.0
Water bodies	0	0.0
Total	**100**	**715**

1.8.3 Key environmental assets

There is a low risk to key environmental assets in the Young Granite SDL area, given that none exist that are groundwater dependent and sensitive to take.

1.8.4 Key ecosystem function

There are no major rivers in the Young Granite SDL area, with only a few small creeks within the SDL area. These creeks are thought to be ephemeral and do not receive significant amounts of baseflow. Hence the SDL area has been classified as low risk in terms of key ecosystem function.

1.8.5 Productive base

Recharge

Modelled dryland diffuse groundwater recharge derived from WAVES modelling (Crosbie et al., 2010) has been used to calculate recharge to the alluvial aquifer. The historical climate scenario for a median 15-year period, results in a recharge rates ranging from 55 to 121 mm/year for this SDL area. This results in a total recharge of 86 GL/year within the SDL area (Table 45).

Table 45. Recharge calculation for the Young Granite SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	710	4.8	0	0
Diffuse recharge (mm/yr)	121	55	N/A	N/A
Total recharge (GL/yr)	**86**	**0.26**	**N/A**	**N/A**

Storage

The water bearing fractures within the Young Granite do not typically extend beyond 30 m depth. Five geologists logs across the area were analysed, and showed an average depth of highly weathered granite of 21 m. Moderately weathered granite was found at an average depth of 21 to 25 m, with very slightly weathered to fresh granite found below this. The water bearing component of the granite is typically the more weathered area, and as such a saturated thickness of approximately 25 metres has been estimated for the Young Granite. Given that there is no hydrogeological data specific to the Young Granite, a specific yield value of 1 percent has been used, as it is typical of a fractured granite aquifer. Based on these assumptions, the total groundwater storage estimates for this SDL area is 178 GL (Table 46).

Table 46. Storage calculation for the Young Granite SDL

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	710	4.8	0	0
Saturated thickness (m)	25	25	N/A	N/A
Specific yield	0.01	0.01	N/A	N/A
Total storage (GL)	**177**	**1.2**	**N/A**	**N/A**

Storage Relative to Recharge

The ratio of storage to recharge ranges from 2 to 5. This indicates that there is a high 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 47 provides a summary of the risk ranking associated with; eey 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 that none have been identified that are groundwater depenendent
- the SDL area is ranked low risk in terms of ecosystem function, given that only minor losing creeks exist in this SDL area
- the SDL area is ranked high risk in terms of the productive base, given that the storage/recharge ratio is less than 20
- there is no risk to the key environmental outcomes (i.e. groundwater salinity)
- there is a high level of uncertainty given that the RRAM is derived from diffuse groundwater recharge derived from WAVES modelling only. It does not include other potential components of groundwater recharge, including river leakage, irrigation returns, throughflow etc

Table 47. 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 Young Granite SDL area is 4.3 GL/year (Table 48).

Table 48. Preliminary extraction limit summary for the Young Granite SDL

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	86	0.26	0	0
Sustainability factor	0.05	0.05	N/A	N/A
Extraction limit (GL/yr)	**4.3**	**0.013**	**N/A**	**N/A**

1.9 Eastern Porous Rock – Namoi Gwydir (GS27)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the RRAM for the Eastern Porous Rock – Namoi Gwydir SDL area.

1.9.1 Background

The Eastern Porous Rock – Namoi Gwydir SDL area is made up of the Permo-Triassic deposits of the Gunnedah and Oxley Basins. Deposits of the Gunnedah Basin are predominantly marine and terrestrial, and are fine to coarse grained. The Oxley Basin contains a series of sandstone and shale units which are essentially a continuation of the formations of the Great Artesian Basin. The Oxley Basin sediments have been separated from the GAB because there are hydrogeological discontinuities between the two. The Gunnedah and Oxley Basins are extensive, lying at depth underneath other SDL areas; however their outcrop is limited to regions in the Namoi, Gwydir and Macquarie-Castlereagh Basins. The area of the Eastern Porous Rock – Namoi Gwydir SDL area encompasses the outcropping Gunnedah Basin and Oxley Basin in the Namoi and Gwydir catchments.

Current groundwater use in this SDL area is 10 GL/year (Table 49) which includes all of the use from the Gunnedah Basin and part of the use from the Oxley Basin (the remaining use from the Oxley Basin is captured in the Eastern Porous Rock – Macquarie Castlereagh SDL area). There is substantial exploration for coal-seam gas in the sediments of the Gunnedah Basin and it is expected that future groundwater usage will relate to the development of this resource. For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

Table 49. Groundwater take summary for the Eastern Porous Rock – Namoi Gwydir SDL area

Eastern Porous Rock – Namoi Gwydir SDL area	GL/year
Total 2007/2008 entitlement*	**12**
Current use for entitlement bores**	7.0
Estimated use for stock & domestic bores***	3.3
Total current use	**10**

*2007/2008 groundwater entitlement was supplied by DECCW
**Current Use is equivalent to 60 percent of the entitlement volume
***Stock and domestic use was based on estimates provided by DECCW

1.9.2 Salinity zoning

The Eastern Porous Rock –Namoi Gwydir SDL area is characterised by three salinity classes (Figure 9). Most groundwater is characterised as salinity zone 1, with the remaining 28 percent characterised by salinity zone 2 and 3 (Table 50).

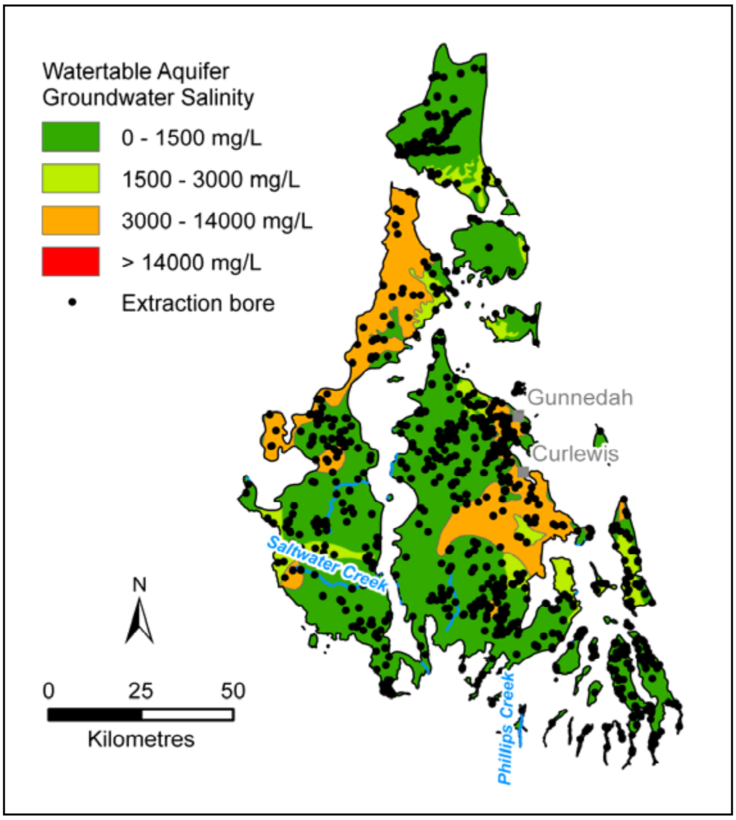

Figure 9. Eastern Porous Rock – Namoi Gwydir watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 50. Summary of salinity zones in the Eastern Porous Rock – Namoi Gwydir SDL area

Watertable salinity zone	Portion of total area	Area (km^2)
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	72	4835
Zone 2 (1500–3,000 mg/L TDS)	9	577
Zone 3 (3000–14,000 mg/L TDS)	19	1285
Zone 4 (>14,000 mg/L TDS)	0	0
Water bodies	0	0
Total	**100**	**6696**

1.9.3 Key environmental assets

There are no groundwater dependent key environmental assets that are sensitive to groundwater extraction, associated with the Eastern Porous Rock – Namoi Gwydir SDL area.

1.9.4 Key ecosystem function

Small tributaries of the Namoi and Gwydir Rivers originate within the Eastern Porous Rock – Namoi Gwydir SDL area and are unregulated.

Given that the Eastern Porous Rock – Namoi Gwydirds SDL area contains unregulated tributaries that are likely to recieve baseflow from the groundwater, this SDL area is considered at high risk in terms of the key ecosystem function.

1.9.5 Productive base

Recharge

Recharge has been calculated by dryland diffuse groundwater recharge derived from WAVES modelling (Crosbie et al., 2010). The historical climate scenario for a dry 15-year period, results in a recharge rate ranging between 31 mm/year and 38 mm/year. This results in a total recharge of approximately 215 GL/year for the SDL (Table 51).

Table 51. Recharge calculation – WAVES recharge

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	4835	577	1285	0
Diffuse recharge from WAVES modelling (mm/yr)	31.2	37.9	32.5	N/A
Total recharge (GL/yr)	**151**	**22**	**42**	**N/A**

Storage

The specific yield adopted in the Eastern Porous Rock – Namoi Gwydir SDL area is 0.02. There is no particular information available for the specific yield of the Oxley or Gunnedah basin sediments so a typical specific yield value for fine sand or consolidated sandstone has been used (Johnson, 1967).

The Gunnedah Basin and Oxley Basin sediments are extensive and thickness is variable. An average saturated thickness of the Eastern Porous Rock – Namoi Gwydir SDL area is assumed to be approximately 100 m. The depth of this SDL area is substantially deeper than this value, however for the purposes of this assessment 100 m saturated thickness is sufficient to indicate that recharge is significantly lower than storage.

Total storage of this SDL area is approximately 13,000 GL (Table 52).

Table 52. Storage calculation for the Eastern Porous Rock – Namoi Gwydir SDL

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	4835	577	1285	0
Saturated thickness (m)	100	100	100	N/A
Specific yield	0.02	0.02	0.02	N/A
Total storage (GL)	**9669**	**1154**	**2570**	**N/A**

Storage relative to recharge

The ratio of storage to recharge ranges from 52 to 64. 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 53 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 that none have been identified that are groundwater dependent
- the SDL area is ranked high risk in terms of ecosystem function, given that unregulated gaining river reaches exist in this SDL area
- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio is greater than 40
- there is no risk to the key environmental outcomes (i.e. groundwater salinity)
- there is a high level of uncertainty given that the RRAM is derived from diffuse groundwater recharge derived from WAVES modelling only. It does not include other potential components of groundwater recharge, including river leakage, irrigation returns, throughflow etc

Table 53. Risk matrix

<table>
<tr><th>Risk ranking</th><th>Environmental assets</th><th>OR</th><th>Ecosystem function</th><th>OR</th><th>Productive base</th><th>Sustainability factor</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></td><td>In the current state, groundwater discharge provides baseflow to the unregulated river reach. Groundwater extraction is likely to result in stream flow depletion.</td><td></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. uniform 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 class 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></td><td>The rivers in the SDL area are regulated and they are highly connected to the groundwater system (i.e. > 50 % impact of pumping on stream flow within 50 years)</td><td></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 area</td><td></td><td>The rivers in the SDL area are regulated or unregulated and they have low-moderate connection with the groundwater system (i.e. < 50 % impact of pumping on stream flow within 50 years)</td><td></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>

1.9.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Eastern Porous Rock – Namoi Gwydir SDL area is 9.1 GL/year (Table 54). This extraction limit can be increased to equal current use (i.e. 10 GL/year) given the highly connected nature of the system. The extraction limit for this SDL area for groundwater and surface water should be set taking into account the connectivity and to eliminate double accounting.

Table 54. Preliminary extraction limit summary for the Eastern Porous Rock – Namoi Gwydir SDL

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	151	22	42	0
Sustainability factor	0.04	0.045	0.05	NA
Extraction limit (GL/yr)	**6.0**	**0.98**	**2.1**	**NA**

1.10 NSW Border Rivers Tributary Alluvium (GS48)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the RRAM for the NSW Border Rivers Tributary Alluvium SDL area.

1.10.1 Background

The NSW Border Rivers Tributary Alluvium is located in the Border Rivers Basin in northern New South Wales. The Alluvium is associated with the lower Macintyre River, near its convergence with the Dumaresq River. The Alluvial sediments of both the Macintyre and the Dumaresq Rivers upstream of the confluence are confined to narrow valleys. They are dominated by sandy to silty clay, with minor gravels. The upper alluvial SDL area is approximately 10 to 30 m thick. 2007/2008 groundwater use was 0.53 GL/year (Table 55). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

Table 55. Groundwater take summary for the NSW Border Rivers Tributary Alluvium SDL area

NSW Border Rivers Tributary Alluvium SDL area	GL/year
Total 2007/2008 entitlement*	**0.64**
Current use for entitlement bores**	0.38
Estimated use for stock & domestic bores**	0.15
Total current use	**0.53**

*2007/2008 groundwater entitlement data was provided by DECCW
**Current use is equal to 60 percent of the entitlement volume
***Stock and domestic use was provided by DECCW

1.10.2 Salinity zoning

The NSW Border Rivers Tributary Alluvium SDL area is dominated by relatively fresh groundwater, with 90 percent of the area falling within Salinity Zone 1 (< 1,500 mg/L TDS). The remaining area falls within salinity zone 3. The salinity distribution can be seen in Figure 10 and is summarised in Table 56.

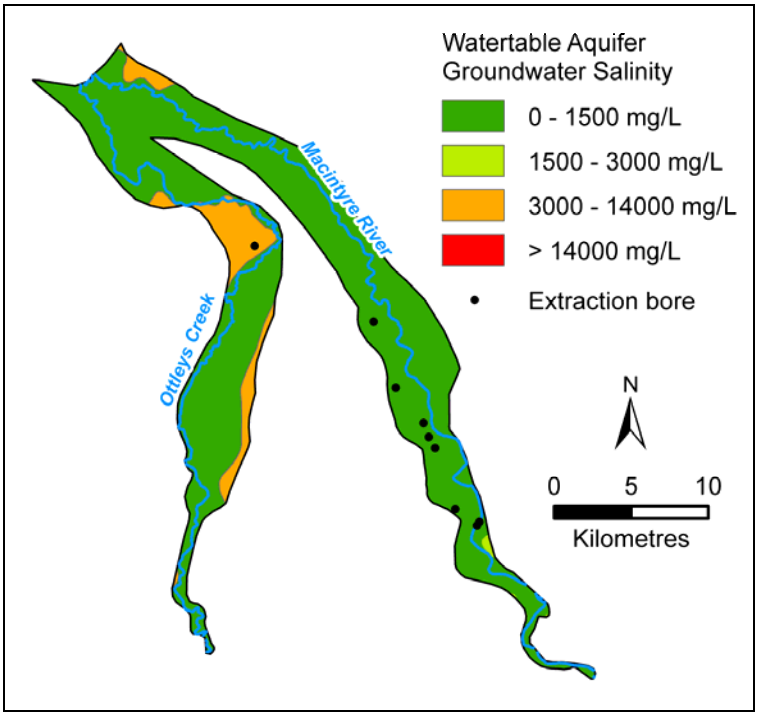

Figure 10. NSW Border Rivers Tributary Alluvium SLD Unit watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 56. Summary of salinity zones NSW Border Rivers Tributary Alluvium SDL area

Watertable salinity zone	Portion of total area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	91	244
Zone 2 (1500–3000 mg/L TDS)	0	0
Zone 3 (3000–14,000 mg/L TDS)	9	26
Zone 4 (>14,000 mg/L TDS)	0	0
Water bodies	0	0
Total	**100**	**270**

1.10.3 Key environmental assets

There are no groundwater dependent key environmental assets that are sensitive to groundwater extraction, associated with the NSW Border Rivers Tributary Alluvium SDL area. Therefore the risk to the key environmental asset is low.

1.10.4 Key ecosystem function

In the Border Rivers catchment there is a high degree of connectivity between the unregulated streams and the underlying groundwater systems. The alluvial sediments in this SDL area are highly connected with the Macintyre River. Any groundwater extraction will ultimately affect the flow in the river and consequently existing irrigation use from surface water supplies. Consequently, the risk to key ecosystem function through groundwater extraction is considered high.

1.10.5 Productive base

Recharge

Recharge has been calculated by dryland diffuse groundwater recharge derived from WAVES modelling (Crosbie et al., 2010). The results generated for a historical climate scenario for a median 15-year period have been used here. Total recharge across the SDL area equates to 4.5 GL/year (Table 57).

Table 57. Recharge calculation of the NSW Border Rivers Tributary Alluvium SDL

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	244	0	26	0
Diffuse recharge from WAVES modelling (mm/yr)	17	N/A	10	N/A
Total recharge (GL/yr)	**4.2**	**N/A**	**0.26**	**N/A**

Storage

The specific yield adopted for the alluvial deposits of the NSW Border Rivers Tributary Alluvium SDL area is 0.07. Given a lack of information particular to this geology, a typical specific yield value for sandy clay has been used (Johnson, 1967). The thickness of the alluvium is approximately 10 to 30 m, the saturated thickness is assumed to be approximately 10 m.

The total storage for the NSW Border Rivers Tributary Alluvium SDL area is approximately 189 GL (Table 58).

Table 58. Storage calculation of the NSW Border Rivers Tributary Alluvium SDL

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	244	0	26	0
Saturated thickness (m)	10	N/A	10	N/A
Specific yield	0.07	N/A	0.07	N/A
Total storage (GL)	**171**	**N/A**	**18**	**N/A**

Storage relative to recharge

The ratio of storage to recharge ranges between 41 and 69. 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 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 low risk in terms of key environmental assets, given that none have been identified that are groundwater dependent
- the SDL area is ranked high risk in terms of ecosystem function, given that there is good connection between the unregulated rivers and alluvial aquifers in this SDL area
- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio is greater than 40
- there is no risk to the key environmental outcomes (i.e. groundwater salinity)
- there is a high level of uncertainty given that the RRAM is derived from diffuse groundwater recharge derived from WAVES modelling only. It does not include other potential components of groundwater recharge, including river leakage, irrigation returns, throughflow etc

Table 59. Risk matrix of the NSW Border Rivers Tributary Alluvium SDL

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 NSW Border Rivers Tributary Alluvium SDL area is 0.23 GL/year (Table 60). This extraction limit can be increased to equal current use (i.e. 0.53 GL/year) given the highly connected nature of the system. The extraction limit for this SDL area for groundwater and surface water should be set taking into account the connectivity and to eliminate double accounting.

Table 60. Preliminary extraction limit summary for the NSW Border Rivers Tributary Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	4.2	-	0.26	-
Sustainability factor	0.05	-	0.05	-
Extraction limit (GL/yr)	**0.21**	**-**	**0.013**	**-**

1.11 Upper Gwydir Alluvium (GS56)

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

1.11.1 Background

The Upper Gwydir Alluvium SDL area is located in the east of the Gwydir Catchment in New South Wales. From a hydrogeological perspective, the Gwydir Region is divided into two main areas – the hilly highland country to the east and the broad flat alluvial plains to the west. The highland reaches hydrogeology is dominated by fractured rock aquifer. The Upper Gwydir Alluvium SDL area is comprised of the unconsolidated alluvial sediments associated with the Gwydir River in the valleys of the highlands. These alluvials are limited in their extent and not expected to be large groundwater resources, this is supported by the low volume of current groundwater use in this area (Table 61). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

Table 61. Groundwater take summary for Upper Gwydir Alluvium SDL area

Upper Gwydir Alluvium	GL/year
Total 2007/2008 entitlement*	**1.2**
Current use for entitlement bores**	0.71
Estimated use for stock & domestic bores***	0.075
Total current use	**0.78**

*2007/2008 groundwater entitlement data was provided by DECCW
**Current use is equal to 60 percent of the entitlement volume
***Stock and domestic use was provided by DECCW

1.11.2 Salinity zoning

The Upper Gwydir Alluvium SDL area is characterised by two salinity classes of roughly even proportion. Groundwater salinity distribution can be seen in Figure 11 and is summarised in Table 62.

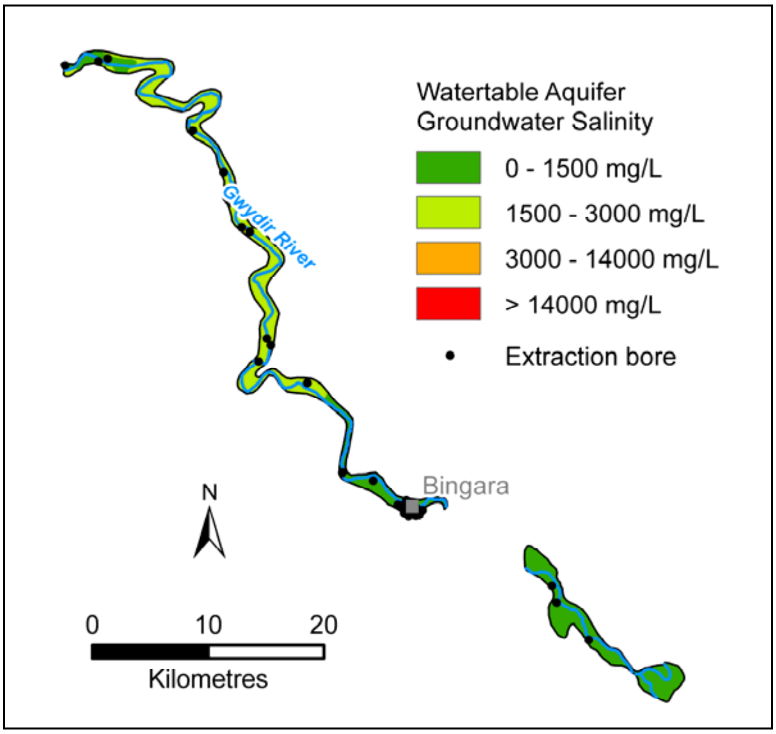

Figure 11. Upper Gwydir Alluvium watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 62. Summary of salinity zones in the Upper Gwydir Alluvium SDL area

Watertable salinity zone	Portion of total area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	48	50
Zone 2 (1500–3000 mg/L TDS)	52	54
Zone 3 (3000–14,000 mg/L TDS)	-	-
Zone 4 (>14,000 mg/L TDS)	-	-
Water bodies	-	-
Total	**100%**	**104**

1.11.3 Key environmental assets

There are no groundwater dependent key environmental assets that are sensitive to groundwater extraction, associated with the Upper Gwydir Alluvium SDL area and therefore there is a low risk to the key environmental asset.

1.11.4 Key ecosystem function

These upper reaches of the Gwydir River are unregulated and are conceptualised as being gaining in nature. There is a high risk to the key ecosystem function in this SDL area.

1.11.5 Productive base

Recharge

Recharge has been calculated via dryland diffuse groundwater recharge derived from WAVES modelling (Crosbie et al., 2010). The results generated for a historical climate scenario for a median 15-year period have been used here. Total recharge across the SDL area equates to 7.6 GL/year (Table 63).

Table 63. Recharge calculation for Upper Gwydir Alluvium SDL area – Waves recharge

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	50	54	0	0
Diffuse recharge from WAVES modelling (mm/yr)	72	73	N/A	N/A
Total recharge (GL/yr)	**3.6**	**4.0**	**N/A**	**N/A**

Storage

The specific yield adopted for the alluvial deposits of the Upper Gwydir Alluvium SDL area is 0.07. Given a lack of information particular to this SDL area, a typical specific yield value for a sandy clay has been used (Johnson, 1967). The thickness of the alluvium is estimated at approximately 30 m and a saturated thickness of 15 m has been used for the purpose of the storage calculation. The total storage for the Upper Gwydir Alluvium SDL area is approximately 110 GL (Table 64).

Table 64. Storage calculation for the Upper Gwydir Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	50	54	0	0
Saturated thickness (m)	15	15	N/A	N/A
Specific yield	0.07	0.07	N/A	N/A
Total storage (GL)	**53**	**57**	**N/A**	**N/A**

Storage relative to recharge

The ratio of storage to recharge ranges from 14 to 15 for each of the salinity zones. This indicates that there is a high 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 65 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 that none have been identified that are groundwater depenendent
- the SDL area is ranked high risk in terms of ecosystem function, given that the unregulated upper reaches of the Gwydir River are well connected with the alluvial aquifer
- the SDL area is ranked high risk in terms of the productive base, given that the storage/recharge ratio is less than 20
- there is no risk to the key environmental outcomes (i.e. groundwater salinity)
- there is a high level of uncertainty given that the RRAM is derived from diffuse groundwater recharge derived from WAVES modelling only. It does not include other potential components of groundwater recharge, including river leakage, irrigation returns, throughflow etc

Table 65. Risk matrix for the Upper Gwydir Alluvium SDL area

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 Upper Gwydir Alluvium SDL area is 0.38 GL/year (Table 66). This extraction limit can be increased to equal current use (i.e. 0.78 GL/year) given the highly connected nature of the system. The extraction limit for this SDL area for groundwater and surface water should be set taking into account the connectivity and to eliminate double accounting.

Table 66. Preliminary extraction limit summary for the Upper Gwydir Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	3.6	4.0	0	0
Sustainability factor	0.05	0.05	N/A	N/A
Extraction limit (GL/yr)	**0.18**	**0.20**	**N/A**	**N/A**

1.12 Manilla Alluvium (GS44)

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

1.12.1 Background

The Manilla Alluvium SDL area is located in the Namoi River Catchment in New South Wales. The Alluvium is associated with Yarramanbully Creek, Manilla River and Namoi River. The SDL area is centred around Manilla in NSW. Current groundwater use is 1.9 GL/year (Table 67). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

Table 67. Groundwater take summary for the Manilla Alluvium SDL area

Manilla Alluvium SDL area	GL/year
Total 2007/2008 entitlement*	**3.0**
Current use for entitlement bores**	1.8
Estimated use for stock & domestic bores***	0.07
Total current use	**1.9**

*2007/2008 groundwater entitlement information was supplied by DECCW
**Current use is equal to 60 % of entitlement
***Stock and domestic use was estimated by DECCW

1.12.2 Salinity zoning

The Manilla Alluvium SDL area is characterised by two salinity zones, however the majority of the area is characterised by salinity zone 1. The groundwater salinity distribution can be seen in Figure 12 and is summarised in Table 68.

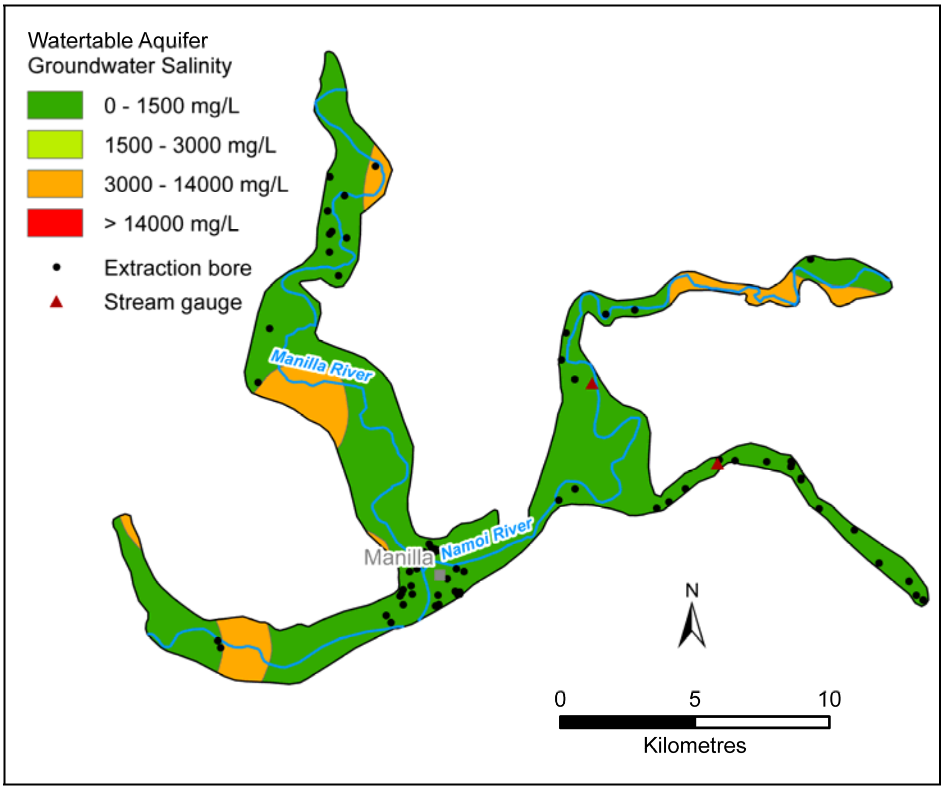

Figure 12. Manilla Alluvium watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 68. Summary of salinity zones in the Manilla Alluvium SDL area

Watertable salinity zone	Portion of total area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	85	94
Zone 2 (1500–3000 mg/L TDS)	0	0
Zone 3 (3000–14,000 mg/L TDS)	15	16
Zone 4 (>14,000 mg/L TDS)	0	0
Water bodies	0	0
Total	100	110

1.12.3 Key environmental assets

There are no groundwater dependent key environmental assets that are sensitive to groundwater extraction, associated with the Manilla Alluvium SDL area.

1.12.4 Key ecosystem function

The connectivity between the Manilla Alluvium and Yarramanbully Creek, Manilla River and Namoi River is considered high. The alluvial groundwater aquifer will be in close hydraulic connection with the River Systems and consequently groundwater extraction is likely to impact rivers. River reaches within the area are unregulated. This SDL area has been assigned a high risk ranking, given that it incorporates unregulated rivers that are likely to receive baseflow from the small tributary alluvial aquifers.

1.12.5 Productive base

Recharge

Recharge has been calculated by dryland diffuse groundwater recharge derived from WAVES modelling (Crosbie et al., 2010). The results generated for a historical climate scenario for a median 15-year period have been used here. Total recharge across the SDL area therefore equates to 13 GL/year (Table 69).

Table 69. Recharge calculation for the Manilla Alluvium SDL area – WAVES recharge

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	94	0	16	0
Diffuse recharge from WAVES modelling (mm/yr)	117	N/A	97	N/A
Total recharge (GL/yr)	**11**	**N/A**	**1.6**	**N/A**

Storage

The specific yield adopted for the alluvial deposits of the Manilla Alluvium SDL area is 0.07. Given a lack of information particular to this geology, a typical specific yield value for sandy clay has been used (Johnson, 1967).

The thickness of the alluvium is approximately 30 m and the saturated thickness has been estimated at approximately 15 m, in the absence of available data.

The total storage for the Manilla Alluvium SDL area is approximately 116 GL (Table 70).

Table 70. Storage calculation for the Manilla Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	94	0	16	0
Saturated thickness (m)	15	N/A	15	N/A
Specific yield	0.07	N/A	0.07	N/A
Total storage (GL)	**99**	**N/A**	**17**	**N/A**

Storage relative to recharge

The ratio of storage to recharge ranges from 9 to 11 for each of the salinity zones. This indicates that there is a high 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.

1.12.6 The risk matrix

Table 71 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 that none have been identified that are groundwater dependent
- the SDL area is ranked high risk in terms of ecosystem function, given that the unregulated rivers and the alluvial aquifers are in strong hydraulic connection
- the SDL area is ranked high risk in terms of the productive base, given that the storage/recharge ratio is less than 20
- there is no risk to the key environmental outcomes (i.e. groundwater salinity)
- there is a high level of uncertainty given that the RRAM is derived from diffuse groundwater recharge derived from WAVES modelling only. It does not include other potential components of groundwater recharge, including river leakage, irrigation returns, throughflow etc

Table 71. Risk matrix for the Manilla Alluvium SDL area

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%

1.12.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Manilla Alluvium SDL area is 0.63 GL/year (Table 72). This extraction limit can be increased to equal current use (i.e. 1.9 GL/year) given the highly connected nature of the system. The extraction limit for this SDL area for groundwater and surface water should be set taking into account the connectivity and to eliminate double accounting.

Table 72. Preliminary extraction limit summary for the Manilla Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	11.0	-	1.6	-
Sustainability factor	0.05	-	0.05	-
Extraction limit volume (GL/yr)	**0.55**	**-**	**0.08**	**-**

1.13 Upper Namoi Tributary Alluvium (GS61)

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

1.13.1 Background

The Upper Namoi Tributary Alluvium SDL area is located in the Namoi River Catchment in New South Wales. The SDL area is centred near the township of Werris Creek and the alluvial sediments discussed below are associated with the Currabubula, Werris, Quipolly and Quirindi Creeks. These alluvial aquifers are shallow, limited in their spatial extent and not expected to be large groundwater resources. This is supported by the low volume of current groundwater use in this area (Table 73). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

Table 73. Groundwater take summary for Upper Namoi Tributary Alluvium SDL area

Upper Namoi Tributary Alluvium SDL area	GL/year
Total 2007/2008 entitlement*	**3.2**
Current use for entitlement bores**	1.9
Estimated use for stock & domestic bores***	0.076
Total current use	**2.0**

*2007/2008 groundwater entitlement data was provided by DECCW
**Current use is equal to 60 percent of the entitlement volume
***Stock and domestic use was provided by DECCW

1.13.2 Salinity zoning

The Upper Namoi Tributary Alluvium SDL area is characterised by three salinity classes but dominated by salinity zone 1. Groundwater salinity distribution can be seen in Figure 11 and is summarised in Table 74.

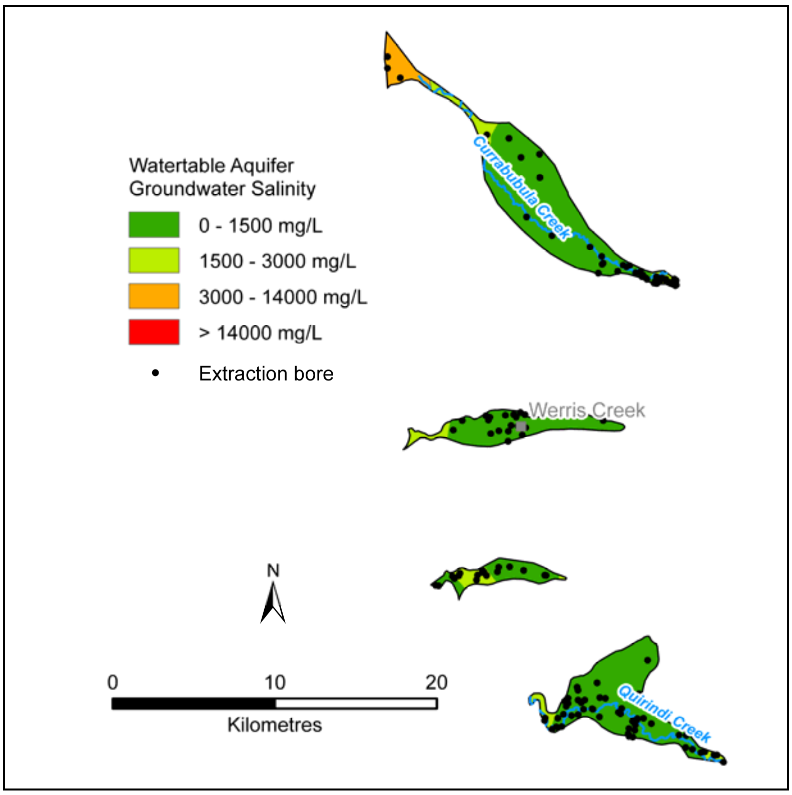

Figure 13. Upper Namoi Tributary Alluvium watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 74. Summary of salinity zones in the Upper Namoi Tributary Alluvium SDL area

Watertable salinity zone	Portion of total area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	86	85
Zone 2 (1500–3000 mg/L TDS)	10	9.5
Zone 3 (3000–14,000 mg/L TDS)	4	4.3
Zone 4 (>14,000 mg/L TDS)	0	0
Water bodies	0	0
Total	**100**	**99**

1.13.3 Key environmental assets

There are no groundwater dependent key environmental assets that are sensitive to groundwater extraction, associated with the Upper Namoi Tributary Alluvium SDL area. Therefore the risk to the key environmental asset is low.

1.13.4 Key ecosystem function

The connectivity between the alluvial sediments and the Currabubula, Werris, Quipolly and Quirindi Creeks is considered high. The alluvial groundwater aquifer will be in close hydraulic connection with these creeks and consequently groundwater extraction is likely to impact on them. The key ecosystem function of this SDL area is therefore considered to be at high risk, due to the presence of highly connected alluvial aquifer systems and unregulated creeks.

1.13.5 Productive base

Recharge

Recharge has been calculated via dryland diffuse groundwater recharge derived from WAVES modelling (Crosbie et al., 2010). The results generated for a historical climate scenario for a median 15-year period have been used here. Recharge rates vary from 23 to 37 mm/year for each of the salinity zones (Table 75). Total recharge across the SDL area equates to 2.4 GL/year.

Table 75. Recharge calculation for the Upper Namoi Tributary Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	85	9.5	4.3	0
Diffuse recharge from WAVES modelling (mm/yr)	23	37	28	N/A-
Total recharge (GL/yr)	**1.9**	**0.35**	**0.12**	**N/A**

Storage

The specific yield adopted for the alluvial deposits of the Upper Namoi Tributary Alluvium SDL area is 0.07. Given a lack of information particular to this area, a typical specific yield value for a sandy clay has been used (Johnson, 1967). The thickness of the alluvium is approximately 10 to 30 m. Due to a lack of information on the average saturated thickness of the alluvium, it has been assumed to be approximately 10 m. The total storage for the Upper Namoi Tributary Alluvium SDL area is approximately 69 GL (Table 76).

Table 76. Storage calculation for the Upper Namoi Tributary Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	85	9.5	4.3	0
Saturated thickness (m)	10	10	10	N/A
Specific yield	0.07	0.07	0.07	N/A
Total storage (GL)	**59**	**6.7**	**3.0**	**N/A**

Storage relative to recharge

The ratio of storage to recharge ranges between 19 and 31. This indicates that there is a high 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.

1.13.6 The risk matrix

Table 77 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 that none have been identified that are groundwater dependent
- the SDL area is ranked high risk in terms of ecosystem function, given that the alluvial aquifer and the unregulated creeks are likely to be highly connected
- the SDL area is ranked high risk in terms of the productive base, given that the storage/recharge ratio ranges between 19 and 31
- there is no risk to the key environmental outcomes (i.e. groundwater salinity)
- there is a high level of uncertainty given that the RRAM is derived from diffuse groundwater recharge derived from WAVES modelling only. It does not include other potential components of groundwater recharge, including river leakage, irrigation returns, throughflow etc

Table 77. Risk matrix for the Upper Namoi Tributary Alluvium SDL area

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%

1.13.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Upper Namoi Tributary Alluvium SDL area is 0.12 GL/year (Table 78). This extraction limit can be increased to equal current use (i.e. 2.0 GL/year) given the highly connected nature of the system. The extraction limit for this area for groundwater and surface water should be set taking into account the connectivity and to eliminate double accounting.

Table 78. Preliminary extraction limit summary for the Upper Namoi Tributary Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	1.9	0.35	0.12	-
Sustainability factor	0.05	0.05	0.05	-
Extraction limit (GL/yr)	**0.096**	**0.018**	**0.0060**	**-**

1.14 NSW Border Rivers Alluvium (GS47)

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

1.14.1 Background

The Border Rivers Alluvium SDL area is located within the topographic depressions of the river valley, where the parent rock has been eroded and riverine sediments deposited. Current groundwater use is 6.6 GL/year (Table 79). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

The SDL area incorporates two aquifers that overlie basement rock and are separated by an aquitard. The watertable aquifer consists of unconsolidated clay, sand and gravel to about 10 to 30 m thick. It is unconfined and responds hydraulically to flooding. The aquitard comprises low permeabilty clay layers. The deeper aquifer is semi-confined and comprises consolidated clay, sandstone and gravel up to about 50 m thick and extends to about 50 to100 m below ground surface (Welsh, 2007).

Nested observation sites indicate that across the Border Rivers Alluvium (NSW) SDL area, the upper and lower alluvial aquifers are in hydraulic connection (Figure 14). For this reason a single SDL has been determined for the Border Rivers Alluvium (NSW).

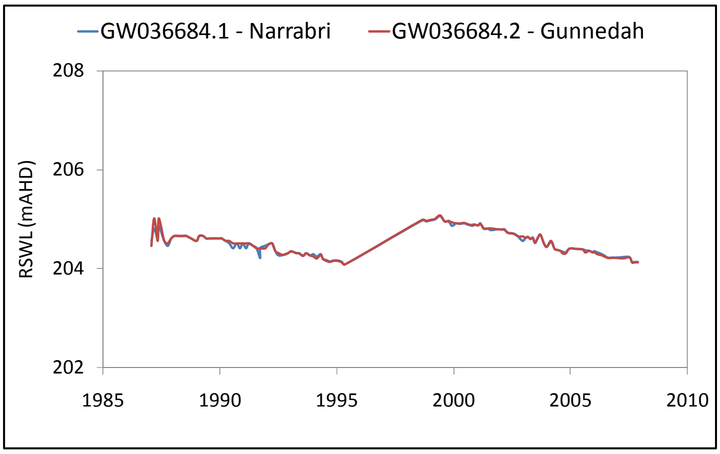

Figure 14. Hydrograph for bores screening the shallow and deep alluvial aquifers

Table 79. Groundwater take summary for the NSW Border Rivers Alluvium SDL area

Border Rivers Alluvium (NSW)SDL area	GL/year
Total 2007/2008 entitlement*	**15**
Current Use for entitlement bores**	6.3
Estimated use for stock & domestic bores***	0.30
Total 2007/2008 Use	**6.6**

*2007/2008 groundwater entitlement volume was adopted from the Dumaresq-Barwon Border Rivers Commission (2008) report
**Current use is the average annual use volume reported in the Dumaresq-Barwon Border Rivers Commission Annual Statistics Reports from 2003/2004 to 2007/2008
***Stock and domestic use was provided by DECCW

1.14.2 Salinity zoning

The NSW Border Rivers Alluvium SDL area is characterised by groundwater salinity ranging from 0 to > 14,000 mg/L TDS, however it is dominantly characterised by salinity zone 1 groundwater. The groundwater salinity distribution can be seen in Figure 15 and is summarised in Table 80.

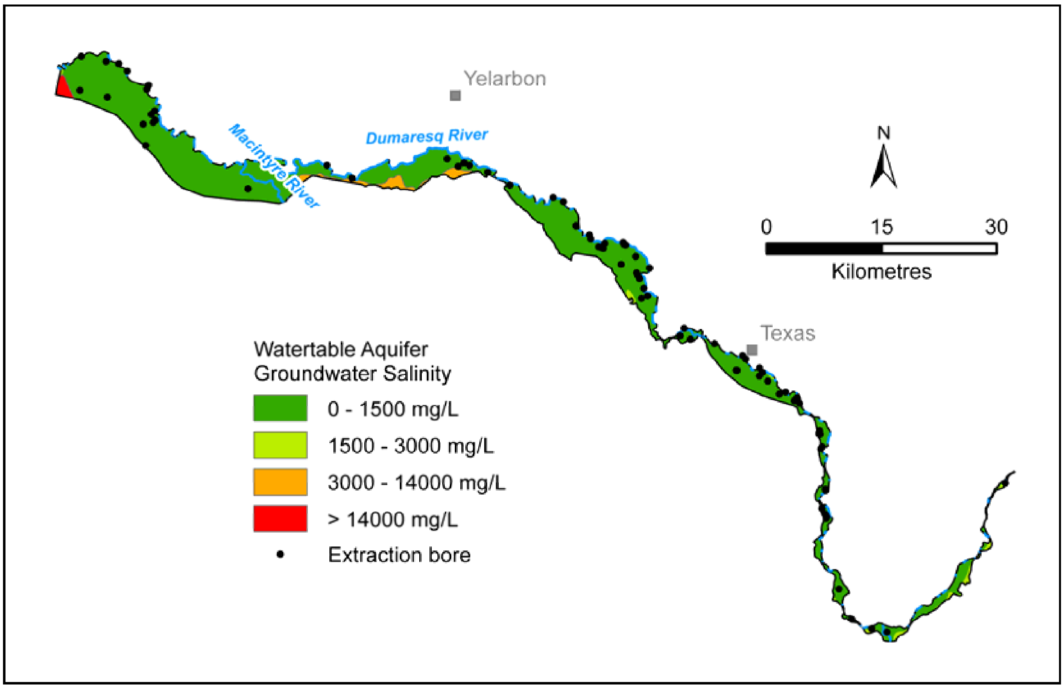

Figure 15 NSW Border Rivers Alluvium SDL area watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 80. Summary of salinity zones in the NSW Border Rivers Alluvium SDL area

Watertable salinity zone	Portion of total area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	94	388
Zone 2 (1500–3000 mg/L TDS)	2	8.9
Zone 3 (3000–14,000 mg/L TDS)	3	12
Zone 4 (>14,000 mg/L TDS)	1	4
Water bodies	0	0
Total	**100**	**413**

1.14.3 Key environmental assets

There are no groundwater dependent key environmental assets that are sensitive to groundwater extraction, associated with the NSW Border Rivers Alluvium SDL area.

1.14.4 Key ecosystem function

Figure 16 shows the annual net river loss of the Dumaresq River, as indicated by the numerical model, under a historical climate and 2004/2005 pumping regime (Welsh, 2007). This indicates that when 11 GL/year was extracted from the alluvial aquifer, 5 GL/year was derived from the river (within a typical planning timeframe of approximately 50 years), implying a connectivity of approximately 45 percent.

A study of the interaction between groundwater and surface water in the Border Rivers Catchment was undertaken by Baskaran et al. (2005) using environmental isotopes (including; major ions, stable isotopes and radon-222). The results of the hydrochemical and environmental isotope sampling indicated that the river and the shallow alluvial aquifers close to the river in the area upstream of Keetah have a close hydraulic relationship. In this upper catchment area, the streams are losing and recharge the shallow aquifers.

Based on this information, the NSW Border Rivers Alluvium SDL area is considered medium risk in terms of the key ecosystem function.

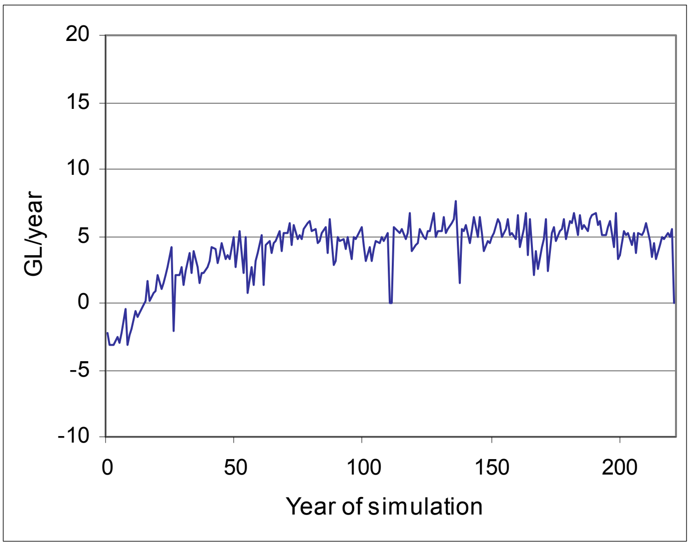

Figure 16. Annual net river loss of the Dumaresq River under a historical climate and 2004/2005 level of groundwater development (from Welsh, 2007)

1.14.5 Productive base

Recharge

Recharge to the NSW Border Rivers Alluvium has been derived from WAVES modelling and an allowance for irrigation recharge. River water pumping licences and pumping records could not be obtained within the timeframe required to determine the extraction limit for this SDL area. In the absence of this information, half of the irrigation recharge volume from the Border Rivers groundwater model (under the 2004/2005 level of development) has been added to the WAVES recharge volume. This equates to 0.5 GL/year (Welsh, 2007).

WAVES modelling indicates recharge ranges from 2.4 mm/year to 98 mm/year across the SDL area.

Total recharge to the NSW Border Rivers Alluvium is 20 GL/year (Table 81).

Table 81. Recharge calculation for the NSW Border Rivers Alluvium

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	388	8.9	12	4.0
WAVES recharge rate (mm/year)	45	98	47	2.4
WAVES recharge rate (GL/year)	18	0.87	0.56	0.0096
Irrigation recharge rate (GL/year)	0.47	0.01	0.01	0.0
Total recharge (GL/year)	**18**	**0.88**	**0.57**	**0.0096**

Storage

The specific yield of the unconfined shallow aquifer ranges between 0.007 and 0.051 (Welsh, 2007). For the purpose of this calculation, a specific yield of 0.051 has been used. An average thickness of 50 m has been estimated to represent the alluvial aquifers (Welsh, 2007). Estimated storage for this SDL area is approximately 1,000 GL (Table 82).

Table 82. Storage calculation for the NSW Border Rivers Alluvium

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	388	8.9	12	4.0
Saturated thickness (m)	50	50	50	50
Specific yield	0.051	0.051	0.051	0.051
Total storage (GL)	**989**	**23**	**30**	**10**

Storage relative to recharge

The ratio of storage to recharge ranges from 26 to 1,042 for each of the salinity zones. 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.

1.14.6 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 that none have been identified that are groundwater dependent
- the SDL area is ranked medium risk in terms of ecosystem function, given that groundwater and surface water connectivity is close to 50 percent (Welsh, 2007) and the highly connected nature of groundwater and surface water upstream of Keetah (Baskaran et al., 2005)
- the SDL area is ranked medium risk in terms of the productive base, given that the storage/recharge ratio ranges from 26 to 1046
- there is no risk to the key environmental outcomes (i.e. groundwater salinity)
- there is a high level of uncertainty given that the RRAM is derived from diffuse groundwater recharge derived from WAVES modelling only. It does not include other potential components of groundwater recharge, including river leakage, irrigation returns, throughflow etc

Table 83. Risk matrix for the NSW Border Rivers Alluvium

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%

1.14.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the NSW Border Rivers Alluvium SDL area is 4.9 GL/year (Table 84). This extraction limit can be increased to equal current use (i.e. 6.6 GL/year) given the highly connected nature of the system. The extraction limit for this SDL area for groundwater and surface water should be set taking into account the connectivity and to eliminate double accounting.

Table 84. Preliminary extraction limit summary for the NSW Border Rivers Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	18	0.88	0.57	0.0096
Sustainability factor	0.25	0.25	0.25	0.25
Extraction limit (GL/yr)	**4.5**	**0.22**	**0.14**	**0.0024**

1.15 Billabong Creek Alluvium (GS22)

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

1.15.1 Background

The Billabong Creek Alluvium SDL area is located in southern New South Wales between the Murray and Murrumbidgee Rivers. The alluvial deposits contain basal sands and gravels with finer grained material overlying and interbedded such as silty and sandy clays. The alluvial aquifer is relatively narrow and deep, with the deposit deepening from east to west (ANRA, 2010).

The Billabong Creek Alluvium is hydrogeologcially different from east to west. To the east, the shallow alluvial aquifer is highly connected to surface water and groundwater quality is good. To the west, groundwater exists in a deeper palaeochannel and connection with surface water is lower. Groundwater salinity is also greater to the west of the SDL area. Given that either end of this SDL area behaves differently, a separate extraction limit has been determined for each. ‘Either end’ of the SDL area is assumed to be represented by the area of salinity zone 1 groundwater and the area of higher salinity groundwater.

Groundwater entitlement and use has been summarised in terms of the eastern and western parts of the SDL area. Where location information could not be attributed to a groundwater licence, the licence was assumed to reside in the eastern portion of the SDL area (this equated to 20 percent of entitlements) (Table 85). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

Table 85. Groundwater take summary for the Billabong Creek Alluvium SDL area

Billabong Creek Alluvium SDL area	West (GL/year)	East (GL/yr)
Total 2007/2008 entitlement*	**2.7**	**4.5**
Current use for entitlement bores**	0.41	1.0
Estimated use for stock & domestic bores***	0.32	0.32
Total current use	**0.73**	**1.3**

*2007/2008 groundwater entitlement data was provided by DECCW
**Current use is equal to avearge annual metered groundwater use over the 5 year period 2003/2004 to 2007/2008
***Stock and domestic use was provided by DECCW

1.15.2 Salinity zoning

In the eastern portion of the SDL area the groundwater salinity is low and mainly characterised by salinity zone 1.

To the west of the SDL area the groundwater salinity is poor and is mainly doiminated by groundwater salinity zone 3. In this area there is a distinct variation in groundwater salinity with depth and for this reason a salt interception scheme has been implemented just north of Walla Walla. The salt interception scheme pumps fresher groundwater from the deeper alluvial sediments, into Billabong Creek. This decreases the rate of baseflow from the more saline shallow groundwater, by decreasing the hydraulic gradient between the river elevation and the groundwater table. This subsequently decreases the salinity of the creek, by the addition of relatively fresh groundwater and by reducing the volume of saline groundwater discharge (DECCW, 2010).

The watertable salinity distribution for the SDL area is shown in Figure 17 and is summarised in Table 86.

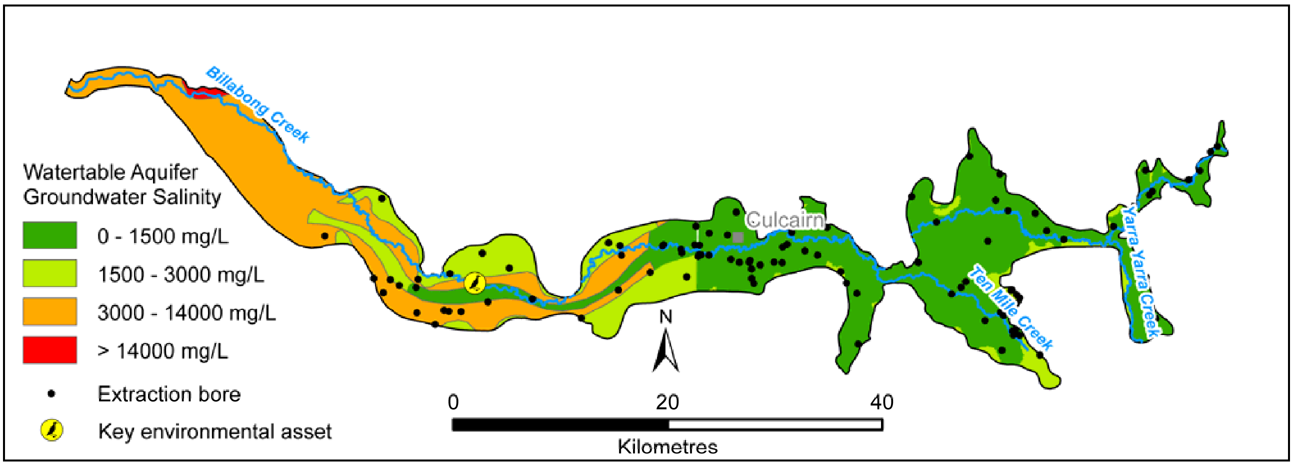

Figure 17. Billabong Creek Alluvium watertable aquifer salinity distribution

Table 86. Summary of salinity zones in the Billabong Creek Alluvium SDL area

Watertable salinity zone	Portion of total area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	51	357
Zone 2 (1500–3000 mg/L TDS)	18	126
Zone 3 (3000–14,000 mg/L TDS)	30	210
Zone 4 (>14,000 mg/L TDS)	0.49	3.4
Water bodies	0.05	0.3
Total	**100**	**697**

1.15.3 Key environmental assets

The riparian vegetation along Billabong Creek upstream of Mahonga is considered a groundwater-dependant ecosystem. However, it is not considered sensitive to take as the water table is high and there is a large storage buffer. Therefore the risk to the key environmental asset is considered medium.

1.15.4 Key ecosystem function

The upstream portion of Billabong Creek is unregulated and it is considered to be recharged by groundwater baseflow. The alluvial aquifer is therefore considered to be at high risk in terms of the key ecosystem function.

The downstream portion of Billabong Creek is regulated. Given that an SIS scheme is in place to reduce baseflow of the saline shallow groundwater to the stream, the risk to the key ecosystem function is considered low in this part of the SDL area.

1.15.5 Productive base

Recharge

Modelled dryland diffuse groundwater recharge derived from WAVES modelling (Crosbie et al., 2010) has been used to calculate recharge to the eastern and western portions of the alluvial aquifer. The historical median climate scenario was used to calculate recharge for the eastern part of the SDL area (i.e. the area characterised by salinity zone 1 groundwater) and total recharge is 12 GL/year (Table 87).

For the western end (characterised by salinity zones 2, 3 and 4) the historical dry climate scenario was used to calculate recharge. Total groundwater recharge is 7.2 GL/year (Table 88).

Table 87. Recharge calculation for the Billabong Creek Alluvium SDL area – Eastern End

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	357	0	0	0
Diffuse recharge (mm/yr)	33	N/A	N/A	N/A
Total recharge (GL/yr)	**12**	**N/A**	**N/A**	**N/A**

Table 88. Recharge calculation for the Billabong Creek Alluvium SDL area – Western End

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	0	126	210	3.4
Diffuse recharge (mm/yr)	N/A	28	18	8.1
Total recharge (GL/yr)	**N/A**	**3.5**	**3.7**	**0.028**

Storage

The thickness of the aquifer for the Billabong Creek Alluvium is estimated at 100 m, given that the SIS scheme pumps water from approximately 80 m depth (DECCW, 2010). Given that there is no hydrogeological data specific to the Billabong Creek Alluvium, a specific yield value of 10 % has been used (Johnson, 1967), as it is typical of an alluvial aquifer with variable grain size. Based on these assumptions the total storage for the eastern part of the SDL area is approximately 3500 GL and for the western part, is approximately 3400 GL (Table 89).

Table 89. Storage calculation for the Billabong Creek Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3/4	Salinity zone 4
Area (km^2)	357	126	210	3.4
Saturated thickness (m)	100	100	100	100
Specific yield	0.1	0.1	0.1	0.1
Total storage (GL)	**3572**	**1264**	**2100**	**30**

Storage relative to recharge

The ratio of storage to recharge ranges from 298 to 1071 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.

1.15.6 The risk matrix

Table 90 and Table 91 provide summaries of the risk ranking associated with; key environmental assets, key ecosystem function, the productive base and key environmental outcome (for the east of the SDL area and the west, respectively.

- the eastern part of the SDL area is ranked medium risk in terms of key environmental assets as riparian forests exist along the bank of the river. The western part of the SDL area is ranked low risk because the groundwater is salinity and is removed so that it does not move into the surface water. It is unlikely that the riparian vegetation are dependent on this saline groundwater
- the eastern part of the SDL area is ranked high risk in terms of ecosystem function given that the SDL area represents an alluvial aquifer and unregulated gaining river reaches exist within it. It is ranked low risk in the western part of the SDL area, given that an SIS is in place to prevent groundwater discharge to the stream
- the SDL area is ranked low risk in terms of the productive base for the entire SDL area
- there is a risk to groundwater salinity in the eastern part of the SDL area, but not in the western part of the SDL area
- there is a low uncertainty associated with the entire SDL area (DECCW, Februay 2010, pers. comm.)

Table 90. Risk matrix – East

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%

Table 91. Risk matrix – West

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%

1.15.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the eastern part of the Billabong Creek Alluvium SDL areas is 0.93 GL/year (Table 92). This extraction limit can be increased to equal current use (i.e. 1.3 GL/year) given the highly connected nature of the system. The extraction limit for this SDL area for groundwater and surface water should be set taking into account the connectivity and to eliminate double accounting.

The extraction limit resulting from the RRAM for the western part of the Billabong Creek Alluvium SDL area is 4.8 GL/year (Table 93). This is greater than the volume of current use (0.73 GL/year). This means there is a volume of unassigned water (4.1 GL/year) associated with this SDL area.

Table 92. Preliminary extraction limit summary – Eastern part of Billabong Creek Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	12	0	0	0
Sustainability factor	0.08	N/A	N/A	N/A
Extraction limit (GL/yr)	**0.93**	**N/A**	**N/A**	**N/A**

Table 93. Preliminary extraction limit summary – Western part of Billabong Creek Alluvium SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	0	3.5	3.7	0.028
Sustainability factor	N/A	0.63	0.70	0.70
Extraction limit (GL/yr)	**N/A**	**2.2**	**2.6**	**0.019**

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