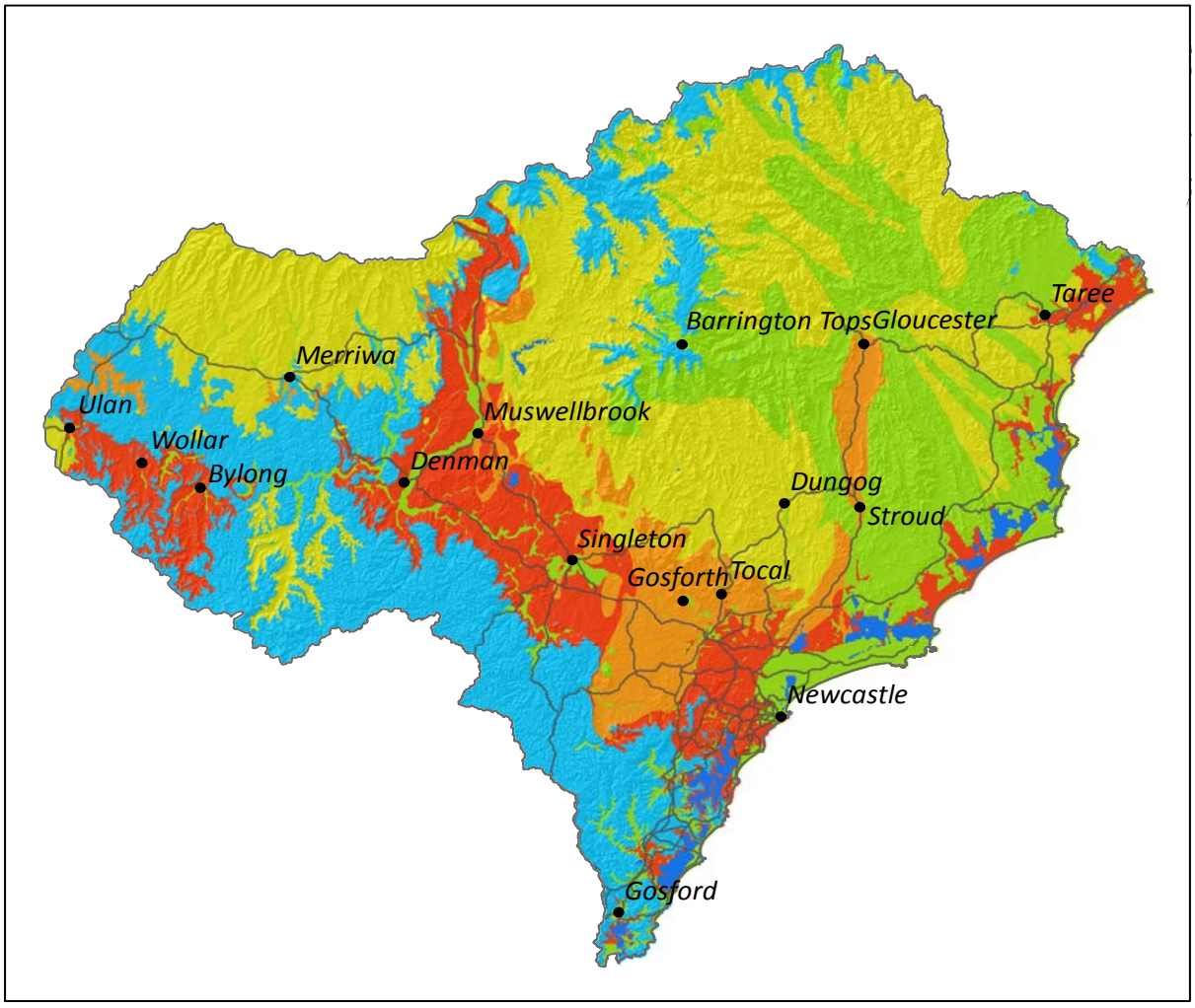
NSW GOVERNMENT | Department of Primary Industries

# Salinity hazard report for Catchment Action Plan upgrade – Hunter-Central Rivers CMA



Publisher: NSW Department of Primary Industries

*Salinity hazard report for Catchment Action Plan upgrade – Hunter-Central Rivers CMA*

First published February 2013

Print ISBN: 978 1 74256 451 7

Web ISBN: 978 1 74256 452 4

This document should be cited as: Nicholson, A., Winkler, M., Muller, R., Jenkins, B.R., Cook, W. and Wooldridge, A. 2012, *Salinity hazard report for Catchment Action Plan upgrade – Hunter-Central Rivers CMA*, NSW Department of Primary Industries / NSW Office of Environment and Heritage – Department of Premier and Cabinet, Parramatta

**More information**

Prepared by Landscape Management Technical Group – a cross agency group involving Catchments Unit - Department of Primary Industries and Office of Environment and Heritage

Allan Nicholson (team leader) / Wellington, Marion Winkler / Parramatta, Wayne Cook / Queanbeyan, Andrew Wooldridge / Cowra (DPI); and Rob Muller / Wagga Wagga and Brian Jenkins / Queanbeyan (OEH)

www.dpi.nsw.gov.au

**Acknowledgments**

We gratefully acknowledge funding provided by Catchment Action NSW to enable the project to be completed. A number of people have provided technical and critical support for the project. Special thanks to Steve Eccles, Joe Thompson, Grahame Price and Andrew Nowakowski. Thanks are also given to Jan Wightley of NSW Department of Primary Industries for assistance with editing and document control.

*Cover image: Salinity hazard map of Hunter-Central Rivers catchment management area*

Trim No. BN13/1151

# Contents

# 1 Introduction

## 1.1 Background

The eleven NSW Catchment Management Authorities (CMAs) are required to update their Catchment Action Plans (CAPs) in a process to be completed by early 2013. The CAPs are required to be "Whole of Government" in order to provide greater coherence between policies and plans as they develop strategic direction at regional levels. CAPs must align with or take into account common elements of agency activity, and require a high level of co-ordination.

A cross-agency team was engaged in December 2011 to produce a salinity tool for the 2012-13 CAP update process. The Salinity Hazard for CAP Updates project is funded by Catchment Action NSW, and delivers state-wide information.

The project work associated with this report was carried out prior to the formation of the new Local Land Services (LLS) areas. The boundaries used for hazard identification in this report relate to the CMA boundaries as they were prior to October 2012.

The primary output of the Salinity Hazard for CAP Updates project is a broad scale salinity hazard spatial coverage and report for each CMA. This report is produced for the Hunter-Central Rivers Catchment Management Authority (HCR CMA) for use in upgrading its Catchment Action Plan. The Hunter-Central Rivers CAP is a cabinet approved document which outlines the investment priorities and delivery targets for natural resource management (NRM) across the HCR CMA area. The HCR CMA is currently reviewing and upgrading the CAP which was developed in 2004-05.

Salinity information is required to guide the ten year strategic plan (CAP), the priority for actions, target specific landscapes and spatially explicit management actions on ground. The CAP must

- comply with the NRC Standards for Quality Natural Resource Management (the Standard)
- demonstrate "Adaptive Management"
- deal with emerging issues such as the MDBA Basin Plan / Strategic Land use Plans etc
- consider the resilience of landscapes and systems

This project will utilise state-wide data sets and collect and integrate Hydrogeological Landscape (HGL) information where it exists. The project has the potential to be expanded to a detailed HGL project targeted at the areas identified in the state-wide approach.

This document describes the hazard posed by salinity for different parts of the HCR CMA catchment. The associated Salinity Hazard for CAP Update map is a specific product for CAP planning. It is appropriate at the catchment scale. More detailed investigations are required for sub-regional works.

## 1.2 Resilience

The Natural Resource Commission (NRC) has released The Framework for Assessing and Recommending CAPs (2011). A key component of this document is a shift towards resilience thinking. This approach influences CAP targets, partnerships and the type of knowledge that the HCR CMA should draw on to analyse, understand and communicate how the landscape functions.

*"Resilience thinking aims to identify a small number of important variables that control the way a complex landscape system is functioning, and the thresholds within which the system can continue to function in a desired way*" (NRC 2011).

Salinity is one of the 'small set of important variables' that control the function, thresholds and resilience of landscapes. The 5 salinity hazard classes (see Section 2.1) used as part of this

Salinity Hazard for CAP Updates project provide a simple system for understanding how salinity influences landscape resilience.

The following is the resilience definition of the Stockholm Resilience Centre (Walker et al., 2004; Folke et al. 2010). It is the definition adopted for the Salinity Hazard for CAP Updates project.

*"The capacity of a system to absorb disturbance and reorganise while undergoing change so as to still retain essentially the same function and feedbacks and therefore identify, that is, the capacity to change in order to maintain the same identity."*

Salinity is an important variable in landscape systems and is often a determining factor in the capacity of the landscape to absorb change. It has a three-pronged impact on landscapes namely land salinisation, in-stream salt load and in-stream salt concentration. Any of these can of themselves or in concert impact on landscape resilience.

*"Management can then be designed to maintain a functioning system either by remaining within thresholds or transforming to a desirable (or least undesirable) alternative stable state."* (NRC 2011)

Salinity as a major landscape degradation issue can determine the nature of thresholds and tipping points. If thresholds within landscapes are to be understood and managed then salinity must be understood and managed in a landscape context.

The drivers, variables, thresholds, priority actions and gap analysis for salinity in the HCR CMA is provided in Appendix 1.

# 2 Methodology

## 2.1 Overview of the descriptors

Each hazard area has a descriptor which includes a hazard ranking; a location diagram and description; a statement on the significance of the salinity hazard in that unit; a resilience statement; a confidence statement; and the decision rules used to derive the hazard ranking.

The report relied partly on the unpublished Groundwater Flow Systems Framework for the Hunter Valley: A process for salinity management (Thomas and Evans) (working draft April 07); on field work; and on data from surrounding Hydrogeological Landscape reports of Capertee Valley and Western Sydney (Nicholson et al. 2010, Winkler et al. 2011a).

Texts on specific aspects of the environment were extensively consulted and included geology maps and reports such as Geoscience Australia (2011) and geological maps – Roberts (1991), Banks (1966), Brunker (1970), Anderson (1969), Bryan JH (1966) and Morgan (1999); land resource information (Emery, 1985); groundwater availability studies DLWC (2004); vegetation surveys DEC (2006), Keith (2004), Tozer et al. (2010); and soil landscape maps and reports – Kovac, Murphy and Lawrie (1990) and Murphy and Lawrie (1990).

### Hazard ranking

Areas are given a salinity hazard ranking – Very High, High, Moderate, Low or Very Low. Rankings are determined from a number of variables including salt stores, salinity outbreaks, water quality, salt loads, onsite and offsite impacts, presence of acid sulfate soils, presence of highly sodic soils, aquifer systems, ground water salinity and ground water depth.

### Location diagram

A simple overview of where the hazard areas occur within the CMA catchment. Hazard areas are coloured using the following colour scheme.

**Table 1 Salinity hazard colour**

| Attribute | Range | Colour | RGB Colour Scheme |
|---|---|---|---|
| Salinity Hazard | Very High | Red | 255, 50, 0 |
| | High | Orange | 255, 150, 0 |
| | Moderate | Yellow | 230, 230, 0 |
| | Low | Green | 150, 230, 0 |
| | Very Low | Blue | 0, 200, 255 |

This colour scheme is also used in the hazard descriptor headers and in the *Salinity Hazard for CAP Update* map (Figure 1).

### Overview / location

General statements on the terrain and geological characteristics of the hazard area, and where it is located.

### Significance

Salinity characterises such as salt stores, salinity outbreaks, water quality, onsite and offsite impacts, and other land degradation issues that may be relevant to salinity processes.

### Resilience statement

Factors that drive salinity development and the salinity related variables which control, impact or influence the resilience of landscapes.

### Confidence

High, moderate or poor. A qualifier is provided where relevant (e.g. poor due to lack of field investigation).

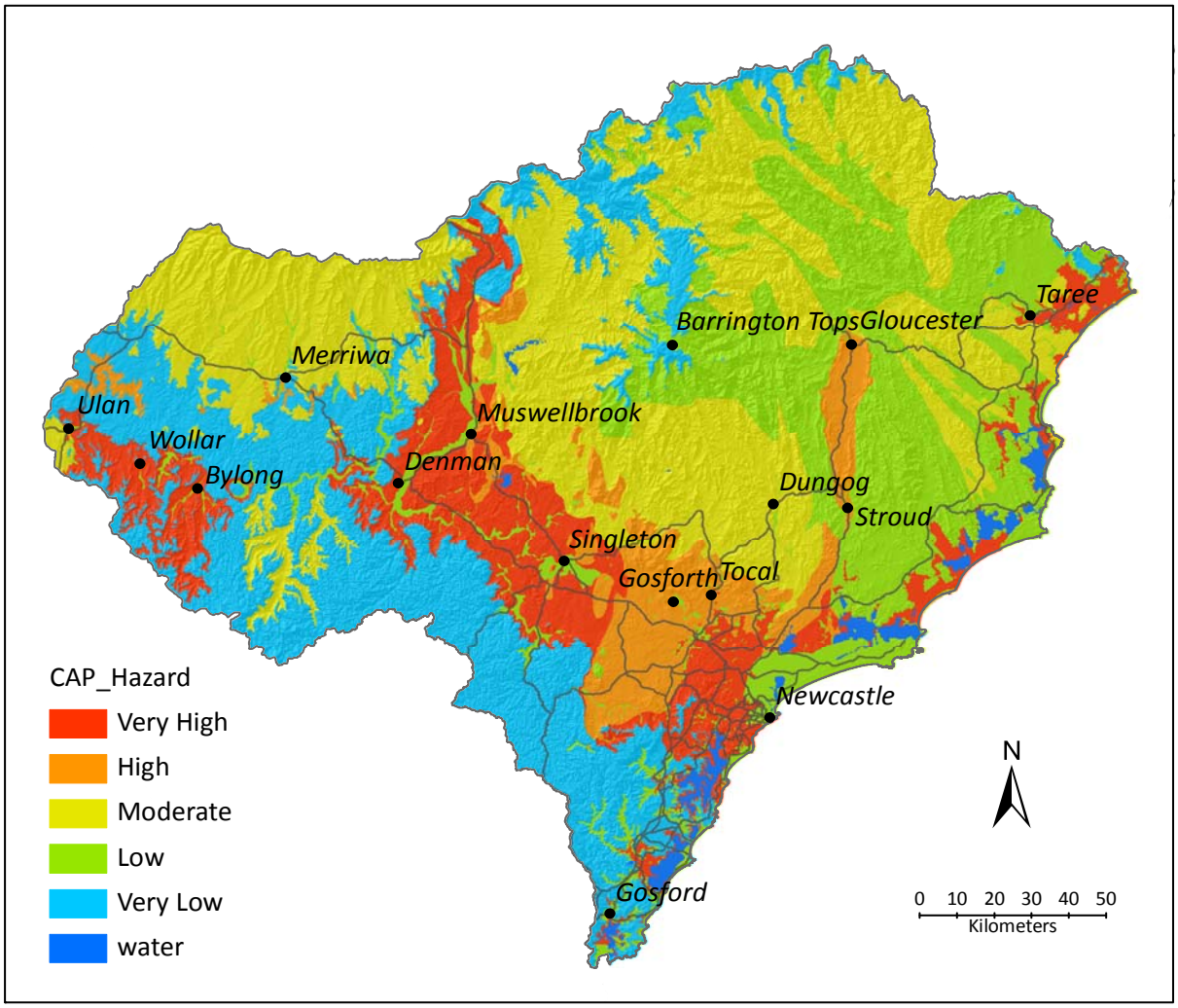
### Decision rules

Decision rules for why a particular hazard rating was assigned (e.g. moderate hazard rating is based on field assessment which recognised significant areas of moderate levels of land salinity, moderate in-stream salt loads and moderate water EC).

## 2.2 Overview of the salinity hazard for CAP update map

The Salinity Hazard for CAP Update map (Figure 1) shows the broad salinity hazard distribution across the Hunter-Central Rivers CMA. It is appropriate for planning at a CMA catchment scale. More detailed investigations are required to target sub-regional works.

**Figure 1Salinity Hazard for CAP Update map for the Hunter-Central Rivers CMA area**

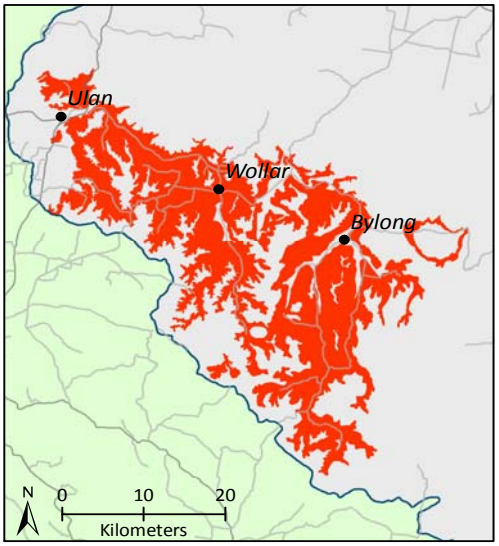



# 3 Descriptors

## 3.1 Very high hazard – Area 1

| | | | |
|---|---|---|---|
| **VH1** | **Wollar** | **Hazard:** | **Very High** |

**Figure 2 Location diagram of very high hazard area 1**




## Overview / location

This category comprises lower landform units, colluvial slopes, valley constrictions and bowl shaped landforms on Illawarra Coal Measures and Shoalhaven Group Permian aged sedimentary rocks of the Sydney Basin. These particular landforms and sediments are known to be found between Ulan, Wilpinjong and Wollar; and are extensively mined for coal extraction (Ulan, Moolarben and Charbon coal mines).

This very high salinity hazard differs from other categories on Permian geology due to the specific morphology of these landscapes involved in salinity development, and the stratigraphy of local geology.

## Significance

These landscapes have a very high salinity hazard dominated by large numbers of severe salt sites, saline streams and saline groundwater discharge. These colluvial slopes, bowl formations and valley constrictions have formed on sediments that are horizontally bedded and contain highly saline layers. Sandstone cliffs sit above them providing a hydraulic head. Salt store in the Permian sediments is moderate to high and salt is moderately to highly available. The very high salinity hazard is related to this stratigraphic sequence: wherever water filters through saline strata before discharging on the surface, salinity is likely to express on the land surface or in streams. Groundwater salinity is brackish to saline and salinity is concentrated due to the constricted nature of water flow.

On-site impacts include multiple location surface scalding (salt sites), large seasonal saline sites, marginal to brackish stream flow, sheet and minor gully erosion with dispersive soils on colluvial slopes, and seasonal water-logging on colluvial slopes and alluvial plains. Off-site impacts include declining water quality along the Cox's Creek, in both salt load and localised EC increases. These impact downstream in wetter climatic sequences.

There are a number of salinity demonstrations in the area (Wilpinjong, Cooks Gap), a salinity offsets project (Ulan Mine), and an old Environmental Services Scheme (ESS) salinity project, which demonstrate how the geological and landscape setting of the area predisposes it to very high land salinity.

Detail on the processes of salinity development in this hazard category are similar to processes in the Capertee Valley in Hawkesbury-Nepean CMA, and are described in Hydrogeological Landscape (HGL) models prepared for the Hawkesbury-Nepean CMA – specifically the HGLs of Nile HGL, Glencoe HGL, Bourbin Creek HGL, Horse Gap HGL and Marlyn Gate HGL (Nicholson et al. 2010).

## Resilience statement

Drivers of salinity development in these landscapes include poor grazing management on colluvial slopes and clearing of native vegetation. Disturbance due to mining and aquifer interference are major drivers as the landscape is increasingly mined for coal.

The major variables influencing resilience in these landscapes include mining activity, soil salt store / availability, soil stability, and local groundwater rise / depletion.

### Confidence

Significant salinity mapped and observed with a long history of salinity treatment and extension work. Stream EC tested.  Landscape and geological processes predispose area to salinity.

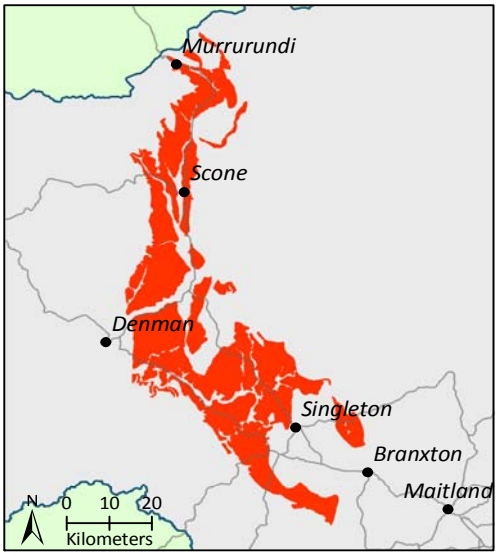
### Decision rules

Very High hazard rating is based on HGL assessment of similar landscapes within HNCMA and CWCMA areas, which recognised high levels of land salinity, high in-stream salt load and highly saline water (Nicholson et al. 2010).

## 3.2 Very high hazard – Area 2

| VH2 | Wittingham Coal Measures | Hazard: | Very High |
|---|---|---|---|

**Figure 3 Location diagram of very high hazard area 2**




### Overview / location

This category comprises the undulating hills, rises and colluvial slopes of the Wittingham Coal Measures in the extensive coal bearing area between Muswellbrook and Singleton. The area encompasses the major coal extraction areas of the Hunter, and has significant disturbed land and associated infrastructure (roads, railway). The area includes some of the largest mines in the Hunter (Mt Arthur, Bengalla, Drayton, Dartbook, Muswellbrook Coal).

### Significance

These landscapes have a very high salinity hazard dominated by large numbers of severe salt sites and saline groundwater discharge. The greatest salinity impacts are associated with the coal measures, which are thick and close to the surface in this landscape. The landscape is formed on sediments that are horizontally bedded and contain highly saline layers, above and below the coal layers. The coal also has significant salt storage within the fabric of the coal measure.

A hydraulic head of upper landscape units, sits above the salt store in these Permian sediments, which have a moderate to high store, and moderate to high salt availability. The very high

salinity hazard is related to this stratigraphic sequence: wherever water filters through saline strata before discharging on the surface, salinity is likely to express on the land surface or in streams.

Salinity poses a major issue to the coal mining industry. Saline water bodies (voids) are a consequence of the mining process, and need to be managed for water quality purposes. This is currently undertaken by the Hunter Salinity Trading Scheme, which allows releases under strict guidelines in high flow situations to streams and rivers.

The groundwater quality is highly variable throughout the unit, but usually highly saline. There is considerable aquifer interference induced by the mining activity. The rehabilitated mining land also has a higher recharge rate than undisturbed land.

**Undisturbed state**: On-site impacts include multiple location surface scalding (salt sites), large seasonal saline sites, marginal to brackish stream flow, sheet and minor gully erosion with dispersive soils on colluvial slopes, and seasonal water-logging on colluvial slopes and alluvial plains. Off-site impacts include declining water quality along creeks, streams, and rivers; in both salt load and localised increases in salt concentration (EC). These impact downstream in wetter climatic sequences.

**Disturbed state**: On-site impacts include surface scalding and waterlogged sites around mine areas (induced by higher recharge), highly saline voids, induced sites due to infrastructure construction of roads and railway lines impeding natural flow, saline dust and aerosol material, marginal to brackish stream flow, and saline groundwater. Off-site impacts include declining water quality along creeks, streams, and rivers; in both salt load and localised EC increases. In times of Hunter Salinity Trading Scheme operation, an impact on EC and salt load occurs in the Hunter River.

### Resilience statement

Drivers of salinity development in these landscapes in an undisturbed state, include poor grazing management on colluvial slopes, isolated cropping and clearing of native vegetation. The major driver of salinity in the disturbed area is due to mining activity and aquifer interference.

The major variables influencing resilience in these landscapes include mining activity, soil salt store / availability, soil stability, and local groundwater rise / depletion. In addition, the operation of the Hunter Salinity Trading Scheme is a variable to be considered in the long term. As the voids store more water and concentrate salt; more leakage to the aquifer occurs, and associated with this is the need to discharge higher quantities of more saline water.

The landscape is in a “Transitionary or Poor State” and is a sensitive landscape due to mining activity.

### Confidence

Significant salinity mapped and observed. Significant monitoring for legislative purposes (groundwater and surface water). Landscape and geological processes predispose area to salinity.

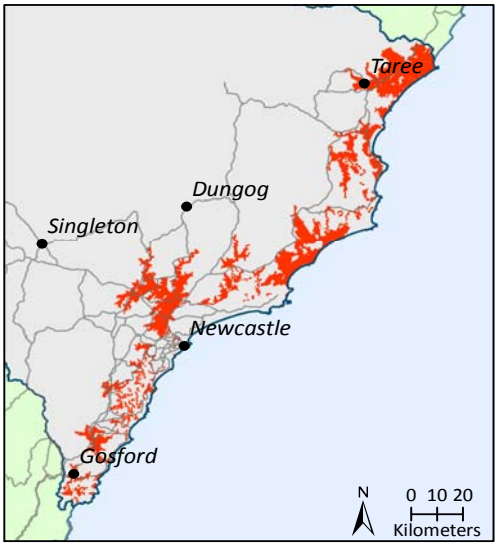
### Decision rules

This category is defined by geology (the Wittingham Coal Measures). The area encompasses small exposures of other Permian sediments (minor) and Jurassic Basalt hills (also minor). The very high salinity rating is based on extensive monitoring, research and investigations conducted by many organisations.

## 3.3 Very high hazard – Area 3

| | | | |
|---|---|---|---|
| **VH3** | **Acid Sulfate Potential** | **Hazard:** | **Very High** |

**Figure 4 Location diagram of very high hazard area 3**




## Overview / location

This category comprises all occurrences of potential acid sulfate soils in the Hunter-Central Rivers area (excluding areas of 'no known occurrence', 'disturbed terrain' and 'beaches' from acid sulfate soil risk mapping.) It also includes estuarine tidal flats, floodplains, terraces and fluvial sediments which are regularly inundated. Locations include along major water bodies such as the Hunter River, Port Stevens, Myall Lakes, and Wallis Lakes.

## Significance

These landscapes with potential acid sulfate risk have predominantly a very high salinity hazard, high salt load, high salt store and low water quality (high EC). Soils generally tend to be highly acidic and highly saline. Regular inundation from brackish tidal water contributes to salt store. Disturbed landscapes that have potential acid sulfate risk can present a significant salinity hazard.

On-site impacts include frequent locally severe salt sites which cause damage to buildings and infrastructure at all points across the landscape, corrosion from sulfate salts, flooding and water logging. Off-site impacts include a decline in water quality.

## Resilience statement

Salinity is primarily driven by shallow cyclic flows, estuarine and acid sulfate influences.

Drivers of salinity development in these landscapes also include increased urbanisation, over use of water, leakage of stormwater infrastructure and water delivery systems and inappropriate siting of infrastructure which will all have significant impact on hydrological pathways, and building and construction practices that are not sensitive to saline or acid sulfate conditions.

Variables controlling the resilience of these landscapes include exposure of potential acid sulfate soils, planning, policy, siting of infrastructure, construction methods, water use patterns and volumes, localised volume of saline substrate, and extent of saline land.

## Confidence

Moderate. Landscape salinity is mapped and observed and stream EC tested. Acid sulfate soil risk mapped (Naylor et al. 1998).

## Decision rules

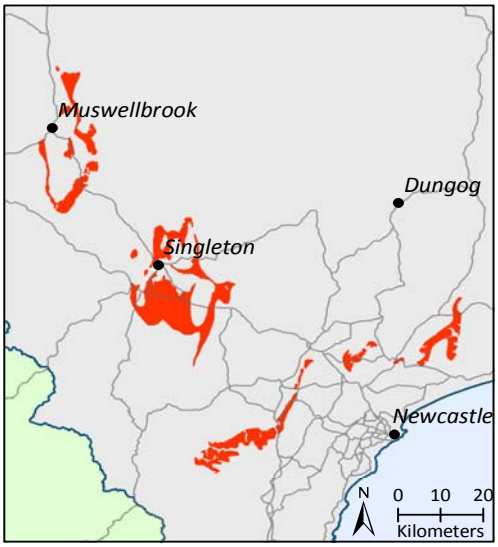
Very High hazard rating is based on acid sulfate soil risk mapping and Hydrogeological Landscape (HGL) assessment which recognised high levels of locally severe land salinity, high in-stream salt load and saline water in similar areas of Sydney Metropolitan CMA (Winkler et al. 2011b). The unit encompasses areas of low and high acid sulfate soil risk defined in acid sulfate

soil risk mapping (Naylor et al. 1998), but excludes areas mapped as disturbed, disturbed terrain or beaches.

## 3.4 Very high hazard – Area 4

| VH4 | Mulbring | Hazard: | Very High |
|---|---|---|---|

**Figure 5 Location diagram of very high hazard area 4**




### Overview / location

This category comprises a landscape of complex undulating hills and rises, with short colluvial slopes and alluvium of Permian sedimentary landscapes (mainly siltstone with sandstone and conglomerate ) in an area extending from Glennridding, Belford and Minimba (south of Singleton) and south Cessnock and Ellalong. The unit comprises the Mulbring Siltstone Formation.

### Significance

These landscapes have a very high salinity hazard dominated by large numbers of severe salt sites in upper landform areas, and saline groundwater discharge.

The landscape is undulating and is a complex rolling landscape, with many colluvial slopes and alluvial areas. Salinity is expressed across the landscape at many locations, but sites on creek lines that are very evident in the landscape.

The area differs from the H3 – Branxton Formation due to the large numbers of sites across the landscape and higher in-stream salt concentrations (EC). Like this Branxton unit, salt sites are also common on the edges of the unit (on geological boundary conditions). There is a substantial and increasing urban and peri-urban pressure in this area. The current urban infrastructure to the south of Cessnock shows significant salinity damage.

These complex landscapes have formed on siltstone sediments that are folded and contain saline layers. The landscape is variably weathered and there is a moderate-high salt store across the landscape. There is a high local recharge component from the surrounding landscape, especially in urban areas. Land use is grazing of native and introduced pasture, with increasing urban pressure. There is likely to be an increased recharge component when poor grazing practises are conducted, and poor urban water use occurs. Groundwater salinities are highly variable, but can be marginal to brackish (local saline groundwater situations exist)

On-site impacts include multiple location surface scalding (salt sites), large seasonal saline sites, marginal to brackish stream flow, sheet and minor gully erosion with dispersive soils on colluvial

slopes, and seasonal water-logging on colluvial slopes and alluvial plains. On-site impacts also include changes in ground cover and damage to infrastructure and buildings. Off-site impacts include declining water quality in both salt load and localised EC increases. These impact downstream in wetter climatic sequences.

### Resilience statement

The drivers of salinity development in this landscape have been clearing and overgrazing that allow salts to be mobilised from geologies and increased local recharge with high potential for salinity impact. Reducing groundcover (resulting from overgrazing or isolated cropping) drives increased recharge.

Drivers of urban salinity include urbanisation, particularly peri-urban development and subdivision which may alter hydrological pathways. Impacts can be managed with urban and rural salinity management practices.

The major variables influencing resilience in these landscapes include soil stability, clearing, soil salt store / salt availability and poor grazing management. Variables that impact the resilience of the urban landscape include sodic soils and urban planning which should consider potential impacts of salinity on infrastructure and assets

### Confidence

Significant salinity mapped and observed. Saline stream spot sampling conducted. Landscape and geological processes predispose area to salinity. Preliminary urban investigation activity conducted.

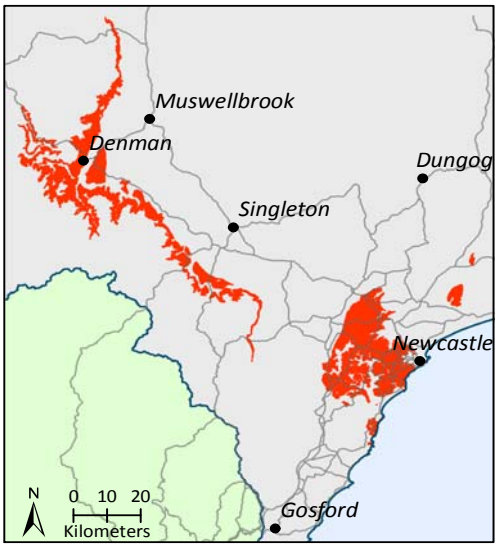
### Decision rules

This category is defined by Permian siltstone sedimentary landscapes comprising the Mulbring Siltstone Formation. The impact of urban salinity is a major component in this ranking.

## 3.5 Very high hazard – Area 5

| VH5 | Newcastle Coal Measures | Hazard: | Very High |
|---|---|---|---|

**Figure 6 Location diagram of very high hazard area 5**




### Overview / location

This category comprises the mid slope and lower landform units of the Newcastle Coal Measures in two distinct areas – the Denman area and the Newcastle area. The Newcastle area has a long history of coal mining, and the coal seams are deep, having been mined using

underground mining techniques. In the Denman area the coal seams are shallow and form a topographic line on the midslope (at the base of adjacent sandstone cliffs), with salinity expression highly visible.

### Significance

These landscapes have a very high salinity hazard dominated by large numbers of severe salt sites, extremely saline streams and extremely saline groundwater discharge. The Yarrawa site at Denman has recorded 42ds/m EC as a natural discharge into the creek, which impacts on stream EC in the Goulburn River (a local rise of 1 dS/m occurs at the confluence with the large volume of the river water). In the Denman area there are multiple sites on midslopes that are stratigraphically controlled, and appear as saline sites on the midslope and impact lower landform units. The upper slopes give a higher recharge in this unit.

These midslopes sites have formed on sediments that are horizontally bedded and contain highly saline layers, above and below the coal layers of the Newcastle Coal Measures. Sandstone cliffs and other recharge elements sit above them providing a hydraulic head. Salt store in these Permian sediments is moderate to high and salt is moderately to highly available. The very high salinity hazard is related to this stratigraphic sequence: wherever water filters through saline strata before discharging on the surface, salinity is likely to express on the land surface or in streams.

In the Newcastle area the coal seams are deeper in the landscape generally, but where they outcrop on the surface they cause severe local salinity.

Groundwater salinity is extremely saline and salinity is concentrated due to the constricted nature of water flow through the stratigraphic control, which corresponds to coal layers.

On-site impacts include specific landform location surface scalding (salt sites), large seasonal saline sites on lower slopes and alluvial deposits, extremely saline stream flow, sheet and minor gully erosion. Off-site impacts include declining water quality along creeks and rivers (Goulburn River), in both salt load and localised in-stream salinity increases (EC). These impact downstream in wetter climatic sequences.

There are key salinity demonstrations sites in the area, mostly in the Yarrawa area, which demonstrate how the geological and landscape setting of the area predisposes it to very high land salinity.

### Resilience statement

Drivers of salinity development in these landscapes include poor grazing management on colluvial slopes and clearing of native vegetation. Disturbance due to mining and aquifer interference are major drivers as the landscape is increasingly mined for coal.

The major variables influencing resilience in these landscapes include mining activity, soil salt store / salt availability, soil stability, and local groundwater rise.

The landscape is in a “Transitionary or Poor State” and is a sensitive landscape due to salinity issues and potential large scale mining.

### Confidence

Significant salinity mapped and observed with a long history of salinity treatment and extension work. Stream EC tested. Landscape and geological processes predispose area to salinity. A state MER Soils – Salinity site is established in the area, and has been extensively investigated.

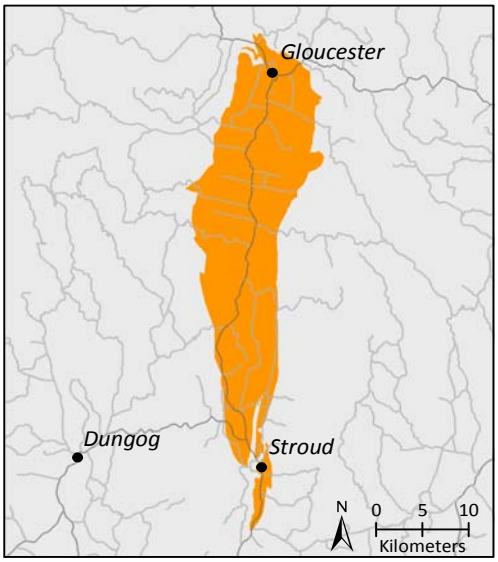
### Decision rules

This category is defined by geology (the Newcastle Coal Measures and Tomago Coal Measures). The very high salinity rating is based on extensive monitoring, research and investigations conducted by many organisations, particularly in the Yarrawa area.

## 3.6 High hazard – Area 1

| H1 | Gloucester Basin | Hazard: | High |
|---|---|---|---|

**Figure 7 Location diagram of high hazard area 1**




### Overview / location

This category comprises flat plateau landscapes, surrounded by steep timbered hills and shallow soils over Permian Coal Measures (Craven Coal Measure and Gloucester Coal Measure). The steep enclosing hills are Permian to late Carboniferous – Alum Mountain Volcanics, and the alluvium is Quaternary Alluvium. The unit is confined to a small area from Gloucester to Wards River & Forbesdale.

### Significance

These landscapes have a high salinity hazard due to the flat nature of the landscape, over shallow coal measures with constricted drainage outlets and confined by a rim of Carboniferous volcanics.

These landscapes are dominated by large numbers of readily identifiable salinity signals (tree death and species change), salt sites, saline streams and saline groundwater discharge. These low rolling hill (plateau landforms), bowl formations and valley constrictions have formed on sediments that are horizontally bedded and contain highly saline layers. The volcanic rim sits above them providing a hydraulic head.

Salt store in the Permian sediments is moderate to high and salt is moderately to highly available. The high salinity hazard is related to this stratigraphic sequence i.e. wherever water filters through saline strata before discharging on the surface, salinity is likely to express on the land surface or in streams. This landscape is also folded providing preferred locations for groundwater discharge, as is the intersection of the Permian folded geology with the Quaternary Alluvium. Groundwater salinity is brackish to marginal; and salinity is concentrated due to the constricted nature of water flow.

The landscape is moderately to highly weathered and there is a moderate to high salt store across the lower landform units. Water-logging sites are also numerous. Land use is grazing of native and introduced pasture, dairying and cropping.

On-site impacts include multiple locations of surface scalding (salt sites), large seasonal saline sites, water-logging on alluvial plains, marginal to brackish stream flow and sheet erosion with slightly dispersive soils on colluvial slopes. Off-site impacts include declining water quality along

the Wards, Avon and Gloucester Rivers, in both salt load and salinity concentrations (localised increases in EC). These impact downstream locations in wetter climatic sequences.

### Resilience statement

The drivers of salinity development in this landscape have been clearing and overgrazing that allows salts to be mobilised from geologies and increased local recharge with high potential for salinity impact. Reducing groundcover (resulting from overgrazing or cropping) drives increased recharge.

The major variables influencing resilience in these landscapes include soil stability, clearing, soil salt store / salt availability and poor grazing management.

### Confidence

Salinity mapped and observed.  Saline water measured in seeps at boundary conditions and in creeks. Landscape and geological processes predispose area to salinity.

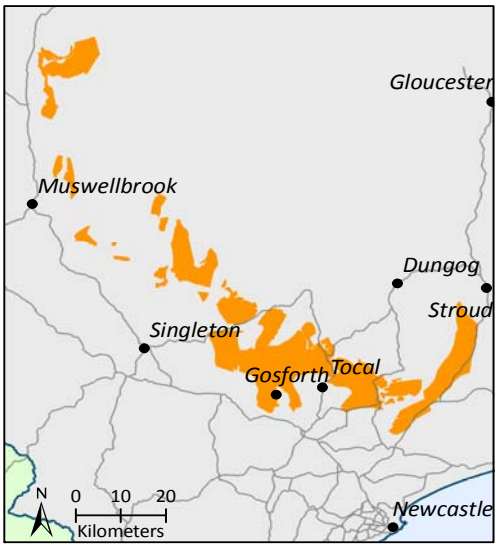
### Decision rules

This category is defined by the Gloucester Basin Major Structural Geology Unit (NSW Mineral Resource 1976) which is an elongated basin shaped landform surrounding the Wards river. Contained within the Gloucester Basin are Permian Coal Measures (Gloucester Coal Measures), Alum Mountain Volcanics, Mammy Johnsons Formation and Quaternary Alluvium. The landform of the constrictive surrounding geology forms a unique scenario for salinity development within the Hunter Central Rivers catchment.

## 3.7 High hazard – Area 2

| | | | |
|---|---|---|---|
| **H2** | **Carboniferous Faulted** | **Hazard:** | **High** |

**Figure 8 Location diagram of high hazard area 2**




### Overview / location

This category comprises undulating hills and rises, with colluvial slopes and valley floors of Carboniferous sedimentary landscapes in an area including Tocal, Paterson, Lambs Valley, Stanhope and Gosforth. The area is highly complex being faulted and fractured, and strongly folded. The main Carboniferous units are the Seaham Glacial Beds, Paterson Volcanics, Mt Johnstone Formation and undifferentiated material.

### Significance

These landscapes have a high salinity hazard dominated by very complex geology that is faulted and fractured, as well as being strongly folded.

The landscape is undulating and rolling with colluvial slopes and alluvial areas. Salinity is expressed across the landscape at many locations, predominately in association with faults and fractures. Sites are numerous with sites high in the landscape on creek lines that are very evident in the landscape, and are also evident in creek lines on the lower colluvial slope elements.

The landscape is variably weathered and there is a moderate to high salt store across the landscape, and adjacent to fault lines. There is a high local recharge component from the surrounding landscape. Land use is grazing of native and introduced pasture. There is likely to be an increased recharge component when poor grazing practises are conducted. Groundwater salinities are highly variable, but can be marginal to brackish (local saline groundwater situations exist)

On-site impacts include surface salinisation (salt sites) in upper, mid and lower colluvial situations and associated with faults / dykes. The landscape is sodic. Off-site impacts include decline in water quality where salt load is high, and where salinity concentration (EC) spikes occur in-stream.

### Resilience statement

The drivers of salinity development in this landscape have been clearing and overgrazing. Mobilisation of salts occurs from geologies with high potential to deliver salts to the landscape. Variables influencing resilience in these landscapes include soil stability and percentage of ground cover. The landscape is in a transitionary state.

There is significant regrowth and the area has potential to return to natural state.

### Confidence

Salinity mapped and observed. EC sampling has been undertaken. Further investigation would be informative.

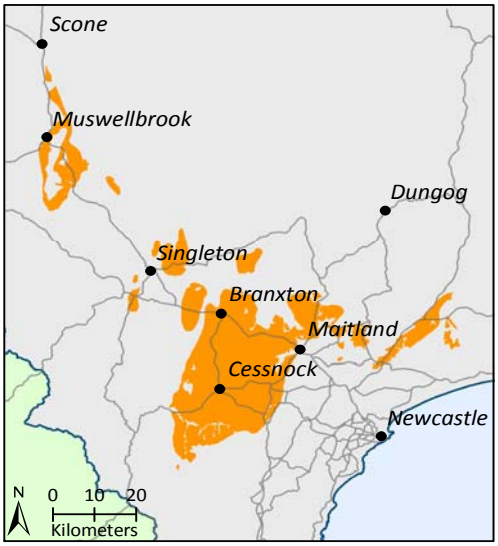
### Decision rules

This category is defined by Carboniferous metasediments (including Seaham Glacial Beds, Paterson Volcanics, Mt Johnstone Formation and Undifferentiated material) within the central area of the catchment.

## 3.8 High hazard – Area 3

| | | | |
|---|---|---|---|
| **H3** | **Branxton Formation** | **Hazard:** | **High** |

**Figure 9 Location diagram of high hazard area 3**




## Overview / location

This category comprises a variable landscape of undulating hills and rises, with long colluvial slopes and alluvium of Permian sedimentary landscapes (sandstone/ conglomerate/siltstone) in an area extending from Greta, Cessnock and Ellalong. The area is faulted and folded. The unit comprises the Maitland Group (principally the Branxton Formation) and the Dalwood Group.

## Significance

These landscapes have a high salinity hazard dominated by large numbers of salt sites, saline streams and saline groundwater discharge.

The landscape is undulating and rolling with colluvial slopes and alluvial areas. Salinity is expressed across the landscape at many locations, sometimes in association with faults and fractures. Sites are numerous with sites on creek lines that are very evident in the landscape.

Salt sites are also common on the edges of the unit (on geological boundary conditions). There is a substantial and increasing urban pressure in this area, particularly with the extension to the Newcastle Freeway. The current urban infrastructure shows significant salinity damage.

These colluvial slopes and lower landforms have formed on sediments that are folded and contain saline layers. The landscape is variably weathered and there is a moderate to high salt store across the landscape, and adjacent to fault lines. There is a high local recharge component from the surrounding landscapes, especially urban and vineyards. Land use is grazing of native and introduced pasture, with increasing urban pressure and established vineyards. There is likely to be an increased recharge component when poor grazing practises are conducted, and poor urban water use. Groundwater salinities are highly variable, but can be marginal to brackish (local saline groundwater situations exist)

On-site impacts include multiple location surface scalding (salt sites), large seasonal saline sites, marginal to brackish stream flow, sheet and minor gully erosion with dispersive soils on colluvial slopes, and seasonal water-logging on colluvial slopes and alluvial plains. On-site impacts also include changes in ground cover and damage to infrastructure and buildings. Off-site impacts include declining water quality in both salt load and localised in-stream salinity (EC) increases. These impact downstream in wetter climatic sequences.

## Resilience statement

The drivers of salinity development in this landscape have been clearing and overgrazing that mobilise salts from geologies and increased local recharge with high potential for salinity impact. Reducing groundcover (resulting from overgrazing or isolated cropping) drives increased recharge.

Drivers of urban salinity include urbanisation, particularly peri-urban development and subdivision which may alter hydrological pathways. Impacts can be managed with urban and rural salinity management practices.

The major variables influencing resilience in these landscapes include soil stability, clearing, soil salt store / salt availability and poor grazing management. Variables that impact the resilience of the urban landscape include sodic soils and urban planning which should consider potential impacts of salinity on infrastructure and assets.

### Confidence

Salinity mapped and observed, EC sampling undertaken. Preliminary urban investigation activity conducted with Cessnock Council. Further investigation would be informative.

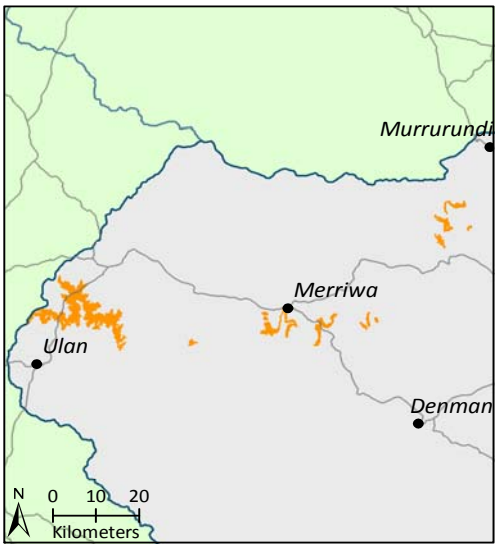
### Decision rules

This category is defined by Permian sedimentary landscapes comprising the Maitland Group (principally the Branxton Formation) and the Dalwood Group. The impact of urban salinity is a major component in this ranking.

## 3.9 High hazard – Area 4

| | | | |
|---|---|---|---|
| **H4** | **Purlewaugh Formation** | **Hazard:** | **High** |

**Figure 10 Location diagram of high hazard area 4**




### Overview / location

This category comprises colluvial slopes and minor valley floor areas on Jurassic Purlewaugh sedimentary rocks. These particular landforms and sediments are known to be found between Ulan and Turill. This high salinity hazard differs from other similar geological situations known in the CW CMA area due to thinner layers of sediment, and recharge from upper sandstone units flushing this midslope unit.

### Significance

These landscapes have a high salinity hazard dominated by frequent salt sites with varying severity, marginal saline streams and saline groundwater discharge. These colluvial slopes have formed on sediments that are horizontally bedded and contain highly saline layers. Sandstone or basalt layers sit above them providing a hydraulic head. Salt store in these sediments is moderate to high and salt is moderately to highly available. The high salinity hazard is related to this stratigraphic sequence: wherever water filters through saline strata before discharging on

the surface, salinity is likely to express on the land surface or in streams. Groundwater salinity is marginal.

On-site impacts include surface scalding (salt sites) on midslope areas associated with the Purlewaugh Sediments, and salt sites in flow lines. Off-site impacts include declining water quality in both salt load and localised EC increases. These impact downstream in wetter climatic sequences.

There are a number of salinity demonstrations in the area including the salinity offsets project (Ulan Mine), which demonstrate the geological and landscape setting of the area which predisposes it to very high land salinity.

### Resilience statement

Drivers of salinity development in these landscapes include clearing of native vegetation and poor grazing management on colluvial slopes.

The major variables influencing resilience in these landscapes include soil salt store / salt availability, soil stability, and local groundwater rise/ depletion.

### Confidence

Significant salinity mapped and observed with a long history of salinity treatment and extension work. Salinity mapped as part of Ulan Salinity Offsets Program. Stream EC tested. Landscape and geological processes predispose area to salinity.

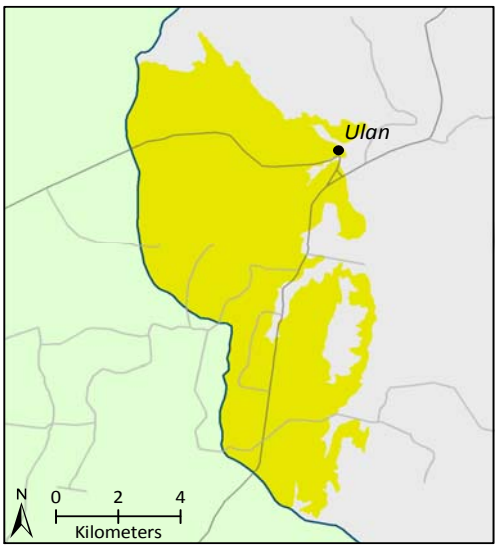
### Decision rules

High hazard rating is based on Hydrogeological Landscape (HGL) assessment of similar landscapes within the CW CMA area (Wooldridge et al. 2012), which recognised high levels of land salinity, and instream impacts. The area is defined by geology – Jurassic Purlewaugh (Jpsu) unit.

## 3.10 Moderate hazard – Area 1

| | | | |
|---|---|---|---|
| **M1** | **Ulan Monzonite** | **Hazard:** | **Moderate** |

**Figure 11 Location diagram of moderate hazard area 1**




### Overview / location

This category comprises a quartz monzonite landscape on the western margin of the catchment in the vicinity of Ulan. This granitic area has steep partially cleared slopes, and extensive

colluvial slopes. Some alternative granodiorite landscapes have been included in the low salinity hazard category L1 – Granodiorite due to their low salinity potential under native forest.

### Significance

These landscapes have a moderate salinity hazard due the large colluvial footslope landform that stores and mobilises salt. The landscape is steeply undulating and rolling in upper elements, with long colluvial slopes where salinity is expressed as localised groundwater discharge in swamp areas, high in-stream salinity concentrations (high EC), and land salinity on the lower slopes associated with creek lines. At the intersection with other sedimentary geologies, very large saline sodium chloride (NaCl) dominated sites occur.

A feature of this landscape is the high EC in streams and the continuous flow of streams. The landscape is variably weathered and there is a moderate to high salt store in the lower landform colluvial units. Soils in this landscape can be highly sodic. Land use is grazing of native and introduced pasture, with some fodder cropping undertaken. There are large areas of hobby farm development on upper slopes.

On-site impacts include surface salinisation (salt sites) in lower colluvial situations, particularly on creek lines and adjacent to change in geology. Saline swampy discharges are scattered throughout the long footslope. There are areas of gully erosion and the landscape is acidic.

Off-site impacts include decline in water quality where EC and salt load is high, from perennial stream with high EC and occasional spikes.

### Resilience statement

Drivers of salinity development in these landscapes include poor grazing management, clearing, loss of groundcover and loss of soil health from historical cropping that mobilised salts from geologies. Variables influencing resilience in these landscapes include soil stability and percentage of ground cover. The impact of hobby farm development in the upper slopes has increased recharge. The landscape is in a transitionary state.

### Confidence

Salinity mapped and observed, with the area having a long history of salinity investigation, associated with the Ulan Mine Salinity Offsets Scheme, and previous Landcare extension activities.

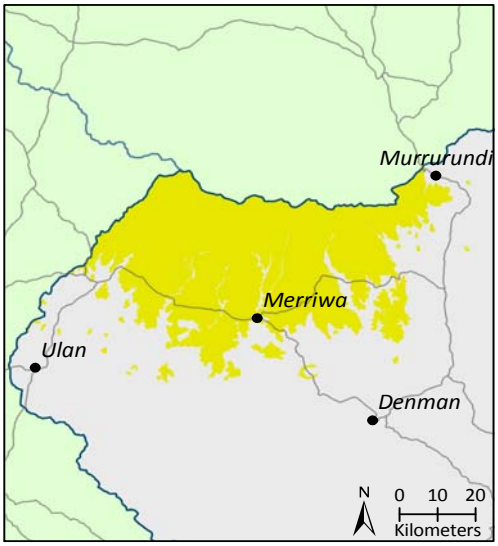
### Decision rules

This category is defined by Carboniferous Quartz Monzonite (Cggu) and Tannabutta Group (Swt) geology within the western portion of the catchment.

## 3.11 Moderate hazard – Area 2

| | | | |
|---|---|---|---|
| **M2** | **Merriwa** | **Hazard:** | **Moderate** |

**Figure 12 Location diagram of moderate hazard area 2**




## Overview / location

This category comprises the Tertiary Volcanic (Tv) landscapes of the northern section of the catchment along the rim of the Liverpool Range. The area extends from Cassilis to Merriwa on what is locally called the “Merriwa Plateau”. The volcanics variably overlay the sedimentary Jurassic Pilliga and Purlewaugh Formations, incising deeply into these often saline geologies in some locations.

## Significance

These landscapes have a moderate salinity hazard due to the moderate salt store in the landscape. Salt sites are usually relatively small and carbonate dominated. They can occur at contact with underlying geology and where there are perched water tables, often with associated fresh springs. Some saline springs occur on “bench” landforms in the strongly columnar basalt areas of the landscape.

Salinity is also associated with texture change between black and other clays in the basalt landscape, and there is a high stream EC (salinity concentration), particularly where underlying units are exposed in flow lines (e.g. Bow Creek where water passes through saline underlying strata).

The groundwater quality is highly variable throughout the unit. There are a number of landcare and Environmental Service Scheme salinity demonstrations in the area which demonstrate how the geological and landscape setting of the area predisposes it land salinity. The predominant locations are changes in slope (break of slope) as well as contact with other geologies, change in texture, under basalt caps, on the edge of creek lines and associated with underlying sediments and weathered basalts.

The basalt derived soils have a high salt store, heavy texture, and are often heavily cropped – leading to more recharge locally, driving salinity. On-site impacts include multiple location surface scalding (salt sites) and water-logging. Off-site impacts include decline in water quality in both salt load and localised EC increases. These impact downstream in wetter climatic sequences. In-stream salinity concentration (EC) is more significant than land salinity.

A feature of the landscape is the extensive contour banking systems which are a response to the locally high extensive sheet and rill erosivity of the soils. When banks have less grade (or flat) they can often locally induce water-logging and low level salinity. These basalt landscapes are generally fertile, and extensively cropped.

This hazard area is more saline than the similar VL3 - Basalt Cap (Barrington) landscape, due to climatic conditions (drier), and because it is an extensively changed (cleared and cropped) landscape.

### Resilience statement

The drivers of salinity development in this landscape have been clearing; intensive cropping and overgrazing which allows for mobility of salts from regolith; landscape shape (colluvial sites and under basalt caps); and increased local recharge which has a high potential for salinity impact. Reducing groundcover (resulting from overgrazing or cropping) drives increased recharge on a local scale in many locations in the landscape.

The major variables influencing resilience in these landscapes include soil salt store / salt availability, soil stability (erosion), and local groundwater rise.

The landscape is in a “Transitionary or Poor State” and is a sensitive landscape due to soil health issues and intensive cropping. The landscape is buffered by the high cation exchange capacity (CEC) in clay rich basalt soils which masks progress of salinity development until a threshold of salt store is reached and onsite impacts become evident.

### Confidence

Salinity mapped and observed. Saline stream spot sampling conducted. Landscape and geological processes predispose area to salinity.

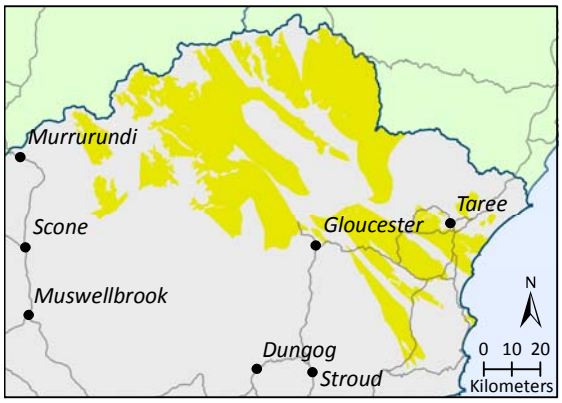
### Decision rules

This category is defined by Tertiary Volcanics mapped within the western portion of catchment. The landscape is differentiated from VL3 – Basalt Cap (Barrington) which has higher rainfall, steeper landform, higher relief and a lesser salinity hazard.

## 3.12 Moderate hazard – Area 3

| | | | |
|---|---|---|---|
| **M3** | **Devonian** | **Hazard:** | **Moderate** |

**Figure 13 Location diagram of moderate hazard area 3**




### Overview / location

This category comprises highly variable, deformed (faulted and fractured) Devonian sedimentary landscapes in the north east of the catchment around the localities of Nabiac, Belbora, Cells River, Tobins Camp , Glenrock , Mernot and Bowman. There are a range of Devonian geologies that are mapped (Bowman Beds, Timonee Beds, Belbora Beds) and some that are undifferentiated.

### Significance

These folded landscapes have a moderate salinity hazard due to the fractured and faulted nature of the sediments. The landscape is steeply undulating and rolling with colluvial slopes and valley floors. Salinity is expressed on the mid and upper slopes on contacts with other geologies (often in association with structures), on colluvial slopes and valley floors. Streams are

saline which is the biggest salinity impact. There are numerous small salt sites and discharges at particular localised situations on slopes. There is high runoff in the area.

The landscape is variably weathered and there is a moderate salt store in the lower landform units. There are numerous salt sites in localised areas, especially associated with structures. Land use is grazing of native and introduced pasture, with some fodder cropping undertaken. Salinity is driven by land clearance. Significant areas of the unit remain uncleared.

On-site impacts include surface salinisation (salt sites) in lower colluvial situations and associated with faults / dykes. Some gullying is associated with saline discharge on slopes. Water-logging is common, particularly on the lower slopes and alluvium. Off-site impacts include decline in water quality where salt load is high, and where salinity concentration (EC) spikes occur in-stream.

### Resilience statement

The drivers of salinity development in this landscape have been clearing and overgrazing and some fodder cropping that mobilises salts from geologies with high potential to deliver salts to the landscape. Variables influencing resilience in these landscapes include soil stability and percentage of ground cover. The landscape is in a transitionary state, where cleared, and stable where uncleared.

### Confidence

Salinity mapped and observed. EC recorded in spot sampling. The area is a low confidence area that needs more investigation.

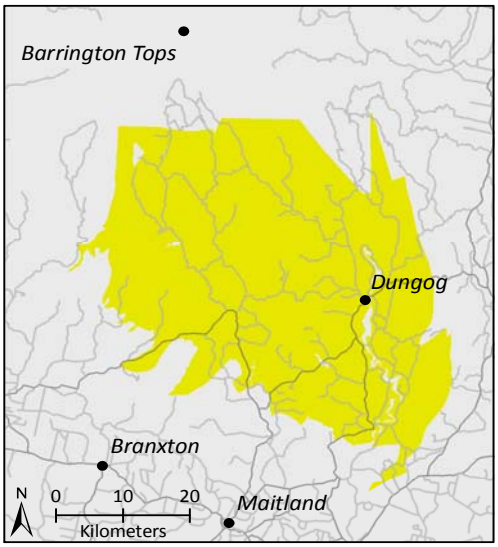
### Decision Rules

This category is defined by Devonian metasediments (such as Bowman Beds, Timonee Beds, Belbora Beds, and undifferentiated units) in the north eastern portion of the catchment.

## 3.13 Moderate hazard – Area 4

| M4 | Gresford Carboniferous | Hazard: | Moderate |
|---|---|---|---|

**Figure 14 Location diagram of moderate hazard area 4**




### Overview / location

This category comprises a highly variable landscape of steep and undulating hills and rises, with colluvial slopes of Carboniferous sedimentary landscapes in an area extending from Dungog, Gresford, north of Paterson, Mirannie and Salisbury. The area is faulted and folded.

### Significance

These landscapes have a moderate salinity hazard due to the folded, fractured and faulted nature of the sediments. The landscape is frequently undulating and rolling to steep with colluvial slopes and minor alluvial areas. Salinity is expressed on the colluvial slopes, and is mostly evident in creek lines with high salinities (5 dS/m), often in association with structures. Salt is also evident on valley floors, and at changes in geology.

The landscape is variably weathered and there is a moderate salt store in the upper and lower landform units. There are numerous salt sites in localised areas, most noticeably in the upper and mid-slope situations. Land use is grazing of native and introduced pasture, with some fodder cropping undertaken. There is likely to be an increased recharge component when poor grazing practises are conducted. Groundwater salinities are highly variable, but can be marginal.

On-site impacts include surface salinisation (salt sites) in upper, mid and lower colluvial situations, and associated with faults / dykes. Off-site impacts include decline in water quality where salt load is high, and where salinity concentrations (EC) spikes occur in-stream.

### Resilience statement

The drivers of salinity development in this landscape have been clearing and overgrazing and some isolated cropping that mobilises salts from geologies with high potential to deliver salts to the landscape. Variables influencing resilience in these landscapes include soil stability and percentage of ground cover. The landscape is in a transitionary state.

### Confidence

Salinity mapped and observed. EC sampling has been undertaken. Further investigation would be informative.

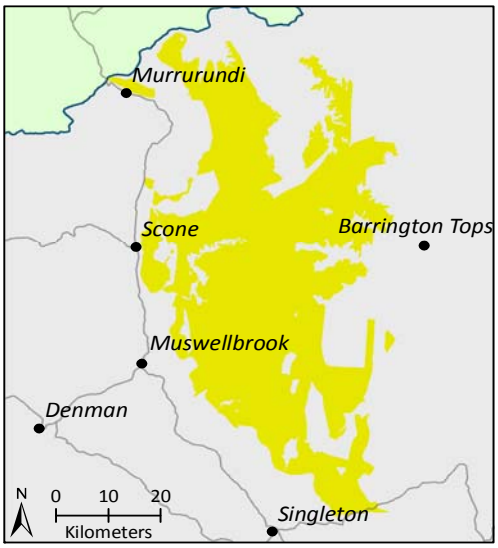
### Decision rules

This category is defined by Carboniferous metasediments within the central area of the catchment.

## 3.14 Moderate hazard – Area 5

| | | | |
|---|---|---|---|
| **M5** | **Carboniferous (Isismurra Formation)** | **Hazard:** | **Moderate** |

**Figure 15 Location diagram of moderate hazard area 5**




### Overview / location

This category comprises undulating hills and rises, with colluvial slopes and valley floors of Carboniferous sedimentary landscapes in an area including Goorangoola, Westbrook and Davies Creek. The area is significantly faulted and fractured. The main Carboniferous units are the Wallaringa Formation and the Gilmore Group

### Significance

These landscapes have a moderate salinity hazard due to the strongly fractured and faulted nature of the sediments. The landscape is undulating and rolling with colluvial slopes and large alluvial areas. Salinity is expressed predominately on valley floors in association with major fault lines. Sites are often large (2 -5 ha) with strong precipitate (sodium bicarbonate) on the surface. Salt sites are also evident in creek lines on the lower colluvial slope elements.

The landscape is variably weathered and there is a moderate to high salt store in the lower landform units, and adjacent to major fault lines. There is a high local recharge component from the surrounding landscape. Land use is grazing of native and introduced pasture, with some fodder cropping undertaken. There is likely to be an increased recharge component when poor grazing practises are conducted. Groundwater salinities are highly variable, but can be marginal to brackish (local saline groundwater situations exist)

The HCR CMA has applied large quantities of mulch to many of these sites to good effect.

On-site impacts include surface salinisation (salt sites) in lower colluvial / alluvial situations and strongly associated with faults / dykes. There is on-site sodicity and significant gully erosion on these sites.  Off-site impacts include decline in water quality where salt load is high, and where salinity concentration (EC) spikes occur in-stream.

### Resilience statement

The drivers of salinity development in this landscape have been clearing and overgrazing and some isolated cropping that mobilises salts from geologies with high potential to deliver salts to the landscape. Variables influencing resilience in these landscapes include soil stability and percentage of ground cover. The landscape is in a transitionary state.

### Confidence

Salinity mapped and observed. Investigations have been undertaken as part of HCR CMA implementation program, with electro-magnetic (EM) and groundwater investigations undertaken.

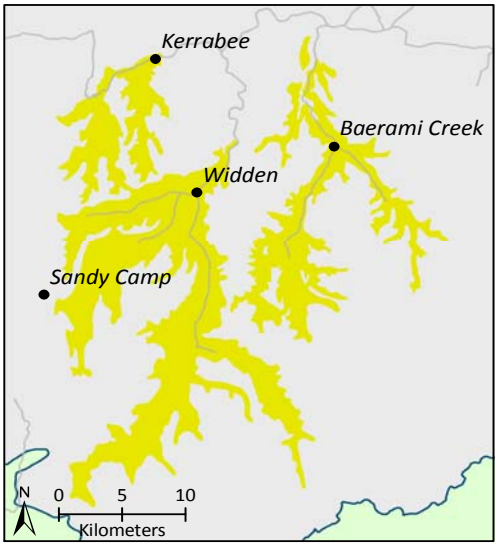
### Decision rules

This category is defined by Carboniferous metasediments (Wallaringa Formation and the Gilmore Group)  within the central / northern area of the catchment.

## 3.15 Moderate hazard – Area 6

| | | | |
|---|---|---|---|
| **M6** | **Singleton Supergroup** | **Hazard:** | **Moderate** |

**Figure 16 Location diagram of moderate hazard area 6**




## Overview / location

This category comprises lower landform units and colluvial slopes of Permian aged sedimentary rocks of the Singleton Supergroup (Pos). These particular landforms and sediments are known to be found in valley locations in the Widden, Holbrook and Beramie areas. The area is surrounded by extensive sandstone units that are heavily timbered.

## Significance

These landscapes have a moderate salinity hazard dominated by common salt sites, particularly in the valley floors and adjacent to creek lines. Saline streams and higher EC spikes saline with groundwater discharge are a feature of this unit. Salinity impacts are associated with the coal measures, which are close to the surface in this landscape. The landscape is formed on sediments that are horizontally bedded and contain saline layers, above and below the coal layers.

A hydraulic head of upper landscape units, sits above the salt store in these Permian sediments, with a moderate store, and moderate availability. The moderate salinity hazard is related to this stratigraphic sequence: wherever water filters through saline strata before discharging on the surface, salinity is likely to express on the land surface or in streams. The groundwater quality is highly variable throughout the unit.

On-site impacts include surface scalding (salt sites) on lower colluvial areas, seasonal saline sites, marginal to brackish stream flow with EC spikes common. Off-site impacts include declining water quality along the creeks in the unit, in both salt load and localised EC increases. These impact downstream in wetter climatic sequences

## Resilience statement

Drivers of salinity development in these landscapes include poor grazing management on colluvial slopes and clearing of native vegetation.  The impacts are mostly to streams in this landscape.

The major variables influencing resilience in these landscapes include, soil salt store / salt availability, soil stability, and potential mining activity

## Confidence

Some salinity mapped and observed with Natural Sequence Farming Research conducted by a number of Universities. Landscape and geological processes predispose area to salinity.

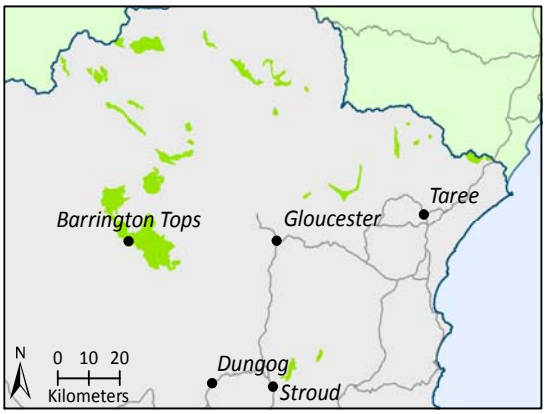
## Decision rules

This category is defined by geology (exclusively the Singleton Supergroup). The moderate salinity rating is based on monitoring, research and investigations conducted in the area.

## 3.16 Low hazard – Area 1

| L1 | Granodiorite | Hazard: | Low |
|---|---|---|---|

**Figure 17 Location diagram of low hazard area 1**




### Overview / location

This category comprises high and low relief landforms on granodiorites between Gloucester Tops and Stewarts Brook, around the area of Edwards Plain. The area is partially cleared and forms part of the Barrington Tops area.

### Significance

These landscapes have low salinity hazard, and feature a granitic landscape which has the potential to store salt in the landscape, if cleared (hence the low rating). Similar landscapes in the Northern Rivers and Murray CMA areas have a slight salinity potential. The landscapes are steep, have good drainage and a low to moderate capacity for storing salt. Areas are variably treed. The landscapes generally occur in relatively high rainfall areas so most salt is flushed out by rainfall and higher recharge. Streams and groundwater are generally fresh.

On-site impacts include seasonal water-logging on lower slopes, rare seasonal salt sites on the lower footslope areas, along drainage lines and/or near the boundary of granites and neighbouring geology.

The distribution of salinity within L1 – Granodiorite landscapes is likely to relate to both landform and chemical variation between different geological ages or types of rock.

### Resilience statement

Drivers of salinity development may include clearing of native vegetation and poor grazing management. Variables influencing resilience in these landscapes include clearing and percentage of ground cover.

### Confidence

Little salt mapped or observed. Not a well known area, but geology would suggest some inherent risk if major landscape change occurred.

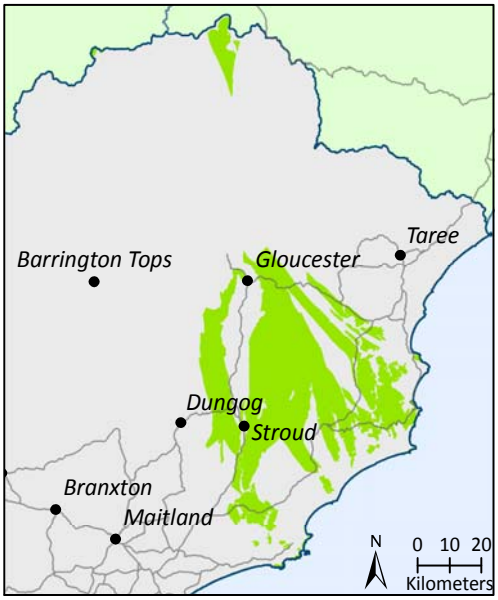
### Decision rules

The area is defined by geological polygons of Granodiorite phase geology. Geological features of chemistry and age could produce variable salinity responses in the granite landscapes.

## 3.17 Low hazard – Area 2

| L2 | Linear Carboniferous | Hazard: | Low |
|---|---|---|---|

**Figure 18 Location diagram of low hazard area 2**




## Overview / location

This category comprises steep, undulating hills and rises, with short colluvial slopes and valley floors of Carboniferous sedimentary landscapes in an area including Bulladelah, Markwell, Cabbage Tree Mountain and Upper Myall. The area is strongly folded with geology trending in a NNE direction. The main Carboniferous unit is the Crawford Formation.

## Significance

These landscapes have low salinity hazard, and feature steep heavily timbered landscapes that have folded sediments.

The landscape is steeply undulating and rolling with short colluvial slopes and minor alluvial areas. Salinity and water-logging are expressed on the lower slopes, and is mostly evident adjacent to creek lines. Salt is also sometimes evident at changes in geology.

The landscape is only slightly weathered and there is a low salt store in lower landform units. The water-logging sites are numerous, and small salt discharges are rare and localised. Land use is native vegetation, timber operations and grazing of native pasture. Groundwater salinities are fresh.

On-site impacts include minor surface salinisation (salt sites) in lower colluvial situations and water-logging. Off-site impacts include minor potential for decline in water quality.

## Resilience statement

The drivers of minor salinity development in this landscape have been clearing and construction of barriers to groundwater flow such as roads. Variables influencing resilience in these landscapes include percentage of ground cover. The landscape is in a natural state, for most of the landscape.

## Confidence

Little salt mapped or observed.

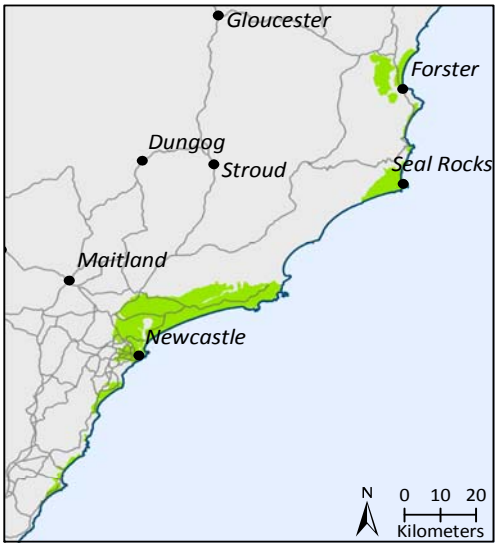
## Decision rules

This category is defined by various Carboniferous metasediments with similar landform shapes within the north-eastern area of the catchment.

## 3.18 Low hazard – Area 3

| L3 | Coastal Sand Dunes | Hazard: | Low |
|---|---|---|---|

**Figure 19 Location diagram of low hazard area 3**




### Overview / location

This category comprises coastal dune fields located from Stockton to Anna Bay; reworked aeolian dunefields on coastal headlands; and beach sands from Gosford to Taree. They are often under conservation or recreational land use.

### Significance

These landscapes have a low salinity hazard. The unconsolidated sand dunes have low salt store. There are occurrences of land salinity, often associated with clay lenses in the sand body.

Groundwater is brackish but dominated by freshwater lenses. High recharge from rainfall flushes salt through porous substrate. Cyclic salt not held in substrate, hence very low store.

On-site impacts include occasionally salt sites occurring as a saline halo on boundary between sand units and surrounding substrate unit, or rare saline site development associated with clay lenses.

### Resilience statement

The likelihood of salinity development is low. Drivers of salinity development may include extraction of perched freshwater lenses, for example at Anna Bay, which allows saline ground water to rise; or clearing of native vegetation above clay lenses.

Variables that influence the resilience of this landscape in relation to salinity include depth to ground water.

### Confidence

Moderate. Some saline sites observed, but little mapped.

### Decision rules

This category groups together the Aeolian and Marine Sand soil landscapes within the Hunter-Central Rivers CMA. Salinity hazard rating is based on soil landscape descriptions. Boundary definitions are based on distribution of Quaternary aged dunes and coastal dunes.

## 3.19 Low hazard – Area 4

| | | | |
|---|---|---|---|
| **L4** | **Alluvium** | **Hazard:** | **Low** |

**Figure 20 Location diagram of low hazard area 4**


### Overview / location

This category comprises landscapes formed on Quaternary aged alluvial deposits throughout the Hunter-Central Rivers Catchment. The Hunter Alluvium has been a productive landscape since early settlement, and is widely irrigated. It is located on the current floodplain and Quaternary Alluvium adjacent to the Hunter River.

### Significance

These landscapes have a low salinity hazard. The landscape is an alluvial plain landscape on alluvial sediments on or close to current floodplain of the Hunter River, and as such has very sandy, free draining nature generally. The landscape has unconfined and semi confined aquifers with variable salinities.

The floodplain soils have silts, clays and sands, and hence a variable salt store. Periodic flooding flushes salt through soils, decreasing land salinity and contributing salts to channel flow. Prior streams sometimes occur in the landscape and little surface salinity has been mapped. Occasional scalds develop at the base of terraces or where footslopes of adjoining landscapes meet the alluvial plain. Irrigation occurs locally which increases the salinity risk. There is some subsoil sodicity in the area.

Salt sites occur at textural changes, breaks in slope and as discharge into drainage lines. The area is a transition zone from upland to riverine environments, and sometimes acts as a temporary salt sore.

On-site impacts include water-logging, and seasonally responsive salt sites particularly at texture changes locations. There are some residual impacts from estuarine and acid sulfate soils in low lying coastal areas. Off-site impacts are realised in the large river systems, and are diluted. There are some local water quality issues in both salt load and localised increases in stream salinity (EC), which manifest in wetter climatic sequences, particularly when the Hunter Salinity Scheme is in operation, taking saline water from mines in high flow situations.

### Resilience statement

The drivers of salinity development in this landscape have been intensive cropping, irrigation, clearing of native grasslands, and historical overgrazing of “dairy land” that mobilised surficial processes in the landscape. Irrigation can drive salinity development especially with the use of water from rivers and creeks that have high salt concentrations. Salty groundwater or water

recycled from salty streams will contribute salt to on-site salt store, which is an issue in some vineyard operations.

Reducing groundcover (via intensive cropping) drives increased recharge locally and mobilises salt into streams. Barriers to water pathways (building of roads) can alter the hydrology and salinity processes.

The major variables influencing resilience in these landscapes include soil health, soil salt store / salt availability and intensiveness of cropping and associated irrigation.

The landscape is in a “Transitionary or Poor State” and is a sensitive landscape due to soil health issues, cropping, level of irrigation and poor grazing management. Landscape factors and increased recharge from cropping (reduced groundcover) can increase the salinity risk.

### Confidence

Salt sites observed and mapped, and historical salt extension activities around these areas.

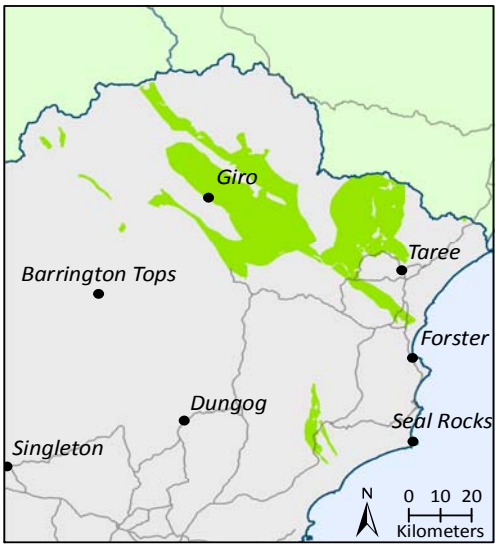
### Decision rules

Low salinity hazard rating is based on knowledge of drainage patterns and salinity expression in studied areas of Quaternary Alluvium. All areas of Quaternary Alluvium are treated similarly.

## 3.20 Low hazard – Area 5

| | | | |
|---|---|---|---|
| **L5** | **Permian Flat-lying Remainder** | **Hazard:** | **Low** |

**Figure 21 Location diagram of low hazard area 5**




### Overview / location

This category comprises landscapes formed on Permian aged landscapes throughout the Hunter-Central Rivers Catchment. The units are predominately in the north-east section of the catchment, around the localities of Giro, Wapra, Bobin, Tiri and Long Flat. The Permian units are the Manning Group, Giro Beds and Myra Beds.

### Significance

These landscapes have low salinity hazard, and feature steep heavily timbered sedimentary landscapes.

The landscape is steeply undulating and rolling with short colluvial slopes and minor alluvial areas. Salinity and water-logging are expressed on the lower slopes, and is mostly evident adjacent to creek lines. Salt is also sometimes evident at changes in stratigraphy and geology.

The landscape is only slightly weathered and there is a low salt store in lower landform units. The water-logging sites are common, and small salt discharges are rare and localised. Land use is native vegetation, timber operation with grazing of native pasture. Groundwater salinities are fresh.

On-site impacts include minor surface salinisation (salt sites) in lower colluvial situations and water-logging. Off-site impacts include minor potential for decline in water quality.

### Resilience statement

The drivers of minor salinity development in this landscape has been clearing and overgrazing. Variables influencing resilience in these landscapes include percentage of ground cover. The landscape is in a natural state, for most of the landscape. Reducing groundcover (resulting from overgrazing or clearing) drives increased recharge in a landscape where there is some potential for minor salinity development.

### Confidence

Little salt mapped or observed. Low confidence.

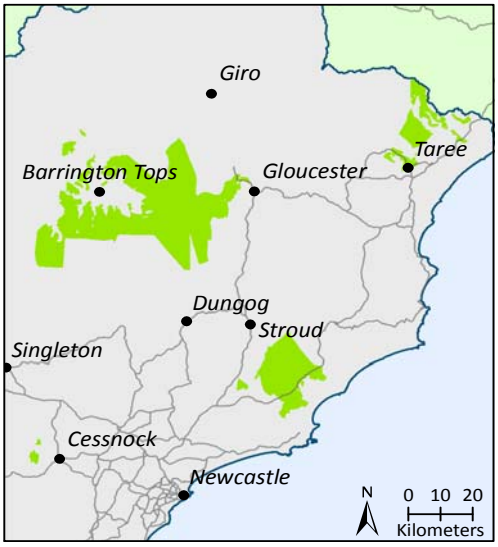
### Decision rules

This category is defined by the Permian units (Manning Group, Giro Beds and Myra Beds) in a non coal bearing landscapes.

## 3.21 Low hazard – Area 6

| | | | |
|---|---|---|---|
| **L6** | **Wootton Beds** | **Hazard:** | **Low** |

**Figure 22 Location diagram of low hazard area 6**




### Overview / location

This category comprises steep, undulating hills and rises, with short colluvial slopes and valley floors of Carboniferous and minor Devonian sedimentary landscapes in two principal areas. An area that includes part of the Barrington Tops National Park between Upper Chichester and Gloucester Tops, and an area between Hawks Nest and Girvan.The main Carboniferous unit is the Wootton Beds and an undifferentiated area that may include some Devonian sediments.

### Significance

These landscapes have low salinity hazard, and feature steep heavily timbered landscapes that have folded sediments in the Barrington tops area, and a more cleared landscape to the south-east, closer to the coast.

The landscape is steeply undulating and rolling with short colluvial slopes and minor alluvial areas to the north, and an undulating and rolling landscape to the south east where salinity and water-logging are expressed on the lower slopes, and is mostly evident adjacent to creek lines. Salt is also sometimes evident at changes in geology.

The landscape is only slightly weathered (to the north) and moderately weathered (to the south-east) and there is a low salt store in lower landform units. The water-logging sites are numerous, and small salt discharges are rare and localised. Land use is native vegetation, timber operations and grazing of native pasture. The landscape closer to the coast is more heavily cleared. Groundwater salinities are fresh.

On-site impacts include minor surface salinisation (salt sites) in lower colluvial situations and water-logging. Off-site impacts include minor potential for decline in water quality.

### Resilience statement

The drivers of salinity development in this landscape have been clearing and overgrazing that mobilises salts from geologies with low-moderate potential to deliver salts to the landscape. Variables influencing resilience in these landscapes include soil stability and percentage of ground cover. The south east landscape is in a transitionary state (being partially cleared), with the Barrington Tops area close to natural state.

### Confidence

Little salt mapped or observed- Low confidence area with little investigation.

### Decision rules

This category is defined by Carboniferous metasediments (Wootton Formation) and undifferentiated area that may include some Devonian sediments. The landscape exists in two areas: Barrington Tops and closer to the coast (north-west of Hawks Nest).

## 3.22 Very low hazard – Area 1

| VL1 | Triassic Sandstones | Hazard: | Very Low |
|---|---|---|---|

**Figure 23 Location diagram of very low hazard area 1**


### Overview / location

This category comprises landscapes formed on massive sandstones of the Triassic Period. These landscapes occur on the southern margin of the catchment from Gosford to Ulan. The area has considerable National Park areas including Wollemi and Goulburn River National Parks.

### Significance

These landscapes have a very low salinity hazard but are major sources of dilution flow. The areas are steep escarpments that are heavily forested with native forest. The massive

sandstones have low salt store. There are only rare occurrences of land salinity, often associated with pockets of clay derived from layers of rock strata, or in association with overlying basalt remnants. Drainage is deep and water is fresh.

The sandstones often provide recharge to other adjacent areas to impact on salinity such as in the Denman area.

### Resilience statement

The likelihood of salinity development is low. Drivers of salinity development may include clearing of native vegetation and urbanisation, which may alter hydrogeologcial pathways. There are few salinity variables that influence the resilience.

### Confidence

High.

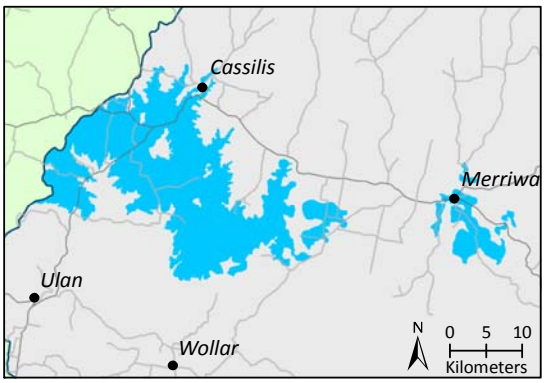
### Decision rules

This category groups together the Triassic aged sandstones of the Hunter CMA which are known to function as fresh water sources in other studied areas where they are located (Winkler et al. 2011a). It also includes minor representations of Jurassic Basalt which overlie sandstone in some locations.

## 3.23 Very low hazard – Area 2

| VL2 | Pilliga | Hazard: | Very Low |
|---|---|---|---|

**Figure 24 Location diagram of very low hazard area 2**




### Overview / location

This category comprises rises and colluvial slopes of sandy soils over Jurassic Pilliga Sandstone (Jsip) and Tertiary Basalt caps (Tb) around Turill and Cassilis area. The sandstone based geology is widely distributed in the western area of the catchment.

### Significance

These landscapes have very low salinity hazard. The massive sandstones have low salt store. There are only rare occurrences of land salinity, often associated with basalt caps and pockets of clay derived from layers of rock strata, or in association with boundary conditions to other units. Drainage is deep and water is generally fresh.

The area is often highly vegetated, and is a major recharge landscape. The landforms often have remnant vegetation on undulating hills, rises and low hills. Soils are sandy, and often sodic.

There are some rare on-site salinity impacts associated with basalt caps, and little off-site salinity impact. Recharge is either deep to local units where there is often a dilution flow impact. In some situations the recharge may mobilise salt store in adjoining units, such as in the Wollar and Purlewaugh Formation unit areas.

### Resilience statement

The likelihood of salinity development is low. Drivers of salinity development may include clearing of native vegetation and poor grazing management. There are few salinity variables that influence the resilience, and the landscapes are stable in native situation, and subject to acidity, groundcover issues and soil stability in cleared slopes.

### Confidence

No salt mapped. No salt observed. Limited salt store, except under basalt caps.

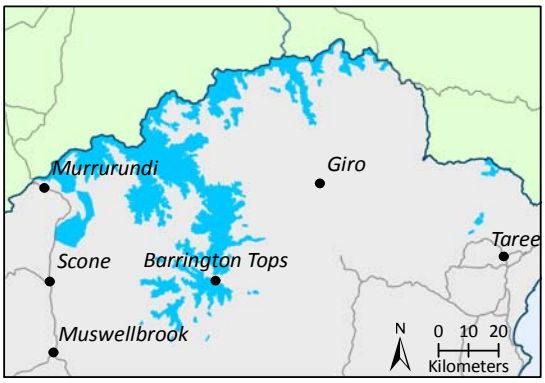
### Decision rules

This category is defined by the Pilliga Sandstones landscapes, and associated basalt caps within western margin of the Hunter-Central Rivers CMA.

## 3.24 Very low hazard – Area 3

| VL3 | Basalt Cap (Barrington) | Hazard: | Very Low |
|---|---|---|---|

**Figure 25 Location diagram of very low hazard area 3**




### Overview / location

This category comprises landscapes formed on basalt geology, and basalt capped landscapes (Tb – Tertiary Basalts) on the northern margin of the catchment in the vicinity of the Liverpool Ranges. The area includes significant national park (Barrington Tops National Park) with steep heavily timbered and partially cleared landscapes.

### Significance

These landscapes have very low salinity hazard. Salt store is potentially moderate, but is mitigated by high rainfall and extensive native vegetation. Salt sites are rare and relatively small, and areas are flushed by high rainfall. They usually occur at contact with underlying geology and where there are perched water tables, often with associated fresh springs. Water quality is generally fresh and salt export is low. Groundwater salinity is fresh.

These landscapes are generally fertile, due to basalt derived soils. There is little on-site or off-site salinity impact. Recharge is either deep or local to other units where there is often a dilution flow impact. In some minor situations the recharge may mobilise salt store in adjoining units.

This hazard area is different to the M2- Merriwa Tertiary Volcanics which overlay saline sediments, and has a much higher salt store in the landscape.

### Resilience statement

The likelihood of salinity development is low. Drivers of salinity development may include clearing of native vegetation and poor grazing management. There are few salinity variables that influence the resilience, and the landscapes are stable in native situation, and subject to groundcover issues and soil stability in steep cleared slopes.

### Confidence

No salt mapped. No salt observed. Salt store mitigated by high rainfall and vegetation, and limited salt store.

### Decision rules

This category groups together the Tertiary Basalt landscapes in the north of the catchment, and is defined by geology.

## 4 References

Anderson CL et al (1969- Reprinted 2006) Singleton 1:250 000 Geological Sheet NSW Geological Survey, Sydney

Banks MR et al (1966 – Reprinted 2006) Newcastle 1:250 000 Geological Sheet, Dept of Mines First edition

Brunker R.L. (1970 Reprinted 2006) Hastings 1:250 000 Geological Sheet, NSW Geological Survey , Sydney

Bryan, J. H. (1966). Sydney 1:250 000 Geological Series Sheet SI 56-5, Third Edition, New South Wales Department of Mines

Department of Land and Water Conservation (DLWC) (2004). Groundwater Vulnerability Mapping. Department of Infrastructure, Planning and Natural Resources, Parramatta. Metadata Reference: http://canri.nsw.gov.au/nrdd/records/ANZNS0359000209.html

Emery, K.A. (1985). Rural Land capability mapping- scale 1:100 000. Soil conservation service of NSW, Sydney (NSW).

.Folke, C., S. R. Carpenter, B. Walker, M. Scheffer, T. Chapin, and J. Rockström (2010). Resilience thinking: integrating resilience, adaptability and transformability. Ecology and Society 15(4): 20. [online] URL: http://www.ecologyandsociety.org/vol15/iss4/art20/

Geoscience Australia (2011) Australian Stratigraphic Units Database, Canberra, Australia [accessed 24/02/11 <http://dbforms.ga.gov.au/www/geodx.strat_units.int>]

Keith, D. A. (2004). Ocean Shores to Desert Dunes: the Native Vegetation of New South Wales and the ACT, Department of Environment and Conservation Hurstville (NSW).

Kovac M & Lawrie JW (1991). Soil Landscapes of the Singleton 1:250 000 Sheet, Soil Conservation Service, DLWC

Mineral Resources, NSW (1976). Major Structural Units ESRI Shapefile, NSW Mineral Resources [accessed from OEH spatial corporate database].

Mitchell P.B. (2003). NSW ecosystems database mapping unit descriptions. Unpublished report to the NSW National Parks and Wildlife Service, Hurstville.

Moore L., Nicholson A. and Winkler M. A., (2010). Using geomorphology and stratigraphy to clarify a dryland salinity, soil sodicity and vegetation distribution puzzle at Capertee Valley, Western Blue Mountains, NSW, Proceedings of the Australian Earth Sciences Convention 2010, page 161.

Morgan EJ et al (1999). Dubbo 1:250,000 Geological Sheet, NSW Geological Survey, Sydney

Murphy, B.W. & Lawrie, J.W. (1999). Soil Landscapes of the Dubbo 1:250 000 Sheet Map, Department of Land & Water Conservation, Sydney (NSW).

Murphy, B. W. and McKenzie, D. C. (2007). Graph to predict instability to wetting in soils based on Exchangeable Sodium Percentage and Electrical Conductivity (1:5). Extension Note

Natural Resources Commission (2011). Framework for assessing and recommending upgraded catchment action plans, August 2011, NRC, Sydney

Naylor, S.D., Chapman, G.A., Atkinson, G., Murphy, C.L., Tulau, M.J., Flewin, T.C., Milford, H.B., Morand, D.T. (1998). Guidelines for the Use of Acid Sulfate Soil Risk Maps, 2nd ed., Department of Land and Water Conservation, Sydney.

Nicholson, A., Moore, L., Pavan, N., Taylor, L., Cull, V., Winkler, M., Copley, S., Preston, Y., Muller, R., Jenkins, B., Marchand, A. (2010). Hydrogeological Landscapes for the Hawkesbury-Nepean Catchment Management Authority, Capertee Valley and Coxs River (Lithgow Valley): Volume 2 – Hydrogeological Landscape Units, NSW Department of Environment, Climate Change & Water, Parramatta.

Pavan N., Nicholson A., Winkler M. A. and Moore L., (2010). Constraining dryland salinity hazard in the Lithgow Valley, NSW, Proceedings of the Australian Earth Sciences Convention 2010, page 103.

Rasmus, P.L., Rose, D.M. and Rose, G. (1969). Singleton, New South Wales, 1:250 000 geological series map. Sheet SI/56-01, 1st edition. Geological Survey of New South Wales

Roberts J et al (1991). Dungog 1:100 000 Geological Sheet 9233, NSW Geological Survey , Sydney

Walker, B., C. S. Holling, S. R. Carpenter, and A. Kinzig. 2004. Resilience, adaptability and transformability in social–ecological systems. Ecology and Society 9(2): 5. [online] URL: http://www.ecologyandsociety.org/vol9/iss2/art5/

Winkler, M., Nicholson, A., Pavan, N., Taylor, L., Cull, V., Copley, S., Jenkins, B., Muller, R. and Moore, L. (2011a). Hydrogeological Landscapes for the Hawkesbury-Nepean Catchment Management Authority, Western Sydney: Volume 2 – Hydrogeological Landscape Units, NSW Department of Environment, Climate Change & Water, Parramatta.

Winkler, M., Nicholson, A., Pavan, N., Taylor, L., Cull, V., Copley, S., Jenkins, B., Muller, R., Moore, L and Shoemark, V. (2011b). Hydrogeological Landscapes for the Sydney Metropolitan Catchment Management Authority, Western Study Area: Volume 2 – Hydrogeological Landscape Units, NSW Department of Environment, Climate Change & Water, Parramatta.

Wooldridge, A., Nicholson, A., Muller, R., Cook, W., Winkler, M., Jenkins, B., Grant, S., Agar, B. and Brennan, N. (2012). Hydrogeological Landscapes for the Western Central West Catchment – Final Report, NSW Office of Environment and Heritage, Department of Premier and Cabinet, Wagga Wagga.

# Appendix 1: Factors influencing resilience in Hunter-Central Rivers CMA

**Table 2 Factors influencing resilience in Hunter-Central Rivers CMA**

| Drivers | Main Variables | Thresholds | Priority Actions | Evidence gaps/needs |
|---|---|---|---|---|
| • Increasing urbanisation<br>• Inappropriate planning and construction methods for salinity<br>• Inappropriate grazing management<br>• Inappropriate vegetation management<br>• Inappropriate cropping practices<br>• Inappropriate irrigation practices<br>• Decreasing depth to water table and/or rising groundwater pressures<br>• Clearing of native vegetation<br>• Loss of perenniality<br>• Loss of soil via erosion<br>• Loss of soil health (physical, biological, chemical) | • Water table depth<br>• Groundcover percentage<br>• Total grazing pressure<br>• Perenniality<br>• Soil stability (erosion, gullying, sodic soil)<br>• Degree of soil degradation<br>• Type of salt (salt species)<br>• Extent of land salinity<br>• Stream EC<br>• Salt load in streams<br>• Extent of potential acid sulfate soils<br>• Climatic variability<br>• Planning control and policy related to salinity hazard<br>• Groundwater quality | • Land salinity develops when groundwater is within 2 m of surface<br>• Threshold for soil salinity impacts: 2 dS/m ECe<br>• Threshold for soil stability ESI = EC/ESP <0.02 instantaneous dispersion on wetting; <0.05 unstable (Murphy & McKenzie 2007)<br>• Groundcover 70%<br>• Riparian vegetation can buffer saline discharge into streams<br>• Point where increasing recharge exceeds plant water uptake (water balance)<br>• Loss of soil A horizon (topsoil)<br>• Exposure and wetting of sodic soils<br>• Exposure of acid sulfate soil (anaerobic to aerobic)<br>• Stream salinity thresholds: human consumption (preferred) = 500 mg/L (800 EC); ecological system function threshold will depend on asset to be protected<br>• Land management within capability / land management not within capability threshold<br>• Building of infrastructure (irreversible) | • Water management (irrigation and flow regime)<br>• Appropriate grazing management<br>• Discharge management<br>• Soil health management<br>• Vegetation management for production<br>• Vegetation management for ecosystem services<br>• Soil amelioration<br>• Urban design catering for salinity<br>• Riparian management<br>• Planning related to salinity hazard<br>• Policy related to salinity hazard | • Salinity investigations in a landscape context not complete across entire CMA area<br>• Salinity landscape management system to a landscape facet scale required for appropriate, targeted management<br>• MERI<br>• Time series groundwater data<br>• Time series stream EC data<br>• Time series load data (including flow data)<br>• Water use of systems used in agricultural practices<br>• Surface-groundwater connectivity information<br>• Salinity-sedimentation relationship information<br>• Land use change data<br>• Salinity outbreak data (out of date and incomplete)<br>• Continuous spatial soil coverage (unpublished or incomplete)<br>• Spatial Land management within Capability (LMwC) (only partial coverage) |