# Hydrogeological landscapes – an expert system for salinity management

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**Abstract**
Salinisation of land and rivers is a major environmental problem in Australia and around the world. The correct management options to counter this threat are paramount if salinity is to be brought under control. The Hydrogeological Landscape (HGL) concept provides a structure for the understanding of how salinity manifests itself in the landscape and how differences in salinity are expressed across the landscape. The HGL framework is an expert management system that integrates the spatial distribution of salinity processes with the most effective management options for any given area. In the Braidwood area of NSW, Australia, 20 HGLs have been identified and assigned specific management options based on the manner in which salinity is expressed within the landscape.

**Key Words**
Salinity, salt stores, water quality, salinity management, EC, Braidwood.

**Introduction**
A Hydrogeological Landscape (HGL) spatially defines areas of similar salt stores and pathways to salt mobilisation. The process of HGL determination relies on the integration of a number of factors: geology, soils, slope, regolith depth, and climate; an understand of the differences in salinity development ("plumbing"); and, the impacts (land salinity/ salt load/ EC) in landscapes (Wilford *et. al.* in press). Information sources such as soils maps, site characterization, salinity site maps, hydrogeological data, surface and groundwater data are incorporated into standard templates. Each HGL has been assessed for a range of salinity characteristics: including Salt Land, Salt Load (export) and Water Quality as well as overall hazard.

A number of HGL projects are currently underway including the Hydrogeological Landscapes for the Southern Rivers Catchment Management Authority, Braidwood 1:100,000 map sheet (in prep). The Braidwood 1:100,000 sheet study area lies in the southern tablelands of NSW, Australia and covers approximately 2500 km². It is bounded by latitudes 35º 00'S and 35º 30'S and longitudes of 149º 30'E and 150º 00'E. The mapped area encompasses the towns of Braidwood, Windellama, Tarago, Lake Bathurst and Mongarlowe.

**Methods**
The methodology used to arrive at a HGL involved a structured comparison of salinity characteristics. These included water pathways through the landscape; salt stores; relative mobility of salt within the landscape; salinisation processes; and, salt signatures within streams. Concept models were developed to describe unique characteristics within each HGL. A multi-staged approach was used to arrive at the HGL units. Firstly existing information was assessed. Information sources such as soils maps, site characterisation, salinity site maps, hydrogeological data, surface and groundwater data were incorporated into standard HGL templates.

The project relied upon a number of different disciplines and skill sets to obtain an integrated understanding of the landscape. Groups involved in the project include geologists, hydrologists, geomorphologists, pedologists, land resource planners and local extension staff. In the Braidwood area the prime method of HGL determination was lithologic boundaries followed by terrain, soils, climate and local knowledge. The Braidwood 1:100,000 Geology map (Fitzherbert *et al.* (in prep)) was used to separate the map sheet into major lithological groups that had similar hydrological properties, regolith depth and weathering characteristics. Bedrock structures including dykes, faults and major lineaments were also used to delineate



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HGLs. Field reconnaissance confirmed the depths of bedrock and any salinity manifestations.
Soil landscapes (Jenkins 1996) were used to better understand the terrain and the surficial deposits such as the ancient Shoalhaven floodplain sediments and aeolian sand deposits. Field reconnaissance backed up with regolith bore logs confirmed the depths of soils, the nature of soil materials and the presence of any saline scalds. The soil landscapes were also used as a basis for splitting terrain based on modal slope (relief and slope inclination).

Climatic zones were drawn on the provisional HGL map and field reconnaissance was used to ascertain the critical climatic gradients. The vegetation mapping and classification of Keith (2006) was used to cross check provisional HGL units. Groundwater flow systems were determined from the geology, soil landscapes, field work and expert panel assessment. HGL units were verified against field observation, EC measurements, historical bore log data, expert knowledge, local knowledge and known saline site mapping. Once HGL units were established and verified landscape functions were assigned (Table 1). A landscape may provide one or more functions in a catchment context. Catchment scale management involves understanding how functions are maintained, improved or degraded. It is important to consider the full range of salinity and hydrology functions to understand which mix of strategies (Table 2) and related management actions (Table 3) are appropriate for salinity management. Some strategies and management actions could have negative offsite impacts to catchment management unless their applicibility to functions is understood.

**Table 1. Landscape function descriptions for the Braidwood area.**

| Function | Description |
|---|---|
| A | The landscape provides fresh water runoff as an important water source |
| B | The landscape provides fresh water runoff as an important dilutions flow source. |
| C | The landscape provides important base flow to local streams |
| D | The landscape generates saltloads which enter the streams and are redistributed in the catchment |
| E | The landscape receives and stores saltload through irrigation or surface flow. |
| F | The landscape generates high salinity concentration water |
| G | The landscape contains important land based assets which are being impacted by salinity processes. |
| H | The landscape contains high hazard for generating sodic and saline sediment. |
| I | The landscape contains high hazard for acid sulfate processes. |

Management strategies are aimed at maintaining or improving the landscape functions. One or more strategies may be applicable to any landscape in order to maintain or improve the function of the landscape (Table 2).

**Table 2. Management strategies for the Braidwood area.**

| | Management strategy |
|---|---|
| Strategy 1 | Buffer the salt store – keep it dry and still |
| Strategy 2 | Intercept the shallow lateral flow and shallow groundwater |
| Strategy 3 | Stop discrete landscape recharge |
| Strategy 4 | Discharge rehabilitation and management |
| Strategy 5 | Increase agricultural production to dry out the landscape and reduce |
| Strategy 6 | Dry out the Landscape with diffuse actions over most of the landscape |
| Strategy 7 | Access and use of groundwater to change water balance |
| Strategy 8 | Maximising recharge to dilute water tables with engineering actions |
| Strategy 9 | Minimising recharge with engineering actions |
| Strategy 10 | Maintaining and maximising runoff |
| Strategy 11 | Manage & avoid acid sulfate hazards |

Management actions for salinity deliver on the strategies at an operational level. One or more management actions may be needed to deliver on any strategy. A management action which is highly suitable for delivering on a particular strategy may by unsuitable to deliver on a different strategy.
There are over 100 defined management actions and new management actions are added as required. Management actions are grouped into several categories (Table 3). A feature of the HGLs is the apportioning of management areas (MA) so that specific landform elements within a landscape can be targeted within any given HGL (Figure 1).

## Results

By not only denoting the functions for each HGL, but also ranking them for Salinity Hazard (Figure 2), land managers can target the correct works to an area and are able to prioritise the landscapes most at risk. The

Very High Hazard HGLs, (Spa Road, Nadgigomar and Budjong Creek) all have demonstrated onsite and offsite salinity impacts. Every flow line examined in these HGLs exhibited salinity.

The functions, strategies and salinity hazard vary widely across the landscape (Table 4). Some HGLs such as Mongarlowe, Palerang and Butmaroo Range provide sources of fresh water and dilution flow. Strategies for these landscapes, for one or more management area, will include maintaining and maximising runoff. Actions include not planting excessive amounts of woody vegetation as this action will compromise the fresh water contribution from this HGL.

**Table 3. Management Action groups and an example management action from the Braidwood area.**

| Management action group | Example Management Action |
|---|---|
| Vegetation for ecosystem service VE | VE2 - Interception planting of trees to target shallow groundwater |
| Vegetation for production VP | VP9 - Perennial horticulture to manage recharge |
| Farming systems FS | FS7 - Controlled Traffic farming systems |
| Engineering E | E3 - Diversion banks to avoid recharge on low areas |
| Irrigation systems IS | IS3 - Effluent disposal systems specific to site conditions |
| Soil Ameliorants SA | SA5 - Address soil biological health by application of compost |
| Saltland rehabilitation SR | SR6 - Water ponding on dry scalds |

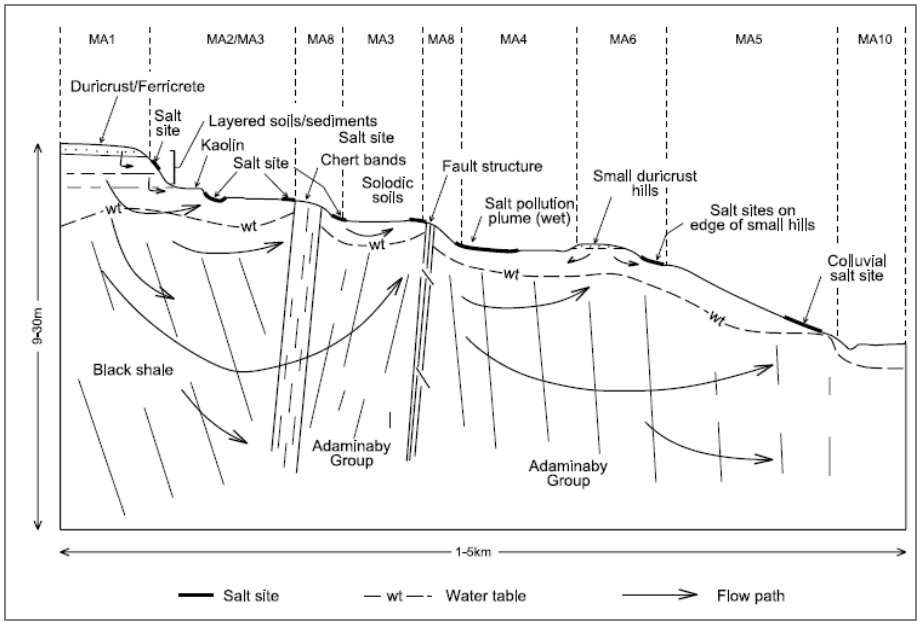


**Figure 1. Management Areas (MA) cross section for the Spa Road HGL, Braidwood 1:100,000 map sheet.**

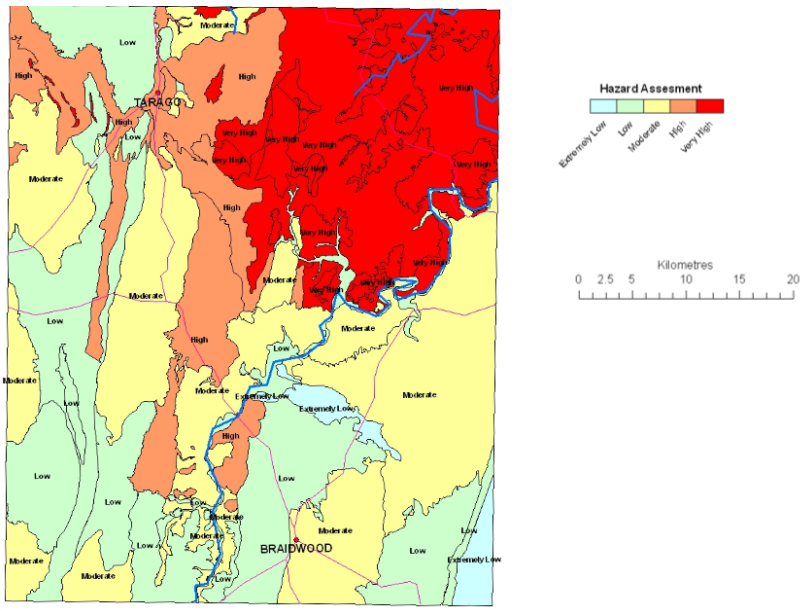


**Figure 2. Braidwood 1:100 000 Salinity Hazard Map.**

HGLs such as Spa Road and Long Flat North generate salt loads which enter streams. In such cases strategies include reducing discrete landscape recharge, rehabilitation and management of discharge sites and the interception of shallow lateral flow and shallow groundwater. For these HGLs management actions for one or more management area will include maintaining and improving native pastures to manage recharge and the rehabilitation of salt land to minimise onsite and offsite degradation.

**Table 4. Function, strategy and hazard analysis.**

| No | HGL | Function | Strategy | Hazard | Confidence |
|---|---|---|---|---|---|
| 1 | Mongarlowe | A, B,C | 4,10 | Low | High |
| 2 | Cookanulla | D,G | 3,4,6 | Medium | Medium |
| 3 | Spa Road | D,G,F,H,I | 3,4,6,2,11 | Very High | High |
| 3 | Moura Creek | D,G | 4,6,2 | Low | Medium |
| 5 | Budjong Creek | D,G,H,I | 3,4,6,2,11 | Very High | High |
| 6 | Palerang | A,B | 4,10 | Very Low | Low |
| 7 | Bobbaduck Hills | D,E,G,I | 10,4,2,11 | High | Medium |
| 8 | Long Flat North | D,F,G | 4,2,6 | High | Medium |
| 9 | Long Flat South | A,B | 10,4 | Medium | Low |
| 11 | Butmaroo Range | A,B,C | 10 | Low | High |
| 12 | Mulloon | A,B,D | 1,2,4,6,7 | Medium | Medium |
| 13 | Braidwood East | A,B,D,G | 1,4,6,7,10 | Medium | High |
| 14 | Braidwood West | A,B,G | 1,2,4,7,10 | Low | High |
| 15 | Hollow Wood | A,G | 10,4 | Low | Low |
| 16 | Merimbula-Minuma | A,B, | 10 | Very Low | Medium |
| 17 | Nadgigomar | D,G,H,I | 1,2,3,4,6,11 | Very High | Medium |
| 19 | Illogen Park | D,G | 1,2,4,6,10 | High | Low |
| 20 | Euradux | A | 4,6,10 | Very Low | Medium |
| 22 | Lake Bathurst | D,E,F,G | 1,4,6 | High | High |
| 24 | Larbert | A,B,G | 1,2,3,4,6 | Low | High |

## Conclusion

The main HGL features are the identification of salinity processes relevant to each parcel of land, the specific management actions to be undertaken relevant to landscape function and the prioritisation of actions based on salinity hazard. Management actions to be avoided within a HGL and within management areas are highlighted. The lists of prescriptive management actions for each part of the landscape allows land resource managers to better target on ground rehabilitations and mitigation works.

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