

Guidelines

to accompany

Map of Salinity Potential in Western Sydney 2002



Guidelines to Accompany Map of Salinity Potential in Western Sydney

August 2002

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1 Introduction

1.1 *Why is the map of salinity potential needed?*

Salinisation is the process where salts stored in the soil profile are mobilised by the movement of water. Subsequent evaporation and accumulation cause an increase in salt levels to the extent that vegetation and building materials such as concrete and steel are affected.

Salinity has the potential to be an expensive land management issue if it is not identified early in the development process. Figures calculated for Wagga Wagga indicate that if no action is taken, salinity could cost the city (60,000 people) up to \$183 million over the next 30 years (DLWC 1998).

Salinity became a topic of interest to local government and state agencies in Western Sydney with the release of the report, "Salinity in the South Creek Catchment" (Dias and Thomas, 1997). Work undertaken by Mitchell (2000) and others since that time has refined ideas about how salinity 'works' in Western Sydney and this map of salinity potential is a representation of these ideas. The map is the first step in providing local government, state agencies and the community with the information they require to manage salinity.

The map depicts the distribution and potential severity of salinity based on a practical understanding of the factors that cause salinity. It should be viewed as a work in progress that can be upgraded as knowledge evolves.

This document explains how the accompanying map should be used and what each mapping category means. The information is intended to be used as a reference for issues associated with urban development. Both this document and the map will be subject to review and refinement as more data and information are acquired.

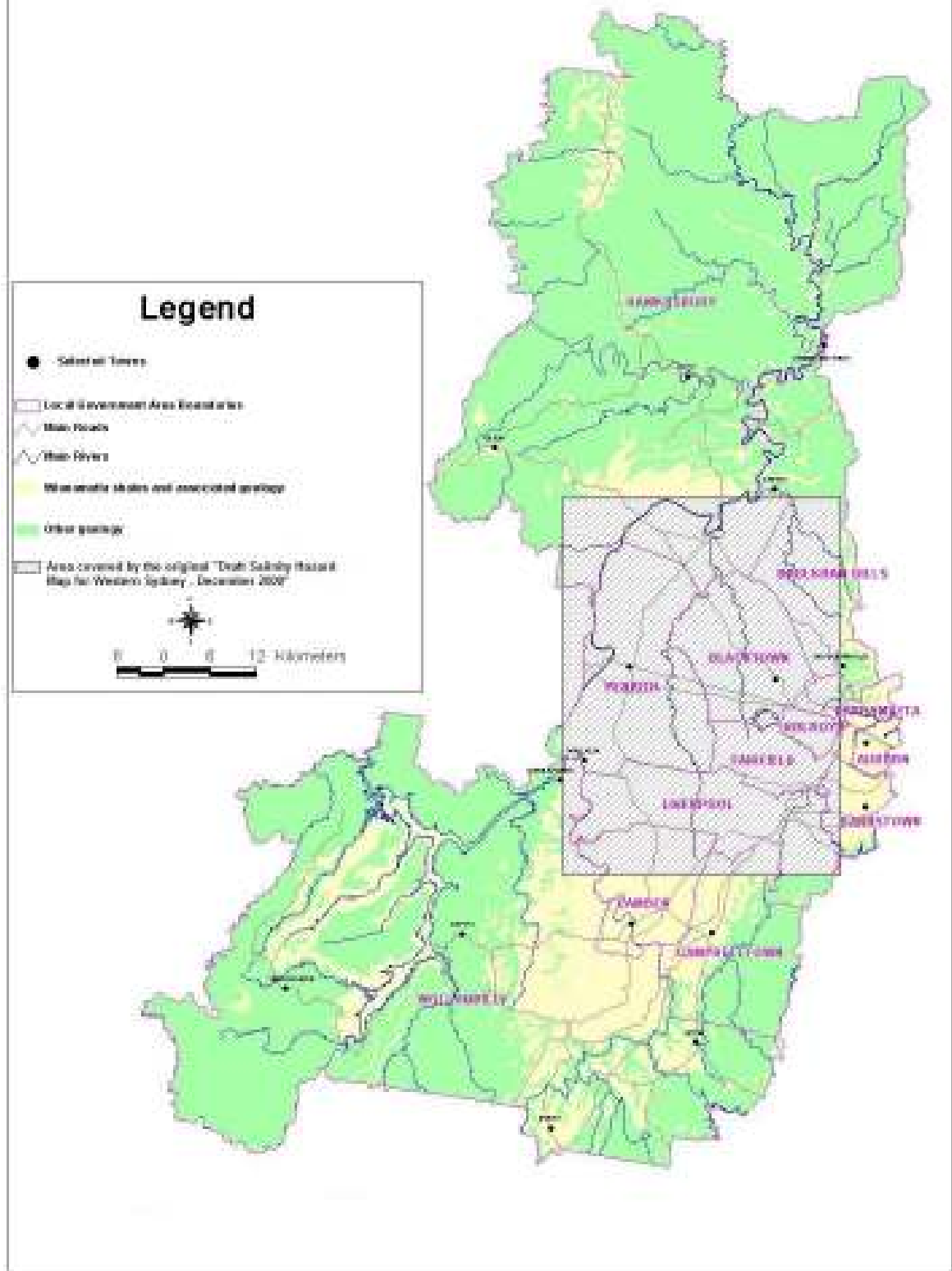
The information in this document applies to those local government areas covered by the Penrith 1:100 000 Map Sheet No. 9030 and parts of the 1:100 000 Wollongong (No. 9029) and Sydney (No. 9130) map sheets. These local government areas are Blacktown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith, as well as parts of Auburn, Bankstown, Baulkham Hills, Hawkesbury, Parramatta and Wollondilly.

Note that use of this map of salinity potential in Western Sydney provides no guarantee that salinity will not develop, even where all possible precautions are taken.

The data presented in this document are the best available as at August 2002. Further information collected through exercises such as the remapping of soil landscapes in Western Sydney will be used to update the map (if required) during the review process.

Reference to the technical notes and publications listed in the back of this document, and other specialist publications and geotechnical expertise, should be made when working in saline areas.

Salinity Potential in Western Sydney - 2002.....Project Area



Reference to the technical notes and publications listed in the back of this document, and other specialist publications and geotechnical expertise, should be made when working in saline areas.

Map showing the extent of the Project Area, with the original (December 2000) Draft Salinity Hazard Map area shown as a hatched box.

1.2 *Statement of limitations of salinity mapping and guidelines*

When using the map of salinity potential, the following should be considered:

- a) The map has been produced to be as accurate as possible as at August 2002. However, map boundaries are only valid at 1:100 000 scale and have been smoothed to accommodate uncertainties and anomalies. Boundaries should not be used at property scale and appropriate investigation should be undertaken on a site-specific basis. The map of potential salinity is not a substitute for on-site investigation.

The information should be used at the scale at which it is published. Enlarging the map will produce distortions whereby map boundaries will no longer correspond to boundaries on the ground. If more detailed information is required, specific purpose surveys should be conducted or professional advice sought.

- b) Field verification has been undertaken where possible, but has been limited by difficulties such as obtaining access to some sites.
- c) Aerial photograph interpretation was undertaken using 1965 and 1967 photography to identify any saline sites that existed before extensive urban development had occurred. Changes to land use since that time may have changed the potential for salinity to occur at a particular site.
- d) Any activities undertaken within Western Sydney with the potential to affect soils and groundwater may affect salinity. This includes, but is not restricted to, clearing of native vegetation, irrigation farming, farm dams, rural cropping and grazing activities, building of homes and infrastructure such as roads and stormwater drainage, and the ongoing aspects of urban management such as watering of lawns and leaking water pipes.

1.3 *How has the map been prepared?*

The map has been developed using geographical information system (GIS) modelling and verified using aerial photograph interpretation to graphically reproduce the model for salinity potential. This computer model was used to provide an assessment of the potential for waterlogging in the area of interest, then overlaid with the aerial photograph interpretation of saline areas. The resulting map was verified in the field where possible and assessed by a technical review committee.

Appendix 1 provides technical notes on the modelling process.

1.4 What will these guidelines do to assist local government, state agencies and the community?

The guidelines and the accompanying map will assist land managers to assess the salinity potential for a particular locality. This information may be used as a basis for the identification of appropriate salinity assessment and management responses.

It is the responsibility of the consent authority to ensure that any development plan considers salinity as a potential land management issue.

2 Explanation and effects of salinity

Salinity has been described as the accumulation of soluble salts in the soil, groundwater and surface waters. Commonly these salts are chlorides, sulphates or carbonates of sodium and magnesium. In Western Sydney, salinity can be either a soil or groundwater issue that affects the ground surface. This may lead to serious land degradation, damage to brickwork, concrete or pipes, or a decline in water quality. Salinity is generally associated with the Wianamatta Group Shales and is sometimes evident on Tertiary and Quaternary sediments. These rock types may be identified on the 1:100 000 New South Wales Geological Survey geology series maps and reports for Penrith (Jones and Clark, 1991), Sydney (Herbert, 1980) and Wollongong and Port Hacking (Sherwin and Holmes, 1986).

For further explanation of how salinity occurs in Western Sydney, reference should be made to "Salinity Processes in Western Sydney" (DIPNR 2003), or advice should be sought from the Department of Infrastructure, Planning and Natural Resources. Further reading and appropriate contacts are listed later in this document.

3 Mapping categories

The mapping shows four classifications of salinity:

- ⇒ Areas of Known Salinity;
- ⇒ Areas of High Salinity Potential;
- ⇒ Areas of Moderate Salinity Potential;
- ⇒ Areas of Very Low Salinity Potential.

These categories have been used because concept modelling has shown that salinity may be an issue almost anywhere in Western Sydney.

3.1 Areas of known salinity

Areas of known salinity may be defined as those areas where there is a known occurrence of saline soil, or where air photo interpretation and field observations have confirmed more than one of the following:

- a) scalding
- b) salt efflorescence
- c) vegetation dieback
- d) salt tolerant plant species
- e) waterlogging.

3.2 Areas of high salinity potential

Areas of high salinity potential are defined as those places where soil, geology, topography and groundwater conditions predispose a site to salinity. These conditions are similar to those occurring in areas of known salinity.

These areas are most common in lower slopes and drainage systems where water accumulation is high (i.e. high relative wetness index).

This category particularly includes lower slopes and streamlines which have a high potential to become waterlogged or where movement of water through the soil profile is slow. It also includes several developed suburbs where a diffuse pattern of salinity problems has been observed but where no detailed observations have been made.

3.3 Areas of moderate salinity potential

These areas cover the remainder of the map wherever Wianamatta Group shales (Ashfield or Bringelly shales) and tertiary alluvial terraces are found. Scattered areas of scalding and salinity indicator plants have been noted but no concentrations have been mapped. Saline areas that have not yet been identified may occur in this zone. Saline areas may also occur in this zone if new risk factors arise.

It should be noted that salinity has been found to affect buildings in these areas. This is due to localised factors that have combined to create a salinity problem at a particular site. The possibility of such factors affecting a site can be assessed using the models for salinity presented in the document, "Salinity Processes in Western Sydney".

3.4 Areas of very low salinity potential

Areas in which salinity processes do not operate or are of minor significance. Soils are rapidly drained and underlying strata (Hawkesbury / Narrabeen Sandstones) are highly permeable, resulting in continual flushing and removal of salts in the landscape. No salinity has been reported in these areas, nor is expected to occur.

4. How to use the salinity map for decision-making

4.1 How can the map be used to make land management decisions?

The map should be used in conjunction with this guideline document as well as other publications listed in the "Further Reading" section at the end of the document.

The map indicates that there are different levels of salinity potential across Western Sydney. As the map has a scale of 1:100 000 it cannot be used to identify the salinity potential of individual lots. However it can be used to identify the general level of potential in the locality of a particular site. This assists in the identification of an appropriate management response for a site.

4.2 General management options

Whilst the Department strongly advises that investigation and matching of appropriate management options be undertaken on a site-specific basis, the following may be used as a guide:

- ⇒ A catchment approach to the management of salinity should be taken in new areas of greenfield development or where salinity has become an issue in an already developed area.
- ⇒ On sites previously developed, calculation of the water balance should be undertaken to determine possible sources of recharge and subsequent paths to discharge. This approach will enable specific areas to be targeted for management.
- ⇒ In developing areas, deep infiltration and throughflow should be minimised in susceptible landscapes to reduce mobilisation of salt stores in the soil. Careful consideration of the design and construction of detention and retention basins in susceptible soils and landscape positions is required. High velocity runoff and subsequent soil erosion should be avoided.
- ⇒ Specific actions include the following:-
 - ☑ Identify limitations for the purpose of providing solutions or exclusion of site from further development. Avoid construction activity in susceptible locations. Avoid disturbance of natural flow lines.
 - ☑ Minimise the disturbance and exposure of any yellow, grey and/or mottled clay subsoil material during construction. All such soils need to be assessed for their capacity to liberate sodium and should be appropriately treated.
 - ☑ Gain an understanding of salinity and the potential investigation and management options available. Reference to technical publications listed in the "Further Reading" section of this document should be made. Note that this is not an exhaustive list.
 - ☑ The use of water on parks and gardens should be minimised.
 - ☑ The application of water with high salt concentrations to new urban landscapes (via water reuse schemes and infiltration technology) should be considered carefully.

- ☑ Maximise tree planting and good management of deep rooted vegetation. Learn to live with salinity by stabilising saline areas with appropriate salt-tolerant plant species.
- ☑ Maintain and repair stormwater conveyance and water supply devices to prevent leakage.
- ☑ Ensure buffer zones and retention of native vegetation along watercourses.

5. Salinity and the future: changing risk factors

Ultimately, salinity in Western Sydney is a reflection of the hydrologic balance in a region with known salt stores and a significant salt input from the atmosphere. Any change in this balance, either natural or induced by land management, is likely to affect the extent and severity of salinity occurring in the future. Predicting the direction of change is difficult and in the absence of certain knowledge, planners and others should apply a precautionary approach to management and aim for the least possible disruption of the hydrologic cycle.

The following provides indications as to possible climate and landscape changes that may have affected, or may affect, the occurrence and severity of salinity in Western Sydney.

5.1 *Recent changes*

- ⇒ The extent of tree cover and ungrazed pasture has increased over the past 30 years, particularly along stream lines. This could be expected to have increased evapo-transpiration and reduced the extent of salinity.
- ⇒ Areas of impermeable surface have increased with the expansion of urban areas. This could be expected to have decreased infiltration and reduced salinity in some areas, but may have increased the number of local site specific outbreaks.
- ⇒ Urban expansion has increased flood volumes and flood frequencies and increased periods of no flow in small streams. This may have had secondary impacts on stream salinity but the directions of change are uncertain. Low or no flow conditions allow salt to accumulate in drying pools but more frequent flooding may have increased flushing.
- ⇒ In larger streams where dry weather flow is driven by output from sewage treatment plants, average stream salinity has probably increased.
- ⇒ Rainfall averages have varied over the El Nino/ Southern Oscillation (ENSO) cycle of 4 - 8 years. There is some evidence to suggest that saline areas on low relief and slope may increase after periods of above average rainfall.
- ⇒ To date, there have been no comprehensive studies of groundwater conditions within Western Sydney, but most groundwaters are extremely saline.

5.2 Possible future changes

There is evidence to suggest that enhanced greenhouse climate change is underway. While regional scale modelling remains crude, the indications for eastern NSW are for an increase in mean temperature of 0.5 - 1.7⁰ C by 2030; an increase in evaporation of 1 - 7%; and an increase in rainfall of perhaps 1 - 6% in summer and 0 - 3% in winter. Of greater concern is the prediction that extreme events of high temperatures and high rainfall may become more common, while effects on ENSO remain unknown. For more detail, see Hennessy *et al.* (1995).

Further reading about the distribution of particular soils may assist in improving understanding of salinity.

6. Further reading

- a. Western Sydney Regional Organisation of Councils (2003); *Western Sydney Draft Salinity Code of Practice*, WSROC Blacktown. Code developed by WSROC, DLWC and local government with the support of a NHT grant.
- b. DLWC (2003); Booklets of the Local Government Salinity Initiative Kit produced by DLWC Penrith.
- c. DLWC (2003); Booklets of *Salinity in Western Sydney* Series developed by DLWC Penrith.
- d. Department of Environment and Natural Resources (1995); *Rising Damp and Salt Attack: the South Australian Perspective* published by the Department of Environment and Natural Resources, State Heritage Branch and the City of Adelaide.
- e. Queensland Department of Natural Resources (1997); *Salinity Management Handbook* published by the Department of Natural Resources, Coorparoo, Queensland.
- f. Standards Australia (1995); *AS 2159 Piling: Design and Installation*. This standard includes tables on exposure classification of soils and groundwater based on their aggressiveness to concrete and steel.

7. References

- Chapman, G.A., Murphy, C.L., Tillie, P.J., Atkinson, G. and Morse, R.J. 1989. Soil Landscapes of the Sydney 1:100,000 Sheet Map, Soil Conservation Service of New South Wales.
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- Hennesy, K.J., Holper, P.N. and Pittock, A.B. 1995. *Regional impacts of enhanced greenhouse effect in New South Wales: Final Report*. CSIRO Climatic Impacts Group.
- Jones, N. R. and Clark, D.C (eds). 1991. *Geology of the Penrith 1:100,000 Sheet 9030*. New South Wales Geological Survey, Sydney.
- Mitchell, P B. (2000). *Salinity Hazard Mapping and Concept Modelling on the Cumberland Plain*. Internal report to the Department of Land and Water Conservation. (A full reference list from Mitchell (2000) is available on request from the Department).
- Sherwin, L. and Holmes, G.G (eds). 1986. *Geology of the Wollongong and Port Hacking 1:100,000 Sheets 9029, 9129* New South Wales Geological Survey, Sydney.
- Standards Australia (1995) *AS 2159 Piling: Design and Installation*

8. Contacts:

Mr Owen Graham, Senior Natural Resource Officer,
PO Box 3935, Parramatta 2124. PH (02) 9895 7503.

Mr Neville Pavan, Senior Natural Resource Officer,
PO Box 651, Penrith 2751. PH (02) 4722 1188.

WSROC Ltd
PO Box 63, Blacktown 2148. PH (02) 9671 4333.

Digital Data and Information:

Mr. Fred de Closey, Resource Information Manager,
PO Box 867, Wollongong 2520. PH (02) 4224 9679.

Appendix 1:

Salinity Potential Mapping in Western Sydney

Technical Notes:

By Martin Mutendeuzi, Natural Resource Officer, DIPNR, Sydney South Coast Region

Introduction

A quick and robust method for rapidly assessing salinity potential in Western Sydney was the primary aim of this work. Salinity potential is defined as the inherent propensity of a site to have a salinity problem due to its geology, soil type, topography and catchment position. A major limiting factor influencing the approach chosen was the lack of data, at 1:100,000 scale, for the main environmental variables that influence salinisation:

- ⇒ elevation
- ⇒ soils
- ⇒ geology
- ⇒ rainfall
- ⇒ vegetation
- ⇒ hydrology, particularly groundwater.

Elevation data, in the form of 25m and 5m Digital Elevation Models (DEMs), were the best spatial resolution data available. Elevation data have the distinct advantage of being intercorrelated with most of the above environmental variables. Further, water movement over and through the landscape, together with any dissolved salts, is influenced by the geometry of the land surface and/or nature of underlying materials. The location of salt scalds and zones susceptible to salinisation has been found to be correlated with the distribution of wetness index (Moore *et al.*, 1991). Groundwater levels often correlate well with topography, causing salinity to occur in low areas, convergent areas and at breaks of slope (Dowling, 2000). In view of these established truths it is logical to try to adapt topographic indices often used in predicting potential waterlogging to analyse patterns of salinisation.

Methods

A Compound Topographic Index (CTI), often referred to as steady-state wetness index, was calculated for the study area. CTI is defined as an estimation of the volume of water draining to each part of the landscape as well as the landscape's ability to retain water due to slope. Derivation of the index employs a depressionless DEM to derive flow from each cell to its downslope neighbours based on relative slopes. Multiple iterations will allow the flow over the landscape to be simulated and a cumulative value of flow through each cell to be calculated (i.e flow accumulation). With this it is then possible to derive the wetness index (Moore *et al.*, 1993) for all cells in the grid as follows:

$$\mathcal{W} = \ln (\mathcal{A} / \tan \mathcal{B})$$

Where \mathcal{W} is the wetness index, \mathcal{A} is the flow accumulation and $\tan \mathcal{B}$ is the slope gradient.

The CTI index for the Salinity Potential Map for Western Sydney was based on a mosaic of 25m and 5m DEMs and calculated using ArcInfo GRID software.

A GIS layer of known/actual existing salinity (evidence layer) was prepared by Dr Peter Mitchell of Ground Truth Consulting based on a combination of aerial photography interpretation and local knowledge. The wetness index (CTI) layer was then overlaid with the ‘evidence’ salinity layer and the outputs analysed. The results of these analyses are presented below.

Results

In **Figure 1**, visual correlation between the CTI index and existing salinity polygons is apparent. The distribution of the CTI index across all known saline polygons and across the whole study area is shown in **Figures 2** and **3** respectively. Simple statistics from the overlay are presented in **Table 2**. Analysis of the overlay shows that the known saline polygons have a mean CTI value of 0.53 and a median value of 0.54. The majority of cells within known salinity polygons had a CTI index value of 0.551.

Table 1: *Summary statistics from CTI and existing salinity GIS overlay*

Statistic	Saline polygon cells	All study area cells
<i>Mean</i>	<i>0.532</i>	<i>0.398</i>
<i>Median</i>	<i>0.535</i>	<i>0.388</i>
<i>Majority</i>	<i>0.551</i>	<i>0.400</i>
<i>Std</i>	<i>0.111</i>	<i>0.128</i>
<i>Min</i>	<i>0.124</i>	<i>0.000</i>
<i>Max</i>	<i>0.955</i>	<i>1.000</i>

In summary, the statistics from **Table 1** and **Figures 1, 2** and **3** show that, on average, known salinity polygons have a CTI index higher than the rest of the study area.

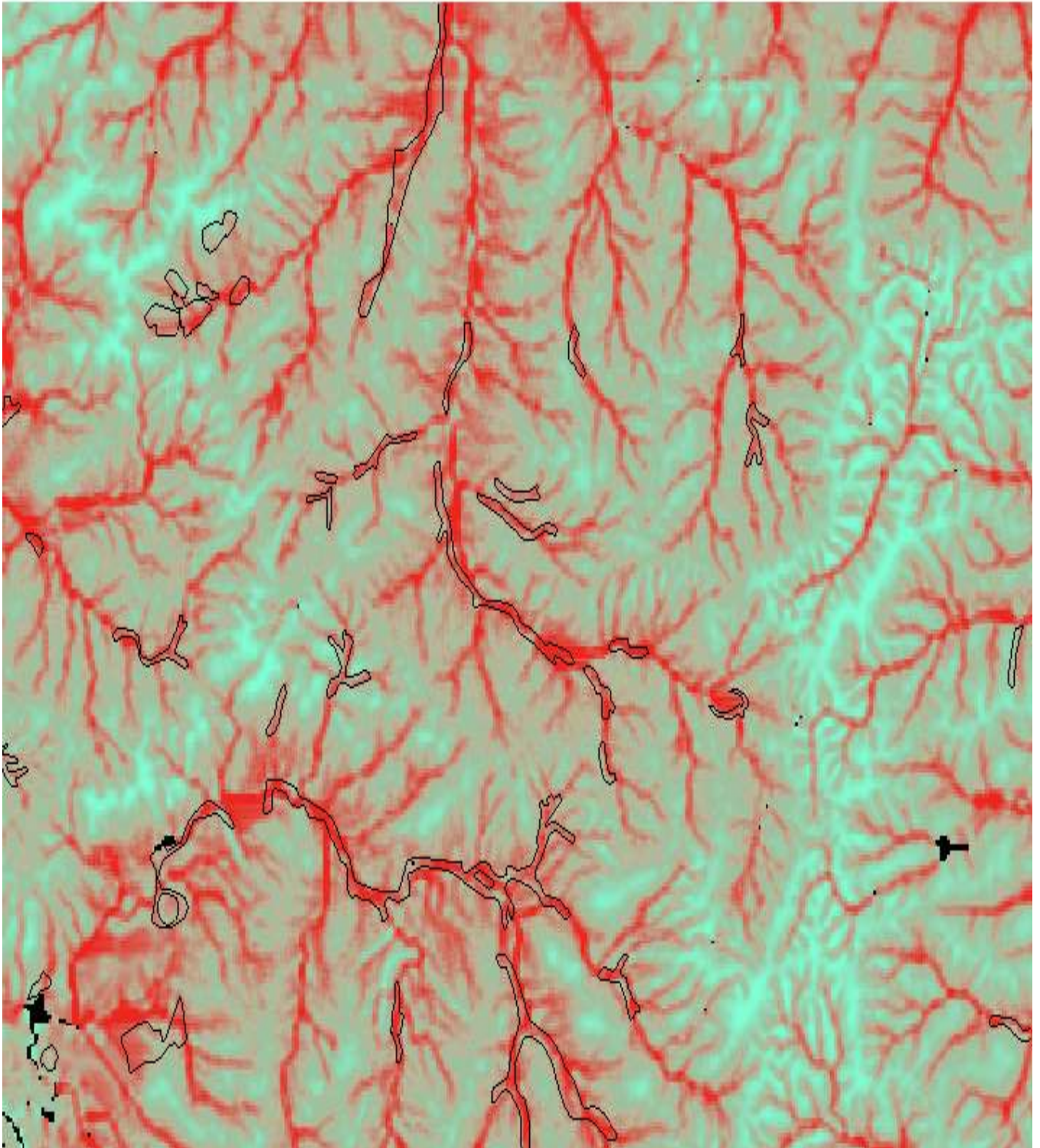


Figure 1. A close-up of CTI wetness index overlaid with known salinity polygons (black outline). Green colours indicate low wetness index values, while red tones, from low to bright, indicate moderate to high wetness index values. This shows a higher correlation with known salinity outbreaks.

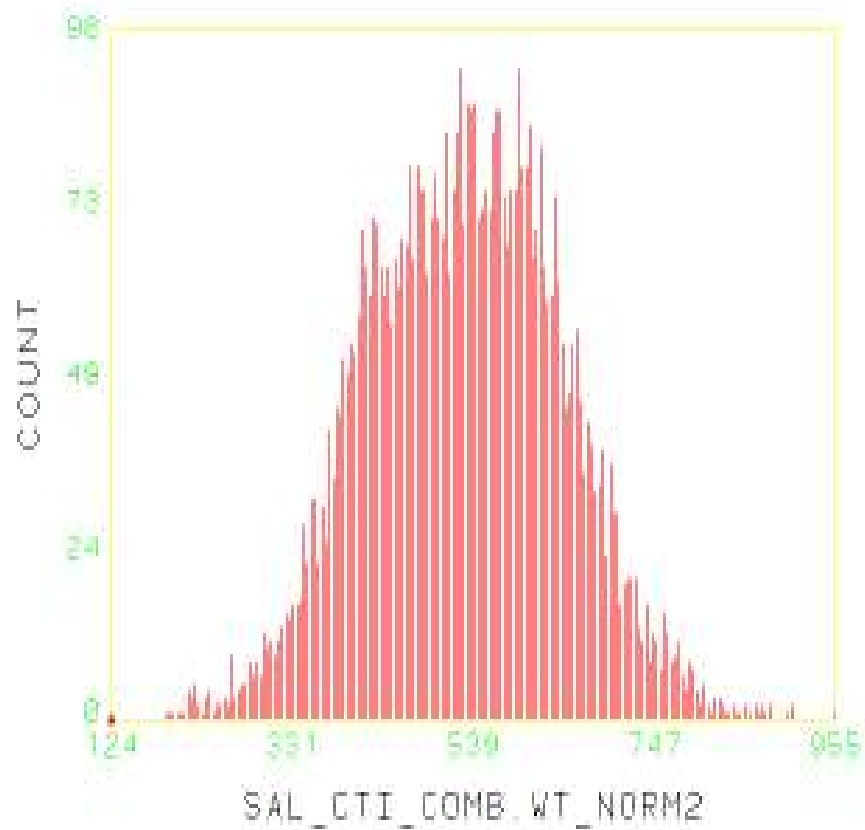


Figure 2. Distribution of CTI index across cells in saline polygons.

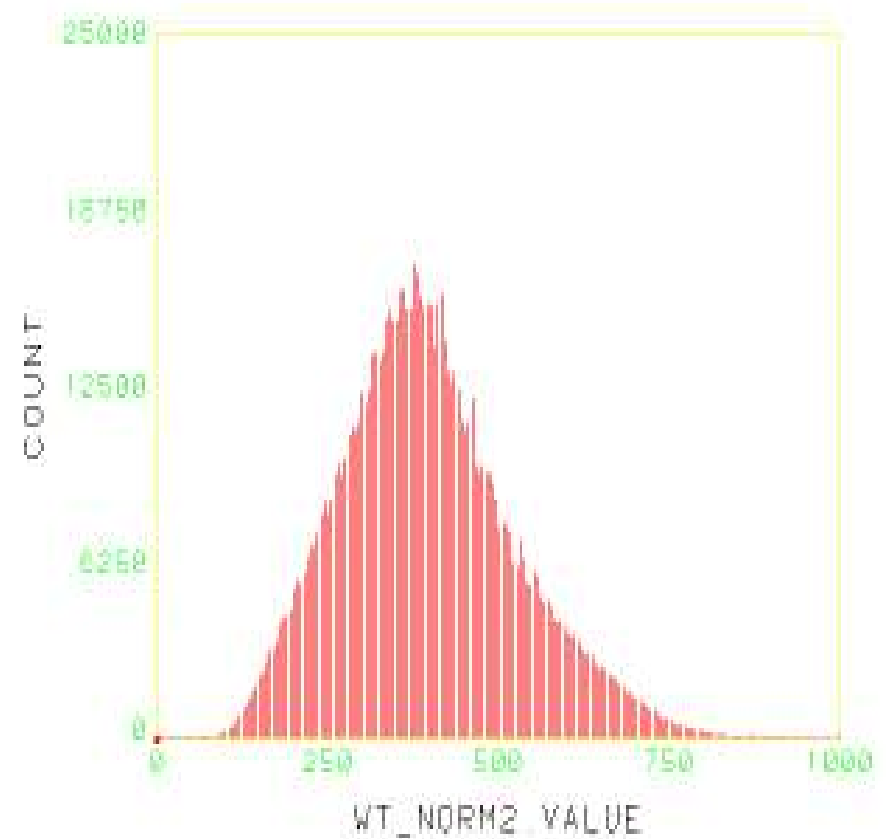


Figure 3. Distribution of CTI index for all cells across the study area

Determining Wetness Index Threshold

The next task was to determine the appropriate range of index values to represent salinity potential. A ‘first cut’ value of 0.551 was used. This choice was based on the figure being the CTI index for the majority of cells intersected by saline polygons. This value was also close to both the mean and median CTI values for the saline polygons.

A series of 1:25k maps, delineating areas of CTI index 0.551 or greater and overlaid with existing saline polygons, were then produced. **Figure 4** shows a close-up from one of the maps.

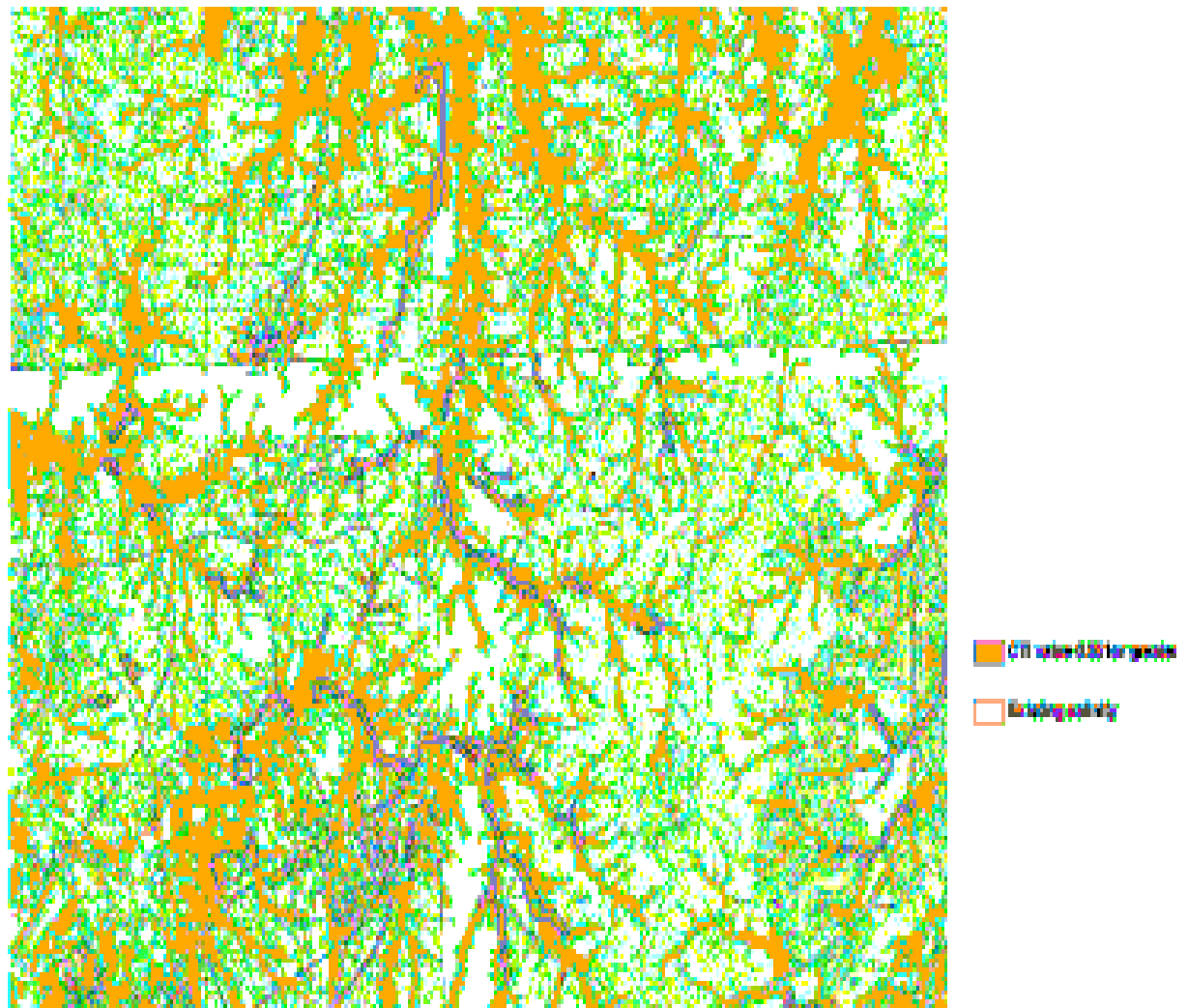


Figure 4. Areas of CTI 0.551 or greater overlaid with existing salinity polygons.

The maps were then taken into the field where extensive on-ground examinations were made to determine the representativeness of the index. A multi-disciplinary team consisting of soil scientists, a hydrogeologist, and spatial analysis scientists was involved in the field verification process. After an initial assessment, the general

consensus of the team was that in many cases the CTI index value of 0.551 tended to over-estimate the extent of ‘high potential salinity potential areas’. In other words, it was felt that a higher CTI index or threshold value would be more appropriate. After several iterations involving desktop analysis and field checks, a higher threshold of 0.6 was settled upon. **Figure 5** shows a close-up image from using threshold values of 0.6.

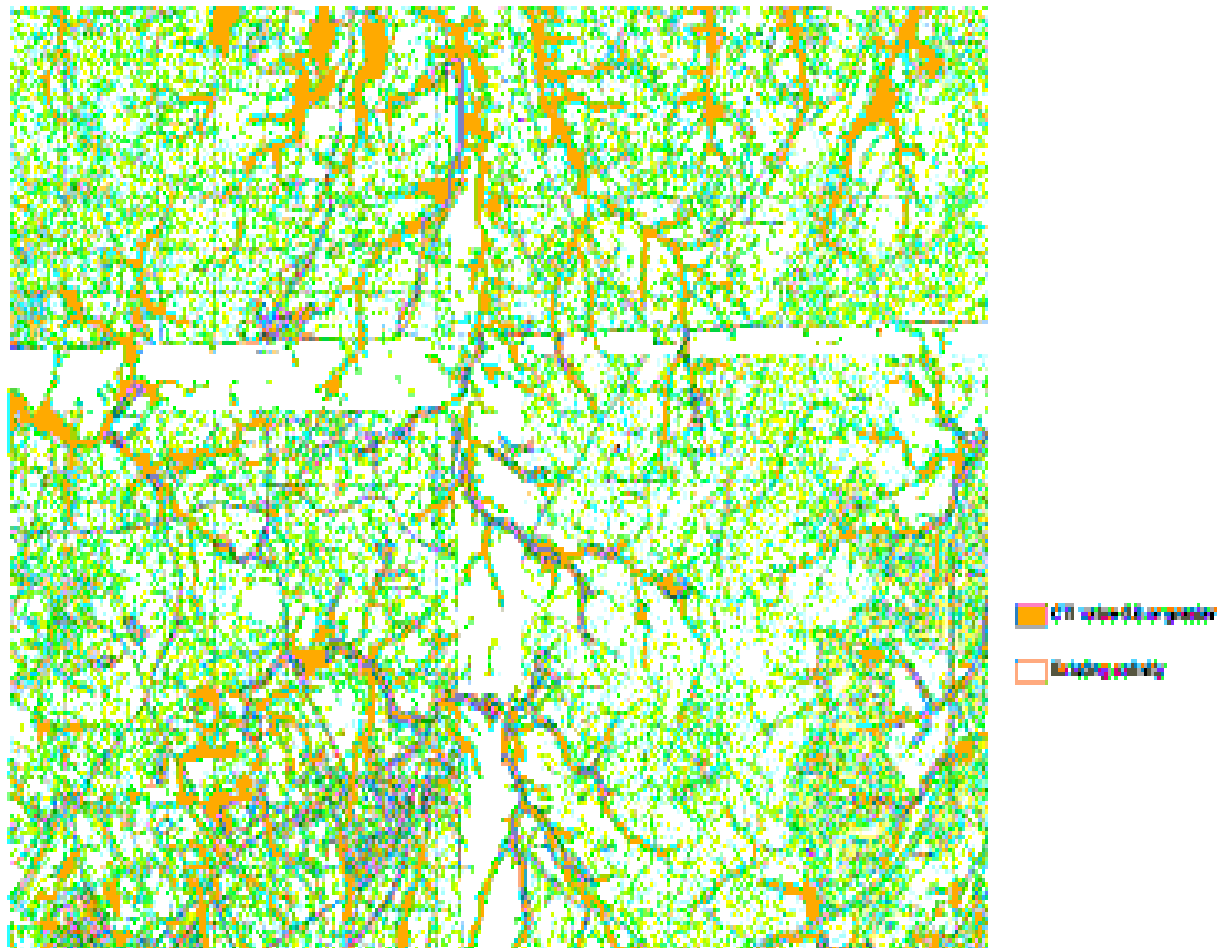


Figure 5. Areas of CTI value 0.6 or greater overlaid with existing salinity polygons

Creating and Cleaning Polygons

The next task was to convert the raster CTI data into polygons. After the polygons had been created (in ArcInfo) all single cell /pixel polygons were identified and removed. The final map was designed for presentation at 1:100k scale and retaining single cell polygons could give a false impression of the precision of the output to the user. Also, most such areas represent ‘noise’ in the data. However, single contiguous/stringed cells were retained. The edges of the final set of polygons were then smoothed out.

Masking

In GIS a mask is a layer defining where analysis should be included or excluded. Based on the expert advice from soil scientists, study areas on Narrabeen and Hawkesbury Sandstone geological formations and/or the following soil landscapes where deemed very unlikely to be prone to salinity:

- ⇒ Warragamba
- ⇒ Hawkesbury
- ⇒ Gynea
- ⇒ Lucas Heights.

A GIS mask (a layer defining where analysis should be included or excluded) was prepared to define the areas covered by the above geology and soil landscape attributes. The mask was then used to 'cookie cut' the polygon layer created from the CTI index. The area covered by the mask is termed 'Very Low Salinity Potential' on the draft map.

The valley floors of streams of higher order than 4 (Strahler ordering) were less likely to be prone to salinity because such systems were effectively flushed (Pers. Comm. Peter Mitchell). In order to incorporate this advice in the model, the remaining polygons were spatially intersected with a Stream Order layer. Polygons intersecting higher than 4th order streams were identified and manually clipped to remove areas below 4th order streams.

The remaining polygons constitute the areas termed 'High Salinity Potential' on the draft map. Most of the existing salinity occurs in these areas. The balance of the area, excluding the areas covered by the mask, constitutes the area termed 'Moderate Salinity Potential'. Isolated but numerous outbreaks have been recorded in these areas.

A close up of the final product is shown in **Figure 6**

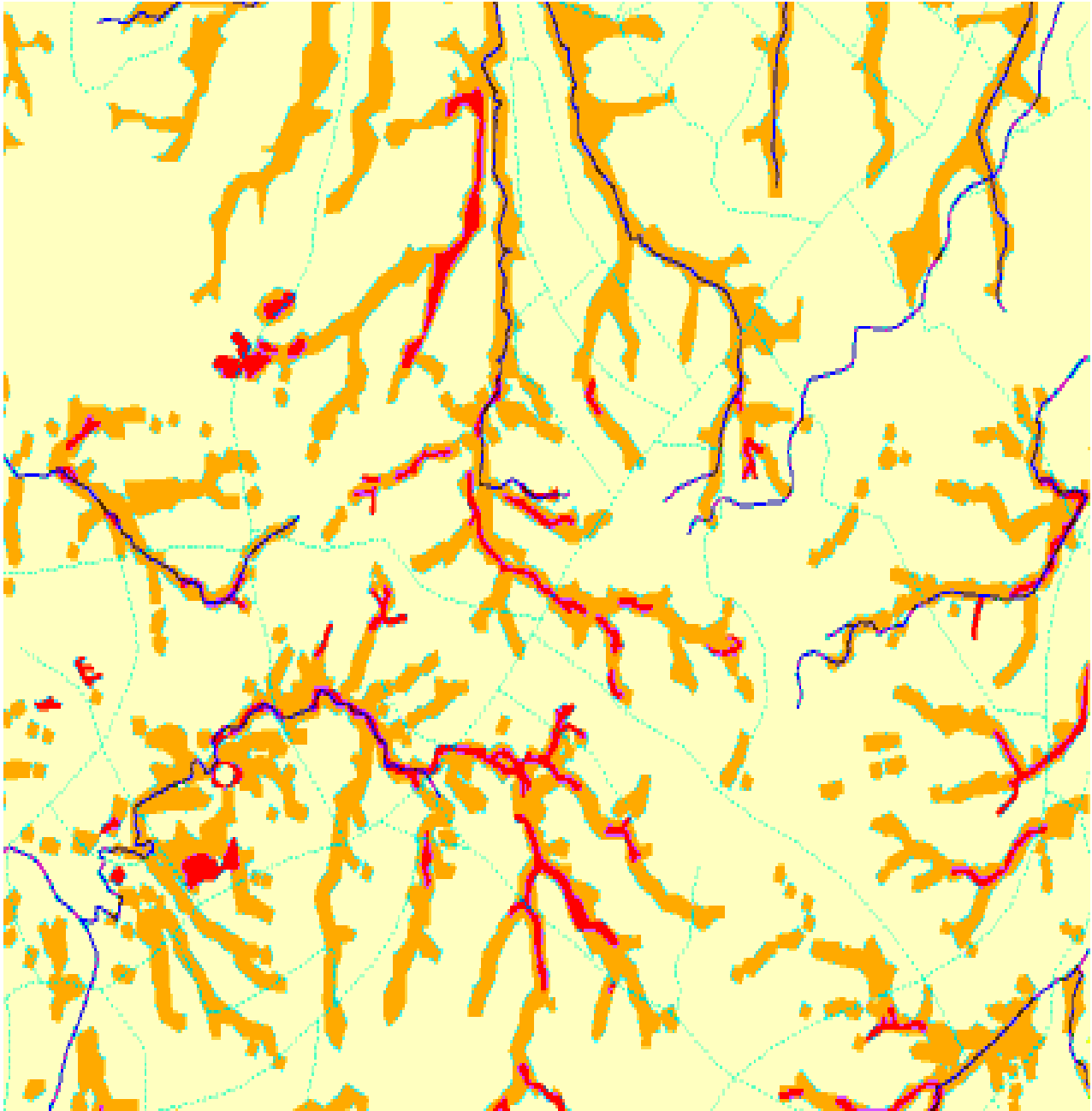


Figure 6. A close-up of masked, polygonised and smoothed CTI.

Limitations of this work

The following factors influence the accuracy of this product:

- Accuracy of the boundaries of existing salinity does have an influence on the CTI threshold value chosen for the project and hence the area included in the 'High Salinity Potential' category. The difficulty of mapping the boundaries accurately in a built-up urban environment must be recognised and appreciated.
- The resolution of the Digital Elevation Models and any inherent errors.
- Accuracy of the boundaries of the masking layer. The masking layer was made from a combination of 1:100000 scale and 1:250000 scale geology and 1:100000 scale soil landscapes.
- The use of one environmental layer to explain a complex problem is acknowledged, and as more appropriate data becomes available the draft map will be updated.
- It must be realised the CTI index does not predict salinity outbreaks. Rather, it ranks the landscape in terms of potential wetness assuming a steady state/saturation (ie. soil characteristics are not taken into account).
- The map is designed for use at a scale of 1:100,000 for planning purposes. It is not, however, a substitute for detailed on-site investigations.

References:

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