IMPROVED SOIL PROTECTION BY CLAY SPREADING / DELVING SANDS IN THE NORTHERN AND YORKE REGION

Prepared for the

Northern and Yorke Natural Resources Management Board

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RURAL SOLUTIONS SA

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EXECUTIVE SUMMARY

The Northern and Yorke Natural Resources Management Region has about 222,900 hectares of cleared sandy soils that have a moderate to extreme inherent susceptibility to wind erosion and a significant portion of this area is also susceptible to water repellence.

Clay spreading and delving is an effective and permanent method to reduce the risk of wind erosion and ameliorate the problem of water repellence on sandy soils as well as increasing soil fertility and water holding capacity, improving plant growth and reducing groundwater recharge that can cause and increase saline areas.

The potential area of sandy soils suitable to clay spreading in the region is 173,600 hectares and the potential area suitable for delving is 46,400 hectares. The area treated for clay spreading and/or delving to date is only about 4,000 hectares.

Based on high susceptibility to wind erosion and a severe susceptibility to water repellence the areas of the highest priority for clay spreading are the areas west and east of Minlaton, western part of the hundred of Muloowurtie, west of Arthurton, part of the hundred of Tippara, in the Port Broughton area and in smaller areas on southern Yorke Peninsula.

The Port Wakefield, Avon, Port Broughton, Bowillia, Nantawarra, Stow, Moonta and Pt Vincent areas would also benefit significantly from clay spreading.

The following strategies are recommended to increase the adoption of clay spreading throughout the N & Y region particularly in the high priority areas:

- Implement a coordinated soil modification program in identified priority areas in the region
- Improve landholder, technical adviser and contractor knowledge and skills in "best practice' claying methods and assessment of target sands and claying material.
- Investigate the longest treated areas on Yorke Peninsula to determine the achieved benefits, the issues encountered and the effectiveness of their methodology.
- Determine suitable claying rates and adjustments to suit the NY regions sands, climate and productivity
- Investigate areas which have little information on availability of clay and the condition of sands that may suitable and benefit from claying. For example western Southern Yorke Peninsula.
- Investigate other sandy texture soils in other soil groups in the region for suitability for claying or modifying methods. For example investigate delving to modify sub-surface inhibiting layers.
- With industry investigate alternative delver design and adjustments to suit a range of soil groups.

CONTENTS

Delving sands to bring up clay material in the NY region

1 INTRODUCTION

Spreading and delving clay on sandy soils has been used by a small number of landholders in the Northern and Yorke region of SA to reduce the risk of wind erosion and ameliorate water repellent sands. Spreading clay or delving on sandy soils also helps to increase soil moisture, retain nutrients, improve productivity and reduce groundwater recharge that can cause and increase saline areas.

Clay spreading requires the physical removal of offsite sub-soil clay, transporting and spreading it on the target sandy surface while delving requires the digging and dragging onsite sub-soil clay through to the surface. The claying material in both cases is then thoroughly mixed through the sandy topsoil to create a new texture and changing a number of properties.

Spreading clay and delving has been successfully used throughout SA to improve the physical and chemical characteristics of sandy soils and has only recently been tried in new districts within the Northern and Yorke region. However, outside of targeted programs, this has generally been on an ad-hoc basis.

This plan has been prepared for the Northern and Yorke Natural Resources Management Board (NYNRMB) to:

- Describe the benefits of clay spreading/ delving
- Identify the problems and issues with clay spreading / delving
- Identify the costs involved.
- Highlight priority areas in the region for clay spreading / delving
- Outline strategies to increase the use of clay spreading and delving to reduce the risk of land degradation.

2 TARGET SOILS AND LAND DEGRADATION RISK

In the Northern and Yorke region there are twelve main soil groups and for the purpose of this report three soil groups have the predominant characteristics of interest. These soil groups include the deep sands, sand over clays and the shallow sands over calcrete or limestone. Other soil groups have characteristics which may also benefit from clay spreading or delving but require further investigation.

The main soil groups of interest have sandy textured topsoils, which have low to very low nutrient retention capacity, and are prone to water repellence, wind erosion and if non-calcareous can be susceptible to acidification. The calcareous types can be affected by carbonate-induced nutrient deficiencies. (Hall, Maschmedt & Billing, 2009). All have overriding limitations of restricted water holding capacity in the surface and some have plant root development and reduced productive capacity from restrictive subsoil constraints.

The areas of cleared agricultural land in the region with these soil groups totals 173,000 hectares (Table 1). Their distribution is depicted in Figure 2.

Table 1: Approximate areas of cleared land in the NY Region with sandy textured soil groups.

Area of sandy textured soil groups (ha)		
Deep Sands	**Sand over clays**	**Shallow sands over calcrete or limestone**
114,700	46,500	12,400

These soil groups can be further differentiated by their inherent characteristics (Table 2) which, when combined with other soil groups that they are associated with in the landscape, will determine their suitability for claying and the more appropriate method of claying to use. Generally the sand over clay soils can be delved if the sub-surface clay material is suitable and within the reach of delving machinery. If the subsoil clay is unsuitable then clay spreading is the alternative method on sand over clays. The deep sands generally require clay spreading (Figure 1). In many situations across the region, a combination of spreading and delving can be used. Clay spreading is the main method used for shallow sands over calcrete or limestone.

Table 2: Approximate areas of selected soil groups by soil description on cleared land within the NY Region.

Soil Groups	Soil Description	Area (ha)
Deep sands	Carbonate sand Siliceous sand Bleached siliceous sand	31,000 83,300 400
Sand over clay soils	Sand over sandy clay loam Bleached sand over sandy clay loam Thick sand over clay Sand over poorly structured clay	13,600 100 8,700 24,000
Shallow soils over calcrete or limestone	Shallow sand over clay on calcrete Shallow sand on calcrete	12,400 50

Source of Soil descriptions: Hall, Maschmedt & Billing (2009

Figure 1: Clay spreading on deep sands

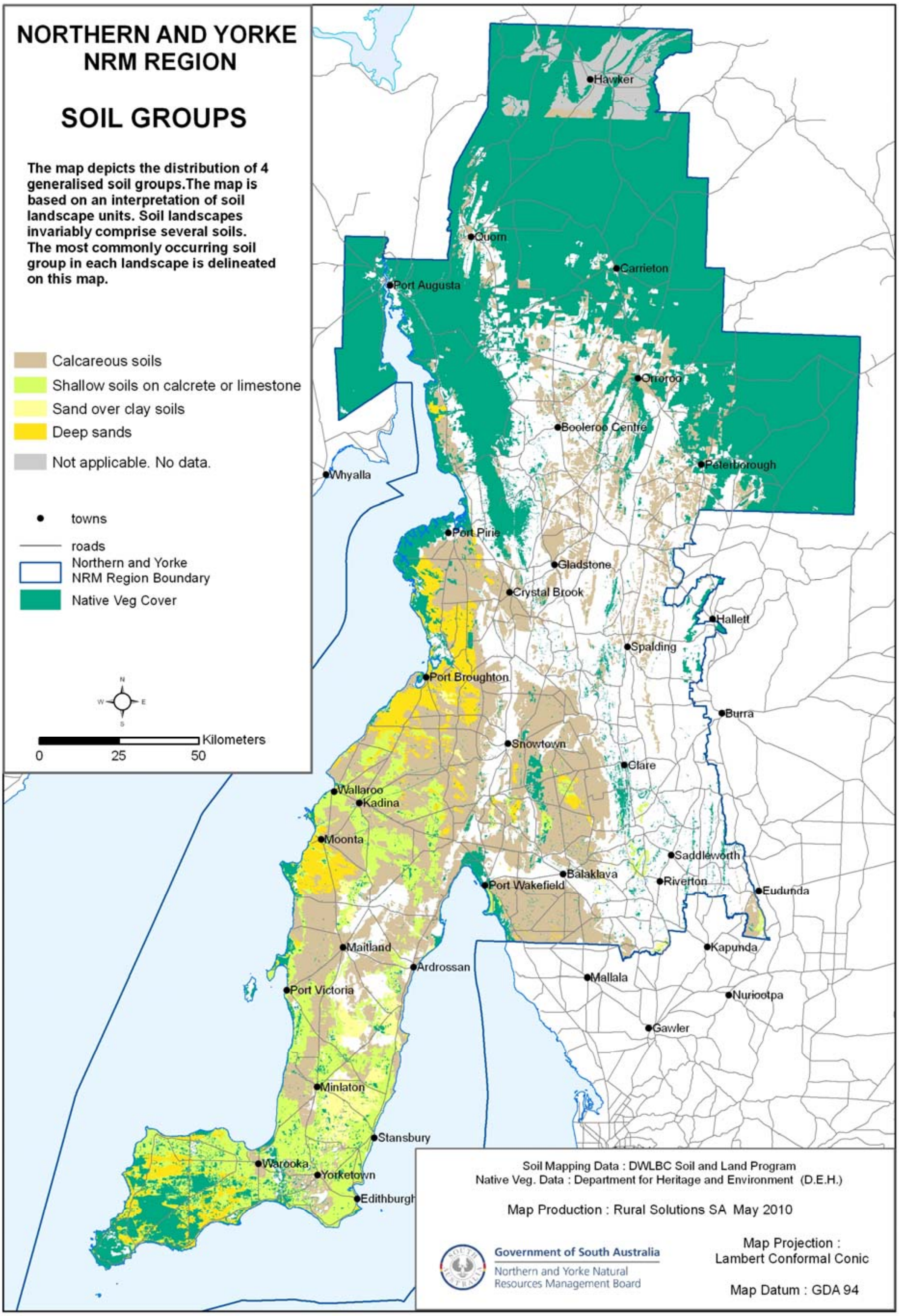

Figure 2: Sandy soil groups of the Northern and Yorke region

Throughout the NY Region there are about 222,900 hectares of cleared agricultural land that have a moderate to extreme inherent susceptibility to wind erosion (Table 3, Figure 3). These largely match the distribution of the three soil groups. These areas occur mostly west of the Hummocks-Barunga Ranges and the Southern Flinders Ranges, on the Yorke Peninsula and on the plains at Avon through to near Blyth and in scattered areas throughout the Lower to Upper North (Figure 4).

Table 3: Approximate areas of cleared land in the NY Region susceptible to wind erosion

Susceptibility to of wind erosion (ha)					
Low	**Mod Low**	**Moderate**	**Mod high**	**High**	**Extreme**
1,291,900	588,700	138,700	74,100	8,000	2,100

Figure 3: Moderate to High susceptibility to wind erosion land drifting in the NY region

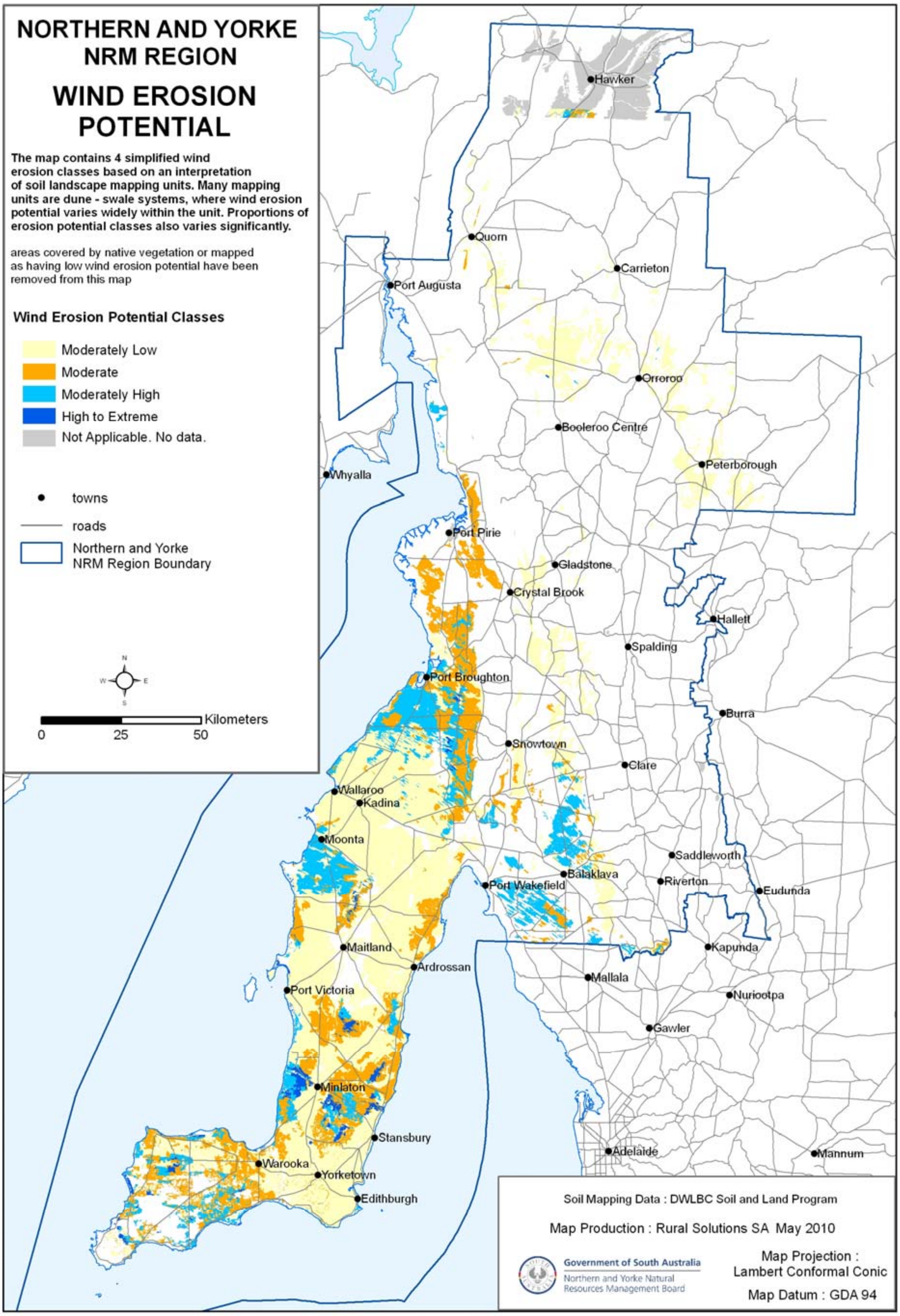

Figure 4: Soil wind erosion susceptibility of the Northern and Yorke region

Water repellence is caused by hydrophobic organic materials mainly waxes, contained in residues from decaying organic matter in the soil. The waxes coat the soil particles causing water to bead on the surface. This causes uneven wetting of the upper part of the profile with significant areas of soil remaining dry (Figure 5).

Water repellent soils reduce soil cover and production by the delays in seeding, patchy plant establishment, uneven and poor growth, increased weed competition, effects herbicide performance and increases the susceptibility to wind erosion and contributes to increase recharge.

Throughout the NY region there are about 221,000 hectares of sandy soils that are water repellent (Table 4, Figure 6). These soils have a similar distribution as to wind erosion potential.

Table 4: Approximate areas of cleared land in the NY Region with water repellent sands (ha)

Non repellent	Repellent	Strongly repellent
1,879,400	201,300	19,600

Figure 5: Water repellence causes patch germination leaving bare areas

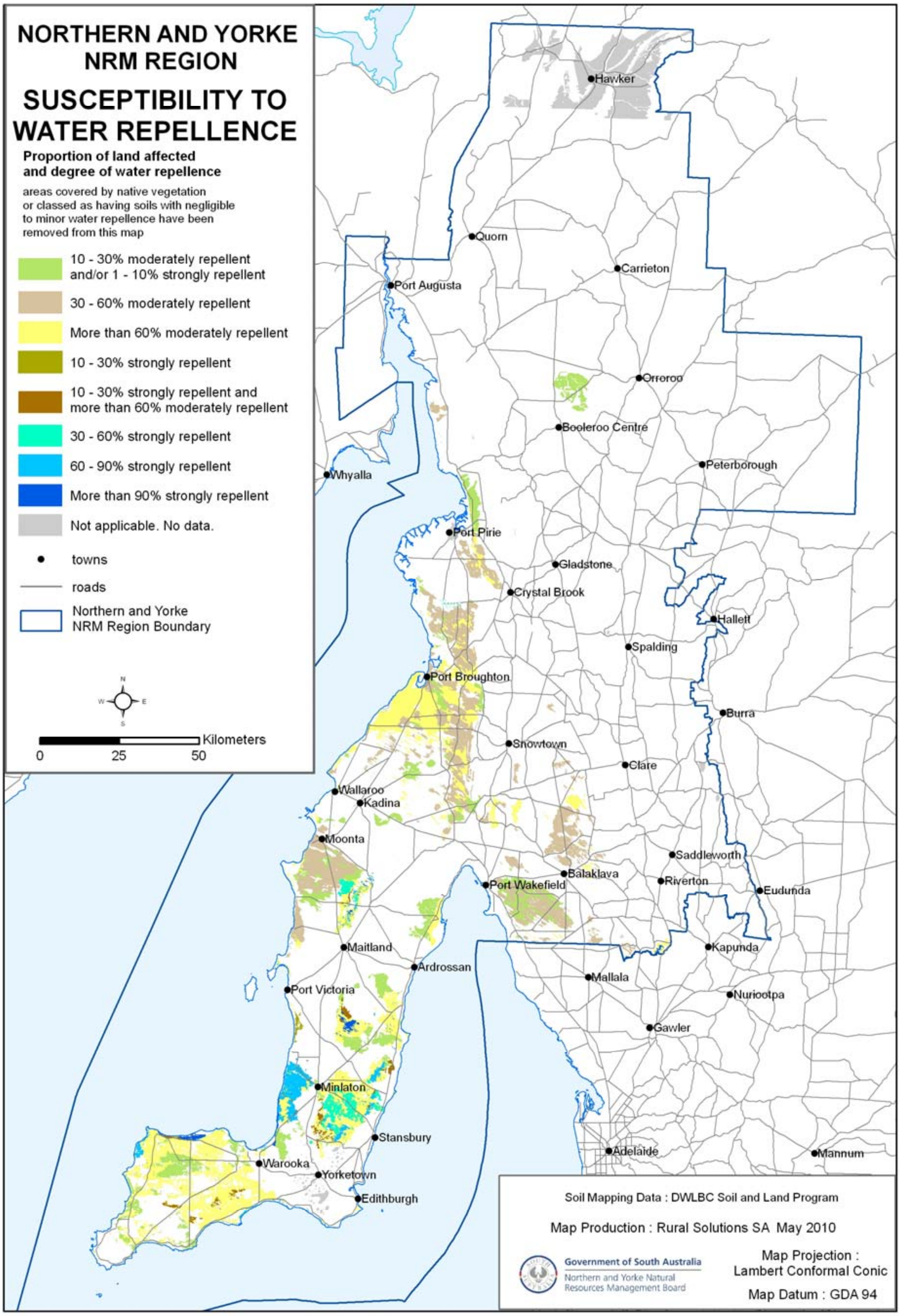

Figure 6: Susceptibility to Water Repellence in the Northern and Yorke region

3 HISTORICAL PERSPECTIVE

Accepted early land management practices to address erosion and water repellence problems was largely based on land use and agronomic grounds such as matching crop type, rotation and intensity to the land type, retaining stubble cover, modifying tillage practices and careful grazing management.

Outside the region, research on spreading clay on sandy soils commenced in the mid 1980s and it was found that overcoming the problem of water repellence significantly improved crop and pasture growth. Since then landcare groups, agricultural bureau groups, other community groups and individual farmers have established demonstrations and trials to evaluate the practice in their own locations.

Delving was tried in the 1990s and was found to have similar benefits to clay spreading.

Clay spreading and clay delving have been successfully tried and used in the South East, Eyre Peninsula, SA Murray Darling Basin and the Northern and Yorke regions to improve the condition of sandy soils.

Clay spreading was first tried on Yorke Peninsula when an agronomist from the Department of Agriculture and a group of landholders engaged a clay spreading contractor from the South East. Results from this early work in the Stansbury district were encouraging.

Since then clay spreading and delving has been promoted through field days, demonstrations and trials by various groups and organisations such as the YP Alkaline Soils Group, Rural Solutions SA, SANTFA and the Northern Sustainable Soils group, individual landholders, claying contractors and various agricultural consultants and client groups.

In recent times major projects targeting the adoption of claying best practice such as the Advisory Board of Agriculture's (ABA) "The Sustainable Land Use and Management of Sandy Soils project" and the "Building resilient farming systems in South Australia through improved knowledge and innovative management of soil constraints" project involved small groups of landholders in local workshops. The availability of the NYNRMB "Northern and Yorke nrm action" program contributed to the success of the ABA program. The on-ground works program provided cost sharing arrangements that were an incentive for farmers to gain first hand experience on their own properties. From these demonstrations and projects a small number of landholders have tried clay spreading and/or delving.

It has been estimated that about 4,000 hectares of sandy soils in the Northern and Yorke region have been clayed, mostly in the Stansbury scrub area of the Yorke Peninsula as well as patches near Nantawarra and Bowmans. Very small areas have been clayed by individual landholders scattered across the other sandy areas in the region. The area that could be spread with clay could be substantially increased to improve the production and sustainability of sandy soils.

4 BENEFITS

There are a number of benefits of clay spreading or delving and these are outlined below.

4.1 REDUCE WIND EROSION

The inherent susceptibility of land to be eroded under the action by wind is determined by its soil type, topography and the climate. Land is susceptible to wind erosion when vegetative protective cover is low and when soil particles are easily detached and transported by the wind. The soils erodibility by wind is largely determined by the mass of the soil particles. The low-clay-content fine-to-medium sands have the highest erodibility because of their low particle mass and low potential for aggregation into larger particles (Maschmedt, 2000).

Water repellent sands generally have higher erodibility than non-repellent sands due to the lack of clay content or carbonate bonding between the grains and moist soils have more coherence than dry ones. Very infertile sands have increased erodibility as they have less organic matter binding particles than the more fertile soils.

Increasing the clay content and changing the texture of sands (<5% clay) to form loamy sand (5% clay) or a loamy sand plus (8% clay), provides some coherence between the larger sand particles allowing some structural development, reducing its erodibility with less potential for particles to drift. Adding clay also improves water infiltration and increases soil fertility, producing greater levels of surface cover which will also reduce erosion risk.

Claying also has a place in emergency drift control especially where the risk of failure of reseeding is high. Claying the eroding area and the drift bank can provide stability immediately the clay crust can form and prevent further damage.

4.2 AMELIORATE WATER REPELLENT SANDS

The severity of water repellence can vary significantly over time and distance. Its effect can be reduced in years with an early seasonal rainfall event which is sufficiently soaking and allowed to stay damp with a follow up rain.

Adding clay to sandy soils masks the hydrophobic sites around the soil particles increasing the wettable surface area. By increasing the moisture retention capacity of the topsoil a greater proportion of rainfall can be held at or near the soil surface. This more even wetting, allows early sowing to be possible which is a key factor for productivity of the sands with a more even germination, greater plant density and reduced risk of sand blast damage. The improved and even germination of weeds improves herbicide efficiency, particularly on hard to control plants such as the brome grasses. Herbicide efficiency is also improved with less crop damage because herbicides are not washed into furrows by surface runoff from water repellent soils.

Landholders report substantial productivity and soil cover benefits that are not evident until an area has been clayed.

4.3 INCREASE SOIL FERTILITY AND MOISTURE HOLDING CAPACITY

Clays are minerals consisting of minute crystals bonded together into larger particles. The surfaces of clay crystals are usually negatively charged and therefore attract positively charged particles called cations. Charged atoms of calcium, magnesium, sodium and potassium are the most common of these cations. Cations that can be dislodged from the clay crystal by other cations from the soil solution, are termed exchangeable cations (Maschmedt, 2000). The number of “exchange sites” on the clay surface is expressed as the cation exchange capacity (CEC) and is a measure of soil fertility. Generally the higher CEC topsoils have a greater capacity to hold nutrients and hence have a higher chemical soil fertility.

Sands have a low clay content of less than 5% clay and so also have low cation exchange capacity (as low as 1.4 cmol/kg) and low organic carbon levels. In most cases adding clay (for example with a CEC 15 to 20 cmol/kg) to increase the texture of the soil to a loamy sand and increase the overall clay content by 3 - 4%, will also increase the cation exchange capacity of the clayed soil and provides the potential for soil organic carbon levels to also increase.

The result is a greater capacity of treated soil to hold and retain nutrients while still keeping them available to plants. The increasing nutrient capacity is also important where soil acidification of the sand is an issue as the addition of clay increases the buffering capacity of the soil to acidification. The selection of an appropriate clay can also be beneficial as a liming agent for acidic sands by increasing the soil’s pH and the subsequent availability of plant nutrients.

Limited information is available to confirm increases in soil organic carbon by claying, but significant increases could occur due to the extra clay protecting carbon from decomposition and changes to water balance with higher water availability and increased vegetative growth. It is expected that higher soil organic carbon levels potentials achieved through claying would be a permanent feature of the modified soils, the actual increase in soil organic carbon and the time taken to achieve the long term equilibrium may vary (Liddicoat, Schapel, Davenport & Dwyer, 2010).

Increasing the clay content of the topsoil also increases the water holding capacity of the topsoil. The soil can retain more moisture during the germination and growth phase, providing more plant water and facilitating nutrient uptake by roots.

4.4 BREAKING UP OF SUB-SURFACE LAYERS

Delving can fracture compacted sub-surface layers or hard pans in sandy layers and increase the root-zones volumes of plants enabling greater access to water and nutrients. Delving also mixes the soil layers within the profile. Mixing layers where bleached infertile and hostile layers occur can lead to large improvements in root growth.

4.5 REDUCE RECHARGE

Clay incorporated throughout the topsoil has the potential to increase the water holding capacity, soil fertility and resistance to erosion of the soil with overall improvement in plant establishment, growth and water use efficiency. This improved plant growth utilises more water, leaving less to percolate through the soil profile to groundwater. On the catchment scale this can reduce the risk of water tables rising and causing soil salinity.

4.6 IMPROVE CROP AND PASTURE PRODUCTION

In the NY region sands have been valued in the drier years because most of the rainfall they receive is available for plant growth. The region has relatively reliable rainfall and the sands are not as productive in the wetter years and in the higher rainfall areas (greater than 375mm average rainfall) because of limits in soil fertility and moisture storage.

Claying sands improves the crop and pasture management in the dry and the better years through reduced risk of erosion, improved water infiltration, improved nutrient capacity and water storage. Landholders will also have increased confidence that the sands are more resilient and able to cover and produce more.

There have been limited replicated experiments within the region. Anecdotal information from landholders in the Nantawarra district suggested that from delving areas produced double the yield compared to adjacent un-delved areas in the 2008 season which had lower than average rainfall and an early finish to the season (Figure 7).

Figure 7: Delved sandhill in the foreground and undelved sandhill in the background with patchy growth (see Figure 5) in 2008

Work in WA on the sandplain soils has shown that added clay on the surface has increased crop yields by 0.3 – 0.6 t/ha (Hall *et al* 2010).

In the South East of SA in the 350-450 mm rainfall zone average yield increases have been in the order of 0.4 -0.8 t/ha (up from 1.7 t/ha). in the 450-500 mm rainfall zone, yield increases have been 0.8 – 1.5 t/ha (Anon a).

On Eyre Peninsula in the Wanilla-Edillilie area (400 – 500 mm rainfall) yield increases have been up to 50% (from 2.5 to 3.75 t/ha) and in the Karkoo, Kapinne and Wharminda districts (400 – 450 mm) average yield increases have been in the order of 0.5 t/ha (up from 1.4 t/ha) (Anon a).

5 BARRIERS TO CLAY SPREADING / DELVING

5.1 EXPERTISE IN CLAYING IN THE REGION

The overall level of experience and expertise in claying sands in the region is very low compared to other regions. Historically, problems with sands in the region have been tackled using agronomic and grazing management methods and knowledge and experience of claying methods was near non-existent until early 2000 when more interest was shown by landholders and advisers.

As the claying methods have not been actively promoted and discussed until recent times awareness and understanding of the practices is very low amongst landholders, technical advisers and local contractors. This lack of awareness has resulted in little demand for or interest in learning opportunities where information and experiences could be shared. To achieve a significant rate of adoption of claying practices the level of understanding, capacity and experience of claying needs the active engagement of landholders, advisers and contractors.

The concerted efforts of landholders, advisers and the YP Alkaline Soils group in the Ramsey or Stansbury scrub area, has seen the adoption of claying on up to 80% of the high erosion risk land in the district, approximately 2,000 hectares (M Richards pers. comm. 2010).

An estimated remainder of 2,000 hectares of clayed sand is scattered through the region and has been conducted on approximately 25 properties. The remaining landholders managing sands across the region are believed to have a cursory awareness of the practice and are unskilled in the methods.

The availability of local or regional skilled claying contractors has also severely restricted the uptake of the practice. A low demand for spreading or delving machinery results in potential contractors having little interest in providing machinery, particularly when transportation is required over long distances. They also do not see value in investing in marketing, promoting and demonstrating practices when there is seen to be low market demand.
The recent dry years and associated economic constraints has also prevented landholders from investing in capital improvements and trying new methods which they are not experienced in.

The delay in the adoption of the claying in the region has an upside in that claying techniques have been fine tuned and problems and solutions identified in other regions. These “best practice” principles and experience gained from other regions can be promoted and adopted in NY region.

5.2 ASSESSMENT OF SITES FOR CLAYING OR DELVING

The critical first step in successful clay spreading or delving is to thoroughly assess the proposed claying site and determine the location of the best available claying material. These will significantly influence the method of claying, either spreading or delving or a combination of the two on big sandhills.

Time should be spent investigating the target sand and potential clay sources by the use of a few simple field tests and digging a network of holes by shovel, posthole digger or backhoe by the landholder before the engagement of a contractor.

The characteristics of the target sand should be considered such as depth, layers by clay percentage, pH and presence of carbonate as this will identify potential problems with the type of clay (Figure 8). Each site can be different, not all sandhills have the same layers and often change in depth leeward to windward and can also be affected by past erosion and deposition areas. Sandrises may appear even but may have lenses of calcareous rubble at shallow depth which needs to be avoided if delving.

The characteristics of the claying material such as depth of clay, type of clay, clay percentage, pH, carbonate percentage and dispersion ability should be determined.

The most effective clays are those that break down to fine particles during the action of rain. Clays that slake or disperse are ideal as they breakdown and spread quickly on the soil surface.

As the result will be permanent, knowing the options and by selecting the best available clay material the operation can be done with confidence and the result predicted.

Poor results in the region and in other regions were achieved where the claying material whether spread or delved had a high pH (very alkaline) and/or a high carbonate percentage which both affect the availability of nutrients to plants, mainly as induced manganese deficiency.

Some decision making by landholders in the past has been guided by contactors who do not necessarily have the skills in assessing soil properties and identifying the appropriate material to be used. Earthmoving contractors have knowledge and skills in using clay spreading or delving machinery and the experience gained from claying a number of sites. However, they are not necessarily interested in the long term results of their work.

Figure 8: Assess the target sand

Mapping the site using these characteristics will assist decision making and with giving instructions to the contractor.

5.3 NUTRITIONAL PROBLEMS

Selection of the clay and treatment after the claying operation can affect plant nutrient supply with subsequent effects to productivity.
Clays with a high pH can cause nutritional problems in crops and pastures, particularly when applied to alkaline sands.

A high level of carbonate in clay can also affect nutrient availability, plant root growth and drainage. Carbonate can reduce the availability of essential plant nutrients including phosphorus, manganese, zinc and iron.

Once a soil is clayed, it's productive and yield potential rises significantly causing a higher demand for plant nutrients. The initial nutrient content of the sand is often poor so unless the clay contains a supply of nutrients, or additional nutrients are supplied by fertilisers, the new potential will not be achieved.

Even though clays have a high capacity to store nutrients, sources of clay are usually low in nutrients. While the application of clay might significantly increase the plant growth potential, extra nutrition is needed to supply the increased demand for nutrients. In South Australia the key macro nutrients in limited supply after claying are usually of phosphorus, nitrogen, and sometimes sulphur. Micronutrients zinc, manganese and copper are often also in short supply.

5.4 CLAY RATES

The amount of clay to apply varies accordingly to the average annual rainfall, actual percentage of clay, carbonate levels and depth of incorporation. Rates may vary from 100 tonnes per hectare when using high percentage clay or up to 200 tonnes per hectare for when a very low clay percentage material is used, or where the sand is deep and loose such as on top of sand hills (Hughes & Eldridge, 2006). Clay with a high carbonate level should be spread no more than 80 tonnes per hectare.

Rates used in the Northern and Yorke region have averaged about 150 tonnes per hectare using material with greater than 30% clay (Figure 9).

160 t/ha **80 t/ha**

Figure 9: Clay rates of 160 t/ha and 80 t/ha, 35% clay at Alford

In the lower rainfall areas (<350 mm rainfall) less clay should be used as it tends to hold water in the topsoil rather than allowing it to move deeper into the soil profile. In these areas about 80-100 tonnes per hectare of clay should be applied. The lower rate is also sufficient to eliminate water repellence problems (Hughes & Eldridge, 2006).

As sites and clay materials as so variable there are no “prescriptive” application rates. Determination of an appropriate claying rate is based on a number of factors pertinent to each site.
Delving is more variable as the clay depth varies especially on sandhills so the level of clay available at or near the surface will vary. More control of the finished product can be achieved with clay spreading as the landholder has the control of the clay source and the rate in which it is spread (Figure 10).

Figure 10: Variation in depth to clay material when delving, note the colour changes

Clay spreading also allows flexibility to initially apply some clay and then more clay can be applied later if more clay is needed. Applying too much clay is expensive and the clay could create a surface seal causing emergence and water infiltration problems as well as problems with incorporation.

Transporting clay to the site greatly increases costs so it is more economic to use the most suitable clay as close to the target sand as possible.

5.5 INCORPORATION

The ideal time to clay spread or delve is preferably in summer through to autumn as this allows the clay a longer time to break down on the soil surface well before seeding. The delving tracks also need to stabilise and pack down sufficiently to reduce trafficability problems at seeding time.
After delving, lumps of clay are generally left in rows that need to be broken up and moved sideways to get an even distribution of clay across the soil surface before incorporation (Figure 11). This can be done using a smudging bar or heavy railway iron, cultivator or similar.

Figure 11: Delving prior to incorporation

Good incorporation is essential to thoroughly mix the clay with the sand (Figure 12). This prevents the clay on the surface sealing and to allow better water infiltration. The clay should be incorporated to a depth of 10-15 cm.

Figure 12: Same area as Figure 11 above, but after incorporation

Spread or delved clay can be incorporated into the surface soil with conventional tillage machinery. Conventional tillage design is based on moving and mixing soil. Thorough mixing may require four or five passes of conventional machinery depending on the size of the clay clods and the clay rate per hectare. Some landholders use wide points and others use off-set disc machines. Specialised machinery such as a spader has the ability to mix the clay within the sand with fewer passes.

Once the clay has been incorporated then landholders can return to using a one-pass seeding system with narrow points or disc seeders.

6 COST

Claying sand is regarded as a capital investment in the soil rather than as an operating cost. Initial work done in the South East of the state has lasted for 40 years with continued improved performance on treated paddocks.

The accurate cost of clay spreading is difficult to determine as it depends on: the type of machine used; the amount of clay applied per hectare; the haulage distance; the amount of overburden of material to be stockpiled from the pit and incorporation.

A study of a trial at Wharminda (EP) in 2002 showed that spreading clay with a “Claymate” machine varied from $86/ha at a clay rate of 50 t/ha to $290 /ha at a clay rate of 250 t/ha. Opening the clay source pits cost $300 and incorporation costs were $1.73/ha for shallow incorporation (one pass with an air-seeder) and $6.92/ha for deep incorporation (one pass with air-seeder, one pass with off-set disc) (Davenport *et al* 2006).

In the SA Murray Darling Basin region an indicative cost was about $250 /ha to apply 175 t/ha with a land plane machine (Anon b).

Simple gross-margin analysis data from the Wharminda trial showed it took two cropping years to recoup the initial cost of clay spreading. Evidence from the South East of the State has shown that the changes by claying last for at least 30 years and therefore there is greater return on investment. (Davenport *et al* 2006.

The costs of delving in 2002 ranged between $130 and $160/ha. While the long term effects of bringing clay to the surface are similar to clay spreading, the long term effect of ripping associated with delving are unknown.

7 POTENTIAL DEVELOPMENT

The potential area for clay spreading and delving in the NY region can be assessed by mapping the responsive soil groups and their characteristics and setting various criteria regarding the depth of sand, depth to clay, clay layer depth and amount of rockiness in the layers.

The wind erosion susceptibility and the susceptibility to water repellence maps are derived from soils and land resource information data base. For the purpose of this study the soil and land assessment unit of DWLBC assumed that any soil with a sandy surface has the potential to benefit from clay spreading. The resultant clay spreading map (Figure 14) takes no account of proximity to or quality of clay sources.

The map showing the location and areas of land with potential for clay delving has used the criteria for delving to include a sandy surface, subsoil clay at less than 60cm depth, clay layers thicker than 30cm and no rock within 60 cm of the surface (Figure 15).

Mapping units used for these maps have an estimated percentage of that soil type attributed to it and so the map should only be used as a general guide to approximate locations and areas of suitable soils. There are large variations in soil properties at the paddock scale that necessitate individual site assessment to determine the best practice for each site (Figure 13).

The mapping statistics derived from each data set indicate the potential area suitable to clay spreading in the region is 173,600 hectares and the potential area suitable for delving is 46,400 hectares.

Figure: 13 Site assessments to determine the soil variation

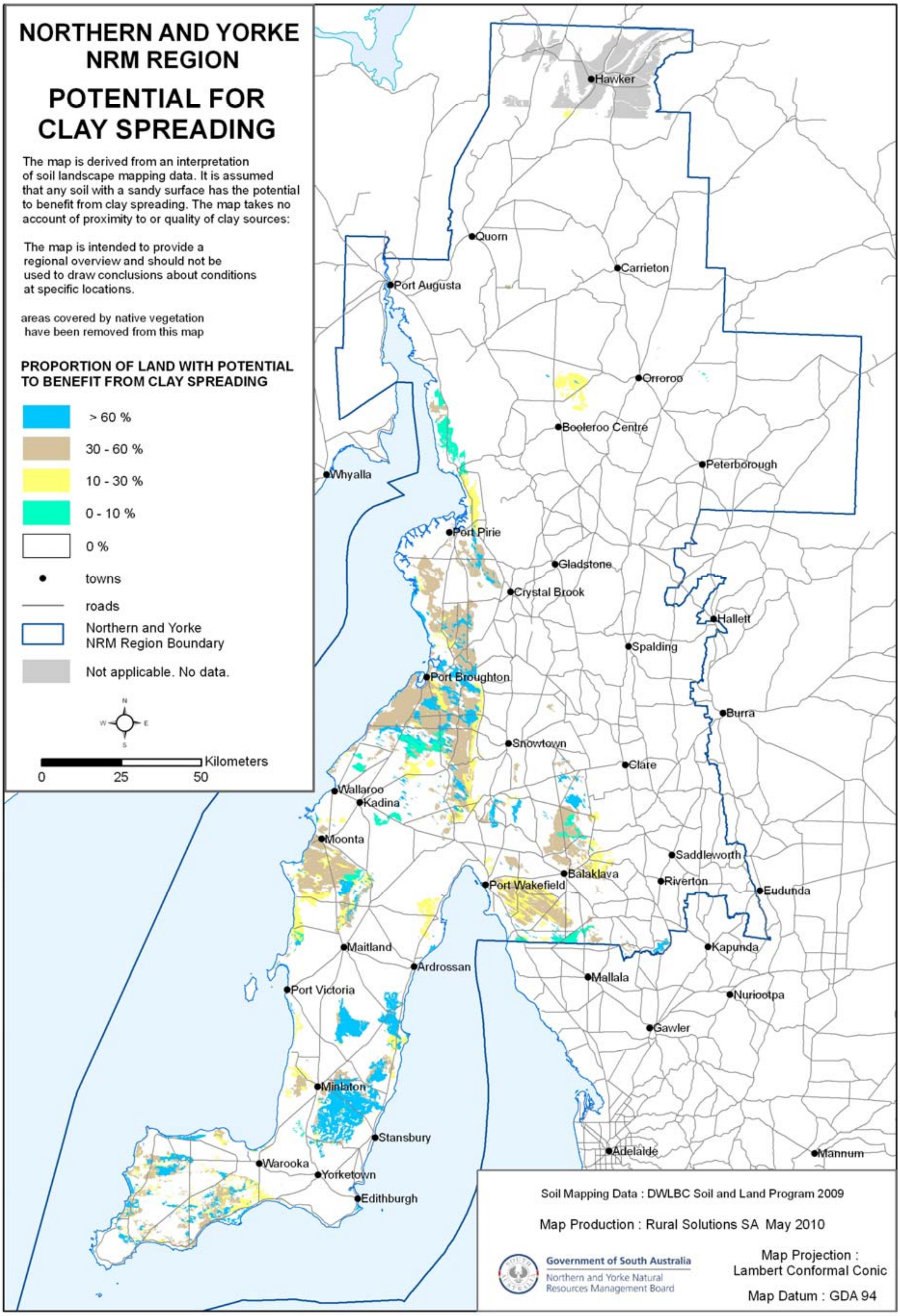

Figure 14: Potential for clay spreading in Northern and Yorke region

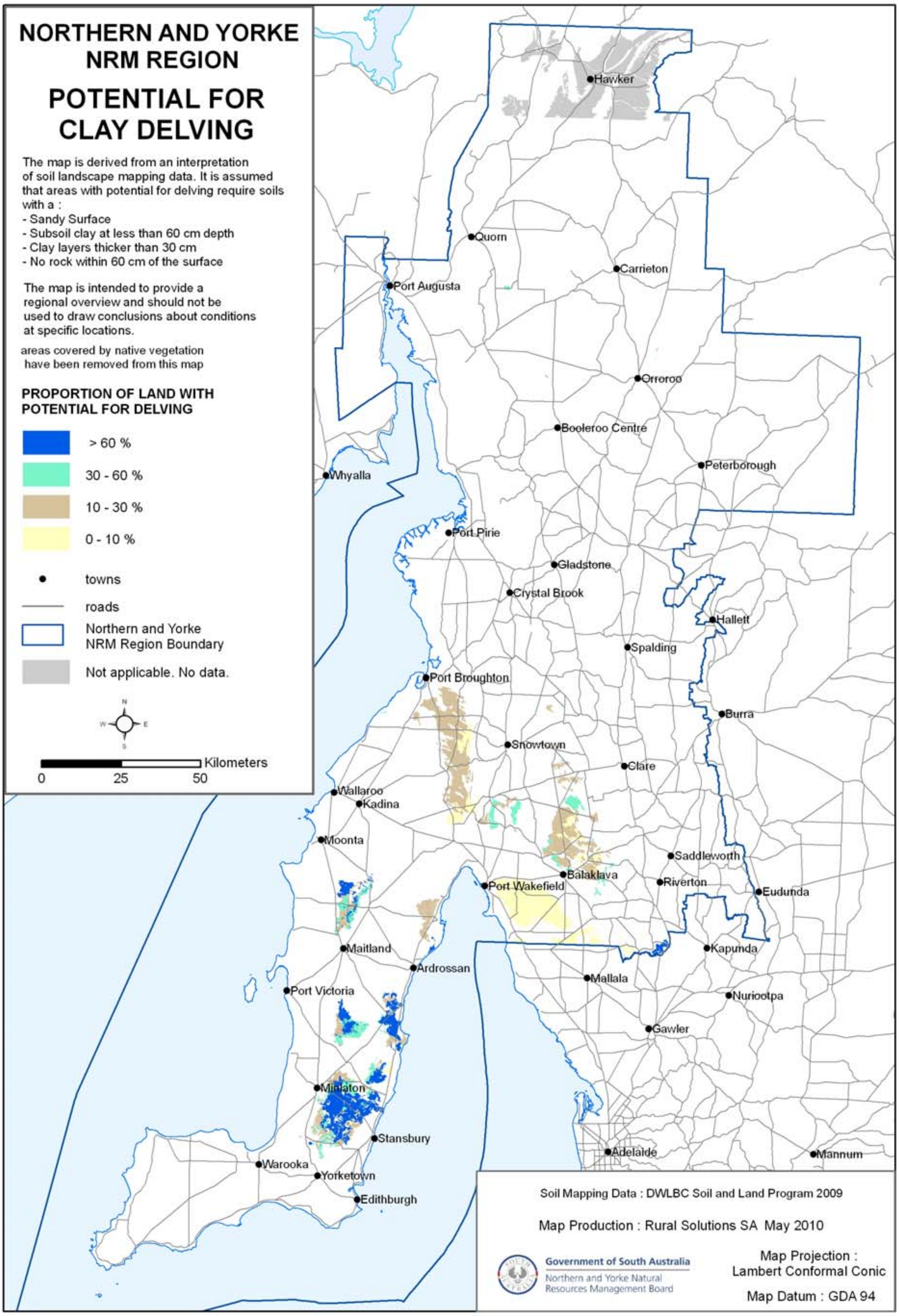

Figure 15: Potential for clay delving in Northern and Yorke region

The map unit classes areas (in hectares) give a guide to the scale of for each class for clay spreading (Table 5) and delving (Table 6) in the region.
It should be noted that the areas (in hectares) stated in the tables are for map classes and does not represent the precise area that could be clay spread or delved. For example, approximately 90,900 hectares of land is regarded as having more than 60% of soils suitable for clay spreading. Another 165,000 hectares has between 30 to 60% suitable for clay spreading.

Table 5: Approximate areas of mapping unit classes with potential of clay spreading (cleared land) in the NY Region (in hectares)

Map class	Class description	Ha of map unit*
1	>60% CS	90,900
2	>30% – 60% CS	165,800
3	>10% - 30% CS	77,100
4	>0% - 10% CS	21,500

* map unit areas, not the area of land suitable for actual spreading

Table 6: Approximate areas of mapping unit classes for potential for delving (cleared land) in the NY Region (in hectares)

Map class	Class description	Ha of map unit*
1	>60% D	28,700
2	>30% - 60% D	17,700
3	>10% - 30% D	60,000
4	>0% - 10% D	36,800

* map unit areas, not the area of land suitable for actual delving

A further guide to planning is to examine the locations in the region where the high potentials to wind erosion match up with the severe susceptibility to water repellence down to those with moderate to low risk.

Table 7 is a simple matrix of the wind erosion susceptibility (Figure 2) and the susceptibility to water repellence (Figure 3) and given a priority rating and approximate locality to show where greatest benefits can be achieved from clay spreading and delving. Tables 3 and Table 4 provide the approximate susceptible area for the broader categories.

The priority matrix ratings range from the very high priority localities through to the low priority localities. These are also depicted in the corresponding map of the priority ratings areas (Figure 16).The areas given for each category of the matrix is again the map unit areas not the actual area of priority sand. Mapping unit variability can also be misinterpreted, for example the sand in a 30 to 60% moderate susceptibility to water repellence unit is not less susceptible than sand in the greater than 60% moderate unit, it is just occupies a smaller area or the dunes may be further apart.

SUMMARY OF MATRIX CLASSES

RATING	MAP POLYGON AREA* (HA)
VERY HIGH	140,800
HIGH	93,500
MEDIUM	118,500
LOW	45,500
TOTAL	**398,300**

* map unit areas, not the area of sand with the specific attributes

Table 7: Priority matrix ratings for wind erosion and water repellence

Susceptibility to Water Repellence	Wind Erosion Susceptibility			
	Extreme and High (18,400ha)	**Mod High (129,100ha)**	**Moderate (202,200ha)**	**Mod low (49,000ha)**
Strong Repellence	**Very High priority**	**Very High priority**	**High Priority**	**Medium priority**
>90% Strong	West Pt Soutar West Hd Muloowurtie (2,100ha)	Stockport (1,200ha)	Stockport (300ha)	(0ha)
60 – 90% Strong	West Minlaton West Pt Vincent (7,300ha)	West Minlaton South Corny Pt West Stansbury (6,900ha)	Agery (200ha)	(0ha)
30 – 60% Strong	SE Minlaton (2,300ha)	East Minlaton (7,100ha)	(0ha)	(0ha)
10 – 30% Strong And 10 - 30% Strong +60%Moderate	Pt Hd Coonarie (600ha)	Hd Coonarie, Warrenben SYP Agery Hd Tippara West Arthurton (2,700ha)	Pt Clinton West (2,900ha)	(0ha)
Moderate Repellence	**Very High priority**			**Medium priority**
>60% Moderate	Stenhouse Bay Nth (3,300ha)	Port Broughton Sth Nantawarra West Bowillia East Muloowurtie (42,200ha)	East Minlaton Nantawarra Hd Coonarie / Carribie Hd Para Wurlie Stockport (83,700ha)	Parts Hd Para Wurlie (15,000ha)
30 – 60% Moderate	Small areas Wokurna (30ha)	SE Pt Wakefield Avon SE Moonta Pt Broughton Wokurna Hamley Bridge West Mambray Creek Hd Stow, Hall (62,300ha)	**Medium priority** Ninnes to Wandearah Pt Broughton Balgowan Pinery Avon Pt Pirie Crystal Brook (47,900ha)	(0ha)
10 – 30% Moderate And 1-10%Strong	West Hd Carribie (2,600ha)	West Hd Carribie (5,200ha)	Clinton Centre Pt Pirie Telowie (21,600ha)	Nth Booleroo Centre Hd Willcox Part Hd Para Wurlie, Carribie West Pasky FDS (34,000ha)
No repellence	**Very High priority**	**High priority**	**Low priority**	**Not Applicable**
	Hd Warrenben (200ha)	(1,500ha)	Part Hd Wauraltee Part Hd Minlacowie (45,500ha)	

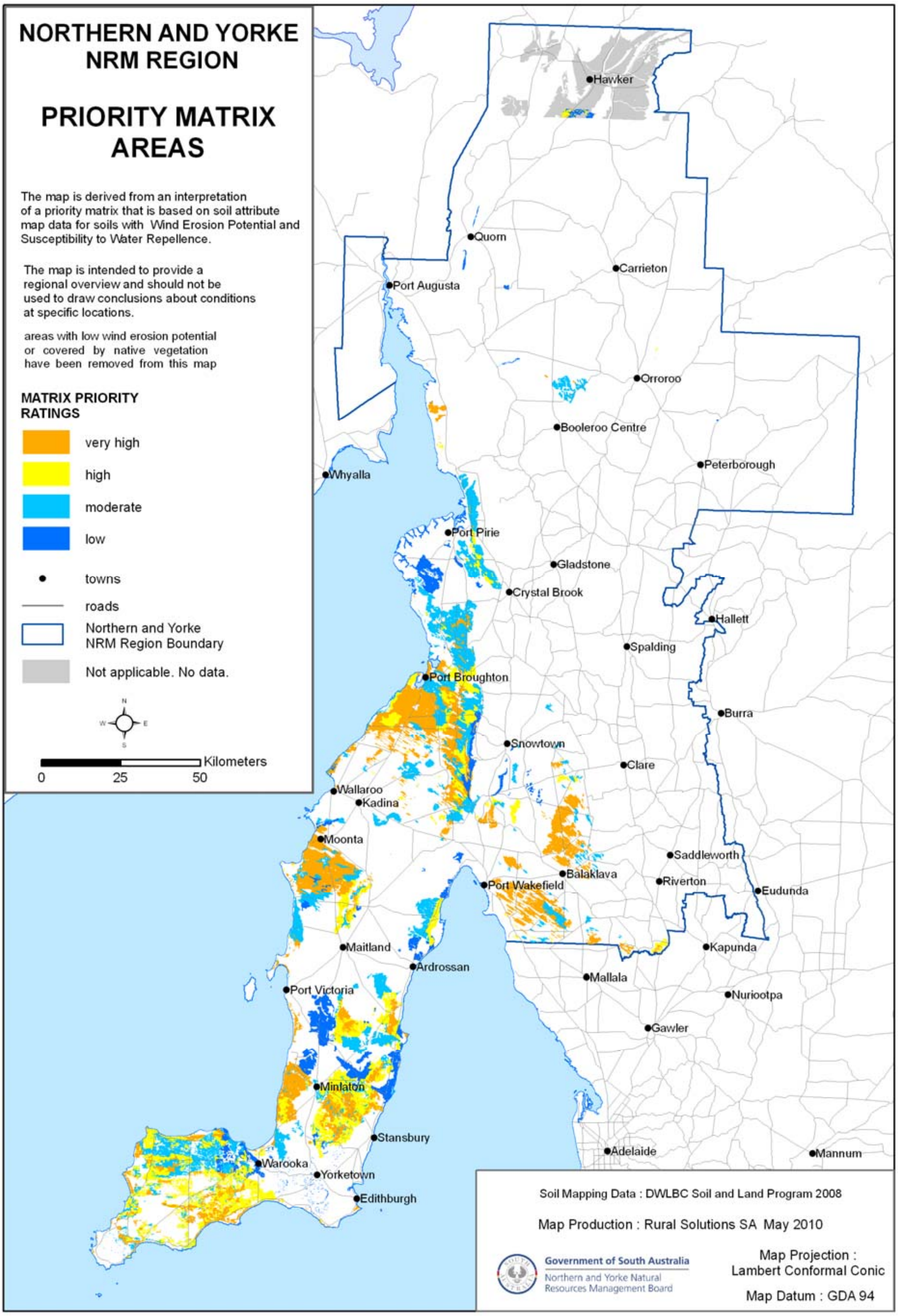

Figure 16: Priority matrix rating areas and distribution

Note: areas with extreme susceptibility wind erosion potential are regarded as not being suitable for agriculture; areas with very high susceptibility to wind erosion are regarded as not suitable for cropping (Maschmedt, 2000).
Therefore, although they might be responsive to clay spreading and delving they may be provide too high a risk to erosion for cropping.

The highest priority (based on where maximum gains can be achieved) are those areas that have a moderately high to extreme wind erosion susceptibility and those areas that are strongly water repellent. These areas occur west and east of Minlaton (may have been already treated), western part of the hundred of Muloowurtie, west of Arthurton, part of the hundred of Tippara, in the Port Broughton area and in smaller areas on Southern Yorke Peninsula. These areas are also moderately to high recharge areas adding to potential or existing salinity problems.

The Port Wakefield, Avon, Port Broughton, Bowillia, Nantawarra, Stow, Moonta and Pt Vincent areas also have significant areas for potential treatment.

Comparing the Potential for clay spreading (Figure 13) with the Potential for clay delving (Figure 14) show that there are areas which overlap but the claying method should be based on the assessment at each individual site. The maps do not take into account the delving of low percentage clay material as an option or the location of clay sources or their suitability.

Targeting areas is more cost effective in providing better education and training activities on a group basis. Bringing together landholders with similar soil types, climate and production systems enables them to learn what is appropriate for their properties and area. Targeting areas is also more attractive for contactors as they can gain significant amounts of work without extensive travelling between jobs, resulting in less costs.

The previous Advisory Board of Agriculture "The Sustainable Land Use and Management of Sandy Soils project" and the "Building resilient farming systems in South Australia through improved knowledge and innovative management of soil constraints" project are a successful model to move groups from the awareness phase of claying to landholders being more informed and with new skills to assess their soils.

The projects allowed the development and delivery of a few "hands on" field workshop on the principles of claying the assessment of target sands and claying material, the steps in the claying process and incorporation. It also drew on the experiences of trials and demonstrations, landholder group experience in other regions and the lessons learnt from these.

8 RECOMMENDED ACTIONS

The following strategies are recommended to improve the uptake of clay spreading and delving as a means to reduce the risk of wind erosion and ameliorate water repellence:

- Implement a coordinated soil modification program in identified priority areas in the region
- Improve landholder, technical adviser and contractor knowledge and skills in "best practice' claying methods and assessment of target sands and claying material.
- Investigate the longest treated areas on Yorke Peninsula to determine the achieved benefits, the issues encountered and the effectiveness of their methodology.
- Determine suitable claying rates and adjustments to suit the NY regions sands, climate and productivity
- Investigate areas which have little information on availability of clay and the condition of sands that may suitable and benefit from claying. For example western Southern Yorke Peninsula.
- Investigate other sandy texture soils in other soil groups in the region for suitability for claying or modifying methods. For example investigate delving to modify sub-surface inhibiting layers.
- Investigate alternative delver design and adjustments to suit a range of soils and landscape changes. This may be best addressed with multi regional and industry collaboration.

Claying workshop to improve landholder knowledge and skills in "best practice' claying methods.

9 SUMMARY

The NY Region has about 222,900 hectares of cleared agricultural land that have a moderate to extreme inherent susceptibility to wind erosion and a significant portion of the soils in this area are water repellent .

Clay spreading and delving is an effective and permanent method to reduce the risk of sands to erosion and can eliminate water repellency with relative low rates of clay material.

Adding clay to sandy soils can significantly improve plant growth, resulting in more soil surface cover and productivity.

The potential area suitable to clay spreading in the region is approximately 173,600 hectares and the potential area suitable for delving is 46,400 hectares.

The area already clay spread or delved in the region is approximately 4,000 hectares by relatively few landholders (approximately 40).

The uptake of clay spreading and delving by landholders is slow in the region and requires a planned program to ensure best practice claying principles are adopted by landholders and implemented on their properties.

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