PREDICTING KEY REGOLITH ATTRIBUTES FOR SALINITY ASSESSMENT – A FLEXIBLE APPROACH FOR BROAD AREAS IN QUEENSLAND

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INTRODUCTION

Salinity, as an emerging natural resource issue, is now assuming a higher priority in Queensland similar to its status in other parts of Australia. The area of land in Queensland affected by salinity is currently estimated at 48 000 ha and is predicted to reach as much as 3.1 million ha by 2050 (NLWRA 2001).

The combination of processes driving salinity present a whole-of-landscape problem that can only be solved by developing an integrated understanding of all components of the landscape - including soils and the deeper regolith, vegetation and groundwater. Regolith materials below the soil profile and above existing groundwater levels have, for the most part, been overlooked in previous studies into salinity processes in Queensland. Consequently, there is a paucity of information on processes acting in the unsaturated regolith at depths greater than *c.* 2m, aside from a limited number of shallow groundwater observation bores and some shallow lysimeter and chloride tracing studies (e.g., Tolmie & Silburn 2002). These materials do however play vital roles in the processes controlling salinity - as a medium of growth for deep-rooted vegetation, as salt stores, and as the zone through which water moves to recharge and discharge from groundwater systems.

The state-wide National Action Plan (NAP) salinity projects currently being undertaken in Queensland aim to address this and other major data gaps. They cover the priority regions of the Burdekin, Fitzroy, Condamine-Balonne-Maranoa, Border Rivers-Moonie, Burnett, Mary and Lockyer-Bremer-Upper Brisbane catchments, which total approximately 475 000 km^2 or 30% of the state (Figure 1).

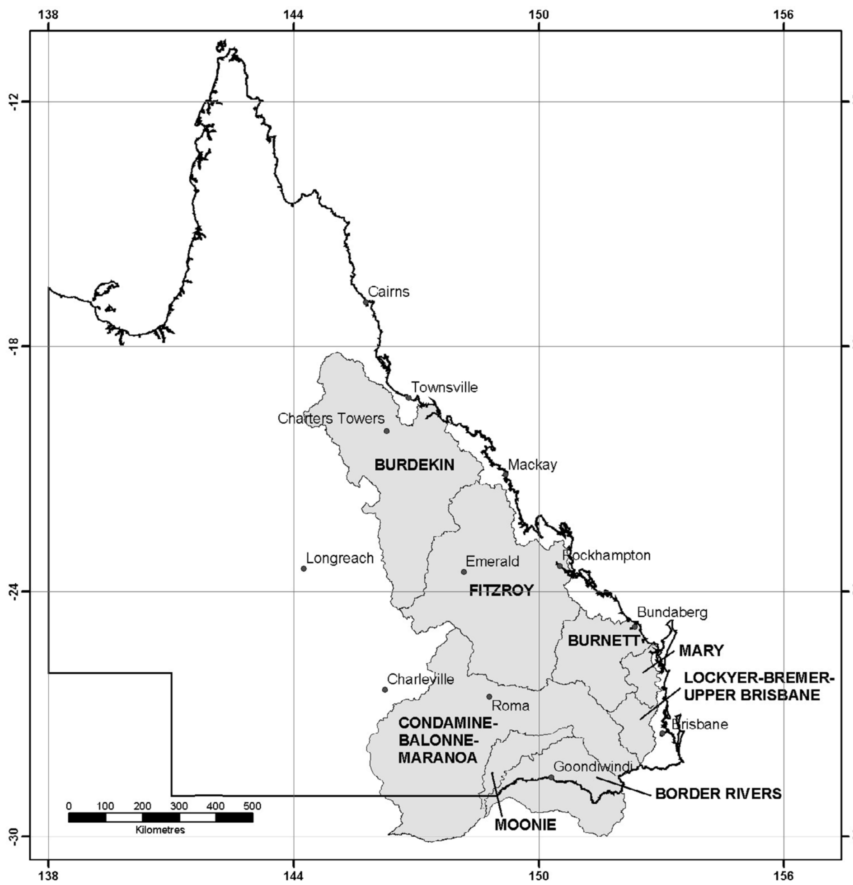

Figure 1: Location of the NAP priority regions in Queensland.

This group of projects commenced with the mapping of salinity hazard using existing data, and with the development of a regional groundwater bore network. The next step in the program involves the development of a range of soil, regolith and landscape attribute layers. This project is now in progress and will be completed in June 2005. These attribute layers will directly contribute to our understanding of salinity processes, as well as supporting integrated salinity modelling. Data layers and models will then be used to address priorities for vegetation and water management and will support the development of regional natural resource management plans. This paper addresses a key component of the project - the spatial representation of regolith attributes, namely hydrologic properties, salt stores and rooting depths.

Explicit spatial prediction methods developed in recent years have proven effective in mapping soil attributes with limited field observations and environmental correlation data (e.g., McKenzie & Ryan 1999, Slater & Grundy 1999), and are being used in this project to generate soil attribute layers. While these techniques have not yet been applied to regolith predictions, they offer a template for effective mapping of these attributes. This paper describes the development of a structured and flexible approach to predicting the spatial distribution of regolith materials. It is a systems approach, focussed on the prediction of functional attributes, and builds on existing frameworks using a wide variety of historic information (including environmental correlatives, surrogates and field observations). It develops hypothetical spatial distributions of attributes, which are then testable through subsequent fieldwork. Following confirmation or refutation, the conceptual models generating these predictions can be refined.

SYSTEMS APPROACH

In developing a systematic approach for the spatial prediction of regolith attributes, it was important to ensure that the method would:

- fully utilise a wide range of data sources
- incorporate data at a variety of scales
- produce explicit and repeatable results
- be flexible – develop hypotheses that can evolve during the life of the project
- include a targeted fieldwork program to test and refine the hypotheses
- be applicable to a range of landscapes

To achieve these aims, a hierarchical framework has been employed that allows data to be incorporated at a variety of scales, and creates a set of steps that explicitly define how the final attribute layers were generated. Through several sequential steps, each priority region was broken down into increasingly smaller mapping areas by examining a range of existing data sources. The results of this approach are maps that delineate functional geomorphic units at a scale practical for detailed modelling and attribute prediction. Conceptual models are developed to predict the distribution of regolith materials in each mapping unit, as well as simpler models at broader scales to capture the interactions between different geomorphic units. This is a flexible method that accommodates new data as it becomes available – increasing levels of detail can be added to the models and mapping unit boundaries as fieldwork progresses, and modifications can be made at any level in the hierarchy. This flexibility also allows the approach to be used in different landscapes with varying degrees of inherent complexity.

Once robust conceptual models have been produced in each mapping area, automated spatial prediction techniques can use them to generate more detailed raster surfaces of the distribution of regolith materials. The techniques available are based on environmental correlation and geostatistical methods, and include rule-based systems, neural networks, fuzzy logic, tree-based methods, generalised linear models and kriging. They make use of high quality explanatory data layers such as DEMs and terrain derivatives (e.g. slope and compound topographic index - Wilson & Gallant 2000) and gamma radiometrics, where they are available. These methods have a number of advantages over traditional mapping using mental models, as they can be quantitative as well as qualitative, can handle large quantities of data and have the capacity to produce accuracy statements. Tree-based methods and fuzzy modelling have been successfully applied to mapping soil attributes in Queensland (e.g., Claridge 2001, Ellis & Wilson in prep).

DATA SOURCES

The broad scale of this work has necessitated the innovative re-interpretation of existing sources of regolith and landscape information. The data sources being utilised include polygon mapping (land systems, geology, land resource areas, soils) at various scales, geophysical data (gamma radiometrics, ground electromagnetics), 50m cell size digital elevation models and terrain derivatives, point data (soil survey sites, groundwater bore logs, exploration drill holes logs) and other information contained in reports.

A small number of studies have been completed in Queensland that include some aspect of regolith science. The more relevant of these for salinity research includes a CRC LEME / AMIRA project that incorporated regolith-landform mapping in the Charters Towers region in north Queensland (Anand *et al*. 2002). Similar mapping has been completed in draft form in the Mundubbera, Maryborough and Gympie 1: 250 000 sheet areas in southeast Queensland (unpublished maps, CRC LEME). These maps are applicable to this project as they provide a landscape framework that can be used in conjunction with other broad-scale landform mapping for interpreting soil and regolith attributes. The remainder of regolith-landform mapping conducted in the state falls outside the NAP priority regions, and includes Shoalwater Bay (Anon. 1993), Mt Isa (Anand *et al*. 2002) and Cape York Peninsula (Pain *et al*. 1995). Some reports are also available for mining and exploration applications that include varying degrees of detail on regolith architecture and landscape evolution (e.g., Beams & Jenkins 1995).

Broad scale land systems mapping has been completed across most of the state, with the exception of the northern Burdekin region and most of south east Queensland. Initial collation and examination of all the available data has confirmed that these surveys are the most suitable base for new interpretations, as they are at an appropriate scale (typically 1: 500 000) and cover the majority of the priority regions. The land systems concept is particularly appropriate as it combines many features of the landscape that are of interest – including soils, landforms, geology and vegetation. Broad scale soil and land resource area mapping will be of some use in areas not covered by land systems (e.g., north Burdekin). The land systems and soils polygons have important limitations that make then unsuitable for directly creating regolith attribute layers, as they miss some subtle geological and landform variation that will influence regolith properties. These subtleties must be superimposed from other data sources and by expert input.

DEVELOPING CONCEPTUAL SPATIAL MODELS

The first step in the approach has involved the interpretation of the land system and soil surveys, along with 1: 250,000 geology mapping, to divide each priority region into several broad provinces with similar geologies and landscapes. Figure 2 illustrates this step with an example based on a land systems survey of the southern Burdekin / northern Fitzroy catchments. These were practical divisions that provided a framework for more focussed interpretation.

Each broad province has been subdivided into functional geomorphic units by identifying increasingly detailed patterns in the land systems, geology and soils data, along with examination of the DEMs and terrain derivatives. These steps progressed with the addition of expert knowledge from experienced local scientists who are familiar with the priority regions. This knowledge will also be utilised during the modelling phase.

Conceptual models of the three dimensional regolith architecture, salt stores and salinity processes are now being developed by incorporating data from groundwater bore logs, exploration drill holes, soil survey sites and an initial stage of fieldwork. These models will be stored digitally in a GIS, and are essentially the explicit hypotheses that will be tested and altered by targeted observations as the field program progresses.

On completion of the polygonal mapping and conceptual modelling, the automated spatial prediction techniques will be tested and refined to predict the distribution of regolith materials in each functional geomorphic unit. A final stage of fieldwork will then be conducted to test the accuracy of the predictions. The accuracy of the spatial predictions will depend largely on the polygonal mapping framework, the conceptual models and the explanatory data layers used, on the quantity and distribution of field observations, and on the inherent complexity of the landscape in each mapping unit. In some areas this complexity may be unable to be resolved within the scope of the project; in this event, the area will be flagged for further detailed study. Where high quality explanatory data is not available, simpler and less robust spatial predictions will be generated that will be open to amendments following more intense fieldwork.

DERIVATION OF ATTRIBUTES

The aim of this work is to map regolith attributes relevant to salinity processes, in particular hydrologic properties (porosity/permeability), salt content and rooting depth. The attribute layers, in conjunction with landform data, can then be used to model water movement through the unsaturated regolith, the distribution of salt throughout the landscape, and the interaction of water and regolith materials with deep-rooted vegetation. Recharge and discharge zones can also be defined, along with preferential flow paths and barriers to water movement.

These attributes cannot be taken directly from existing data, or from field observations; they must be inferred from other more readily observable features of the regolith, and with limited laboratory analyses. In keeping with the explicit approach used in this project, these inferences will be captured in the form of *transfer functions*, which specify the precise relationship between the interpreted attributes and the real features used to derive them. The scale of the project and lack of detailed data will initially limit the attribution to broad categorical values. At a later time, more detailed transfer functions may be developed and analytical data may become available that will allow the attributes to be refined to more precise categories or to real data ranges.

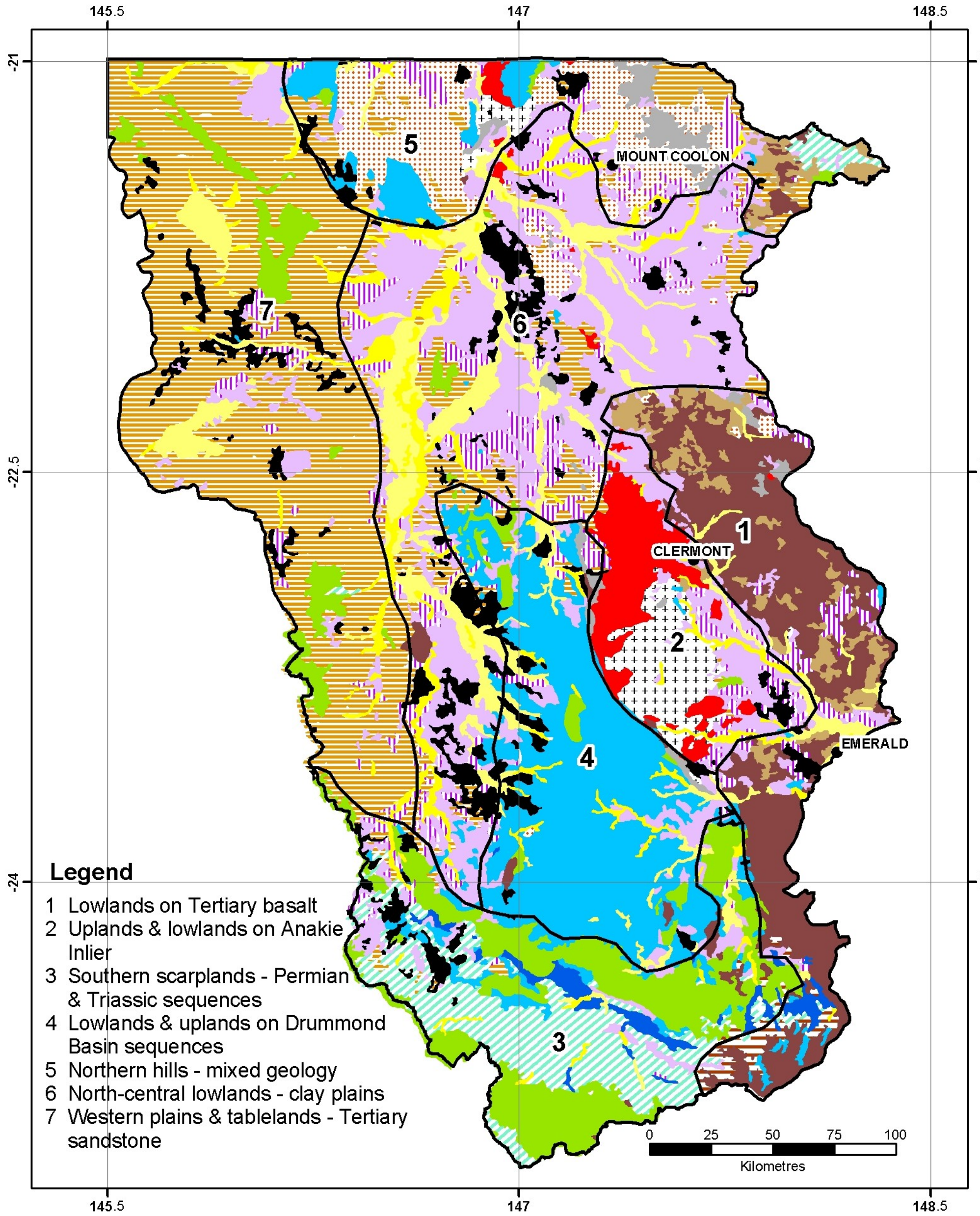

Figure 2: Initial subdivision of the Nogoa-Belyando land systems survey area. Land systems polygons are shaded into broad geological and landform categories.

Hydrologic properties and rooting depth will mostly be inferred from the degree of weathering (which may be expressed more meaningfully as the *strength* of the material), fracturing, induration, grain size and sorting, colour, bedrock structure and lithology. A new approach has been developed, including a field description sheet, that allows for the systematic capture of this information in the field. Determination of regolith salt content represents a challenge due to a lack of available data. It will be inferred from soil and groundwater salinity data, supplemented by expert knowledge and limited laboratory analyses.

The variable nature of the regolith in three dimensions requires that a vertical/depth component be incorporated into the attribution. This presents a major challenge as currently used regolith mapping approaches do not systematically capture detailed information in three dimensions. At this stage it is likely that this problem will be overcome by using the concept of regolith zones that vary considerably in hydrologic properties and/or salt content. These will be delineated in the vertical direction where they are sufficient in size. Depths to different zones will be specified and values then attributed to each. The zone concept used here is based on that described in the RT MAP field handbook (Pain *et al*. in prep.).

INTEGRATED FIELD OBSERVATIONS

An important aspect of the systematic approach to prediction of regolith attributes has been the development of a well-planned fieldwork program to fit in with the various stages of mapping, modelling and prediction. Fieldwork thus far has been of an exploratory nature in order to develop a structured field approach to regolith description. This has been conducted concurrently with other fieldwork focussed on filling geographic gaps in soils information.

A field approach has now been formulated that is based primarily on categories from the RT MAP Field Handbook (Pain *et al*. in prep.) and the Australian Soil and Land Survey Field Handbook (McDonald *et al*. 1998), along with some new observation categories particularly relevant to this project. These handbooks were used as the basis for the field approach as they are used widely, allowing the data from this project to be consistent with other soil and regolith research. Most field officers are familiar with the Australian Soil and Land Survey Field Handbook, which has allowed the new approach to be to be quickly understood. It is currently being modified as the field officers test and provide feedback on the system.

The main phase of fieldwork will begin once preliminary polygonal mapping and conceptual modelling is at a stage where it needs to be tested and refined. Toward the end of this phase, a limited program of shallow drilling will be conducted in areas of particular interest that have been identified in earlier steps. These drill holes will provide a greater level of detail of the regolith architecture and will be sampled for laboratory analyses that will contribute to the development of transfer functions. A final period of fieldwork will also be necessary in the later stages of the project to test the spatial predictions and determine their accuracy.

FUTURE DEVELOPMENTS

Several new avenues of study will be opened up on completion of this project. The improved understanding of salinity processes in Queensland will lead to the identification of high priority areas that are in need of more detailed research. A continued focus on regolith science for salinity assessment will allow spatial prediction techniques for regolith attributes to evolve. Knowledge of regolith architecture, which takes into account factors such as geological features and landscape history, may also be useful in the further development of spatial prediction methods for soil attributes, as it has been recognised that regolith architecture may be a greater control on soil properties than landform in some landscapes (McKenzie & Ryan 1999). More complex and realistic regolith transfer functions could also be developed that would produce increasingly precise results.

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