PRELIMINARY INVESTIGATION OF SALINISATION AT BELLATA, NSW

Michael Smith

CRC LEME, Department of Geology, Australian National University, ACT, 0200

INTRODUCTION & SETTING

Parts of the landscape at Bellata (Figure 1), within the Gwydir Catchment (Barwon Region) of New South Wales, have a recent history of severe and increasing degradation in direct response to soil salinisation. Stream-water quality has also deteriorated via increasing salinity. The Northern Salinity Team in the Departments of Land & Water Conservation (DLWC) and Agriculture has recognised Bellata as a priority area of very high salinity hazard. A study was undertaken to identify the landscape processes and current land-management activities that drive salinisation.

The regional bedrock at Bellata comprises Jurassic to Cretaceous (ca. 160-95 million years) sediments of the Surat Basin. This bedrock is overlain locally by Palaeogene (ca. 23-55 million years) gravel and, in turn, the north-western extension of the Nandewar Volcanic Complex (mainly comprising types of basalt) of Miocene (17-21 million years) age. The region is mantled with widespread deposits of alluvium and colluvium.

The climate at Bellata is warm, dry subhumid. The mean daily maximum temperature, potential evaporation and rainfall peak during December to February. Potential evaporation always exceeds rainfall. The mean annual rainfall is approximately 600-650 mm, but rainfall occurs as temporally variable high-intensity storms. Autumn and Spring are frequently dry and longer-term drought is fairly common.

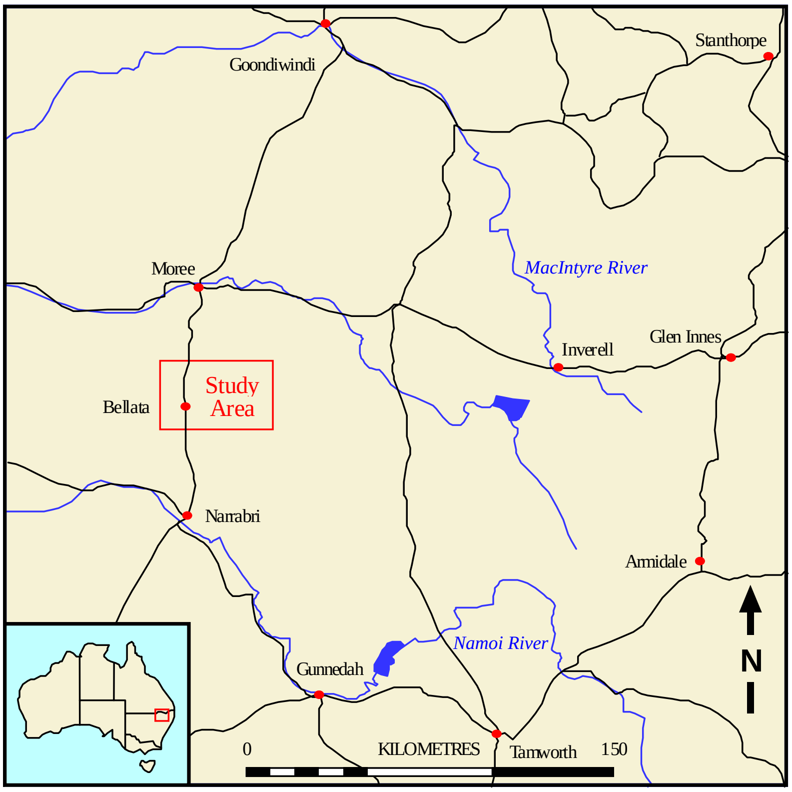

Figure 1: The salinity investigation area is centred immediately east of Bellata, approximately midway between Moree and Narrabri.

IMPACTS OF GROUNDWATER DISCHARGE & SALINISATION

The combined impacts of salinisation, sodification, alkalinisation and waterlogging at Bellata generate four visual expressions of degradation as shown in Plates 1 to 4.

Plate 1 (left): White crust of calcite (lime) and fine quartz sand on agriculturally productive soil with saline, sodic and alkaline subsoil.
Plate 2 (right): Saline, sodic and alkaline soil with a white puffy, powdery surface and limited vegetal cover. The soil surface is subject to sheet and rill erosion and deposition nearby as a laminated crust of quartz sand and minor lime and clay; localised surface ponding and runoff of discharged groundwater during dry weather conditions.

Plate 3 (left): Saline and strongly sodic and alkaline spring mound of swelling clays; surface ponding of discharged groundwater on mound flat during dry weather conditions.
Plate 4 (right): Structurally damaged surfaces of sealed roads.

SALINITY OCCURRENCE IN THE LANDSCAPE

Soil scalds at Bellata generally occur at the break of slope, defined by the margin of volcanic rock, and within localised (first-order) surface catchments (Figure 2). Several of the scalds have developed as little as 1.5 km from the upper boundaries of the first-order catchments. The western-most known scald (Scald 1) occurs on a plain of Quaternary alluvium.

SALINITY OCCURRENCE IN THE PADDOCK

Soil that is prone to salinisation can generally be identified within a paddock by simply looking for slope breaks while in the car or on the tractor. This break of slope occurs at the boundary between the volcanic and underlying basement sedimentary rock. In some areas, the slope break is very subtle or not apparent. For these situations, the boundary between the volcanic and sedimentary rock can be located by the detailed field mapping of the regolith. However, this method is labour intensive and requires specialist skills. Alternatively, electromagnetic induction surveying can produce results relatively rapidly and which can be reliably interpreted with some knowledge of the landscape (Figure 3).

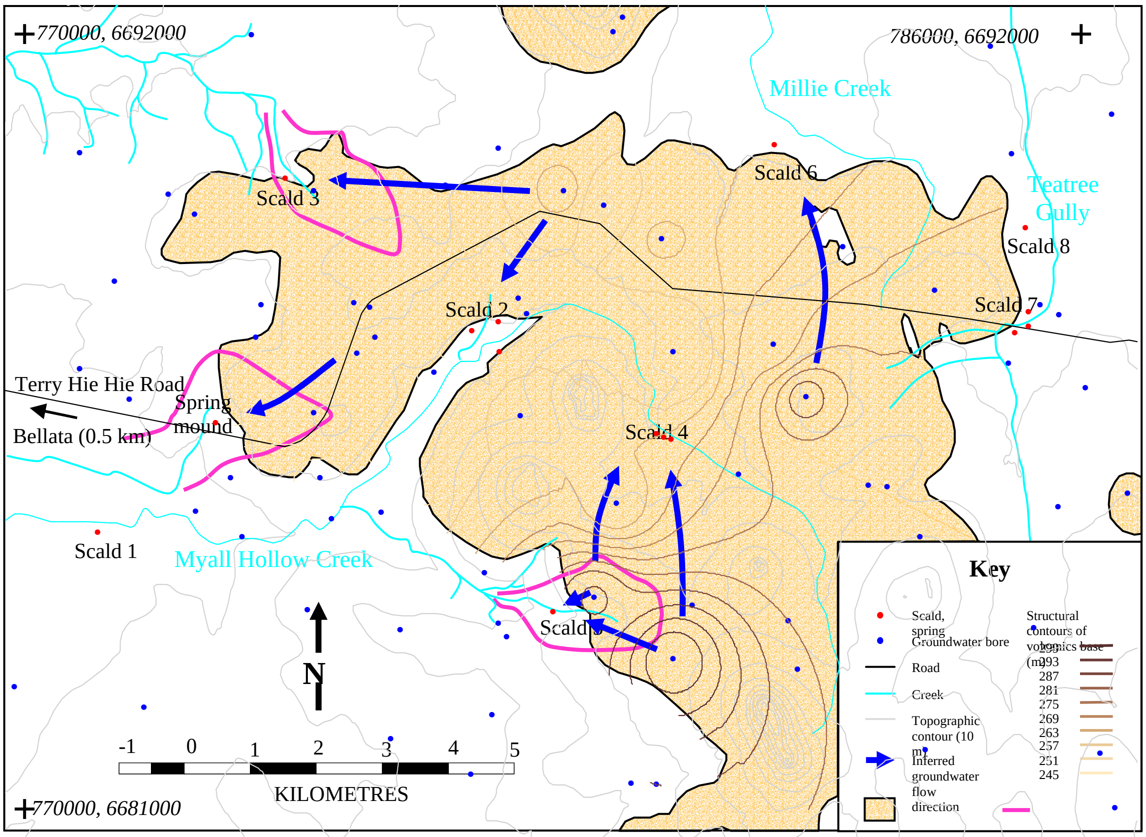

Figure 2 Distribution of known saline scalds and a spring mound in the Bellata area. Also shown are groundwater flow directions inferred from elevation contours of the base of the trachybasalt. These contours were calculated using data in drillers' logs extracted from the DLWC groundwater database.

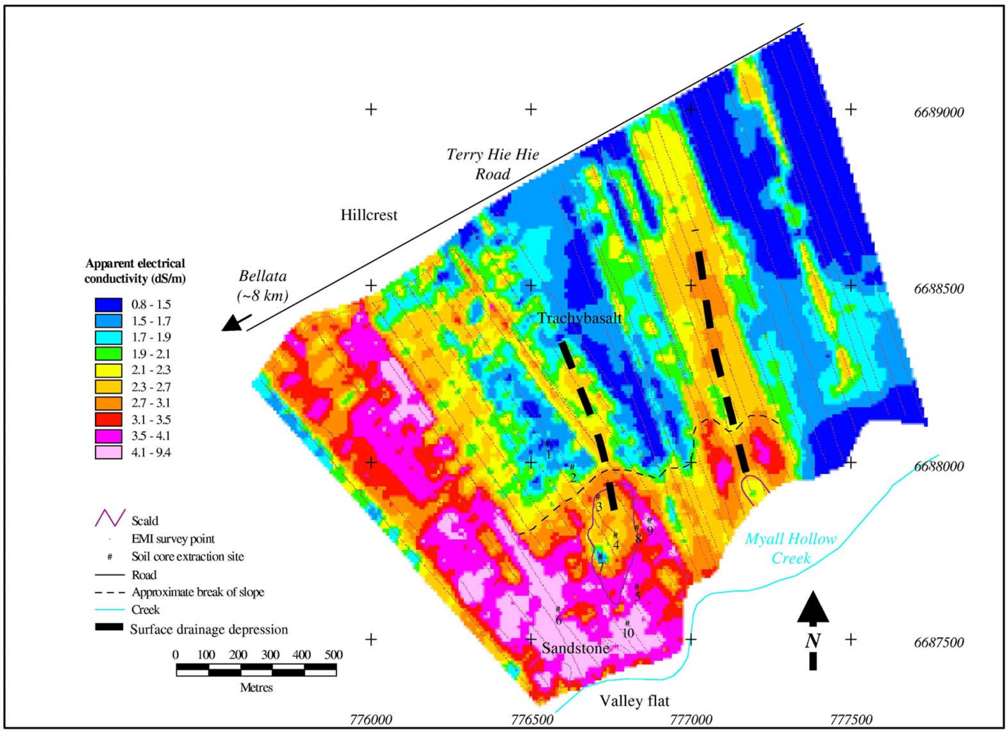

Figure 3 Results of an electromagnetic induction survey over a soil scald (Scald 2 in Figure 2) near Bellata showing zones of different electrical conductivity. These zones are caused by differences of salt, moisture and/or clay content in the regolith.

HYDROGEOLOGICAL PROCESSES OF SOIL SCALDING

Most of the soil scalds at Bellata are the result of the excessive discharge of mineralised groundwater from a local (<5 km) flow system within the deeper portion of a subhorizontal sequence of weathered and fractured trachybasalt, which overlies basement sedimentary rock (Figure 4). The hydrogeological processes behind the development of the scald (Scald 1) on the alluvial plain require investigation.

Many of the ions responsible for salinisation, sodification and alkalinisation are derived predominantly from the weathered trachybasalt. Some of the chloride, sulphate and, perhaps, sodium ions are also probably sourced from the underlying weathered sedimentary rock or from atmospheric salt.

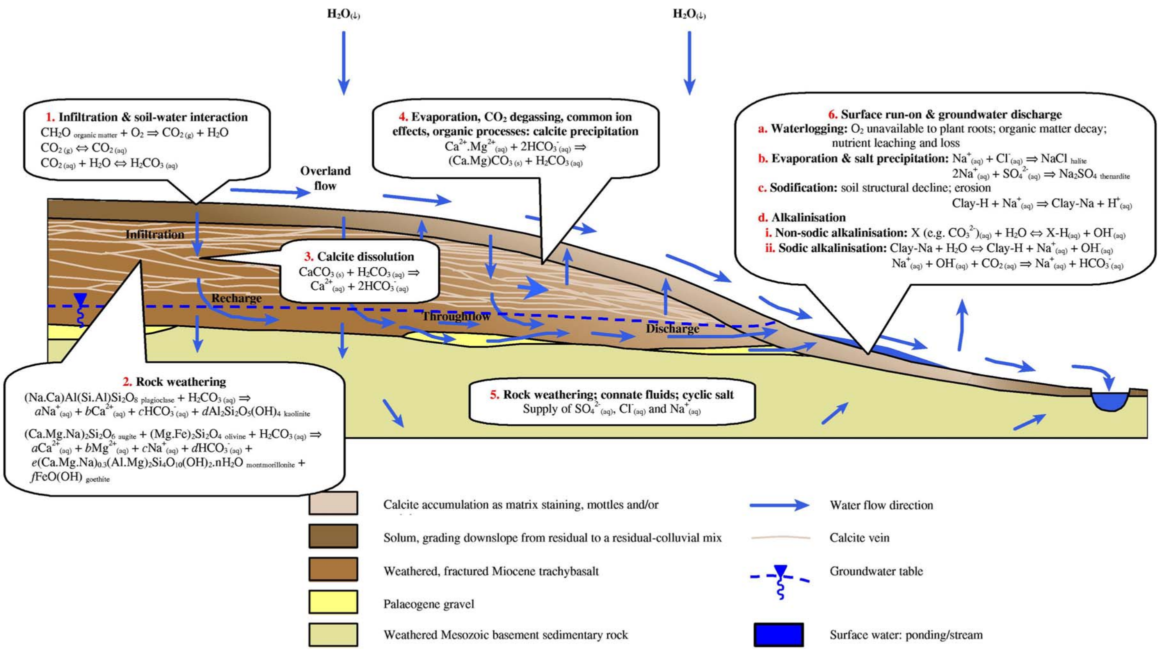

Figure 4: Conceptual hydrological model of soil scalding at Bellata.

SOIL PROCESSES OF SCALDING

Soil scalding at Bellata is due to the cumulative effect (Figures 5 & 6) of:

1) **Salinisation:** the presence of enough salts in soil moisture within the root zone to adversely affect plant growth or land use;
2) **Sodification:** an excess of sodium relative to other cations (calcium, magnesium and potassium) on the surfaces of clay particles surrounded by soil moisture with a relatively low salt concentration; this condition causes the clay to disperse in water and erode; this sodium is referred to as *exchangeable sodium*;
3) **Alkalinisation:** an excess of certain types of ions (OH^- , $CO3^{2-}$, $HCO3^-$) relative to hydrogen ions in soil moisture, and excessive exchangeable sodium, which determine the types of chemical reactions that can occur, including the prevention of the availability of some types of plant nutrients (Fe, Mn, Zn, Cu, P); and,
4) **Waterlogging:** where there is more soil water than can be drained by the soil, which prevents the entry of oxygen into the soil for use by plant roots.

Soil scalding occurs on a self-mulching black vertosol developed on a mix of residuum and colluvium derived from weathered trachybasalt, Palaeogene gravel and basement sedimentary rock. Scalding of the vertosol induces a progression of structural, textural and morphological changes as follows:

1) loss of self-mulching character;
2) development of a crust;
3) partial bleaching and depletion of organic matter throughout the profile to cause a colour change through brown to grey;
4) loss of grade and compound nature of subsoil pedality and the loss of lenticular structure;
5) development of a puffy, powdery soil surface; and,
6) coarsening of topsoil texture to form a strongly texture-contrast sodosol.

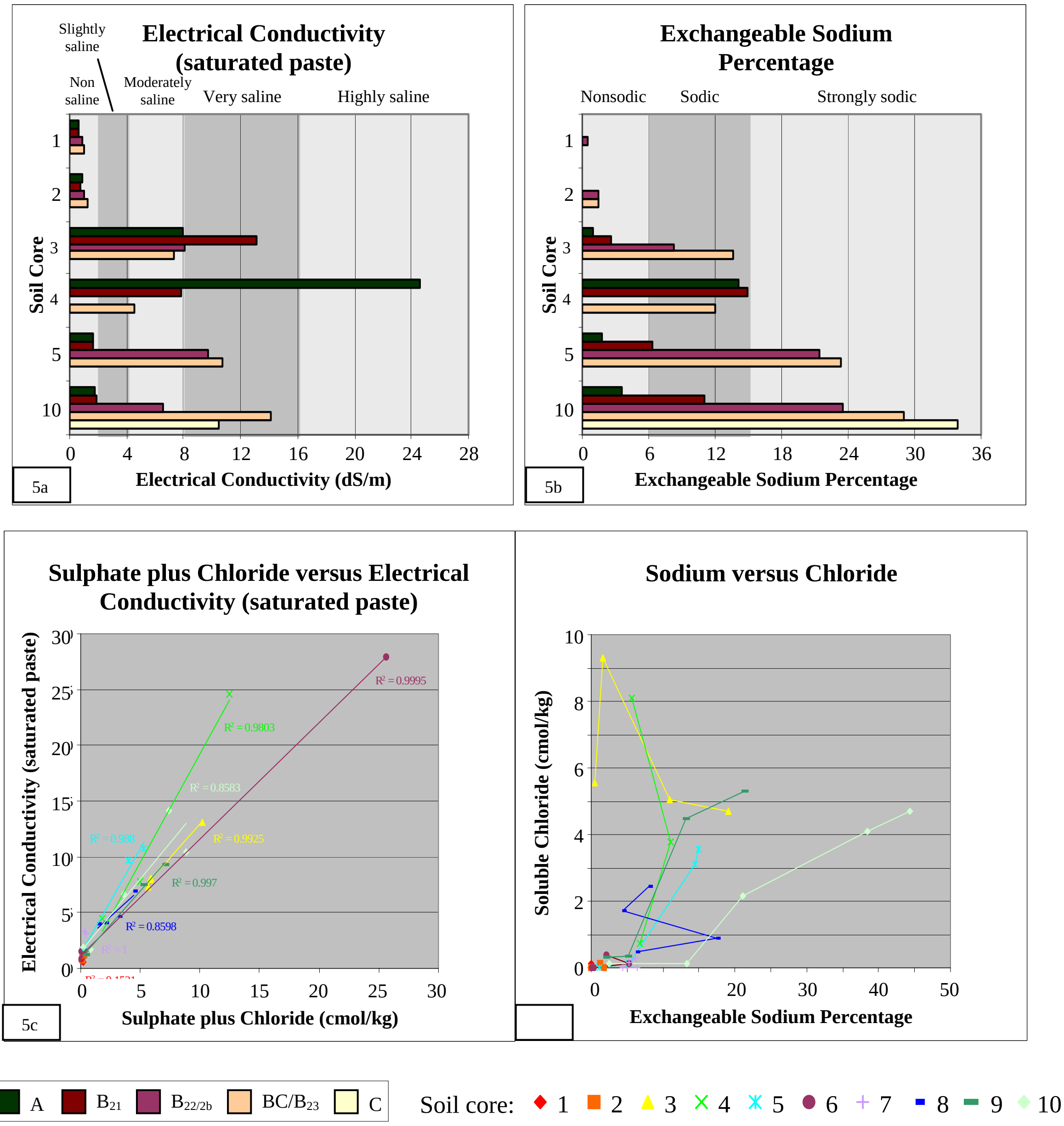

Figure 5a-d Soil salinity is low immediately upslope from Scald 2 (soil cores 1 & 2), but is moderate to high within (cores 3 & 4) and surrounding (cores 5 & 10) the scald (Fig. 5a). Salinity decreases with depth within the scald, but increases with depth in the surrounding soil. These salinity levels are measured as electrical conductivity, which in these soils increases with an increase of chloride and sulphate concentration (Fig. 5c). Sodium and chloride are related only in the soil surrounding the scald (cores 5, 9 & 10; Fig. 5d). Soil within and surrounding the scald is sodic to strongly sodic. Sodicity increases downslope (Fig. 5b).

SALINITY MANAGEMENT

Management of soil salinisation, sodification and alkalinisation associated with groundwater processes should be directed toward both the specific degraded areas and those areas that contribute to the groundwater flow system responsible for scald development.

To develop an appropriate management strategy for the groundwater flow system, the characteristics of, and climatic and land-management impacts on, the flow system are required. This information can be obtained by a detailed hydrogeological investigation and the long-term monitoring of groundwater levels and quality as well as the size and degree of scald development. Salinity management is generally aimed at lowering the groundwater table at discharge sites by reducing recharge and/or increasing discharge.

Management options for groundwater recharge areas include:

- minimise soil disturbance
- residue retention
- engineering (earthworks)
- improve soil fertility
- response cropping
- perennial grasses
- protect remnant trees
- tree planting in strategic locations

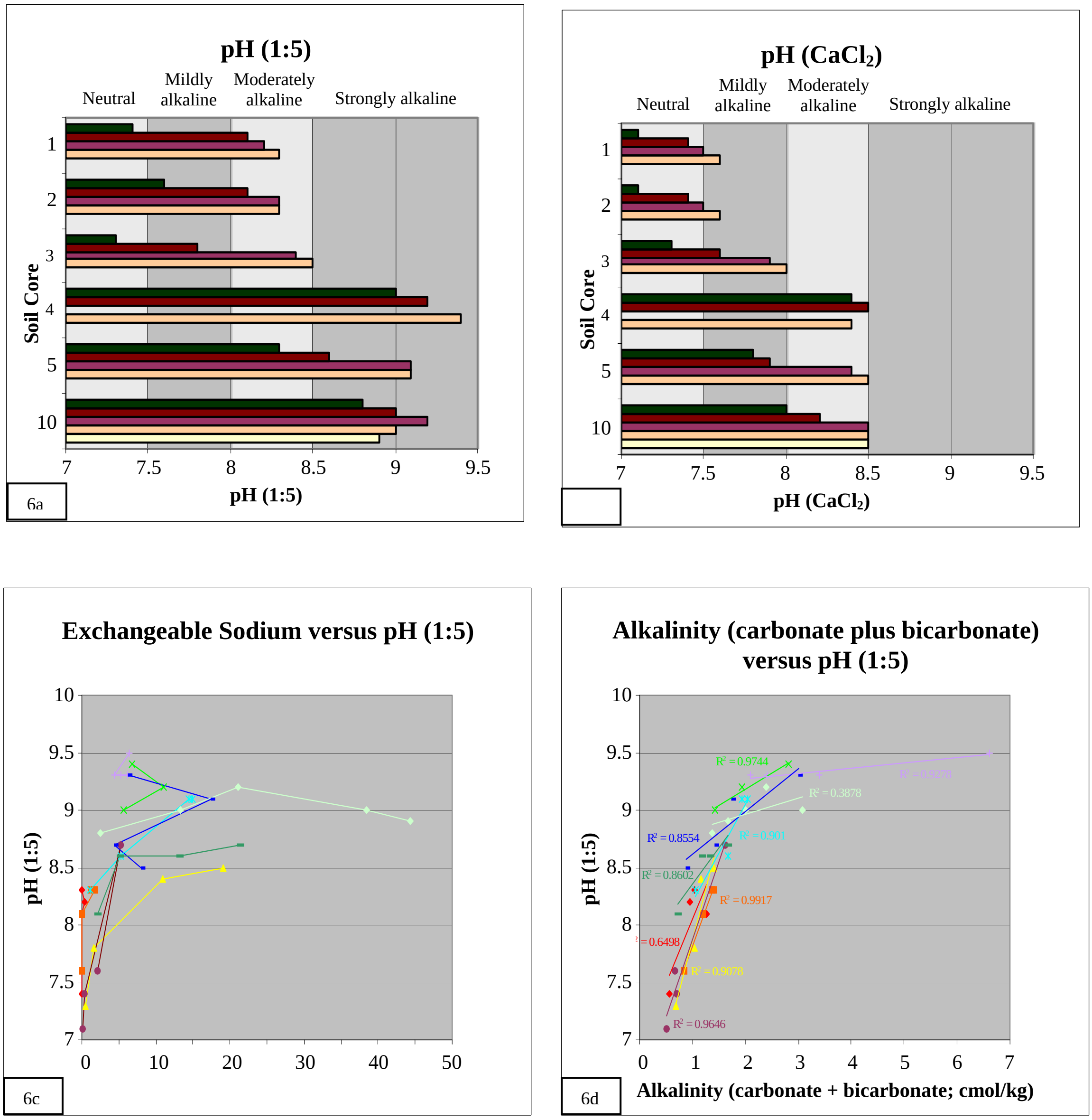

Figure 6a-d Soil within and immediately surrounding Scald 2 is moderately to strongly alkaline (pH1:5 >8). Generally, pH increases with depth in the soil, but decreases into the underlying weathered rock (C-horizon; Fig. 6a). The high soil pH is due to the abundance of and chemical equilibrium between carbonate and bicarbonate ions (Fig. 6c), the abundance of exchangeable sodium (Fig. 6d) and the limited presence of readily soluble salts of sodium. The latter is indicated by the maximum pH in calcium-chloride solution of 8.5 (Fig. 6b), which is caused by the pH buffering effect of the removal of carbonate from the soil solution by its precipitation with calcium as calcite (crystallized lime).

Management options for soil scalds include:

- fencing off
- improve soil fertility and organic matter content
- apply gypsum and sulphur
- establish legumes at scald margins
- protect remnant trees
- tree planting; perennial grasses
- mulching
- engineering (earthworks; groundwater pumping).

REFERENCE

SMITH M.S. 2002. *Conceptual processes of salinisation at Bellata, NSW*. NSW Department of Land & Water Conservation unpublished report, 115 p.

Acknowledgment: This work was undertaken whilst employed as a Salinity Technical Officer of the Northern Salinity Team, Department of Land & Water Conservation.