SOIL HYDROLOGICAL PROCESSES OF SALINISATION IN THE BAMGANIE-MEREDITH DISTRICT, VICTORIA

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INTRODUCTION

Observations in various parts of western Victoria (Dahlhaus *et al*. 2000, Nathan 1999) indicate that deforestation has increased waterlogging and surface runoff, which has spread the primary salinity caused by saline groundwater discharge that occurred even prior to European settlement, and deforestation has not significantly affected groundwater recharge or discharge. These observations contradict the widely accepted view of dryland salinisation processes in Victoria, which is based on the Kamarooka groundwater recharge-discharge model (Figure 2) of Jenkin & Dyson (1983). New groundwater models explaining salinisation processes throughout Victoria must therefore be sought.

Under the sponsorship of the Bamganie-Meredith Landcare group, the hydrological processes responsible for land salinisation and waterlogging in the Bamganie-Meredith district (Figure 1, Plate 1) were evaluated (Smith, 2001). This was achieved through the study of large, structurally undisturbed augered soil cores, together with soil pits, to compare the variability of the regolith with depth and landscape position (Figures 3, 4 & 5). Hydrological results were determined by the testing of soil cores, 30 cm in diameter by 1 m in length, as constant head permeameters using dyed infiltrate. Soil cores were extracted and studied from the three main geological units in the district, including (1) the Ordovician turbiditic bedrock of the Castlemaine Group, (2) Neogene sheet-like shallow marine sands and gravels of the Moorabool Viaduct Sand, and (3) Pliocene-Pleistocene basalt of the Newer Volcanics.

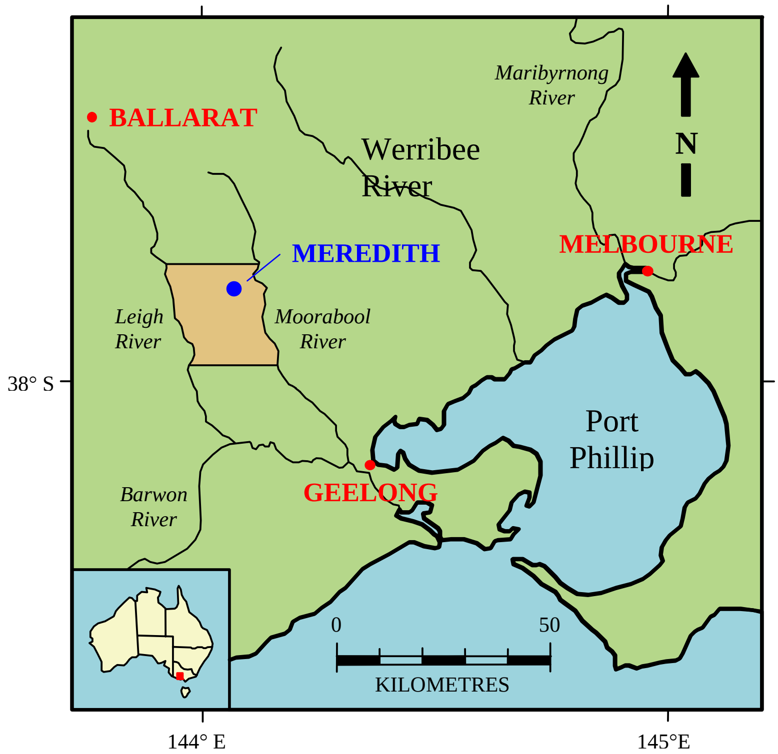


Figure 1: The Bamganie-Meredith district, shown in orange, is located midway between Ballarat and Geelong, approximately 100 km west of Melbourne, and is part of the Corangamite salinity region. The climate of Bamganie-Meredith is temperate, with cool wet winters and warm dry summers. The recorded annual mean rainfall for the areas is 702 mm.

Castlemaine Group

Under dry antecedent subsoil conditions interpedal fractures are wide, enabling rapid deep vertical percolation (potential recharge) through the subsoil and into the underlying saprolite. Coarse roots (live or dead and rotted), earthworm channels and loosely packed pedotubules may also have a strong influence on hydraulic conductivity, but this is only short-term since these macropores are rapidly plugged with illuviation products. During rapid vertical infiltration into the subsoil minor perching and interflow within the shallower subsoil can occur if the infiltration capacity of the deeper subsoil is exceeded. Vertical infiltration continues into the underlying saprolite at some hillslope positions along preferred flow paths including shallow vertical desiccation fractures and remnant bedrock cleavage, joints and fractured quartz veins. At other hillslope positions vertical infiltration may occur only as matrix flow, depending on local variations in the characteristics of the saprolite and, hence, parent rock.

Plate 1: Soil salting in the Bamganie-Meredith district of Victoria, Australia, has caused gullying, replacement of pasture with salt-tolerant weeds, and dieback of native trees.

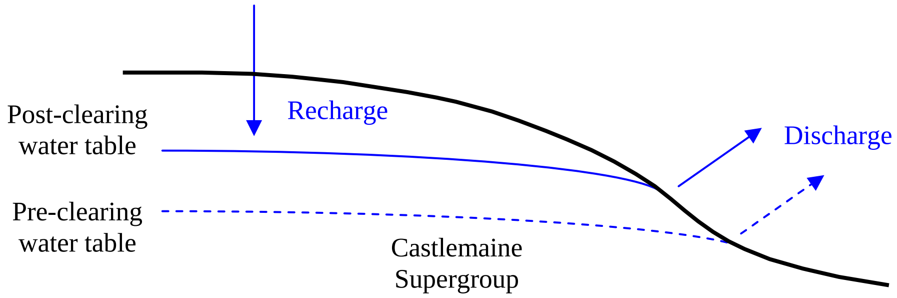


Figure 2 Kamarooka recharge-discharge model (after Jenkin & Dyson 1983). According to the Kamarooka model, the clearing of phreatophytic vegetation (deep-rooted perennial trees) reduces rainwater interception and usage and increases vertical recharge through fractures in deeply weathered Ordovician sedimentary bedrock. This recharge occurs mainly on upper slopes and rocky ridges where soils are thin and dense subsoils are poorly developed. The additional recharge causes the water table to rise, which in turn creates additional discharge of saline groundwater while the discharge of perched water remains insignificant. Based on their model, Jenkin & Dyson (1983) suggested that the most practical salinity remediation is to incorporate tree planting on the upper slopes and rocky ridges where agricultural production is low and recharge is relatively high.

During infiltration through subsoil fractures, water diffuses into their walls causing soil-matrix saturation, soil swelling, macropore contraction and an associated reduction in hydraulic conductivity, which in turn promotes perching and interflow within the sloping topsoil and confinement of the underlying aquifer. The higher matrix hydraulic conductivity of deeper, initially wetter subsoil with narrower interpedal fractures enables more rapid swelling and macropore closure and, thus, has the greatest influence on the initial development and decreasing depth of perching within the shallow subsoil. Macropore flow rates are also very dynamic due to mechanical illuviation and, to a limited extent, entrapped air. The hydraulic conductivity of an individual redoximorphic subsystem can therefore vary by several orders of magnitude.

Soil moisture content, which influences the distribution of macropores associated with bioturbation and desiccation, varies seasonally. Both soil moisture content and soil swelling capacity vary with hillslope position. Thus, the hydraulic conductivity of the solum at any given hillslope position may vary considerably from low to high and at different times and rates relative to that at other hillslope positions. The distribution of water in the regolith is further complicated by cumulative interflow and by variations in texture and structure of the saprolite and lower subsoil. In particular, remnant bedrock cleavage, joints and quartz veins may be present and variably preserved or absent. Localised weather-resistant low-permeability saprolite or saprock may outcrop or occur immediately below the land surface, typically parallel to topographic contours, and act as a barrier to throughflow, promoting return flow. The distribution of these saprolite features is variable at a toposequence scale. Therefore, hillslope hydrological test results cannot be extrapolated to other sites, even within the same catchment.

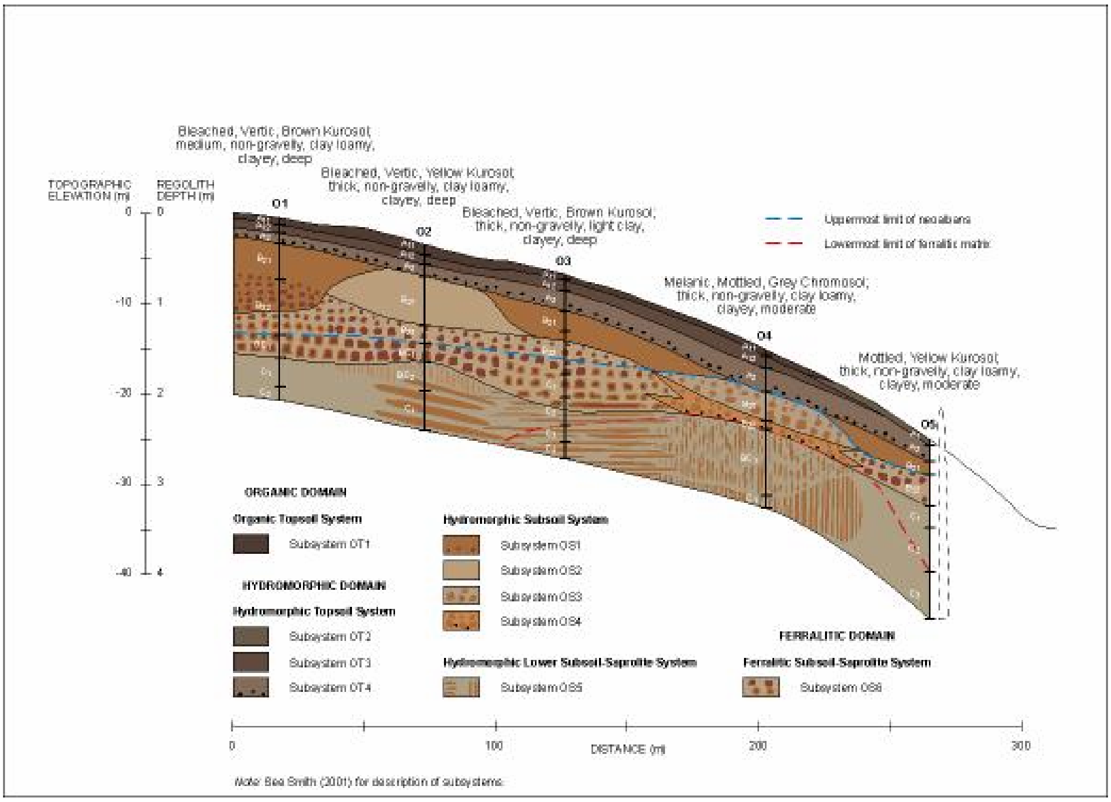


Figure 3: Contemporary redoximorphic systems of the Castlemaine Group.

Moorabool Viaduct Sand

Water infiltrates the solum via topsoil-matrix flow, vertical earthworm channels and, where adjacent to native forest, near-vertical ant channels and live or dead and rotted roots, which are horizontal within the subsoil. However, channel flow is only temporary since channels are rapidly plugged with illuviated topsoil at shallower depths and topsoil or subsoil-argillans at greater depths. Lower rates of preferential flow continue in the subsoil through sandy pedotubules. In addition, under dry antecedent conditions, water infiltrates the uppermost subsoil via narrow vertical fractures within the more clayey ped interiors. The vertical fractures terminate where they intersect laterally continuous desiccation fractures that have developed within subhorizontal clay lamellae, which are generally present in the upper portions of the immediately underlying subsoil. These fractures promote lateral water flow. Discontinuous subhorizontal petroplinthic segregations and perhaps even the continuous bands of preserved ferralitic matrix (tiger mottles), both between these fractures, also assist lateral flow. Macropore flow is generally unsaturated, infrequent and/or of short duration throughout most of the toposequence. Evidence for this includes the only limited development of neoalbans adjacent to macropores, the high proportion of relict ferralitic matrix and the preservation of its morphology in slakable highly permeable regolith. In addition, the bulk of the subsoil matrix, apart from that of the deeper subsoil at the footslope, is rarely, if ever, subjected to long-duration reducing conditions as indicated by the general absence of matrix bleaching.

Subsequent to matrix infiltration and the associated swelling of argillaceous ped linings and clay lamellae, the resultant fracture closure promotes perching and interflow above the subsoil, even though the hydraulic conductivity of the subsoil matrix remains high, the latter suggesting that complete macropore closure is necessary before perching can take place. Cumulative interflow results in prolonged seasonal saturation of the topsoil and upper subsoil at the footslope. This has led to (1) the development of a fragipan with a medium hydraulic conductivity and (2) a decrease in the hydraulic conductivity of the overlying deeper topsoil to a medium value primarily by self-weight collapse and the precipitation of iron-masses. Together, these effects enhance perching and interflow. Interflow is probably also assisted by the presence of a vertical gully face.

Regolith beneath the solum at the footslope undergoes prolonged saturation by non-saline groundwater perched above the saprolite of the Castlemaine Group and accumulated via throughflow, which is probably assisted at the footslope by the existing horizontal slabby ferricrete. A portion of the throughflow water possibly infiltrates the underlying saprolite to recharge the deeper aquifer.

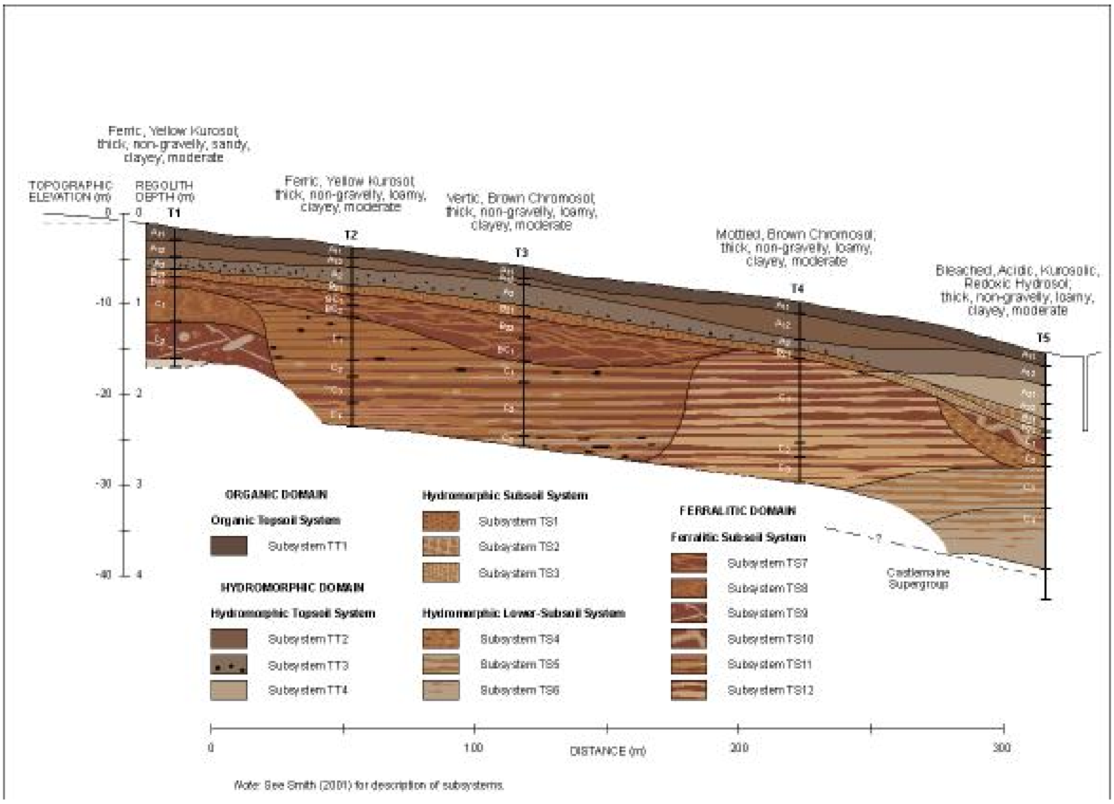


Figure 4: Contemporary redoximorphic systems of the Moorabool Viaduct Sand.

Newer Volcanics

Under relatively dry antecedent conditions water rapidly infiltrates the topsoil and then wide empty or topsoil-lined vertically extensive interpedal fractures and narrower discontinuous horizontal interpedal fractures of the uppermost subsoil. Rapid infiltration through the solum is also assisted by earthworm-, ant- and beetle-channels. The vertical fractures between compound peds narrow with depth due to higher antecedent soil moisture content and associated clay swelling, but may continue into the R_1 horizon between interlocking corestones where they have thick argillan linings. Rapid vertical infiltration continues through these fractures in shallower subsoils where hydraulic conductivities are still high. Once in the fractured rock aquifer of the Newer Volcanics throughflow may occur, but at only extremely low rates where slope gradients are low.

Interpedal fractures in deep subsoil are very narrow or have closed under high antecedent moisture conditions, causing internal catchment of infiltrated water within the upper portion of the profile. Interflow is largely inhibited by the low slope gradient. During infiltration, water within macropores infiltrates the adjacent soil matrix, particularly where topsoil linings are present and, at depth, where antecedent moisture content is greater, causing very rapid swelling, macropore contraction and closure. Longer-duration deep infiltration can therefore occur only where subsoil is thin or absent.

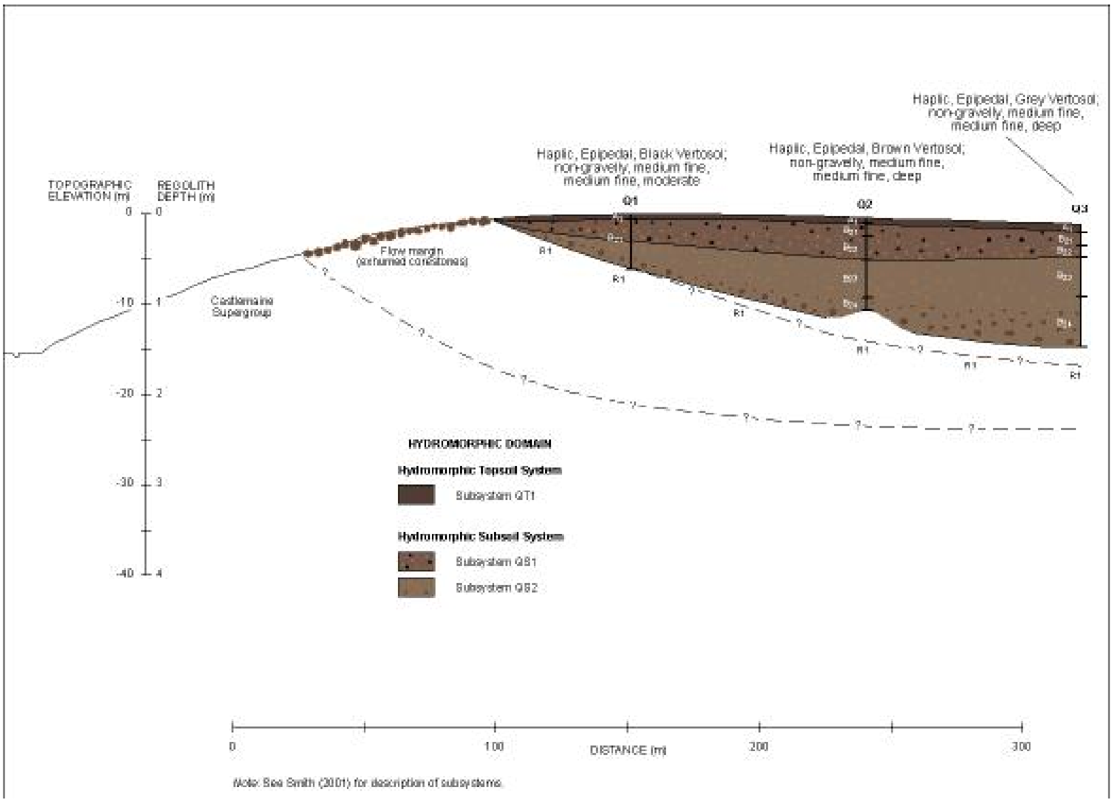


Figure 5: Contemporary redoximorphic systems of the Newer Volcanics.

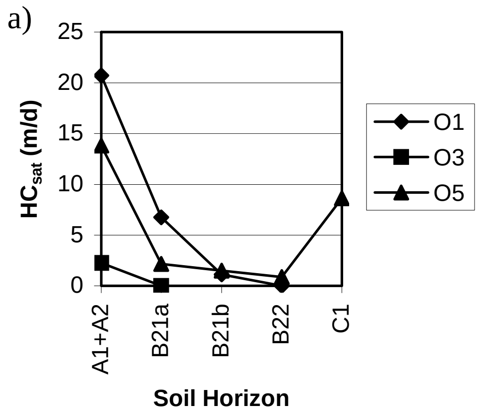
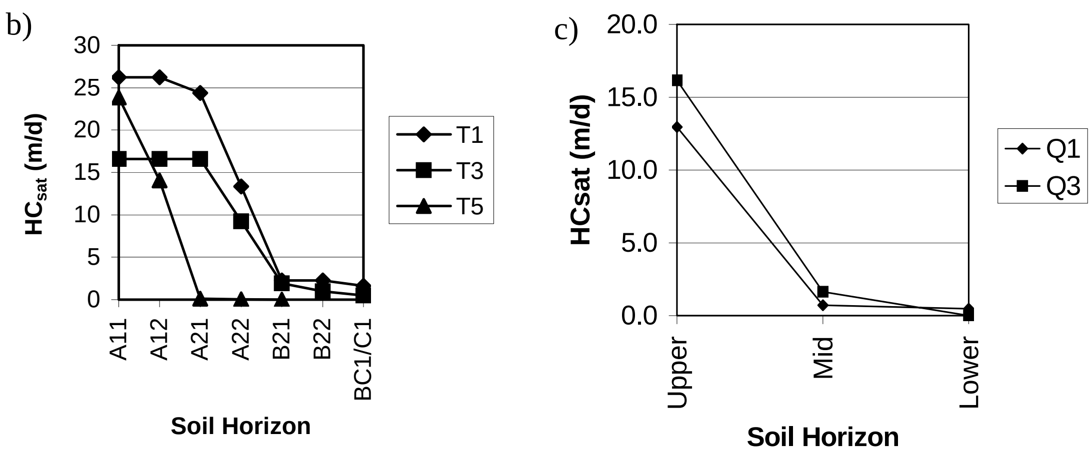


Figure 6: Vertical saturated hydraulic conductivity of various soil horizons in each of the examined toposequences: a) Castlemaine Group, b) Moorabool Viaduct Sand, c) Newer Volcanics.



CONCLUSIONS

In the Bamganie-Meredith district, waterlogging and the spreading of surface-soil salt, derived from localised discharge of baseflow from the Castlemaine Group, are promoted to some degree by fresh water as:

- interflow through the topsoil and, depending on antecedent moisture content, uppermost subsoil of the Castlemaine Group;
- interflow through the topsoil, uppermost subsoil and the argic and tiger-mottled horizons of the Moorabool Viaduct Sand; and,
- discharged baseflow from above the lithological boundary between the Castlemaine Group and the overlying Moorabool Viaduct Sand.

The predominance of interflow, throughflow or recharge is primarily a function of the seasonally variable antecedent soil moisture content and, hence, macropore characteristics. Interflow and/or throughflow may have increased following the clearance of native vegetation from the landscape, but were also prominent prior to clearing. The influence of land clearance on recharge into the deep aquifer of the Castlemaine Group in the Bamganie-Meredith district has yet to be established.

Subsoil and saprolite of the Castlemaine Group have saturated hydraulic conductivities that can vary irregularly with hillslope position. Furthermore, shallow/outcropping saprock at various positions in the landscape promotes return flow. Hillslope hydrology of the Castlemaine Group is therefore liable to vary considerably on different hillslopes even within the same district.

The above conclusions challenge the Kamarooka recharge-discharge model of Jenkin & Dyson (1983), previously used as a basis for saline-land management strategies throughout central and western Victoria. This study has shown that the regolith-hydrological processes of dryland salinisation are primarily influenced by pedological processes and regolith (including soil) development, the latter in turn being influenced by the unique geology and landscape evolution of each site. Furthermore, waterlogging, interflow and throughflow are widespread throughout much of southwestern Victoria and are significant contributors to the spread of salt through various, uniquely derived regolith.

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Acknowledgement: This presentation is based on a project that was enabled through the interest and assistance of the Bamganie-Meredith Landcare group.