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Predicting salinity hazards in Australia: value-adding to Groundwater Flow Systems frameworks in light of advances in regolith geoscience

K. C. Lawrie, J. Coram, P. Please, **J. Clarke**, D. Gibson, J. Wilford and C. Pain

Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME), c/o Geoscience Australia, Canberra, ACT 2601, Australia. ken.lawrie@ga.gov.au

In Australia, the geological/geomorphological characterization of catchments relies mainly on the use of soil, surface landform (from regolith landform maps and digital elevation models), and surface geology maps. Constructs, such as the Groundwater Flow System (GFS) Map of Australia, and similar constructs at regional and catchment scales, rely on this approach to identify and map hydrogeomorphic units with similar geomorphological and hydrogeological characteristics (Coram *et al*., 2000). These constructs provide a useful basis for understanding groundwater flow systems that influence the recharge, transmission and discharge of groundwater involved in dryland salinity, and are a useful starting basis for large-scale salinity management planning and prioritization purposes (Coram *et al*., 2000).

Unfortunately, the existing GFS frameworks are generally not adequate to underpin salinity management at sub-catchment scales. This has been due in large measure to the absence of 3-D data that is required to characterize the structural and hydraulic properties of sub-surface materials at the appropriate scales (Lawrie *et al*., 2002, 2003). However, over the last five years in particular, multi-disciplinary studies have provided new insights into regolith architecture, salt stores and the groundwaters that mobilize these salts in the sub-surface (Lawrie *et al*., 2000, 2002, 2003, 2004; Munday, 2004). These data are now being used to value-add to existing GFS frameworks.

Value-adding to GFS maps in upland landscapes

Bedrock influences tend to be greatest in upland (erosional) landscapes due to a thinner regolith veneer and the influence of fractured rock aquifers and near-surface constrictions in groundwater flow due to bedrock highs, faults, dykes, as well as lithology variations (Lawrie *et al*., 2004). In many of these landscapes, large-scale variability in bedrock textures and compositions (reflected in saprolith hydraulic properties), and structural geological information that is potentially of importance to groundwater flow, is not recorded on published maps of bedrock geology (Lawrie *et al*., 2002). A methodology has been developed to incorporate value-added mineral system data for groundwater and salinity studies in both depositional (Lawrie *et al.*, 2000) and erosional landscapes (Lawrie *et al*., 2004).

Also, it has been demonstrated that surface maps of soils and topography commonly used in GFS frameworks may not be a good guide for predicting sub-surface salt, and groundwater distribution and movement in upland landscape, particularly at sub-catchment scales (Lawrie *et al.*, 2004; Wilford, 2004). This is on account of significant landscape disequilibrium, where a long history of erosion and deposition results in the development of out-of-phase landscapes. This is particularly true in areas with a protracted landscape history and/or in areas where tectonic and volcanic activity has influenced landscape development. Landscape disequilibrium appears to be a common situation in Eastern and Southern Australia, where valley-fill sediments are preserved in erosional landscapes, and vice-versa. One consequence of this is a poor reliability in the use of present day landforms and models based on the use of digital elevation models (DEMs) and terrain indices to predict sub-surface regolith landscapes, salt stores and groundwater movements (Lawrie *et al*., 2004).

Hence, in upland landscapes, a value-added approach to GFS that incorporates updated bedrock mineral system and regolith information is recommended to support targeted salinity management intervention, particularly at sub-catchment and/or farm scales. Importantly, a new approach for mapping salt stores and GFS down to sub-catchment scales has been demonstrated (Lawrie *et al*., 2004). This methodology can be applied both to present day depositional and erosional landscapes.

Value-adding to GFS maps in depositional landscapes

Groundwaters within depositional landscapes are commonly mobilized along preferential pathways often determined by primary variations in sediment facies and/or changes in hydraulic conductivity wrought by overprinting weathering (Lawrie *et al*., 2000, 2002; Fitzpatrick *et al*., 2004; Munday, 2004). In these landscapes, including upland valleys where erosional landscapes may be buried by sedimentation, surface geomorphic processes will differ markedly from those associated with now-buried landscapes. In Australia’s subdued landscapes, the nature of sedimentary fill defines the response time of groundwater flow within a GFS. Hence significant value-adding to GFS frameworks can be achieved through incorporating information on landscape evolution, regolith architecture and sediment infill, and weathering and erosion distribution and processes. The ability to map and predict these properties in the sub-surface aids predictive models of groundwater and salt mobility (Lawrie *et al*., 2004).

The critical attributes required for assisting salinity management in the regional depositional systems are (1) the connectivity of aquifers in different salt-water systems; (2) the existence and extent of by-pass flow (vertical and lateral); (3) the size of the salt store and its potential for mobilization; (4) the 3-D nature of the regolith (and adequate algorithms and models to depict this); (5) the need for a dynamic water balance (Lawrie *et al*., 2003). In these landscapes, only geophysical techniques (e.g. airborne electromagnetics) can provide information on the spatial distribution of regolith materials and groundwaters (Spies & Woodgate, 2004).

Conclusions

A value-added approach has the potential to address these issues both by determining the degree to which nested smaller GFS systems exist (Fitzpatrick *et al.*, 2004), and by developing an understanding of the nature of the regolith landscape materials in terms of water fluxes and plant growth parameters. This approach has led to a demonstrated capacity to provide new salinity management options even in intermediate and regional flow systems (Fitzpatrick *et al*., 2004; Munday, 2004).

The Groundwater Flow Systems GFS approach has enabled broad dissemination of specialist knowledge, highlighted diversity of processes and therefore management requirements, and has been very widely adopted within Australia as a conceptual framework for dryland salinity decision making, particularly at catchment scales. Its continued use and development as a decision platform to assist planning and prioritisation for salinity and groundwater management is encouraged, and its role indeed expanded to support a broader range of NRM issues. Significant value-adding to GFS frameworks can be achieved in all landscapes by incorporating information on regolith architecture and composition, salt store data, and up-dated bedrock mineral systems data (high resolution airborne geophysics, structural geology and mineral systems interpretations of bedrock geology).

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