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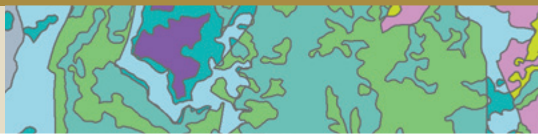
Hydrogeological-Landscapes system: a framework for managing water resources



National datasets support natural resource management

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An understanding of hydrological processes is vital when addressing issues such as water availability, water quality and ecological management, particularly when groundwater-dependent ecosystems are involved. Consideration of water sustainability within the context of climate change, population growth and socio-economic development requires holistic and more sophisticated water management approaches. It is against this background that a Hydrogeological-Landscape framework for more effective management of natural resources has been developed. The framework is used to divide the landscape into areas that have similar hydrological characteristics. The use of the term *Hydrogeological* highlights the importance of geology to hydrologic processes, whereas the use of the term *Landscape* highlights the importance of landforms and regolith (or the weathered material above bedrock).

The Hydrogeological-Landscape framework concept

The Hydrogeological-Landscape framework (HGL) builds on the groundwater flow system (Coram 1998; Walker et al 2003) framework that was developed approximately 10 years ago–primarily to assist in the management of groundwater salinity. The Hydrogeological-Landscape framework is a broad, all encompassing entity which accommodates all forms of water flow (surface, inter-flow and groundwater flow). Hydrogeological-Landscape Units (HGLU) integrate information on lithology, bedrock structure, regolith (including soils), landforms, climate (including rainfall, seasonality, evaporation) and vegetation (figure 1). These components all influence, to greater or lesser degrees, the recharge, transmission, storage and discharge characteristics of a particular hydrological system. The HGL concept has been developed for upland erosional landscapes (such as where hill slopes have a major control on water movement) as documented here; however, it also has the potential to be applied to depositional settings.

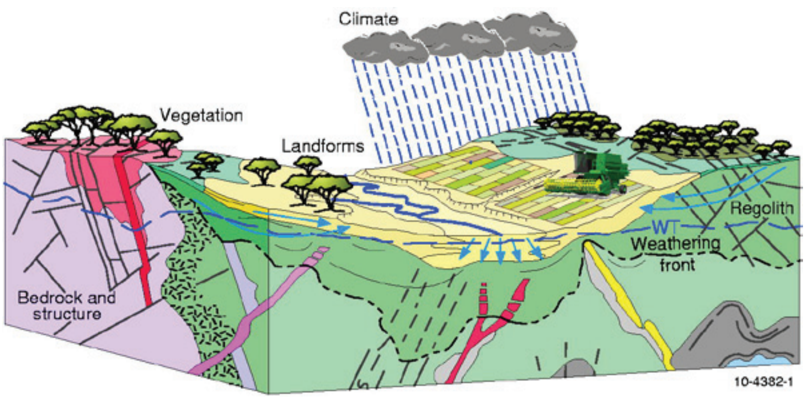

Figure 1. Factors influencing surface and groundwater movement and storage.

Hydrogeological-Landscape frameworks are compiled over a range of spatial scales ranging from landscape facets that may describe, for example, local changes along a hill slope through to regional systems spanning hundreds of kilometres. This multi-scale approach addresses the fact that both hydrologic systems and management strategies are intrinsically linked across different scales. For example, most local flow systems are nested within larger ones and most local land management strategies ideally need to be integrated into regional programs and goals. Different datasets or criteria are used in defining the HGL units across these different spatial scales. At the broadest scale major bedrock types, structural and architectural elements (such as a flat lying sedimentary unit or a fractured granite), landform and climatic characteristics are used. Whereas

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at local scales regolith/soil type and thickness, morphology (hill slope: steepness, curvature and length) and lithostructure (for example, lithologies, fabrics and structures) are used. The latter components assert local controls on water movement and storage and, therefore, provide spatially-explicit information on hydrological processes to support farm-scale management strategies.

Key elements of the framework

Some of the key elements in building a HGL framework included bedrock type, regolith and landform. Geological attributes are derived from state and national scale geological maps (*AusGeo News 93*), whereas regolith and landform components are derived mainly from modelling of gamma-ray radioelement imagery and digital terrain analysis. Emissions of gamma-rays from Earth's surface will largely reflect the geochemistry of bedrock as well as weathering processes and regolith materials. The gamma-ray imagery together with terrain relief has been used to predict the degree to which the landscape has been weathered (Wilford 2010). This approach enables delineation of regolith and bedrock-controlled hydrological systems which typically have very different porosity and permeability characteristics (figure 2). The gamma-ray data uses the new radioelement map of Australia (*AusGeo News 92*) which enables quantitative assessment of the distribution of potassium, equivalent thorium and equivalent uranium in exposed bedrock and regolith.

Landforms, slope facets, valley constrictions and seepage zones are derived from a range of digital terrain process techniques including topographic wetness index (TWI), the UPNESS index from the Fuzzy Landscape Analysis Geographic Information System (FLAG) model (Summerell et al 2005) and a multi-resolution index of valley bottom flatness (MRVBF: Gallant & Dowling 2003).

Central West Catchment HGL map

The Hydrogeological-Landscape map of the Central West Catchment in New South Wales (figure 3) illustrates how this new framework is providing key baseline information for managing water quality in the catchment. The Central West Catchment, which is about 1.5 million hectares in area, is a north-west draining subdivision of the Darling River system and includes the Macquarie and Lachlan rivers. The region falls within the jurisdiction of the Central West Catchment Management Authority which provided financial support for the HGL mapping in the catchment.

Hydrological characteristics within the Central West Catchment are highly variable, reflecting a diversity of climate, geology, vegetation, landform and regolith. The development of the regolith in the catchment varies greatly and typifies many erosional landscapes in Australia where older and more recent landscapes are juxtaposed. Some of the thickest regolith in the catchment is associated with partially preserved palaeo-surfaces that reflect weathering during the Tertiary or older. The palaeo-surfaces are mainly preserved along the south, south-west catchment divide (around Molong, Orange), and in lower parts of the catchment where the rates of erosion are relatively low (around Dubbo and lower reaches of the Cudegong River). Many of these deeply weathered landscapes are associated with sluggish groundwater flow systems, waterlogging and salt scalding.

This HGL map delineates areas with similar hydrological characteristics across different landscape scales. The multi-scaled structure of the HGL framework allows for a broad assessment of recharge, discharge and water quality characteristics over the whole catchment, as well as targeting specific sub-catchments for on-ground actions (for example, targeting high salt producing sub-catchments). Each HGL unit is linked to a conceptual hydrological cross-section which describes surface, inter-flow and groundwater flow characteristics, as well

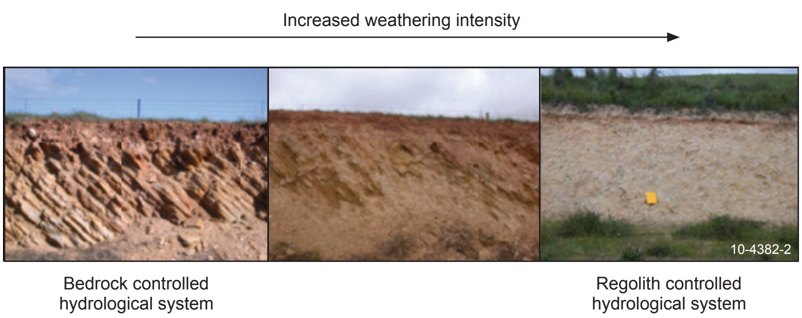

Figure 2. Transition from bedrock to regolith-controlled hydrological systems with increasing weathering intensity from fractured bedrock (left) to residual clay (right).

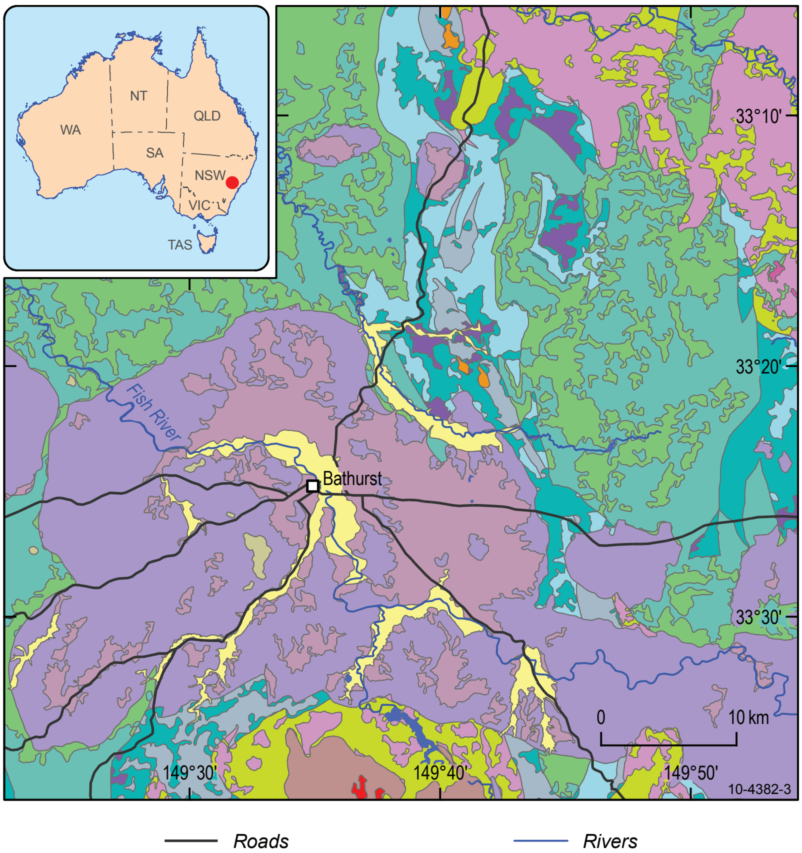

Figure 3. Part of the Central West Catchment Hydrogeological-Landscape (HGL) map. The colours represent areas with similar recharge,transmission, storage and discharge characteristics.

as management approaches for specific parts of the landscape. Such options might include the location of interception plantings to control recharge for salinity management. The HGL framework can be used to support a range of land use, remedial re-vegetation intervention and engineering strategies for salinity management or other natural resource management activities. The combination of climatic attributes, weathering intensity and geology within the HGL framework enables predictions of salt storage and export within different parts of the catchment. The HGL approach also has applications in the urban environment where it can be used to better understand salinity processes effecting infrastructure and water quality.

Although the HGL concept has mainly been used for addressing land and water quality associated with salinity to date, the framework was originally developed to assist with a broad range of natural resource management issues. The New South Wales Department of Environment, Climate Change and Water is currently using or assessing the HGL approach for a number of different natural resource management applications including assessment of:

- soil degradation–sodicity, acidity, acid sulphate soils, and soil erosion
- soil carbon
- surface and groundwater interaction in the landscape
- biodiversity and vegetation
- landscape processes with non-floodplain wetlands such as hanging swamps.

The HGL approach is currently being assessed for application in other catchments in New South Wales and has the potential to be developed as a national framework.

For more information

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