A model of versatility

Management options for lowering groundwater tables and making productive use of saline land have been tossed about by scientists, governments and landholders for decades. Technical reports by the hundred, perhaps thousand, chronicle countless means of manipulating water and soils.

The ability of landholders to select wisely from these options, however, is limited by a lack of knowledge about how catchments work on a regional scale.

Three years ago, a team of Canberra-based scientists, led by Ray Evans from the Australian Geological Survey Organisation, (AGSO) began narrowing this information gap. They recognised that to understand groundwater processes in catchments of a million hectares or more, relatively simple modelling approaches based on widely-available information were needed. Existing data-intensive models worked well at a local scale, but became unwieldy when scaled up.

'In the world of biophysical modelling, data quality and availability at a regional scale is a problem,' CSIRO Land and Water hydrogeologist, Dr Mirko Stauffacher, says.

'A lot of existing models are very powerful, and can simulate all kinds of interactions between groundwater, soil, surface water, vegetation and the atmosphere.

'They're supposedly versatile models applicable anywhere, but in most larger catchments the data to drive them is not available, so "best guesses" would need to be used, limiting their credibility.

'In this project we're taking a different path: a "top-down" approach in which we look at the dominant catchment-scale groundwater-related salinisation processes, relying where possible on readily-available data, local knowledge and previous studies.'

Using this information, the team develops a conceptual model for a given catchment. Conceptual models are simplified versions of the real thing. They form the basis of numerical models in which major processes linking land use, groundwater and salinity are described mathematically, enabling management strategies to be simulated and compared.

Finally, a simple predictive modelling approach is developed. This must reliably predict factors such as the impact on groundwater balance of different landcovers in different parts of the catchment. With this information, areas of the catchment can be targetted for remediation.

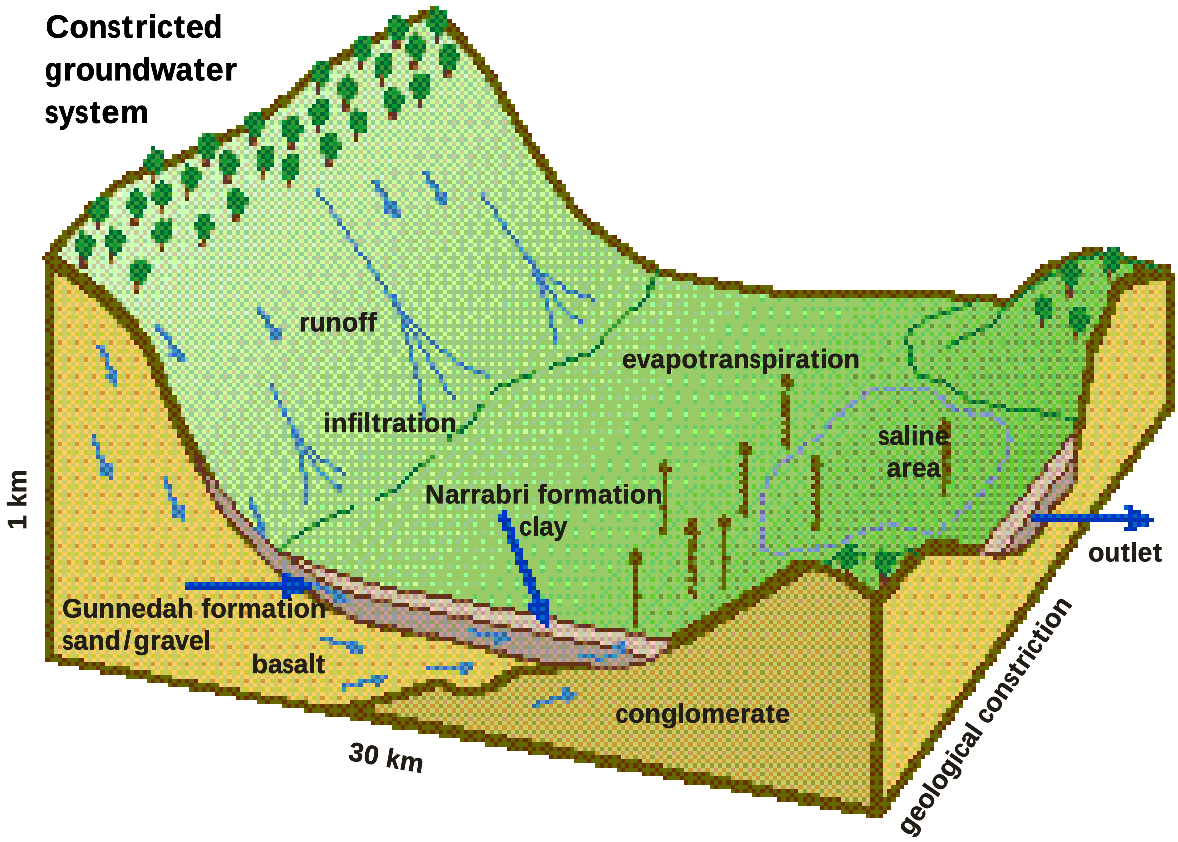
An area in need of such attention was the Liverpool Plains in northern New South Wales. Salinity emerged on the Liverpool Plains in the early 1980s and hydrogeological investigations since then have indicated some 10% of the arable land is underlain by shallow salty watertables (about 2 m below ground level).

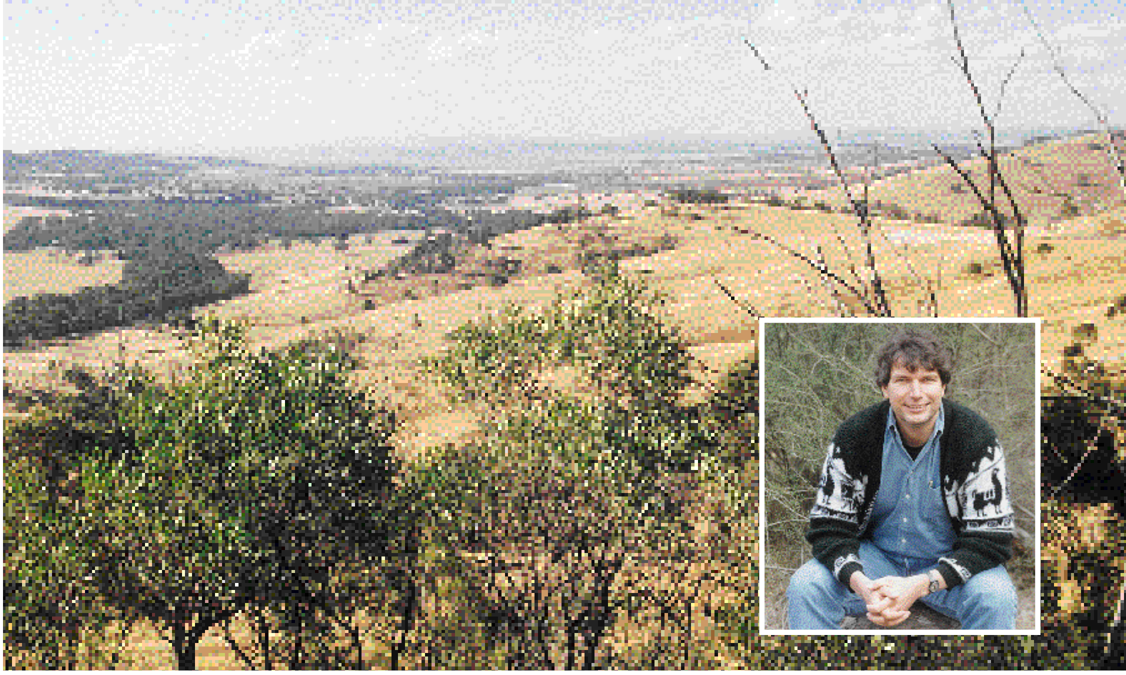
Landholders on the Liverpool Plains, are aware of the need to reassess land-management practices. But until the factors causing salt to appear in their paddocks are understood, change is a risky business, involving heavy investment in strategies of dubious worth.

Through the Liverpool Plains Land Management Committee, landholders have lent their support to the AGSO modelling project, which will culminate next year with the release of catchment-scale recommendations for salinity control.

Information for the Liverpool Plains conceptual model was drawn from reports by the New South Wales Department of Land and Water Resources, fieldwork by CSIRO Land and Water, and discussions with other scientists and landholders. It showed the Liverpool Plains to be made up of five almost-independent sub-catchments or groundwater systems, each defined by bedrock barriers through which groundwater water scarcely escapes.

Of these five sub-catchments, two are at greatest risk of salinisation: Pine Ridge and Lake Goran. A closer look at the Pine Ridge





sub-catchment highlights the importance of understanding all the ins and outs of a regional groundwater system before tackling salinity control.

Groundwater moves through the Pine Ridge sub-catchment in two, clearly defined aquifers. Underneath, rising to 50 to 80 m below ground level, is the Gunnedah aquifer, a deep layer of permeable gravels and sand. Above this is the Narrabri aquifer, made of dense clays, fine sands and silts of low permeability (see diagram).

Water enters these aquifers in two ways: as localised recharge and as diffuse recharge. Localised recharge occurs when surface and sub-surface water from the hills and ranges (runoff and interflow) infiltrates through exposed alluvial streambeds which fan out on the lower hillslopes.

Most of the localised recharge happens during summer storms, where ephemeral creeks lose part of their water in the alluvial fans. Diffuse recharge is the water that percolates down beneath the roots of plants on the plains.

After passing through the alluvial streambeds, the runoff-interflow waters enter the almost-saturated Gunnedah aquifer. Because of this saturation, water entering the Gunnedah aquifer exerts sufficient pressure to force an equivalent amount to exit at its lower end.

At this point, however, the system hiccups. Because the groundwater outlets are constricted by bedrock highs, the groundwater cannot exit fast enough to relieve the pressure. It has nowhere to go but up, into the less permeable clays of the overlying Narrabri aquifer. In this way, the depth of the shallow watertable at Pine Ridge, and consequently its discharge to the surface, are controlled by pressure in the Gunnedah aquifer.

This process has been occurring for hundreds of thousands of years, causing groundwaters to rise and fall in accordance with natural climatic cycles. The entry of greater volumes of water into the Gunnedah aquifer has simply accelerated the process.

Historically, this surplus would often have discharged to the surface, and either evaporated or transpired, leaving salts behind. This store of salts is again being mobilised by the shallow Narrabri watertable, which has electrical conductivity values of up to 35 (dS/m). In contrast, water in the deeper Gunnedah aquifer is uniformly fresh (less than 2 dS/m).

Having developed a conceptual model of the Pine Ridge sub-catchment, the next step for Evans and his team was to give numerical values to the groundwater processes they had identified. This meant determining the amount of runoff-interflow coming from the ranges and hills.

Given that the highlands receive a higher annual rainfall and cover twice as much area as the plains, a large amount of runoff-interflow is generated. Therefore localised recharge is thought to dominate diffuse recharge.

This knowledge supports a belief that clearing of native vegetation on the hills and ranges is largely to blame for rising groundwater pressures. If this is true, replacement of trees might be the key to reversing this trend.

Estimates of diffuse recharge were drawn from the output of three established models. They revealed an average diffuse recharge of 20 millimetres a year across the black soil plains.

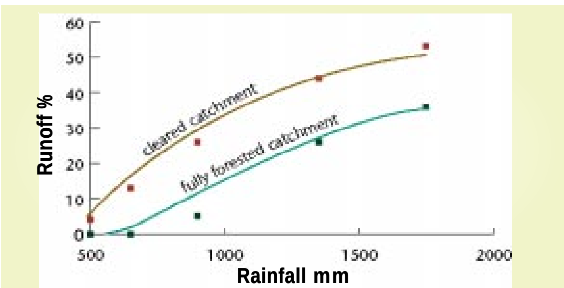
To estimate runoff-interflow recharge, the team borrowed from the work of South Australian researchers JW Holmes and JA Sinclair. During the 1980s, Holmes and Sinclair studied several Victorian catchments, coming up with transferable relationships between rainfall, forest cover and evapotranspiration (see graphs).

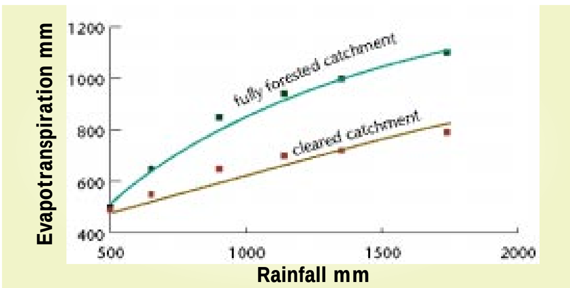
Calculations using the Holmes and Sinclair relationships showed that the runoff-interflow from the ranges and hills is huge and would potentially play an important role in the overall groundwater recharge process. Before land-use recommendations can be made, however, the team has to determine how much runoff-interflow actually recharges the aquifer. This is being done by setting the groundwater model in motion.

When the modelling phase is completed later this year,

Runoff from the Liverpool Plains hills and ranges contributes to watertable rises lower down in the catchment.

Research by Dr Mirko Stauffacher and his colleagues is characterising and quantifying salt and water movements in the catchment, so that the hydrological impact of various landcovers can be predicted. Areas can then be targeted for remediation.





Established relationships between rainfall, forest cover and evapotranspiration were used to calculate runoff from the Liverpool hills and ranges.