



## EXECUTIVE SUMMARY

The clear definition and quantification of the sources and pathways of components of discharge making up stream flow is becoming increasingly important. Indeed the implementation of the National Water Act (1998) requires an understanding and quantification of dominant hydrological processes in order to faithfully manage water resources. This understanding is particularly important in quantifying low flows and the sources thereof; in assessing the impacts of land use change; in quantifying the hydrological perturbations resulting from climate change and in assessing impacts of non-point source pollution, especially where the source of the impact is to be identified.

The aims of this project were therefore to:

- Define key hydrological processes at a range of scales by observation and experimentation at these scales in order to
- Improve deterministic, physically based simulation tools and in particular, the *ACRU* agrohydrological model to represent these processes at a range of scales, so that
- Land use changes, stream flow reduction activities (SFRAs), surface and groundwater interactions and topological runoff generating mechanisms are linked conceptually and spatially to the responses at each scale.

A fruitful study of the source areas, flow pathways and residence time of water in the Weatherley research catchment has been concluded. The key outcome of the research has been the application and combination of a number of different tools and observation techniques, applied to the same area, which has led to a better and more comprehensive understanding of the hydrological processes which underpin the water resource impacts. Hydrodynamics observations, geophysics surveys and tracer methods have been combined to yield a consistent understanding of the catchment water yield mechanisms, despite the limitation of each method used independently.

Specific response dynamics resulting from the combinations of techniques in the catchment are:

- **Overland flow.** Overland flow discharge which reaches a surface water carrying conduit (stream or seepage line) during rainfall events is restricted to areas adjacent to these conduits. This observation has been made through runoff plot analyses,

where, even in an intense event of 31.4 mm in 20 minutes, overland flow distances were estimated to be no more than 30 m. Simulations of the hillslope water balance using the HYDRUS-2D model result in very small contributions from overland flow. However, this analysis was aimed more at the low flow discharge from the soil catena than event based discharge. The contribution to event based runoff from overland flow is clearly dependant on the antecedent moisture content as demonstrated in the rainfall-runoff analyses. In addition, the tracer based, three component hydrograph separation, using EC and Si as tracers, suggests that the direct contribution to event based stream flow from the event rainfall ranges between 14% and 26% of the event discharge.

- **Near surface soil water.** Observations in shallow tensiometers and free water collection tubes have demonstrated the existence of a rapid response, near surface discharge during rainfall events. These zones of near surface, lateral flow have been identified by hydrogeological investigations and have been estimated by tracer aided separation techniques to yield up to 16% of event discharge.
- **Hillslope groundwater water.** Soil water accumulation on the interface of the soil and bedrock has been observed through groundwater observations holes and tensiometer responses. These accumulations generally occur on the hillslopes upslope of parent rock outcrops. During a series of event flows, this source of water has been estimated to yield 70% of the total discharge (EC and Si tracer based hydrograph separation). Using lumped isotope sample end member mixing analysis, this hillslope contribution to flows is estimated at 60% of the stream discharge during the wet season. During the dry season, the soil profile continues to generate stream flow well into the middle of the winter. Discharges estimated from the HYDRUS-2D analyses of measured soil water potentials ranges from 10% to 4% of total flow, slowing down to negligible flows by the end of June. Stream flow discharge during the low flow periods also emanates from the emergence of fractured bedrock flows re-entering the hillslope profiles as is evident from Electrical Resistivity Tomography surveys.
- **Fractured rock groundwater.** The existence of groundwater in the bedrock underlying the hillslopes and valley is evident through deep borehole observations as well as Electrical Resistivity Tomography surveys. It is clear that some proportion of this deep

aquifer water contributes to the event flows, but, without tracer samples from these deep sources, the proportion cannot be estimated. It is also evident that, during the dry season, water percolating through the fractured rock contributes to low flow via two mechanisms. First, bedrock groundwater emerges at parent material outcrops on the hillslopes and contributes to hillslope soil water in the downslope profiles. Second, water enters the valley soil profiles from the bedrock below in response to upslope gradients. During the dry season the seepage water, spilling over the outcrops is estimated to contribute 32% and the subsurface seepage 68% of the winter flows as late as August.

A model algorithm, comprising threshold based subsurface responses and catena based linking has been proposed as a direct emulation of observed stream flow generation dynamics. Future hydrological model performance would be enhanced by including functions which represent the travel times of the different components of flow which could be observed by continuous observations of the combination of techniques applied in this study.

The implications of properly simulating the different components of stream flow should not be overlooked in assessing land use change, climate change, low flow and water quality impacts. Future investigations, using the combination of techniques introduced in this study can be usefully applied in other geologies, soil catenas and climate zones to begin a classification system of typical response dynamics of these hydrological zones.