Exploring Mechanisms of Salt Delivery to Stream within the Kyeamba Valley Catchment New South Wales Australia

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Abstract: Dryland salinity is a major environmental issue in much of Australia's agricultural lands. Salts can move out of catchments via groundwater movement, interflow and surface flow processes. This paper will focus on the surface and near surface fast draining interflow systems (termed "quickflow") found within a depositional environment of the catchment where the accumulation and storage of salts appears to be occurring. This study focuses on the Kyeamba catchment in New South Wales Australia. The depositional areas of the Kyeamba catchment were derived from the UPNESS index in a GIS based Fuzzy Landscape Analysis model, (FLAG). The UPNESS index was calibrated against the seasonally wet to waterlogged saline to sodic soils as mapped in the draft 1:25 000 soil landscape maps of Kyeamba. Rapid stream Electrical Conductivity (EC) and flow surveys determined that an in-filled valley system (alluvial landform) of approximately 9 km^2 in the O'Briens Creek catchment, a major tributary of the Kyeamba Creek was playing an important role in salt delivery. Results showed that during a base flow sequence the EC increased to 1200 from 600 µS/cm after passing a bedrock constriction within the in-filled valley system. The bedrock constriction was the most likely location where near surface groundwaters within the in-filled valley system would discharge back into the creek system during wet conditions and/or concentrate salts in the soil profile during dry periods. About 1 km downstream the EC restabilised to 800 µS/cm as flows gradually increased to about 0.5 ML/day from 0.1 ML/day. Another 4 kms further downstream near the junction of O'Briens and Kyeamba Creeks the flow sharply increased to approximately 2 ML/day at an EC of 1800 µS/cm. The sharp increase in flow was attributed to the interception of the creek with a groundwater system. The groundwater interception site was providing the main source of salt load to O'Briens Creek under base flow conditions. However, after approximately 25mm of rainfall, this groundwater dominated trend in salt load delivery appeared to reverse. The area around the in-filled valley system began to discharge saline water at 2000 µS/cm while further downstream at the presumed groundwater interception site the EC was being reduced to 800 µS/cm. It is proposed that the in-filled valley system is acting as a near surface salt store. Salts may be released as a quickflow response from this landscape feature during wet periods creating a pulsing or spiking of salt load deliveries in stream. Further field experiments are planned to try and monitor the influence of this in-filled valley system for salt delivery to the stream.

Keywords: Salinity; FLAG; Surface washoff; Interflow

1. INTRODUCTION

The hydrological issues driving dryland salinity are defined as a problem of water balance, with a large mismatch between the leakage below current farming systems and the capacity for groundwater systems to accept this leakage [Walker et al, 1999]. These groundwater systems dominate the baseflow discharging to streams. However, from this groundwater imbalance salts can be concentrated within the near surface of the regolith or even at the land surface as scalds. Depending on the groundwater system within a catchment, the dominant processes of salt movement to the stream may not be from direct discharge of groundwater. It may occur during wet catchment conditions mobilising salts from the landsurface as overland flow or from interflow processes within the near surface regolith discharging directly into the stream network.

Tuteja et al. [2000] studied the salt movement from the Kyeamba catchment, New South Wales

(NSW) Australia, using the CATSALT model and determined that the dominant salt load delivery for this system was from overland flow and near surface throughflow processes ("quickflow"). Cresswell et al. [in prep] also confirmed these findings using the FLOWTUBE model, although within this study an attempt was made to better define the quickflow or shallow groundwater processes of this catchment. This paper will present the methodology used to identify the landscapes within the Kyeamba valley that could be acting as the quickflow dominated groundwater systems that may contribute salts to the stream.

2. DEFINING INTERFLOW DOMINATED LANDFORMS

Quickflow processes can operate at the soil profile, hillslope, landform to whole catchment scale. The scale adopted for this study was based on the definition of landforms within a catchment that may be dominated by quickflow and shallow groundwater systems. The quickflow processes at this scale would be induced by deep uniform to texture-contrasted soils found within environments where accumulation and deposition of sediments have occurred through alluvial and colluvial processes. The process of soil landscape mapping defines landforms of this description. Soil landscapes are areas of land that have "recognisable and specifiable topographies and soils" [Northcote, 1978] and are justified as a mapping tool because similar causal factors are involved in the formation of both the landscapes and soils. For the Kyeamba catchment the "O'Briens" and "Big Springs" soil landscape units [Chen and McKane, 1996] defined the areas of the potential quickflow dominated landforms.

2.1 Modelling the Spatial Distribution of the Quickflow Dominated Landforms

Summerell et al. [in prep] used the FLAG UPNESS index to represent the "O'Briens" and "Big Springs" soil landscape units (Figure. 1). Soil landscape mapping only covers limited areas so using the FLAG UPNESS index to represent the main landforms of interest enables areas not previously mapped to be extrapolated using this modelling technique. The UPNESS index is calculated as a contributing area from the set of points (in a raster grid) connected by a continuous, monotonic uphill path [Dowling, 2000]. UPNESS differs significantly from a standard flow accumulation algorithm as the higher values recorded in this index represent the spatial extent of flat landscapes associated with depositional features.

The UPNESS index was applied in the following way. The 25m resolution DEM [NSWLIC, 1999] covering the Kyeamba catchment (~602km^2) was clipped to a 500m buffer. A threshold value was used to determine UPNESS for each cell. This threshold specifies how much higher a neighbouring cell must be in order to be counted in the UPNESS tally and was set to 0.0 for this study.

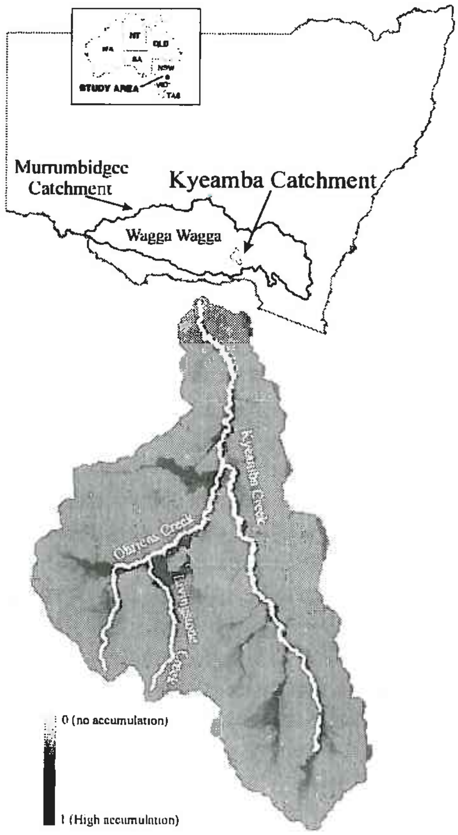

Figure 1. The Kyeamba UPNESS index. The grey to dark shades indicate areas of higher accumulation and these areas also match the boundaries of the Big Springs and O'Briens soil landscape units of Chen and McKane [1996]. Main stream networks are shown in white.

The UPNESS index is presented as a fuzzy index (0.0 – 1.0) and was cut into dry or wet classes. A cut-off value was determined from the areas where the UPNESS index best matched the seasonally wet to waterlogged and sodic to saline soils from a 1:25,000 soil landscape map [Chen and McKane, 1996, Summerell et al., in prep]. Two classes are produced, the position in the landscape where these soils are expected to occur and where they are not. It is expected that a similar cut-off value would be applicable to other catchments within the region.

3. DETERMINING SALINE QUICKFLOW LANDFORMS

A rapid stream Electrical Conductivity (EC) survey was conducted at baseflow throughout the catchment. Many saline tributaries were identified but in the O'Briens Creek catchment (a major tributary of the Kyeamba Creek) a very saline tributary, Livingstone Creek, was identified. Livingstone Creek runs through a large flat, depositional landscape that was field identified as an infilled valley system. This area was also identified by the UPNESS index (Figure. 2).

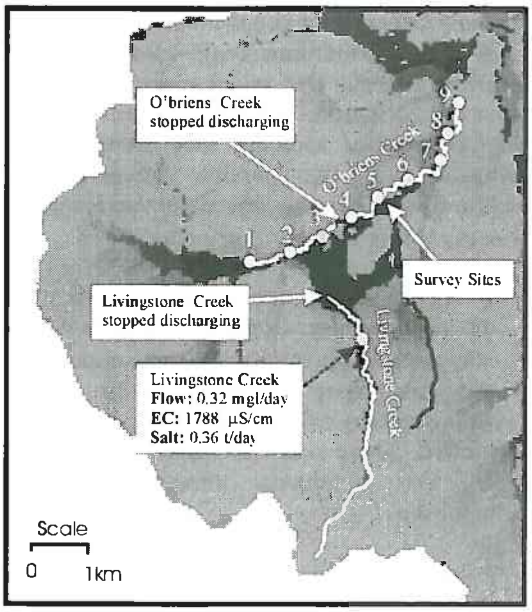

Figure 2. The UPNESS index showing the distribution of the survey sites and the location of the O'Briens and Livingstone Creeks. The dark area in the middle of this figure represents the spatial extent of the infilled valley system that has been described by Chen and McKane [1996] as an alluvial landscape.

Field investigations through this system indicated that at the headwaters of Livingstone Creek a very saline source occurred. A brown coloured fine silt to sandstone bedrock exposed in the stream bed at the top of this catchment had extensive salt crusting within the rock matrix. It was proposed that the sources of salt driving the high stream ECs of the Livingstone Creek were sourced from these headwaters. If the headwaters of this creek have a saline source material, over landscape evolutionary time scales this material could have eroded and been deposited in the infilled valley system at the bottom of the catchment. It was assumed that this infilled valley system would act as a quickflow hydrological system operating via two possible processes. The first being that a deeper groundwater system driven from the head waters of the Livingstone Creek may provide a pressure head large enough for the groundwater to seep into the infilled valley system, thereby concentrating salts in the soil profile. These salts could later be mobilised in wet conditions through quickflow processes. A second process may operate through shallow perched watertables or preferred pathways formed from the alluvial sediments deposited within this alluvial landform feature. Some of these near surface water bearing layers may contain saline waters. When saturated by rainfall these localised systems may begin to discharge into the creek. Dent et al. [1999] also described similar processes to this occurring from paleochannels in other catchments from this region.

The infilled valley system ends at the contact with O'Briens Creek. A 9 km intense EC and Flow survey was conducted up and downstream of the infilled valley system within O'Briens Creek to determine if any obvious leaking of salts was occurring into the creek system (Figure. 2). This survey was conducted at baseflow for the purposes of establishing a base line of data. Figure 3 shows the results of this survey.

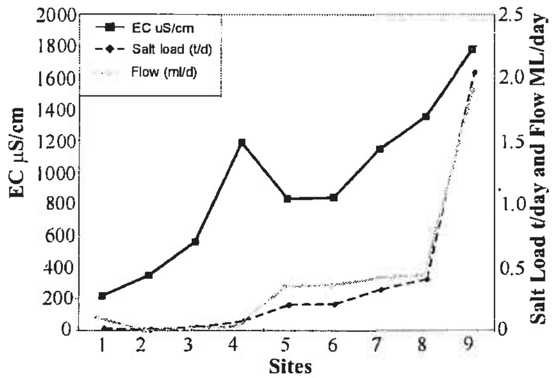

Figure 3. The 9km EC and Flow survey results.

Site 1 (O'Briens Creek) was fresh at around 200 µS/cm. At site 2, before the junction of the Livingstone Creek, the EC rose to about 350µS/cm and the flow had dropped due to a sandy creek bed. Site 3, which is below the junction of Livingstone Creek, only showed a gradual rise in EC to nearly 600 µS/cm. The surface flow of Livingstone Creek which was at 1788µS/cm stopped before it reached O'Briens

Creek and was most likely disappearing into the sandy creek bottom. Before site 4 O'Briens Creek stopped flowing where the bedrock was exposed in the creek bed. Just after the bedrock constriction, but within the main section of the infilled valley system, the flow reappeared and the EC was nearly 1200 μS/cm. The flow measured at site 4 was nearly the same as at site 3. However, the EC had doubled, possibly indicating that an extra saline source had begun to contribute to the stream flow. The bedrock constriction forms part of a hill that sits half buried within the infilled valley system. On the downstream side and around the hill there is topographic depressions indicting that an old flow path may have followed this path. Support for this observation was obtained from an EM31 survey that showed a linear pattern linking up the various topographic depressions. Drilling has confirmed that a water table occurs within this feature at only 1.4m below the surface at an EC of 1100 μS/cm. Just below where the paleochannel runs into O'Brien's Creek after the bedrock constriction, was where the EC spike occurred. Further downstream the flow increased at site 5 and the EC fell, due to the diluting effects of the extra flow, but the EC gradually increased downstream. At site 9 the flow dramatically increased. This increase in flow was attributed to direct discharge of groundwaters into the creek system, as no extra surface flows were contributing. Cresswell et al. [in prep] have shown using the FLOWTUBE model that this location is an area prone to high watertables due to a catchment constriction within the fractured bedrock of a intermediate groundwater system. The high EC and flows obtained at this site indicate that the main salt load contributions from the O'Briens Creek at baseflow are from this groundwater system.

The influence of the shallow groundwater discharging from the infilled valley system to the creek are minimal in terms of salt load contributions during summer baseflow conditions. However, after approximately 25mm of rainfall an opportunity for wet catchment conditions to initiate quickflow processes occurred. The dominance of the salt load delivery mechanisms in the catchment appeared to reverse. At site 9 the EC was diluted to 800 μS/cm, while at the top end of the catchment near the infilled valley system flows were transporting water of some 2000 μS/cm. During this rainfall event flow data was not captured and therefore it could not be concluded if a quickflow system from the infilled valley system was providing this flux of salt into the stream network. It is proposed that field experiments will be conducted at this site to attempt to capture these processes and determine what conditions influence the salt delivery mechanisms from the infilled valley system to the creek.

4. SUMMARY

A conceptual model of quickflow dominated groundwater systems within the Kyeamba catchment was described. It was proposed that these systems would occur in areas where deep uniform to texture contrasted soils have formed within environments where accumulation and deposition of sediments has occurred through alluvial and colluvial processes. These types of soils formed part of the soils landscape units "O'Briens" and "Big Springs" in the Kyeamba catchment, which were represented by the FLAG model UPNESS index. A rapid stream survey of the whole catchment was undertaken to determine if any of these landforms could contain a saline quickflow system. One saline system was found within the Livingstone Creek catchment that had saline headwaters sourcing salts from a salty geological unit. Two possible interactions of quickflow processes may operate in this system to cause saline discharge:

- A deeper groundwater system driven from the head waters of the Livingstone Creek may provide a pressure head large enough for this groundwater to seep into the infilled valley system concentrating salts in the soil profile. These salts could later be mobilised in wet conditions through quickflow processes.

- A second process may operate through shallow perched watertables or preferred pathways formed from the alluvial sediments deposited within this landform feature. Some of these near surface water bearing layers may contain saline waters. When saturated by rainfall these localised systems may begin to discharge into the creek.

A rapid stream EC and flow survey at the outlet of the infilled valley system did indicate that some salts were leaching out of this infilled valley system at baseflow conditions. However, the salt load contribution at baseflow was minimal, compared to the lower reaches of the O'Briens Creek at site 9, where a direct discharge of groundwater into the creek was occurring. After 25mm of rain the catchment wetted up allowing quickflow processes to operate, although on this occasion flow data was not captured and therefore it could not be concluded if a quickflow system from the infilled valley system was providing the flux of salt into the stream network. It is hoped that further field monitoring will be done to demonstrate how the quickflow processes effect stream salt load behavior.

By differentiating catchment landforms and attempting to understand how they control the water movement and salt sources of a catchment better recharge and discharge control measures can be developed by catchment planners. This paper has attempted to look at alluvial landforms and set the groundwork to undertake further studies. It has also demonstrated the usefulness of the FLAG model in representing such landscapes providing a tool that can be used when conventional soil landscape mapping is not available. Rapid stream survey techniques can then be used to help define what areas of a landform may be leaking salts.

5. ACKNOWLEDGMENTS

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