GROUNDWATER AND STREAM INTERACTIONS IN WIDDEN BROOK, UPPER HUNTER VALLEY, NSW - PRELIMINARY RESULTS

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INTRODUCTION

Stream and groundwater connectivity plays a vital role in the health of riverine ecosystems. Groundwater in unconfined shallow alluvial aquifers is an important source of water to stream flow, is more readily accessible and has better yields than confined groundwater aquifers. Stream and unconfined groundwater interactions occur in the hyporheic zone, which is the exchange site of water and materials between the groundwater below, lateral alluvial aquifers and the surface water above (Boulton 2000). Microbial and chemical processes in this zone alter the water chemistry by transforming nutrients & decomposing organic matter. The hyporheic zone also acts as a refuge for many species of riverine invertebrates and other aquatic life (Boulton 2000).

Riverine ecosystems face stresses from current unsustainable land management practices such as overgrazing, groundwater extraction and physical extraction of gravel and mineral sands (Hancock 2002). In addition, satellite data has provided evidence of significant global warming of average sea surface temperatures from the 1970s to the present (IPCC 2001). In the south-west Pacific region, El Nino events have resulted in severe drought conditions across southeastern Australia in 1982/83, 1992/93, 1997/98 and 2003/04. Extended drought conditions and higher evaporation rates have significantly altered the hydrology of catchments in south-east Australia.

Water supply and water quality problems have helped raise awareness of the role that water plays in the environmental and economic health of the nation. The Council of Australian Governments (COAG) has introduced many water reforms in the past decade to halt the widespread degradation of natural resources and to minimise unsustainable use of Australia's water resources. The Water Reform Framework of 1994 had two themes: the need for pricing mechanisms to reflect the true costs in supplying water; and, the need to better balance water allocation between consumers and the environment. The National Water Initiative of 2004 recognised the importance of the connectivity of surface and groundwater in environmental flows and riverine ecosystem health and the need to manage river and groundwater as a single connected system. This measure was introduced to halt the 300% increase in groundwater extraction, much of it from unconfined aquifers in contact with stream water, after the Murray-Darling Basin Commission placed a cap on further diversions of surface waters for agriculture in 1997 (MDBC 1997).

Current protocols in Australia to assess river health do not explicitly consider the hyporheic zone. The key benefit of restoring hydrological connectivity of stream flows with shallow groundwater in unconfined aquifers is increased groundwater recharge, leading to increased stream flows in dry seasons and enhanced ecological function of the hyporheic zone (Boulton 2000). In the Widden Brook, in the upper Hunter Valley, New South Wales, in-stream structures such as weirs and earth structures have been constructed along sections of the Widden to raise stream levels and restore connectivity between stream water and alluvial floodplain aquifers in accordance with Natural Sequence Farming (NSF) methods (NHT 2004). However, the impact of in-stream structures on the dynamic exchanges in the hyporheic zone is currently not well understood. Of special interest is the long-term impact that the connectivity of groundwater and stream water in Widden Brook would have on mobilisation of salts in the floodplain terraces, on the concentration of exchangeable ions and leachable salts in floodplain soils, on stream salinity, on floodplain terrace stability and ultimately on agriculture production in the catchment.

Research at Widden Brook is being undertaken by the Australian National University, Southern Cross University, the University of Newcastle, the Department of Infrastructure, Planning and Natural Resources of New South Wales (DIPNR) and CSIRO. The project seeks to test the hypothesis that *'lateral and vertical hydrological connectivity is important for floodplain sustainability and can be improved by reinstating secondary floodplain channels and wetlands, and creating artificial pools on the main stream'*.

In: Roach I.C. ed. 2005. *Regolith 2005 – Ten Years of CRC LEME*. CRC LEME, pp. 294-298.

Five key research areas of the project have been identified: (1) within-channel and overbank hydraulics; (2) groundwater interactions with floodplain soils and wetland soil processes; (3) changes to channel and floodplain sedimentation patterns; (4) changes to stream salinity, water quality and aquatic habitat; and, (5) major shifts in biogeochemical and biophysical processes in shallow alluvial groundwaters. Preliminary groundwater and stream water chemistry data of the hydrology and geochemistry component of the project are presented here. The hydrology component has the following aims: to determine the water and salt balance for the Widden Brook catchment; to determine the interaction between the stream and groundwater; and, to identify the sources of salt into Widden Brook.

SITE DESCRIPTION

The Widden Brook is located in the south-western part of the upper Hunter Valley. It has its source in the Wollemi National Park and discharges into the Goulburn River, a right-bank tributary of the Hunter River (Figure 1). Widden Brook flows a distance of 40 km to the north from an elevation of 305 m AHD in the upper catchment to 150 m AHD at the confluence with the Goulburn River (White *et al.* 2004). The catchment is characterised by Permian sediments of the Wollombi Coal Measures that are overlain by the high escarpments of Triassic Narrabeen Sandstone (Beckett 1988). A significant Tertiary basalt peak in the catchment dated at Oligocene age (Yoo *et al.* 2001) can be seen at Nullo Mountain (1140 m AHD) in Wollemi National Park. There are other basalt peaks in the catchment at Mount Pomany (1100 m AHD) and Mount Coricudgy (1256 m AHD) (NHT 2004).

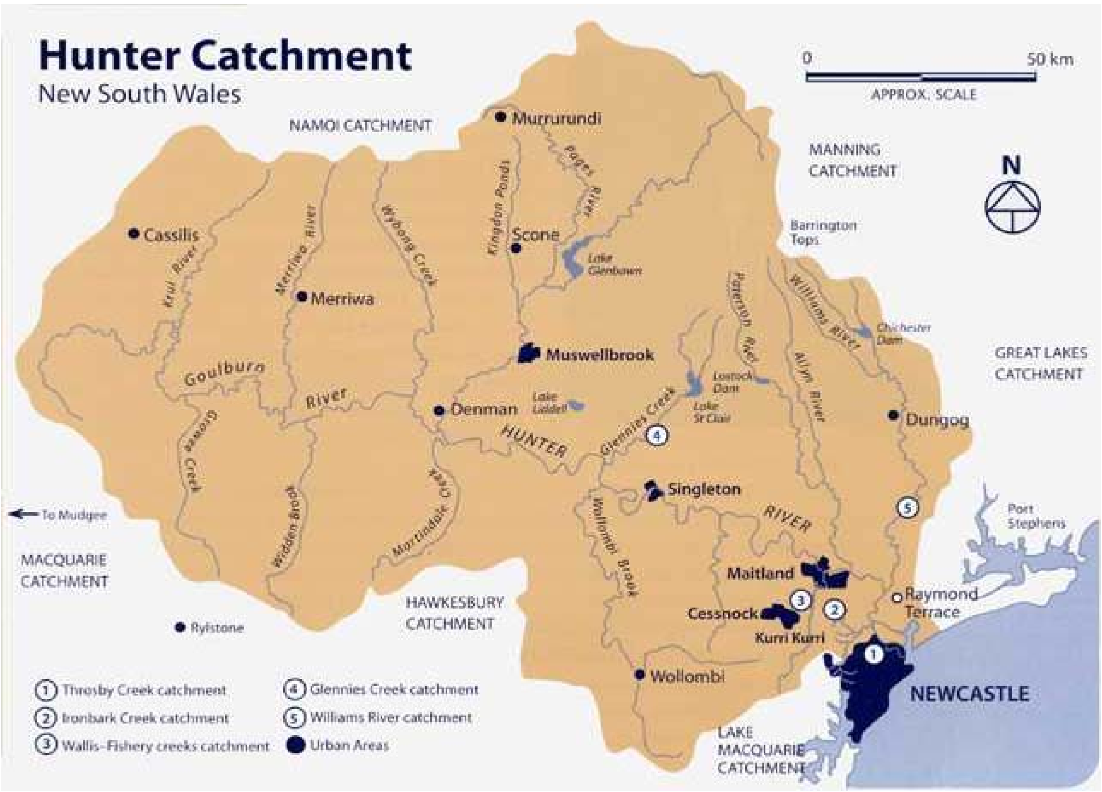

Figure 1: Map of Hunter Valley.

Kellett *et al.* (1989) identified eight geochemical groundwater provinces in the upper Hunter Valley, based on the dominant geology of each province. Given the geology of the catchment, Widden Brook is dominated by Na^+, Mg^{2+} and Cl^- ions (Kellett *et al.* 1989). In a study of the salts inputs into Hunter Valley catchments, Creelman (1994) identified rainfall, ions released by rock weathering and mining as the major contributors to salinity in the Hunter Valley catchments. Total dissolved salts (TDS) in the south-west area of the Hunter Valley was estimated to be 600 mg/L. Salt load was stream flow dependent and therefore based on climate, so that variable weather and rainfall produce variable salt loads (Creelman 1994).

In the upper part of the catchment, the valley floor is narrow and flanked by steep-sided ridges. Sediments in Widden Brook are poorly sorted, consisting of sandstone, sandstone conglomerates, eroded basalt rocks and tree logs. There are sodic, erodible floodplain terraces up to 3-4 m above the stream. In the mid- and lower slopes the valley floor widens into a broad floodplain and a series of depositional floodplain terraces have developed. Stream flow increases significantly in this part of the catchment from the combined flow of Blackwater Creek, Emu Creek and Myrtle Creek and from groundwater discharge into the Widden Brook. The electrical conductivity (EC) of streamwater in the Blackwater Creek is very low, measured at 63 µS/cm in March 2004 (White *et al.* 2004). The lower part of the catchment has been extensively cleared, while the upper catchment remains uncleared, much of it in the Wollemi National Park where there are pockets of remnant rainforest. The dry exposed ridges of the Triassic escarpments support open eucalypt dominated forests.

Average annual rainfall in the Widden Valley is 650 mm. Principle agricultural production consists of horse breeding, cattle, sheep, wheat, oats, olive trees and vines (NHT 2004). There are also coal seams in the upper catchment, however these have been deemed uneconomical for mining because of seam splitting (Beckett 1988).

METHODS

A survey of stream and groundwater was undertaken in the Widden Valley in March and May 2005. Samples were collected and analysed for pH, EC, Dissolved Oxygen (DO), Eh, major cations by Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES), and trace metals by ICP-Mass Spectrometry (ICP-MS). Piezometers were installed in May 2005 upstream and downstream of an in-stream structure in Widden Brook and nearby a groundwater well located on the floodplain terrace above the stream.

Piezometers were installed along four transects perpendicular to the stream bank across a distance of approximately 400 m along Widden Brook. Groundwater in the piezometers was purged and allowed to recharge, and the pH and EC were measured.

RESULTS AND DISCUSSION

Stream water chemistry

Stream water chemistry analyses of samples collected in May 2005 are presented in Table 1. The pH of the stream water along the Widden is slightly alkaline. Electrical conductivity (EC) increases along the flowpath of Widden Brook in the upper catchment reflecting discharge of saline groundwater water from the sodic floodplain terraces into the Widden (Figure 2). The sharp decrease in EC at 20 km is the result of discharge of low EC stream water from Blackwater Creek into the Widden. Sodium is the major cation in the stream water, which increases (in the upper catchment) and then decreases (in the lower catchment) as a proportion of the major cations, consistent with the increase in EC.

Table 1: Stream chemistry in Widden Brook May 2005.

Stream water site	Distance (km)	pH	EC (µS/cm)	Na (mmol/l)	Ca (mmol/l)	Mg (mmol/l)	K (mmol/l)	% Na (meq/l)
Camp Site	0	6.2	113	0.64	0.09	0.15	0.04	55%
Salt Lick Terrace	4	7.7	159	NA	NA	NA	NA	NA
Widden u/s of Blackwater	20	8.8	465	2.90	0.27	0.45	0.10	65%
Raglan Street	26	7.7	288	2.35	0.14	0.29	0.08	72%
Baramul Bridge	30	7.6	310	1.74	0.17	0.30	0.09	63%
Widden Weir	34	7.2	263	NA	NA	NA	NA	NA

Groundwater chemistry

The results of groundwater chemistry in bores and wells are presented in Table 2. The electrical conductivity of the groundwater is quite variable. The groundwater bores at Table Bay, Windmill Creek, Raglan Street and Baramul Homestead are situated on elevated sodic floodplain terraces and hence the EC of the groundwater is in excess of 2000 µS/cm. The bores at Pomany and Holbrook are situated close to Blackwater Creek reflecting relatively lower EC of 544 µS/cm and 381 µS/cm respectively.

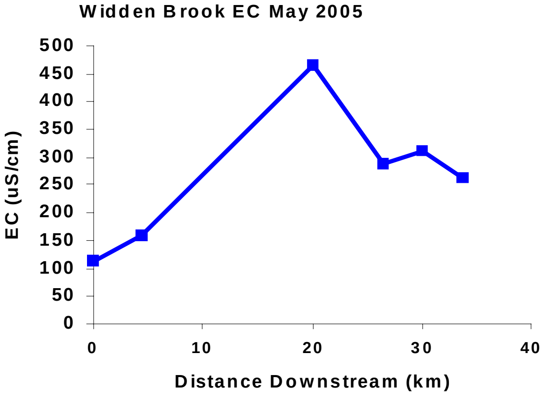

Figure 2: Electrical conductivity (EC) in Widden Brook.

Table 2: Groundwater chemistry in Widden Brook (May 2005).

Groundwater site	Distance (km)	pH	EC (uS/cm)	Na (mmol/l)	Ca (mmol/l)	Mg (mmol/l)	K (mmol/l)	% Na (meq/l)
Table Bay Creek (5.5m)	8	7.7	2012	16.47	0.77	2.84	0.57	68%
Pomany Blackwater (2.4m)	21	7.7	544	2.78	0.94	0.56	0.27	46%
Holbrook windmill	23	7.5	381	NA	NA	NA	NA	NA
Windmill Creek (5.9m)	26	7.7	1530	8.80	0.77	1.41	0.26	66%
Raglan Street (3.0m)	28	8.0	2610	26.08	0.39	0.75	0.13	92%
Baramul home (8.0m)	31	7.9	2085	NA	NA	NA	NA	NA
Emu Creek (3.2m)	32	7.7	363	NA	NA	NA	NA	NA

Water chemistry and soil texture in piezometers

Four piezometers were installed 200 m upstream of the in-stream structure across a transect of 100 m from the stream bank in a line that included the Raglan Street open well (see Groundwater chemistry above). Electrical conductivity of the groundwater in all four piezometers was significantly higher than the stream EC. In two piezometers within 7 m of the stream, EC was in the range 2360-3860 µS/cm. This result suggests either that groundwater is discharging salts into Widden Brook, or that the raising of the stream level by the in-stream structure has mobilised salts in the alluvial aquifer. Texture analysis of samples collected from the auger hole samples in May 2005 shows negligible soil development of the lower floodplain soils close to the stream. In the floodplain terraces soil development is more advanced. The soils here showed alternating layers of clay loam, and clay sandy loam sediments, with coarse sand deposits at the depth of the water table at three metres.

Trace metals

Trace metal analysis (ICP-MS) revealed elevated concentrations of Sr, Ba, Cr, Cu and Ni in stream water (1-10 ppb) and groundwater (10-200 ppb). Higher concentrations in groundwater may reflect groundwater-basalt weathering reactions at depth in the regolith.

CONCLUSIONS

Results confirm that there is saline groundwater in the floodplain terraces in the upper catchment. There may also be multiple groundwater pathways into Widden Brook via (i) groundwater flow through floodplain sediments, and (ii) groundwater-basalt weathering reactions.

The conventional model of the development of dryland salinity in Australia resulting from changes in the hydrological balance in catchments (NLWRA 2000) assumes that the equilibrium between salt inputs via rainwater and salt outputs from streams has been perturbed by the clearing of native vegetation in groundwater recharge zones and its replacement by pastures after European occupation. However, from the preliminary results of water chemistry in the Widden Brook, salinity in the catchment cannot be explained by this model. Only the lower part of the catchment has been cleared, yet the water chemistry indicates that groundwater in the upper catchment is discharging through the floodplain terraces and releasing salt into Widden Brook. It is not yet clear whether the salts in the floodplain terraces have formed primarily as a result of *in situ* mineral weathering or from aeolian deposits. Widden Brook is unregulated (except for minor in-stream structures) and stream flow could be expected to be highly variable. The poorly sorted stream sediments in the upper catchment and the sandy sediments in the floodplain terraces indicate high flood events in the past. Climate variability and changes in the hydrology of the catchment may also be reflected in the sedimentary sequences and channel migration of the mid and lower catchment.

Future research includes: correlation of stream flow data with rainfall data from the Widden catchment to determine seasonal variability in rainfall, stream flow and salt load; retrieval of intact cores from the floodplain terraces and stable isotope analysis ($\delta^{18}O$) of clay species to infer palaeoclimate of the sediments; OSL dating of floodplain sediments; and, clay analysis and the estimation of cation exchange capacity of the regolith.

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