Evidence for Groundwater Surface Water Interactions along the Brunswick River, Western Australia.

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Abstract

Traditionally groundwater and surface water have been managed as separate water resources. However, in many regions they are hydraulically connected and the abstraction from one can influence the other. There is an increasing body of knowledge recognising the significant implications of groundwater surface water interactions. Similarly, there are an increasing number of methods being developed to assess these interactions. Throughout Australia the methodology is still in the developmental stage and with a growing number of methods to choose from, selecting the most suitable one is a challenge. Seven methods were compared for investigating groundwater surface water interactions in the Brunswick River. These included hydrogeological mapping, hydrograph analysis, temperature studies, seepage measurements, a salinity survey, field observations and water budgeting. The suitability, accuracy and results of each method were compared.

1.0 Introduction

The National Water Initiative promotes the management of Australia's water resources as a single resource, recognising the connection between surface water and groundwater systems. This has resulted in a large number of river research projects focusing on the connection between groundwater and surface water. The Department of Water, like many water resource management agencies throughout Australia, are expanding their understanding of these interactions to assist with sustainable decision making. Damming the Brunswick river is among a list of potential options for Western Australia's future water supply sources (Water Corporation 2005). However, it is important to fully understand the functionality of a river system before any adjustments to its natural state can be approved, including reservior development. The purpose of this project is to identify hydraulically connected reaches along the river and determine whether they are gaining (where groundwater discharges into surface water), losing (where surface water infiltrates to groundwater stores) or neutral (neither gaining or losing). In doing so, a comparison of techniques for characterising that spatiral and temporal nature of these connections along the Brunswick river will be made.

2.0 River Setting

The Brunswick River is located approximately 30km north east of Bunbury and passes through the town of Brunswick Junction. Its catchment area is 528km^2 and extends past the Darling Scarp into the State Forest (Figure 1). The Brunswick river joins with Collie river approximately 6km upstream of the Leschenault inlet. The main tributaries running into the Brunswick river are the Wellesley and Augustus rivers.

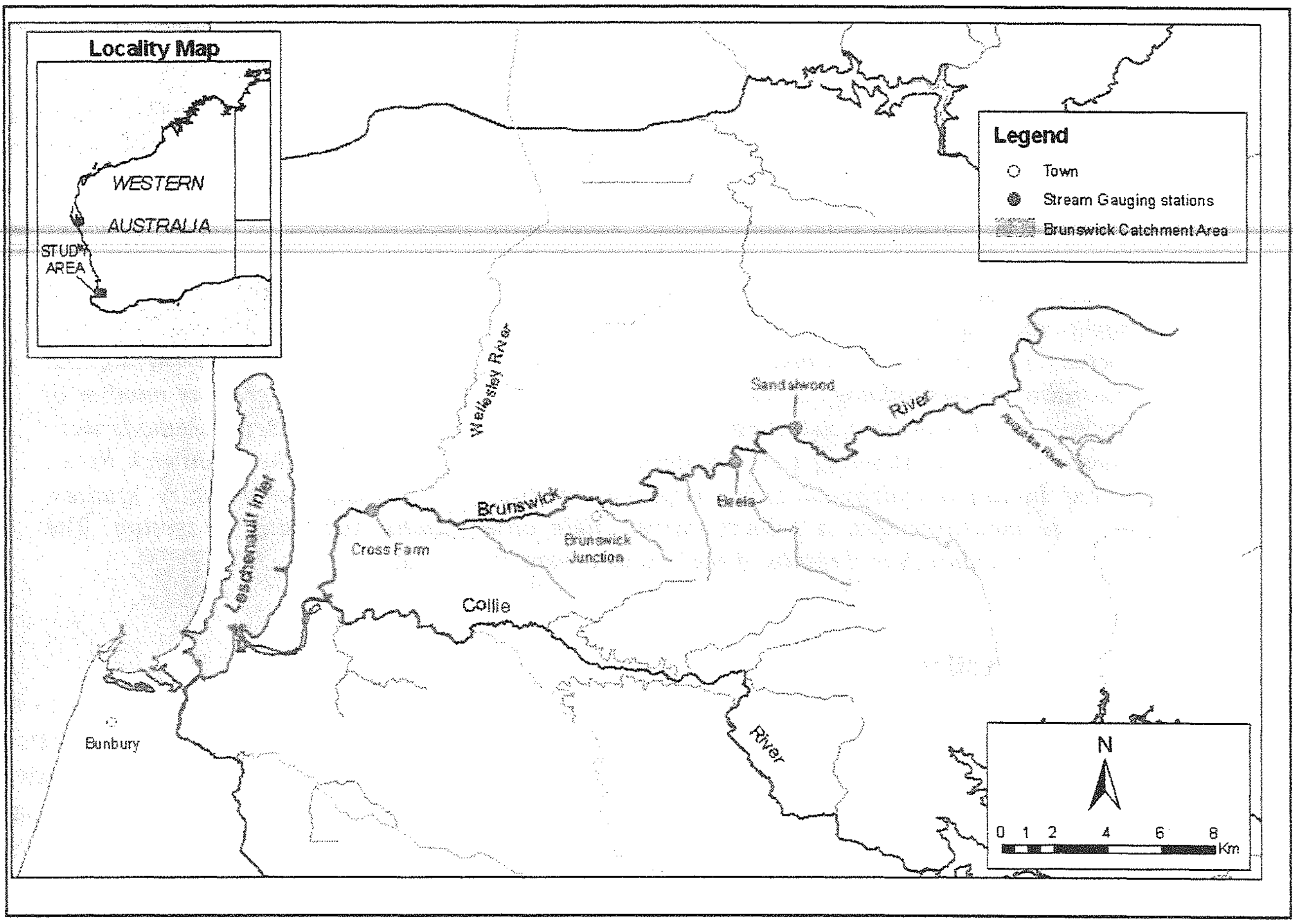

Figure 1. Brunswick River Catchment and location

Land use in the upper catchment (east of Brunswick Junction) is dominated by State Forest and the Worsley Alumina Refinery. Historically known for its large population of cows and dairy framing, the lower part of the catchment is now dominated by private horticultural and agricultural land users, mostly beef livestock.

2.1 Characteristics of a Connected Reach

Hydraulic connection exists where the water table is close to the river bed. In many regions groundwater and surface water are hydraulically connected (Braaten & Gates 2001), and they interact in a variety of physiographical settings (Sophocleous 2002).

2.1.1 Gaining System

For groundwater to discharge into a stream, the elevation of the water table adjacent to the stream must be higher than the elevation of the river bed. This setting creates an upward hydraulic gradient, which promotes groundwater inflow to the stream and thus a gaining system (Figure 2a)

2.1.2 Losing System

For surface water to seep into groundwater the elevation of the water table must be lower than the elevation of the river bed. This creates a downward hydraulic gradient between the stream and aquifer, promoting the outflow of surface water through the stream bed (Figure 2b).

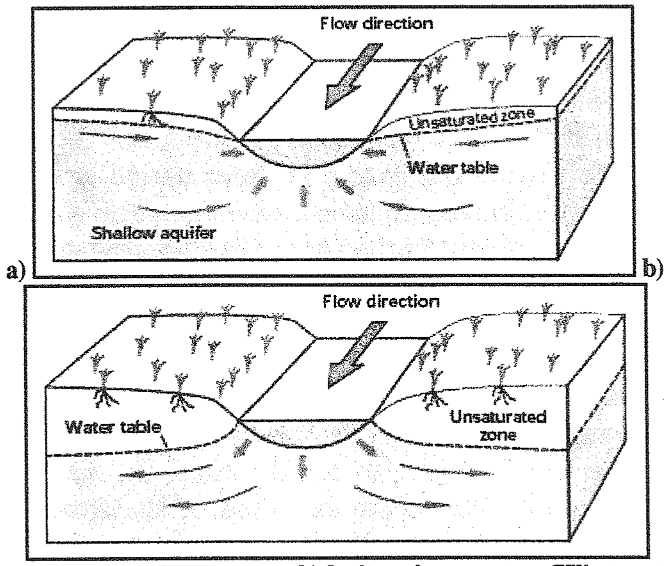

Figure 2. a) Gaining river system, b) losing river system (Winter et al. 1998)

2.1.3 Neutral System

A neutral system occurs where the water table is at the same elevation as the river bed and thus in hydraulic continuity with the stream (Figure 3). A neutral system may also exist when groundwater and surface water are hydraulically disconnected, usually due to the presence of a thick impermeable aquifer between the water table and river bed.

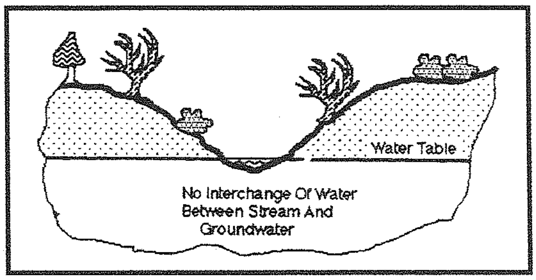

Figure 3. Neutral systems (Silliman & Booth 1993)

3.0 Methodology

Several methods were used to identify and characterise connected reaches along the Brunswick river. The methods involved in this study varied between desktop studies, field studies and a combination of both. Field work was carried out on several occasions to gain information and data to assist with desk top studies. Two sites along the river, Cross Farm and Sandalwood, were selected for focused field investigation (refer Figure 1).

3.1 Hydrogeological mapping

Mapping the river bed and water table elevation was carried out to indicate the presence of connected reaches. River base elevation was determined from a digital elevation model (DEM) based on a series of contour data. The DEM was created in ArcGIS, a geographical information systems programme preferred by the client. Water table elevation, also called piezometric head, was determined from a combination of data sets including bore logs, groundwater contours and water levels measured from bore dipping. Underlying geological structure was investigated from a combination of geological maps and bore logs.

3.2 Baseflow Analysis

A digital filter, developed by Lynne and Hollick (1979) and described by Nathon and McMahon (1990), was applied to separate the quick flow component of the hydrograph (the short term response to a rainfall event) from the baseflow component (the long term groundwater contribution from storage). Daily flow data was sourced from several stream gauging stations located along the river (refer Figure 1). The stations record river level and output flow discharge based on a rating table developed from the historic record of flow data.

3.3 Temperature Survey

Stream temperature varies diurnally due to solar radiation, air temperature, rainfall and stream inflows, including groundwater discharge (Sinokrot & Stefan 1993). In contrast, regional groundwater is constant at the daily time scale. Time-series measurements of sediment and stream temperatures were carried out over a 96 hour period at a reach believed to be either gaining or neutral. Odyssey submersible temperature recorders were used to log temperature at 15 minute intervals. One was placed in the stream and another directly below at 0.6m into the stream bed. Local groundwater temperature was measured from near-by bores and a mini-piezometer.

3.4 Salinity Survey

Analysing and interpreting the chemistry of stream flow can provide valuable insights into groundwater-surface water interactions, particularly where the shallow groundwater is relatively saline and a significant contributor to the salt load of the stream (Brodie et al. 2006). An assessment of surface water salinity along the river was used in an attempt to pick up areas where groundwater is discharging into the river. Electrical conductivity (EC) was measured at 12 sites along the stream and compared with local groundwater salinity.

3.5 Seepage Measurements

Seepage meters were used to directly measure groundwater seepage flux at both sites. Various modifications have been made to the seepage meter design since its development in the 1940's. In this study a meter based on the classic design by Lee 1977 was used and one third of a 55 gallon drum was converted into an open chamber, with an outlet for a flexible plastic tube attached to a collection bag (Figure 4). The bag was housed in plastic flower pots to protect it from being pierced and supported by river rocks to prevent it being detached (Figure 4). The basic concept of the meter is to isolate part of the sediment-water interface with an open chamber and measure the change in volume of water contained in the bag over a measured time interval. An increase, decrease or no change in bag volume represents gaining, losing or neutral conditions respectively. This study used two seepage meters, one at each site, for a period of 24 hours.

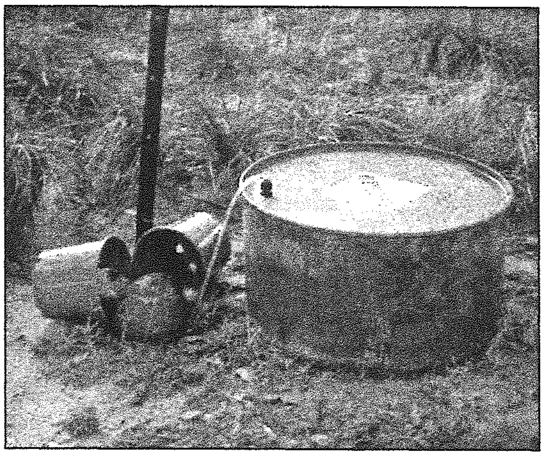

Figure 4. Seepage meter design

3.6 Field Observations

Visual indications of the interaction of groundwater and surface water systems can be observed in certain catchments and settings (Brodie et al. 2006). A field reconnaissance survey was carried out in the early stages of the project (February) to identify locations showing signs of connectivity. These were noted by particular field indicators including; Seepages and springs, pools and the maintenance of pool levels outside the wet season, reaches where flow has ceased, reaches where flow is continuous and water colour and odour.

3.7 Water Budgeting

Inputs (rainfall, stream inflow, tributary inflow) were compared with outputs (stream outflow, evaporation, extraction) and the unaccounted difference is assumed to indicate the volume of water exchanging between groundwater and surface water. Discharge measurements were undertaken and stream gauging stations were used to measure inflows and outflows. Rainfall and evaporation data were sourced from meteorological sites and Harvey Water. Abstraction volumes were estimated from a survey of water useage along the river.

4.0 Results

4.1 Hydrogeological Mapping

A hydrogeological cross section was drawn to she the results of a combination of geological, river bed and water level analysis. The plot also indicates major roads, tributaries and the location of bores, springs and gauging stations.

4.2 Baseflow Analysis

Trends in the baseflow index (BFI) from baseflow analysis showed that there is a decreasing amount of groundwater discharge into surface water downstream. Sandalwood station has a baseflow index of 0.51, Beela 0.48 and Cross Farm 0.38. This is consistent with results from the hydrogeological cross section characterising connected reaches.

4.3 Temperature Survey

Analysis was based upon temperature signals for gaining, losing and neutral reaches hypothesied by Silliman & Booth 1993. Initial results from Cross Farm showed diurnal variation in surface temperature, as expected. Whereas sediment temperature decreased gradually and showed no diurnal variation. An average of groundwater temperature measurements gave a local groundwater temperature of 18^{0}C. At this site sediment temperature is considered to be influenced by groundwater discharge rather than surface water propogation, indicating a gaining reach.

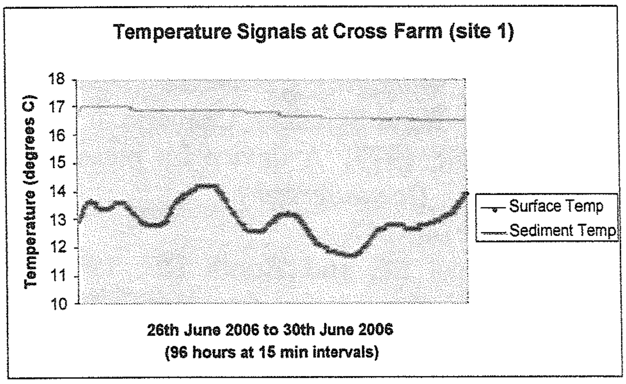

Figure 5. Temperature signals for Cross Farm

4.4 Salinity Survey

EC values did not show any significiant variation, with the exception of three sites taken in stream water affected from irrigation runoff and can not be included. Groundwater salinity in this region is similar to surface water salinity and as a result groundwater discharges are not picked up with this method. Thus this method is not suited for analysis along the Brunswick River.

4.5 Seepage Measurements

Groundwater is discharging into the river near Cross Farm at 0.03 x 10^{-3}m/s and near Sandalwood at 0.012x10^{-3}m/s. A lot of installation error was considered to have occurred and is reflected in these figures. The percentage of error is uncertain. Further seepage meter trials will be conducted in Septemeber to validate these results. Seepage meters were redisigned to prevent flow constraints and minimise installation errors.

4.6 Field Observations

A number of seeps and springs were noted along the landscape. Many pools identified in summer were no longer present in winter, indicating a temperally varing gaining/losing reach. Certain reaches of the river were described by locals as 'flowing all year round' and were flowing on each field visit. These permanent features indicate a year long gaining reach.

4.7 Water Balance

Discharge measurements showed a significant change in flow rates along the river length. A water balance at Cross Farm shows it is gaining up to 40L/s in its upper reach, while Sandalwood is steady, and not gaining any surface water from its upper reaches.

5.0 Conclusion and future work

At this stage, probable areas of gaining and losing reaches have been identified. Hydrogeologcial mapping and water balancing are proving to the most accurate methods so far. Salinity surveys are not suitable to the area and results were inconclusive. Temperature surveys gave valuable information, which could be enhanced with a network of peizometers near the river. Future field work will take place by October 2006 and compare methods in a different season. It will involve another run of seepage meters, temperature surveys, discharge measurements and field observations.

6.0 References

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