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Integrated understanding of urban land, groundwater, baseflow and surface-water quality—The City of Birmingham, UK

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Abstract

Integrated understanding of urban land, groundwater (shallow and deep), baseflow and surface-water quality relationships is required for effective urban water-quality management. Chemical quality data from across these media have been collected for the Birmingham (UK) aquifer—River Tame conurbation to assess chemical transport from contaminated land to groundwater to baseflow to surface water. Although metals concentrations were high in soils, low leachability and attenuation caused concentrations in groundwaters and baseflow discharging to surface water to be generally low with only sporadic elevated concentrations attributed to localised point sources. Hydrocarbon VOCs (volatile organic compounds) were similarly absent or at low concentration attributable to their ready natural attenuation. Chlorinated VOCs, however, were widely encountered in groundwater, discharging as baseflow to surface water and impacting surface-water quality. This is attributed to their DNAPL (dense nonaqueous-phase liquid) properties and relative recalcitrance although there was some evidence of biodegradation, albeit insufficient to protect surface water and groundwater abstraction receptors. Some inorganic trends were evident across the various media; nitrate was the most significant quality concern. Generic conclusions are drawn on urban water-quality management and the need for risk-based management strategies to optimise use of urban, sporadically contaminated groundwater in conjunction with surface water highlighted.

Keywords: Urban; Contamination; Contaminated land; Groundwater–surface-water interface; Birmingham; River Tame; URGENT

1. Introduction

Integrated understanding of land, groundwater, river-baseflow and surface-water quality for the urban environment poses a significant challenge. As urban populations continue to rise, water supply and waste disposal strategies often struggle to keep pace with increasing demands. The problem is perhaps most acute in historic cities with old and failing infrastructure, low-population capacity systems and legacies of contamination or resource depletion. Water is clearly fundamental to sustaining any city and is a commodity that increasingly needs to be holistically managed. An integrated understanding of the urban, often contaminated, water cycle is hence regarded as crucial.

Traditionally monitoring and management of groundwater and surface-water resources and quality are largely undertaken in isolation. Surface-water man-

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agement programmes consider the quality of urban rivers and direct discharges to them, e.g., industry pipe-end or sewage discharges, but often fail to examine the relevance of quality within underlying groundwaters or surrounding land. Clearly relationships exist and contaminated land within conurbations may leach and cause pollution of underlying groundwaters that laterally flow and discharge as baseflows to surface waters. Recent legislation is now requiring more integrated environmental understanding, both in relation to risk assessment of contaminated land (EA, 1999) and management of the water environment, in particular the European Community Water Framework Directive (WFD) (Council of Europe, 2000). The WFD requires that quality-flow compliance at a particular surface-water reach entail consideration of all upstream inputs, including contaminated land and groundwater contributions.

The aim of this paper is to develop integrated understanding of urban land, groundwater, baseflow and surface-water quality relationships, based upon the city of Birmingham, UK. The key environmental pathway considered is the transport of chemical contaminants from contaminated land to groundwater to baseflow to surface water, a significant pathway to consider for many conurbations. Specific objectives were to: identify key contaminant occurrences and quality concerns within the specific urban media; assess contaminant transport through the land–groundwater–baseflow–surface-water pathway and the potential for natural attenuation controls therein. Finally, generic conclusions are drawn relevant to urban water-quality management.

The work presented is drawn from two parallel research programmes undertaken in 1998–2002. Firstly, land and groundwater quality assessment was undertaken by Shepherd (2003) within the wider NERC URGENT research programme on "Sustainable use of urban aquifers"; specific support to this aspect of the programme was provided by Birmingham City Council who hold local area environmental management and regulatory responsibilities. Secondly, groundwater baseflow and surface-water quality assessment was undertaken by Ellis (2003) within a research studentship on "The impact of urban groundwater upon surface-water quality: Birmingham–River Tame study, UK" funded by the Environment Agency (for England and Wales—the EA) who hold national environmental management and regulatory responsibilities. This second programme conveniently bridged the above URGENT research and other URGENT-funded ecological and flow-related research on the River Tame concurrently undertaken (Durr, 2003). A wealth of data was obtained on the above two programmes and as such the scope of this paper is to overview and to selectively illustrate key aspects of each dataset and linkages between; more detailed study-specific interpretations being provided elsewhere (Shepherd, 2003; Ellis, 2003; Rivett et al., 2005).

2. Study setting

The City of Birmingham is the second largest British city after London. The city dates back to the 12th century. It became a centre of tanning and then metal working and in the 18th–19th centuries industrialised becoming home to a large number of industries, many metal-based (Cherry, 1994). These included general metal-working, brass manufacture, jewellery making, automotive engineering, armaments and brewing, the latter being attracted by the quality of Birmingham's groundwater. Industry was concentrated to the east and north of the city centre and in Smethwick to the west. Development in the early 20th Century saw the spread of industry, including many large-scale factories, into the Tame Valley and predominant urbanisation of the Fig. 1 area. Access to groundwater was a key incentive for many industries to locate in Birmingham. Major land-use is residential at ~50% with manufacturing industries occupying ~7% of the total area of the city (Birmingham City Council, 2001). The city is set within the wider West Midlands conurbation that became recognised as the "industrial heartland" of England. In the recent decades, however, there has been a signifi-

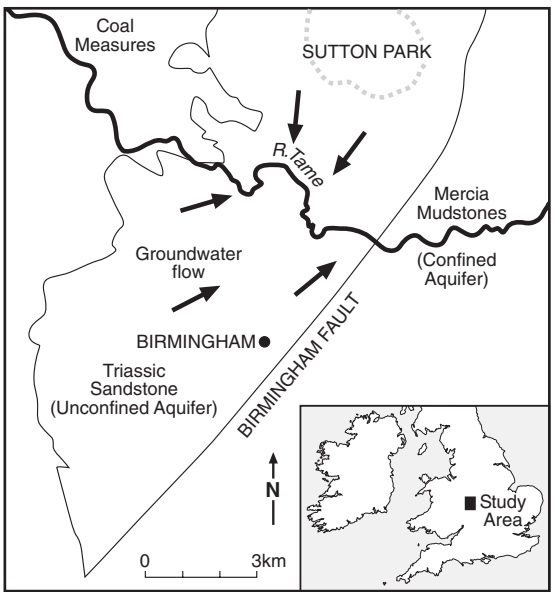

Fig. 1. Birmingham aquifer and River Tame study setting.