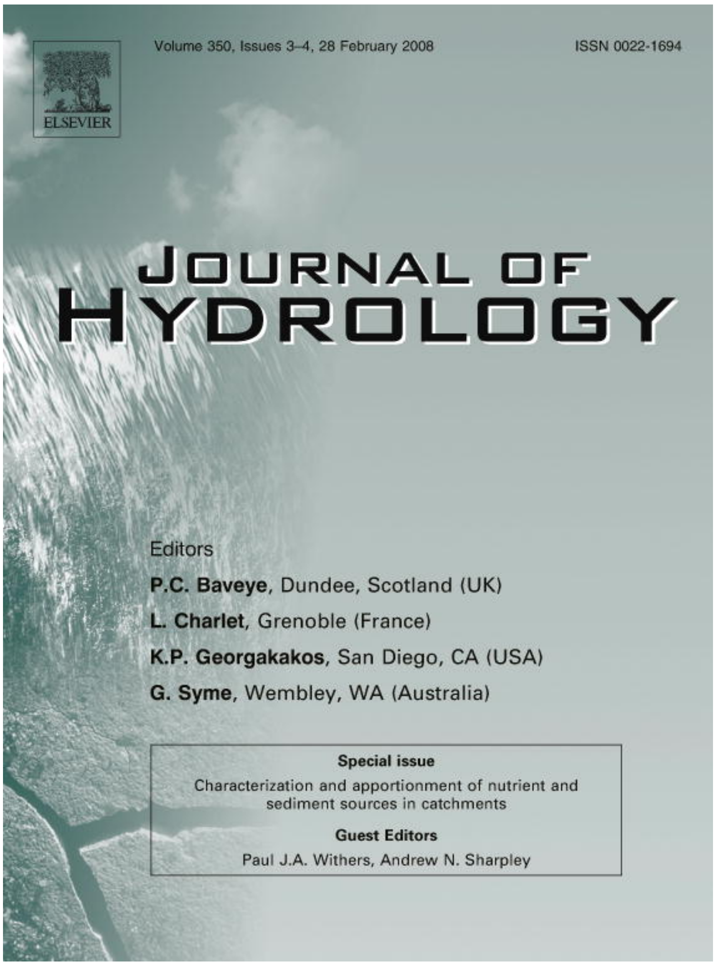
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Special issue
Characterization and apportionment of nutrient and sediment sources in catchments
Guest Editors
Paul J.A. Withers, Andrew N. Sharpley

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PREFACE

Characterization and apportionment of nutrient and sediment sources in catchments

A supply of clean potable water and access to healthy, ecologically diverse waterbodies is a primary requirement for quality of life. In recent decades, deterioration in the quality of water in lakes, reservoirs, aquifers, canals and rivers, and associated habitats, has become an increasing environmental problem for the developed countries (Chartres, 2006; European Environment Agency, 2003; National Science and Technology Council, 2007; US Environmental Protection Agency, 2002). Among the many causal factors has been the enrichment of water with nutrients from anthropogenic sources causing excessive nitrate contamination of ground water and eutrophication of surface waters with threats to human health, habitat diversity, species survival and amenity value (Galloway, 1998; National Research Council, 2000; English Nature, 2003; Parkyn and Wilcock, 2004). Eutrophication can be defined as 'the enrichment of water by nutrients (normally nitrogen (N) and phosphorus (P)) causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned' (UK Eutrophication Forum, 2005). This undesirable disturbance manifests itself in a succession of symptoms including increased algal growth, reduced water clarity, loss of submerged plants, production of algal toxins, deoxygenation, fish kills, and increased water treatment costs (Smith, 2003; Foy, 2005). Excessive sediment accumulation in rivers, lakes and aquatic habitats is also adversely affecting habitat suitability for certain rooted plants and animals with benthic habits or life stages, as well as increasing local flood risk and leading to a number of off-site impacts (Owens et al., 2005). These environmental issues have significant social and economic consequences for both rural and urban communities.

As a consequence of this widespread nutrient enrichment, national and international obligations have been established to develop and implement the range of measures necessary to maintain, or restore, the quality of surface and ground waters, including safeguarding priority sites designated specifically for wildlife conservation. For example, the EU Water Framework Directive (Water Framework Directive, 2000) places ecological quality at the heart of water management and requires that measures to control nutrient and sediment loads from all sources be adequately incorporated into river basin management plans. Similarly in the US, nutrient criteria have been established regionally to define what constitutes impairment (US Environmental Protection Agency, 2001). These criteria have regulatory applications under the Federal Clean Water Act as each State develops nutrient standards (analogous to EU countries), National Pollution Discharge Elimination System (NPDES) permit limits, and Total Maximum Daily Loads (TMDLs) (US Department of Agriculture, 1999; US Environmental Protection Agency, 1996, 2004).

Anthropogenic sources of nutrients entering water include the 'point-source' discharges of municipal and industrial wastewater and those of more diffuse origin arising from agricultural intensification of the wider catchment area. As controls over nutrient discharges from point sources are being implemented more widely in sensitive catchments, inputs of nutrients in catchment runoff will attach a greater proportional significance in terms of nutrient loading. In contrast to point sources, diffuse sources are much more difficult to identify, link to ecological impacts and control (Edwards and Withers, 2007). They originate from a number of different areas within the catchment, are transported by a number of different hydrological pathways and arrive at different times depending on rainfall patterns. The range in concentrations and loads of nutrients and sediment in land runoff is therefore extremely large (Withers et al., 2003; Kronvang et al., 2007).

Successful river basin management must therefore incorporate accurate and cost-effective targeting of measures to control a number of different sources. For diffuse sources, measures must be targeted at those areas of the catchment where combinations of landscape and land management generate the highest risk of nutrient pollution. Targeting all sub-catchment areas equally has been shown to be neither cost-effective (Schleich et al., 1996), nor likely to reduce pollutant discharge (Jokela et al., 2004; Granlund et al., 2005). The fundamental difference in the mode of transport and delivery between N and P suggests different approaches are required to targeting of mitigation actions

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(Heathwaite et al., 2000; Withers and Lord, 2002). While N is transported in soluble form in percolating water, P is often transported in association with soil particles and usually only from specific areas that have rapid hydrological connectivity with the watercourse (Pionke et al., 2000). This reflects the considerable variation in the vulnerability of agricultural land to mobilisation and delivery of sediment and nutrients due to a number of controlling factors. The inherent vulnerability of land as affected by rainfall patterns, soil type, slope, stream density and road/track networks is largely outside the farmer's control. However, this pattern of vulnerability is heavily modified by land use management factors which are under the farmer's control, including land use, N and P inputs, livestock density, cultivation practices, crop management, manure management and presence of under-drainage systems (Evans, 2006; Monaghan et al., 2007; Sharpley et al., 2001).

Sediment and nutrients in waterbodies may also originate from sources other than those associated with local farming practices; for example from the atmosphere (Paerl, 1997); remobilisation of bottom sediments (House, 2003) and bank erosion within stream channels (Walling, 2005), effluent discharges from septic tanks (May et al., 1998) and runoff from roads and tracks (Kayhanian et al., 2007). The more localised heterogeneity in P sources and transfer within fields, farms and villages adds a further tier of complexity to the regional variation that is apparent at the large catchment scale simply through an analysis of nutrient pressures (Hively et al., 2005; Withers and Haygarth, 2007). Hence, for P, a combination of catchment-wide nutrient management goals with more specific measures targeted at small critical source areas on individual farms and fields, and rural point sources, is advocated (Sharpley et al., 2005; Edwards and Withers, 2007). Moreover, these measures vary in effectiveness among catchments and there will be synergistic effects on nutrient loss reductions, where combinations of these measures can further enhance overall reduction, when appropriately targeted to areas of high nutrient source availability and those which are hydrologically active. This is the basis for adaptive management of these measures, such that if nutrient loss reductions are not achieved by implemented nutrient efficiency, edge-of-field buffers or offsite wetlands, then one or all are reassessed and modified (National Research Council, 2004; O'Donnell and Galant, 2007). Critically, an adaptive management approach provides an appropriate way for decision makers to deal with the uncertainties inherent in the environmental repercussions of prescribed actions and their influences on water quality.

To achieve these management goals, qualitative and quantitative decision support tools are required to help identify the major contributing areas within catchments, help pinpoint and prioritise where these measures should best be targeted and what their likely impact will be on achieving the desired environmental outcomes. These decision support tools can take a number of forms and need to operate at a range of scales often with a limited amount of data that is inappropriate to the scale of study (Dørge and Windolf, 2003; Heathwaite et al., 2005). They range from empirical approaches that rely on simple causal relationships (Alexander et al., 2004; Johnes, 1996; Sharpley et al., 2003) to more mechanistic approaches that rely on detailed understanding of the nutrient transfer process (Morgan et al., 1998; Vadas et al., 2005, 2007). In this current period of urgency to find sustainable solutions to land management to meet international objectives, the research community has an important role in communicating current understanding of diffuse nutrient transfer within catchments, the complexity of nutrient and sediment sources and associated uncertainties in their ecological impact, and potential methodological approaches to their characterization and apportionment.

This special issue draws together inter-disciplinary research papers on the characterization of nutrient and sediment sources in catchments and how knowledge of source apportionment informs the cost-effective targeting of control measures. The issue makes particular reference to siltation and eutrophication issues in the UK, especially P which is largely sediment-borne and the nutrient most limiting eutrophication in freshwaters. The development of a pragmatic, process-based model of sediment and P transfer in catchments called PSYCHIC (Phosphorus and Sediment Yield Characterization In Catchments) is also highlighted. Mainstone et al. outline the policy drivers behind the control of siltation and eutrophication problems, the nature and extent of ecological risks and approaches to target-based management within catchments. Edwards and Withers discuss the hydrological and compositional nature of various sources of N, P and suspended solids entering water and implications for catchment management. Six papers report measured data that illustrate the large spatial and temporal variation in diffuse nutrient transfer and the relative importance of point, diffuse and in-stream sources for nutrient loading and river ecology (Neal et al., Jarvie et al., Stutter et al.). For P, the largest range in concentrations invariably occurs in headwater areas, where particulate forms often dominate. The ecological impacts of particulates of organic and inorganic origin in flowing waters remains uncertain and improved tracing techniques appear necessary to better track the relative contributions of the wider range of rural P sources now being encountered in catchment studies. Point sources remain a major concern at periods of high ecological risk and further more stringent controls over these seem inevitable if water quality targets are to be met.

Eight papers discuss methodological aspects of catchment-based research and the facilitation of cost-effective targeting of measures to reduce sediment and P concentrations to an acceptable level. Three of these papers report on the development and application of specific methodologies to characterize the nutrient status, mechanisms of internal P cycling and sediment source apportionment in UK rivers (Ellwood et al.; Jarvie et al.; Walling et al.). Papers by Davison et al.; Strömqvist et al.; and Owens et al., report on the development of the PSYCHIC model which was designed to help identify critical source areas of sediment and P within catchments and farms, and assess what management changes are required at these scales to achieve environmental goals. To assist in the identification of specific hydrological pathways in headwaters, Deasy et al. describe a field methodology incorporating a combination of on-site observation with event-based sampling. Finally, Brink et al. developed a negotiation support system to solve groundwater conflicts over the impact of land use on nitrate contamination in ground waters in the Netherlands and choice of mitigation options. All these methodologies have a role to play in improving our understanding of nutrient cycling and mobility within catchments and developing the most appropriate combinations of measures to tackle water pollution most effectively, economically and sustainably. This remains a major and urgent challenge requiring inter-disciplinary co-ordination at both the research and catchment stakeholder level. We expect that the issue will make a significant and comprehensive contribution to river basin management planning for improved water quality and habitat conservation.

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P.J.A. Withers
Catchment Management Group, ADAS UK Ltd,
Gleadthorpe, Meden Vale, Mansfield,
Nottinghamshire NG20 9PF, UK
E-mail address: Paul.Withers@adas.co.uk

A.N. Sharpley
Crop, Soil and Environmental Science,
115 Plant Sciences Building, Division of Agriculture
University of Arkansas, Fayetteville, AR 72701, USA