

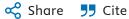
## **Applied Geochemistry**

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# A review of land-sea coupling by groundwater discharge of nitrogen to New England estuaries: Mechanisms and effects

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#### **Abstract**

Hydrologists have long been concerned with the interface of groundwater flow into estuaries, but not until the end of the last century did other disciplines realize the major role played by groundwater transport of nutrients to estuaries. Mass balance and stable isotopic data suggest that land-derived NO<sub>3</sub>, NH<sub>4</sub>, and dissolved organic N do enter estuaries in amounts likely to affect the function of the receiving ecosystem. Because of increasing human occupancy of the coastal zone, the nutrient loads borne by groundwater have increased in recent decades, in spite of substantial interception of nutrients within the land and aquifer components of watersheds. Groundwaterborne nutrient loads have increased the N content of receiving estuaries, increased phytoplankton and macroalgal production and biomass, decreased the area of seagrasses, and created a cascade of associated ecological changes. This linkage between land use and eutrophication of estuaries occurs in spite of mechanisms, including uptake of land-derived N by riparian vegetation and fringing wetlands, "unloading" by rapid water removal, and direct N inputs to estuaries, that tend to uncouple the effects of land use on receiving estuaries. It can be expected that as human activity on coastal watersheds continues to increase, the role of groundwater-borne nutrients to the receiving estuary will also increase.

## Section snippets

## Background

Awareness of the importance of transport of materials by freshwater flow through rivers and streams to receiving coastal waters has existed as long as the history of natural science, but knowledge about the role of subsurface flows has a more recent history. Interest in the interaction of groundwater and coastal waters emerged early. Key features of flow through aquifers were identified in pioneering work by Darcy (1856), and by Baden Ghijben, 1888–1889, Herzberg, 1901, who interpreted vertical ...

## Nutrient transport by groundwater

The magnitude of land-derived nutrient transport by groundwater is set by the concentrations of nutrients near-shore, attenuation processes along flowpaths, and by groundwater flow rates. Of course, to some extent the impact of these exports are mediated by the ambient concentrations in the receiving waters, but in general, groundwater holds considerably higher concentrations of solutes than receiving estuaries. Here the forms of N dissolved in groundwater are focussed on because N is the ...

#### Concentrations

The relative area of diverse types of land covers and biogeochemical processes that occur during groundwater transport greatly alter not only the magnitude but also the composition, or chemical form, of N loads delivered from land to receiving waters (Kroeger, 2003, Kroeger et al., 2006b). On Cape Cod (and elsewhere, Fig. 1), the primary land use change in recent decades has been conversion of forested and agricultural land to residential uses (Bowen and Valiela, 2001a). This conversion to ...

# Effects on nitrogen concentrations in water of receiving estuaries

Nitrogen concentrations in receiving estuaries are directly related to both groundwater N concentration and within-estuary processing in the Waquoit Bay estuaries (Valiela et al., 2000a). Groundwater, the predominant transport mechanism in the Waquoit Bay system, delivers N-rich water to the receiving estuaries (Fig. 6, solid points). The composition of N compounds in groundwater depends on land use mosaics on the watersheds.

Nitrate is the dominant form of N in groundwater entering Childs River ...

## Modifications to degree of coupling between land and estuary

The mass balance and isotopic evidence, and the field measurements clearly argue that there are powerful couplings between land and open waters. In specific settings, it may be that diverse mechanisms work to uncouple receiving waters from the influence of land-derived N loads. Below three of these features: riparian and wetland fringes, and water residence times, are briefly discussed. ...

## Acknowledgements

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