

The impact of irrigation return flow on aspects of the water quality of the Upper Gamtoos Estuary, South Africa

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Abstract

Groundwater quality in the Loerie Flats, and subsurface irrigation return flow to the upper Gamtoos estuary was monitored from November 1992 to April 1994. The nutrient loading of groundwater was highly variable both spatially and temporally, with elevated nitrate-N levels reaching 163 mg·ℓ⁻¹. The elevated nutrient concentrations in the groundwater were directly related to the timing of land-surface application of fertilisers. The nutrient loading to the estuary, via subsurface irrigation return flow was calculated using Darcy's equation together with the mean concentration of nutrients found in groundwater in the Loerie Flats area. Results indicate that an average of 0.52 t nitrate-N, 0.02 t nitrite-N and 0.10 t of total phosphorus enter the Gamtoos estuary from the 5.5 km² Loerie Flats area on an annual basis. Such nutrient loads emanate from less than 20% of the total agricultural area bordering the estuary. Despite the elevated nutrient input to the estuary via groundwater discharge, the nutrient content of the estuary was generally low, but at times elevated concentrations of nutrients were recorded in the upper estuary. It was found that estuarine mixing processes and dilution, with adequate flushing have prevented the periods of low quality water from persisting in the Gamtoos estuary.

Introduction

Intensive agriculture has long been identified as a cause of nutrient loading of shallow groundwater (Konikow and Person, 1985; Hallberg, 1986; Sabol et al., 1987; Schmidt and Sherman, 1987). To determine the impact of irrigation return flow on receiving aquatic environments (Reay et al., 1992; Nuttle and Harvey, 1995), the volume and chemical characteristics of groundwater throughflow need to be assessed (Bokuniewicz, 1980; Johannes, 1980; Capone and Bautista, 1985; Millham and Howes, 1994). Furthermore, to identify the impact which irrigation return flow has on an estuary, it is necessary to assess the physical properties, mixing characteristics and residence times in the estuary (Birch, 1982; Kunishi, 1988; Baker and Horton, 1990).

This study has factors in common with that of Staver et al., (1996) who investigated the spatial and temporal patterns of nutrient inputs into the Choptank River estuary, USA. Like the Gamtoos estuary (South Africa), the Choptank estuary is well-mixed and shallow (less than 3 m deep), with land-use that is predominantly agricultural. Compared to most systems analysed elsewhere in the world, the input of freshwater into South African estuaries is very limited, and has been further reduced by the building of dams in many river catchment areas (MacKay, 1993; Jerling and Wooldridge, 1994). Where the natural flow of aquatic environments is limited, anthropogenic influences will be exacerbated, and may influence the functioning of the receiving estuary. The National Water Act (Act 36 of 1998), however, now recognises the environment as an official user of water and states that the long-term sustainability of aquatic ecosystems cannot be compromised (South African Government Gazette, 1998). The freshwater requirements of each estuary will need to be determined (a fairly complex task) so that the functioning of the ecosystems is

not adversely affected, whether it be caused by an upstream impoundment or the input of contaminants from agricultural or other land use.

This paper examines the nutrient loading of groundwater in the Loerie Flats (Fig. 1), and the subsurface irrigation return flow to the upper Gamtoos estuary from the Loerie Flats. The paper also outlines the resultant effect of this input on the water quality of the Gamtoos estuary.

Methods

The location of the study site - the Loerie Flats is shown in Fig. 1, a 5.5 km² area west of the Loerie River. The Loerie Flats is a narrow alluvial flood plain bordering the Gamtoos estuary and the Loerie River, a minor tributary. Evaporation in this region exceeds the annual average rainfall of ~400 mm (Schulze, 1986). The presence of the Kouga Dam on the Gamtoos River has reduced the natural freshwater flow downstream in the river to less than 1 m³·s⁻¹. Land-use in the Loerie Flats is intensive vegetable cultivation requiring irrigation (using surface water from the Kouga Dam) and supplemental application of fertilisers and pesticides to crops to ensure sustained yields.

To examine groundwater, sixteen shallow (depth: 4.30 m to 5.73 m) boreholes were installed in 4 groups as shown in Fig. 1. The variable underlying alluvial material (Zhang, 1995) necessitated the close positioning of the holes relative to one another. Soil is predominantly clay with thin lenses of sandy clay and sandy clay loam. Rest water levels (RWLs) and groundwater samples were taken monthly from November 1992 to February 1994, with limited monitoring of RWLs in five of the boreholes extended to June 1994.

The Gamtoos estuary was also monitored at 10 stations from the upper tidal limit to the estuary mouth, to determine nutrient content and depth profiles of electrical conductivity (EC), salinity and temperature. The locations of the upper tidal limit near station 1, stations 2 to 6 (bordering the Loerie Flats) and stations 7 to 9

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