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Preface

Groundwater–surface water interactions in wetlands for integrated water resources management

Groundwater–surface water interactions constitute an important link between wetlands and the surrounding catchment. Wetlands may develop in topographic lows where groundwater exfiltrates. This water has its functions for ecological processes within the wetland, while surface water outflow from the wetland may provide water downstream. Wetlands may also receive inflowing surface water, which may become relatively stagnant giving rise to groundwater recharge. This transition of surface water to groundwater provides groundwater resources for human and ecological purposes further down the groundwater basin. Groundwater–surface water interactions in wetlands thus play an important role with respect to spatial and temporal availability of both surface water and groundwater in the entire basin. Understanding (natural) groundwater–surface water interactions may help water resources managers to deal with such issues as flood mitigation, groundwater exploitation, and biodiversity conservation, in a more integrated and sustainable manner.

In July 2004, the 7th International Association of Ecology (INTECOL) International Wetlands Conference was held in Utrecht, The Netherlands. The conference drew more than 900 participants from more than 80 countries representing a wide range of expertise in wetland science, natural resource management, water policy, and nature conservation. Because the ecology of wetlands is intricately linked to hydrology, the contribution of hydrological knowledge to the conference was highly solicited. As a result, a number of symposia with invited speakers were organized around hydrological themes. One of these was entitled *Groundwater—surface water interactions in wetlands for integrated water resources management*, organized and co-chaired by the undersigned. Out of the 14 papers in this special issue, authors presented their work at this or other symposia during the 2004 Utrecht INTECOL Conference.

Among the many possible ways of grouping the papers in this special issue we have chosen to arrange them more or less according to wetland types represented.

1. Riparian wetlands in arid climates

McCarthy presents an overview of groundwater–surface water interactions in the inland Okavango wetland delta in Botswana. The driving force of these interactions is the yearly flood season giving rise to extensive groundwater recharge. The infiltrated flood waters are transported as groundwater to wetland islands bordering the river delta channels driven by the evaporative force of island plants. Dissolved solids in the flood waters are transported in the groundwater leading to salt accretion below and on the island centres thus keeping the surface waters in this arid wetland fresh even after cessation of the floods.

Wolski and Savenije discuss a numerical groundwater model of this same system, which provides a tool for developing a generalized understanding of this type of wetland system and for testing hypotheses about managing such systems.

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Webb and Leake used repeat photography to document long-term changes of riparian vegetation in the southwestern United States as a result of climate variability and land-use changes. They conclude that "The explicit linkage of fate of riparian vegetation and conjunctive use of groundwater and surface water needs to be more thoroughly understood if protection of this type of ecosystem is a future management priority."

2. Riparian wetlands in humid climates

Grapes, Bradley, and Petts discuss the hydrodynamics of floodplain wetlands near the River Lambourn, a chalk catchment in the United Kingdom. They used a MODFLOW model to simulate groundwater discharge to the river throughout the catchment as well as ground water levels in the lower catchment. The results indicated the importance of taking catchment-scale water flow into account when managing isolated wetlands in a permeable catchment.

Langhoff, Rasmussen, and Christensen discuss a field investigation of the interaction between ground water and surface water along an alluvial stream in Denmark. As a result of their field studies, they developed a characteristic of alluvial valleys termed the C-ratio, which is defined as the typical width of the riparian zone divided by the effective width of the stream. When the C-ratio is small, seepage is largely through the streambed. When it is large, groundwater discharges mainly to large diffuse areas within the riparian zone. The physiographic data are easily attainable from maps and areal photographs.

Griffioen, in a study of nutrient-rich groundwater discharging to surface water in the western part of The Netherlands, found that phosphate may be almost completely immobilized during aeration of the anoxic groundwater. This finding is important for managers as it implies that heavy loading of surface water with phosphorus is (at least temporarily) prevented by the immobilization process.

Hunt, Strand, and Walker discuss the relation of benthic organisms to seepage patterns in a wetland stream in Wisconsin, USA. Reaches that had high groundwater discharge had the greatest abundance of organisms compared to reaches that had weak discharge and reaches that recharged groundwater. One conclusion states that '…knowledge of the range of groundwater–surface water interactions operating in a watershed could be critical for applying site-specific results to watershed-scales most often required for integrated water resources management.'

Genereux and Jordan document the significant extent of groundwater discharge from regional flow systems in lowland streams and groundwater in Costa Rica. They indicate that the significant rates of interbasin groundwater flow, together with the substantially different water chemistry compared to local flow systems, need to be taken into account in water resource planning for lowland watersheds.

3. Regional scale (blanket type) wetlands

Harvey, Newlin, and Krupa discuss groundwater and surface water interactions in the Florida (USA) Everglades. They indicate that a small but potentially significant amount of surface water recharges the aquifer, where it is stored for years to decades. This long-term storage of water and solutes in groundwater has implications for restoration of the Everglade's water quality.

Siegel et al. discuss the dynamic balance between organic acids and circumneutral groundwater in the Glacial Lake Agassiz peatlands of northern Minnesota, USA. They conclude that bog organic acids are largely responsible for the low pH of bog waters, and that the variable mixtures of organics acids with bicarbonate groundwater define the ranges of fen water chemistry.

4. Isolated wetlands and lakes

Woo and Young provide an overview of the occurrence and hydrology of wetlands in the high Arctic of Canada. They indicate that the sustainability of these wetlands depends on their water supply exceeding losses to evapotranspiration and lateral drainage. Disturbances such as climate variations, geomorphic changes, and drainage can have an adverse effect on their sustainability.

Turner and Townley discuss the use of hydrochemistry, stable isotopes of water, and numerical modeling to determine the zones of groundwater that discharge to lakes and zones of lake water released to groundwater for two lakes in western Australia. The tools will improve the scientific basis for water resource and environmental managers involved with lake, wetland, and groundwater management.

Cohen et al. in a study of lakes in the Crow Wing watershed in central Minnesota, USA, found that lakes and groundwater respond differently to climate change depending on their position relative to major streams in the watershed. The findings are important to lake and watershed managers who need to develop management strategies that are relevant to the unique characteristics of individual lakes.

Wilcox et al. present a case study of how a water budget was used as the foundation for restoring a wetland in northern Michigan, USA. The study showed that the interaction of groundwater and surface water is critical for maintaining ecosystem processes in the wetland, and need to be considered in any management plan.

Although not all of the papers in this special issue emphasized, or even mentioned, the management implications of their work, all of the papers have relevance to integrated water resources management.

The knowledge of hydrologists well versed in the interactions groundwater and surface water is essential to water resource and natural resource managers who need to deal with such issues as flood mitigation, groundwater exploitation, biodiversity, and conservation in a more integrated and sustainable manner. It is therefore hoped that in the future hydrologists will increasingly make efforts to translate their professional and scientific insights into practical knowledge applicable to the sustainable management of the world's natural resources.

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