Mechanisms of seawater intrusion in Bangladesh and the potential impacts of sea-level rise on coastal groundwater resources

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ABSTRACT

Bangladesh is a low-lying country situated at the Ganges and Brahmaputra river-systems confluence in the Bengal Basin. The coastal region is subject to high rates of fluvial sediment deposition and endures river and saline storm surge flooding during the rainy season. Groundwater is the primary source of drinking water in the region, but aquifer water quality is highly variable and characterized by a ~100-m thick saline layer overlying freshwater. One meter of sea-level rise would inundate nearly 20% of Bangladesh land area (assuming today's topography does not change due to sedimentation) creating millions of displaced residents and a new coastal zone far inland of the current one.

This study evaluates the mechanisms and controls on seawater intrusion in Bangladesh resulting from historical and possible future sea-level rise, and evaluates the impact of groundwater pumping for domestic water supply and irrigation on seawater intrusion. Three basic salinization mechanisms are considered: lateral (classical) seawater intrusion, vertical intrusion from surface or shallow saline sources, and the mixing of pre-existing fresh and saline water in the subsurface due to pumping. Analyses were based on two-dimensional profiles representing typical cross-sections of the aquifer perpendicular to the coastline, and salinization mechanisms were evaluated by numerical simulation using the SUTRA density-dependent groundwater flow and transport code.

Simulations show that the process of lateral intrusion is very slow compared to the vertical infiltration of seawater, and that coastal pumping increases the rate of intrusion due to both mechanisms and increases fresh- and saline-water mixing. Simulations of historical sea level rise show that the current condition of saltwater overlying freshwater may be due to either repeated saline floods or connate seawater trapped by low permeability layers in the shallow aquifer. Long-term simulations also show that the present day transition zone is in a transient state, continuing to migrate inland due to sea-level rise that has been occurring since the last glacial maximum.

The aquifer fabric is heterogeneous, consisting of discontinuous layers of sand, silt and clay. Simulations demonstrate that the highly variable lithologic pattern exerts a strong control on the freshwater-seawater distribution and its evolution in the coastal aquifer. It is likely that some coastal-zone domestic wells are pumping from isolated pockets of freshwater with limited sustainability, rather than from what was thought to be a single deep aquifer overlain by a regionally-continuous confining unit. This indicates that the current coastal freshwater supply in Bangladesh is not permanent, even if the coast remains stationary in the future, due to continued lateral seawater intrusion from past sea-level rise. The rate of lateral intrusion resulting from historical sea-level rise is,

however, slow for the conditions considered in this work, and not imminently threatening the entire coastal water supply.

Should the coast migrate inland as a result of sea-level rise, the primary impact of sea-level rise would be the loss of land to the sea. Within the newly located coastal zone, in this situation, the same salinization mechanisms and problems would exist as in the current coastal zone. Thus, given that today's situation is already a transient state resulting from historical sea-level rise in the Holocene, effective management of today's coastal groundwater resources is a prerequisite to the proper management of any potential salinization resulting from inland migration of the coast.

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