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Hydro-mechanical perturbation of groundwater by rivers: evidence from Bangladesh

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Bangladesh, located at the confluence of the mighty Ganges, Brahmaputra and Meghna (GBM) rivers with a drainage channel density of 0.16 km/km^2, is close to 100% dependent on groundwater for drinking and domestic use, and 75% dependent on groundwater for irrigation and food security. The Bengal Aquifer System (BAS), source of water to over 150 million people, is the largest aquifer in south Asia but subject to multiple threats: arsenic commonly exceeds safe levels in shallow groundwater (<100 m) beneath the Quaternary-Recent GBM floodplains, excessive salinity is common in coastal regions, resource depletion is an issue in Dhaka city and the Barind Tract, and sustainability of deep groundwater abstraction is in question more generally. Therefore, rigorous monitoring of the resource is vital, for which the Bangladesh Water Development Board (BWDB) manages a national network of more than 1035 monitoring boreholes, with screen depths ranging from 5 to 77 m depth below ground level. Recent research has suggested, however, that the basis for all current interpretations of the groundwater monitoring data, *ie* that borehole water levels are a direct measure of changes in groundwater storage, may be mistaken under some circumstances. Rather, the poroelastic character of the BAS should be acknowledged, including that groundwater levels may be susceptible to hydro-mechanical perturbation through changes in water mass at the ground surface (*eg* from individual rainfall and flood events during the monsoon, and by drainage and drying of the land surface during the dry season). In some situations, borehole hydrographs are dominated by the mechanical response, and act as 'geolysimeters', operating essentially as a spring balance, responding to changes in water mass at the Earth's surface rather than to changes in groundwater storage volume. We are currently investigating the BAS poroelastic response to loading from the large and extensive GBM river network. The rivers are among the largest in the world; hydro-mechanical effects should be expected but have not previously been described. Here we show groundwater heads in vertical profile to ∼250 m depth adjacent the bank of the river Meghna in Matlab (south-central Bangladesh) and at ∼100 m depth along a horizontal transect to a distance of ∼10 km from the river bank, the first documentation of river loading effects at this scale. Synchronous daily tidal components are clearly evident to ∼2 km distance from the river, and lunar monthly tidal effects are present in groundwater hydrographs even at the most distant piezometers, which are dominated by the annual river stage cycle. Lunar monthly and annual cycle responses exhibit phase-shift relative to the river source, whereas the daily tide does not. The field observations are considered against results of a scoping study using 2D dynamic hydro-mechanical modelling. The empirical observations suggest that groundwater levels in up to 70% of BWDB monitoring boreholes may be perturbed by hydro-mechanical effects of river loading, and in these cases a more sophisticated approach to groundwater monitoring and recharge estimation is necessary.