HYDRO-MECHANICAL PERTURBATION OF GROUNDWATER AND THE GROUND SURFACE BY RIVERS: EVIDENCE FROM BANGLADESH

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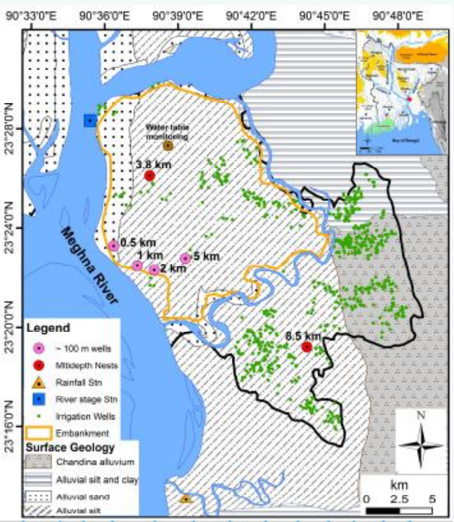
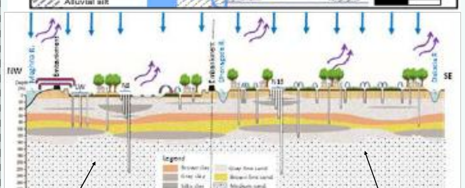
Abstract: The Bengal Aquifer System (BAS) provides water to over 150 million people and the BWDB monitors groundwater status using a national network of >1035 piezometers (5 to 77 m depth). Recent research [1, 2] shows the poroelastic character of the BAS, and suggests ~75% of the BWDB network may suffer hydro-mechanical disturbance; some piezometers are sensitive solely to (mechanical) water loading at the ground surface rather than (hydrological) changes in groundwater volume ie they act as 'geolysimeters'. **The Ganges-Brahmaputra-Meghna (GBM) floodplains are dominated by rivers which are amongst the largest in the world; hydro-mechanical effects should be expected but have not previously been described or attributed to rivers.** Here we present the first empirical documentation of river loading effects at this scale, showing hourly groundwater heads at 100 m depth in a horizontal transect to ~5 km distance from the bank of the river Meghna at Matlab, south-central Bangladesh, and in a vertical profile to 240 m depth at ~10 km distance. Also we present preliminary results from a 2D dynamic hydro-mechanical model, and use the model to illustrate the scale of ground surface movements driven by periodic changes of river stage. In this environment, geodetic studies should account for the spatially variable effects of rivers.

FIELD LOCATION: RIVER MEGHNA, MATLAB

The Matlab district in south-central Bangladesh lies adjacent the eastern bank of the tidal River Meghna, close to its confluence with the Padma River (bottom). The Meghna, ~2 km wide, has a tidal range up to 0.8 m and annual stage fluctuation of ~3 m. The GBM floodplains are underlain by the Bengal Aquifer System (BAS), thick sequences of Quaternary-Recent sand, silt and clay. The map shows the points of measurement of groundwater level (head), river stage and rainfall, and areas of contrasting water management for irrigated agriculture, as illustrated in the diagrammatic cross-section.





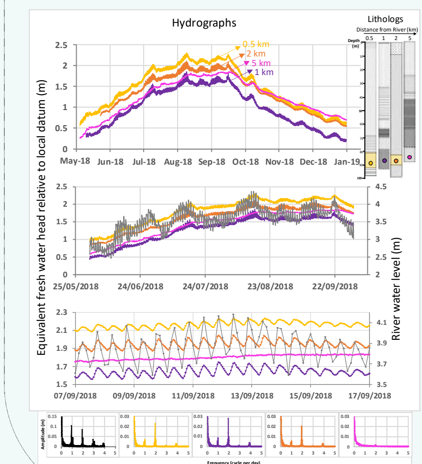
Irrigation by controlled flooding from river, within embankment

Irrigation by groundwater wells 25-75 m

Confluence of Padma & Meghna rivers

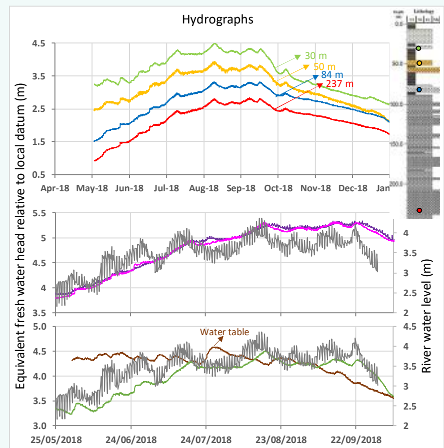
GROUNDWATER TRANSECT TO 5 km DISTANCE FROM THE RIVER AT 100 m DEPTH

Groundwater head variations at ca 100 m depth are synchronous with the river at tidal, spring-neap and annual periodicities to 2 km distance from the river. Amplitude of the twice-daily (M2) tidal component decreases with distance; the spring-neap component is approximately constant. At 5 km and beyond, the spring-neap and annual periodicities are lagged relative to the river.



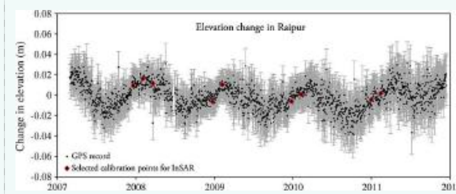
GROUNDWATER VERTICAL PROFILE AT 10 km DISTANCE FROM THE RIVER

At 8.5 km distance, groundwater hydrographs from points in vertical profile between 30 and 237 m depth are conformable with the annual river stage cycle and include lunar spring-neap tidal components; the hydrographs are synchronous with each other (top) but lagged relative to the River Meghna (middle, bottom). At 30 m depth, the groundwater hydrograph appears strongly correlated with the river rather than the water table (bottom).

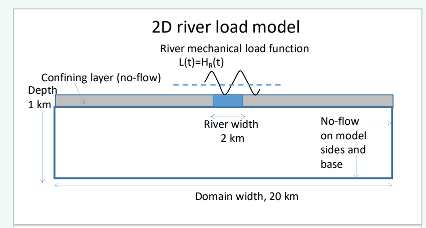


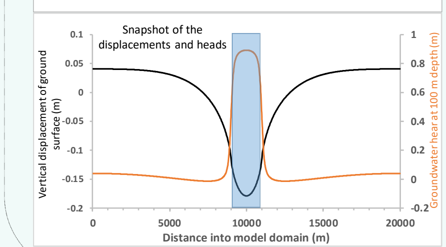
HYDROLOGICAL LOADS AND GROUND SURFACE VERTICAL DISPLACEMENTS

Seasonal ground surface oscillation of the GBM floodplain [3, 4], synchronous with the monsoon, has been attributed to elastic deformation and rebound of the Earth's crust under the weight of monsoon water across the entire region. The InSAR+GPS record (below) is from Raipur [4], ca 11 km from river Meghna, 25 km south of Matlab study area.

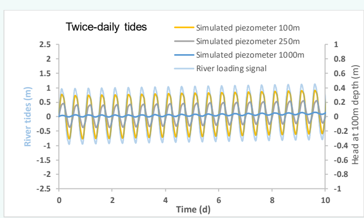


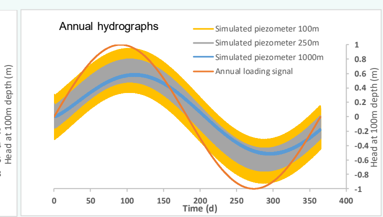
A coupled 2D hydro-mechanical model (schematic below; code COMSOL 5.2a) has been applied to scope the ground surface displacements together with groundwater head fluctuations due to river stage fluctuations. A snapshot of the displacements and heads at 'high-tide' due to a 1 m twice-daily tide (below) shows tidally-driven ground surface displacements ranging from 20 cm at the river edge to 2 cm at 1 km distance. Displacements due to the full annual river stage and tidal fluctuations combined will be a complex outcome of hydro-mechanical interactions, and are the subjects of on-going research.





MODEL SIMULATIONS





The groundwater tidal data are consistent with results of 2D hydro-mechanical modelling (see model arrangement in right-hand column): synchroneity with the river tides and a decline in amplitude to ~1 km distance are predicted in an aquifer subject to hydro-mechanical influences of river tides. In contrast, the apparently synchronous aquifer response to the annual river hydrograph at up to 2 km distance, is at variation with the model prediction of a phase-shift at annual periodicity.

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