The Entrapment of Onshore Seawater within the Ganges-Brahmaputra-Meghna Delta due to Rapid Sedimentation

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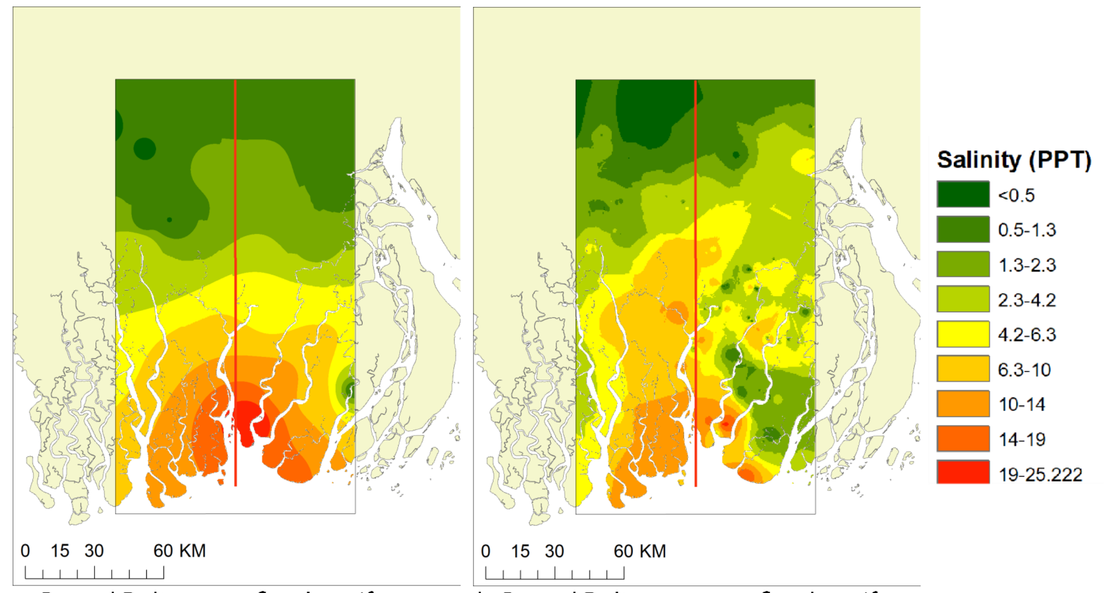
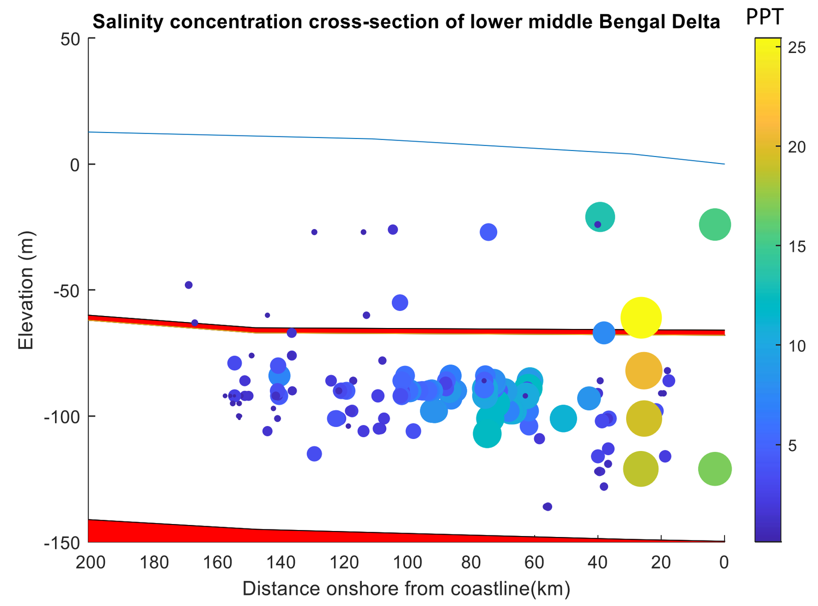
Background

Many delta systems around the world have naturally occurring onshore saline to brackish water up to 100 km inland from the coastline. These delta systems also are characterized by rapid sediment progradation rates. We hypothesize that rapid sediment avulsion is responsible for trapping seawater onshore.

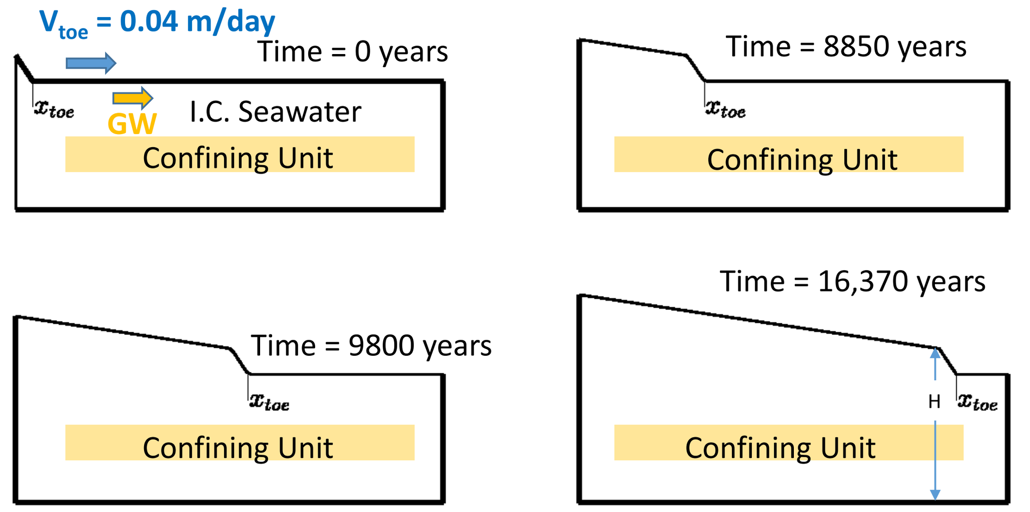


a. Bengal Delta unconfined aquifer salinity (< 67m depth)
b. Bengal Delta upper confined aquifer salinity (within 67-150m depth)



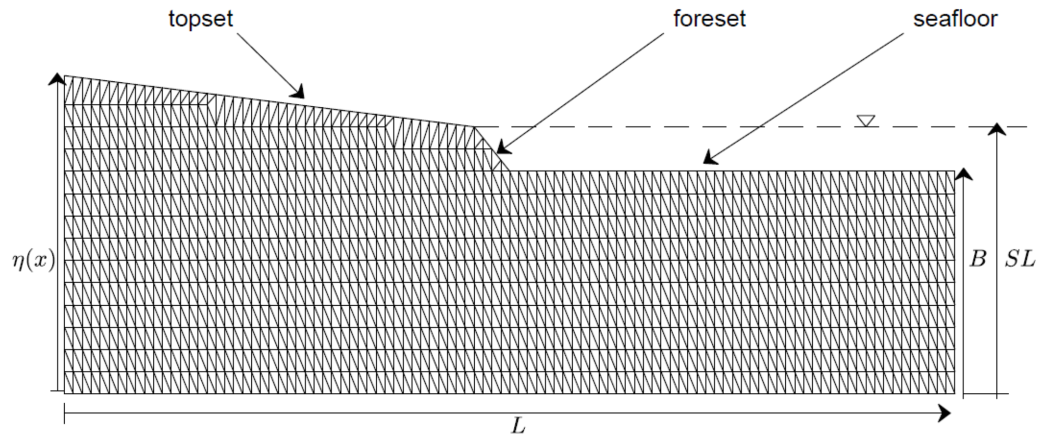
Methodology

To test the above hypothesis, we have developed a Control Volume Finite Element (CVFEM) model consisting lateral sediment transport, variable-density groundwater flow and solute transport (Voller et al. 2022). We use this model to assess whether rapid sedimentation can trap seawater onshore.



Boundary Conditions:

Top Boundary- Specified head boundary conditions with density effects present for top nodes below sea level. Land surface elevation set as specified heads above sea level. Specified concentrations of 0 ppt for onshore nodes and 35 ppt for nodes below sea level. No Flow on Side and Bottom boundaries.



Shoreline velocity (v_{toe}) 0.04 m/day

Voller et al. 2022, WRR, in revision

Governing Equations

Groundwater Flow

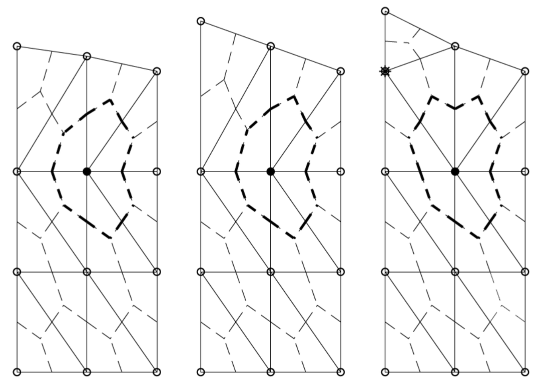
$$S_s \frac{\partial h}{\partial t} = \frac{\partial}{\partial x}\left[K_x \frac{\partial h}{\partial x}\right] + \frac{\partial}{\partial z}\left[K_z\left(\frac{\partial h}{\partial z} + C(\rho_r - 1)\right)\right]$$

Solute Transport

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial x}\left[-v_x C + D_{xx}\frac{\partial C}{\partial x} + D_{xz}\frac{\partial C}{\partial z}\right] + \frac{\partial}{\partial z}\left[-v_z C + D_{zz}\frac{\partial C}{\partial z} + D_{zx}\frac{\partial C}{\partial x}\right]$$

Groundwater Velocity

$$v_x = -\frac{K_x}{\phi}\frac{\partial h}{\partial x} \qquad v_z = \frac{K_z}{\phi}\left[\frac{\partial h}{\partial z} + C(\rho_r - 1)\right]$$



S_s, specific storage; h, freshwater hyd. head; C, normalized concentration; K_x/ K_z , hyd. cond. in x/z directions; D_{xx}, D_{xz}, D_{zx}, D_{zz} components of Disp./Diff. tensor; ϕ, porosity; v_x/ v_x , GW velocity. in x/z directions; ρ_r, ratio of the density of saturated saline to fresh water

Dimensionless Groups

Voller et al. 2022 found two dimensionless number groups that could describe the controls on onshore seawater entrapment. One dimensionless number group was the ratio of toe velocity vs GW velocity. The 2nd number group is the Peclet number which is the ratio between advective to diffusive transport.

$$G_v = \frac{v_{toe}}{v_{gw}} = \frac{v_{toe}\phi}{K_x S_t} \qquad P_e = \frac{SL}{\alpha_L} \qquad G_T = P_e\, G_v$$

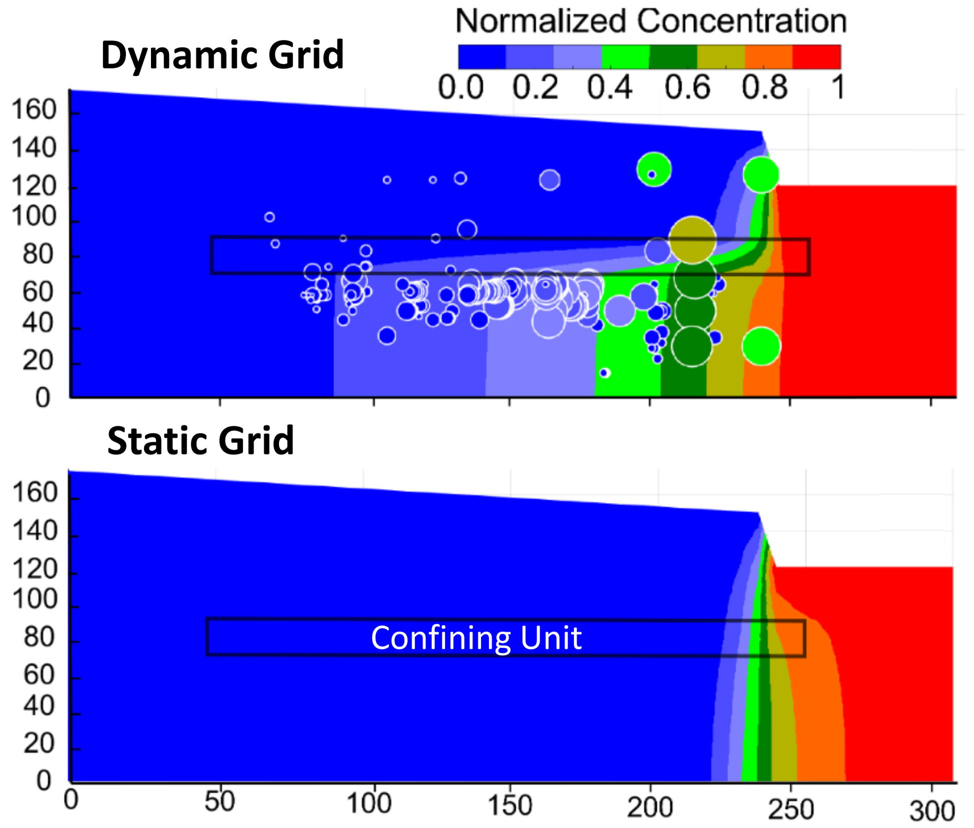
v_{toe} = Toe velocity, ϕ= Porosity, S_t= Topset Slope , K_x= Hydraulic Conductivity, SL= Characteristic Length, α_L= Longitudinal Dispersivity

A larger G_v means that the shoreline advance rate outruns the recharge and enhances entrapment of seawater. When the P_e is larger, lesser mixing between fresh and seawater is expected which leads to increased seawater trapping.

Results

We applied Voller's model to the Bengal Delta in an attempt to test our hypothesis. We used an inverse model to determine best fit parameters (see below). Hydraulic Conductivity, Dispersivity and the presence of confining units played key roles in onshore seawater entrapment.

We recently collected 48 magnetotelluric (MT) soundings along the Bengal Delta to further test our hypothesis (see figures to the right). The inversions of our MT data will be presented at the Fall AGU meeting (Le et al., 2022).



Bengal Delta Test Case

v_{toe} =0.04 m/day,
K_x= 20 m/day,
K_{x_conf}= 0.005 m/day,
α_L= 70m
G_T = 5.4

Static Grid Run Case

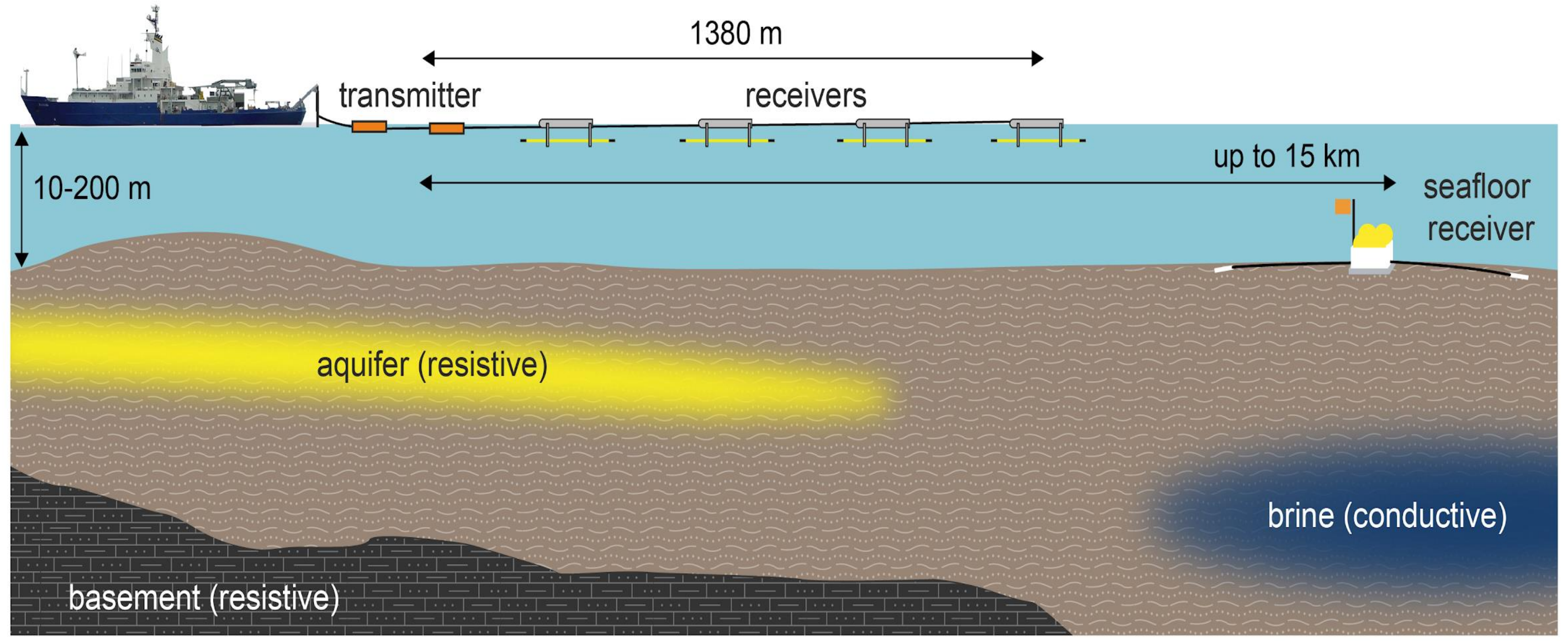
v_{toe} = 0 m/day,
K_x= 20 m/day,
α_L= 70m
G_T = 0

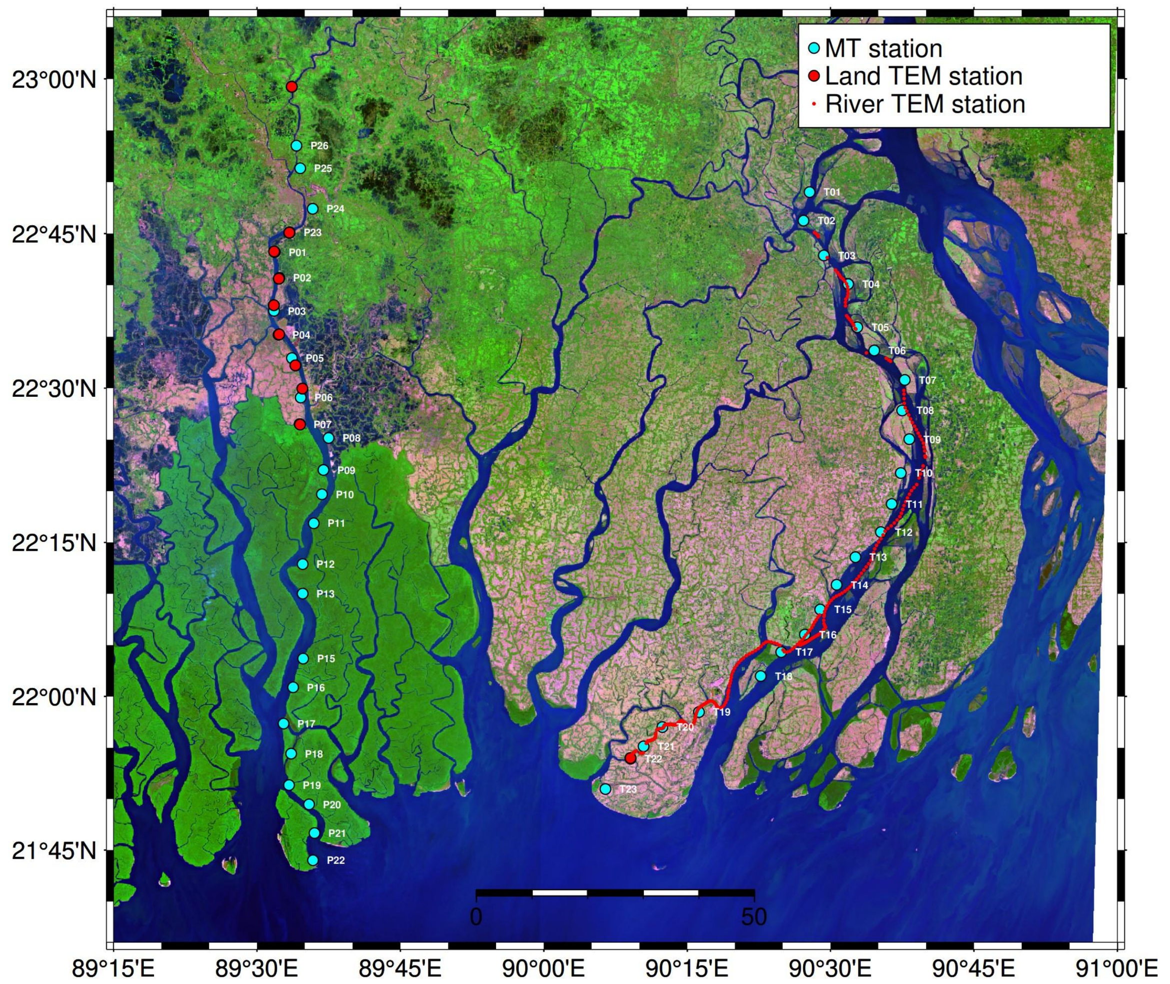
Le et al. 2022, An Electromagnetic Survey for Imaging Large-Scale Groundwater Systems in Ganges-Brahmaputra Delta, Bangladesh, AGU Fall Meeting 2022, Chicago

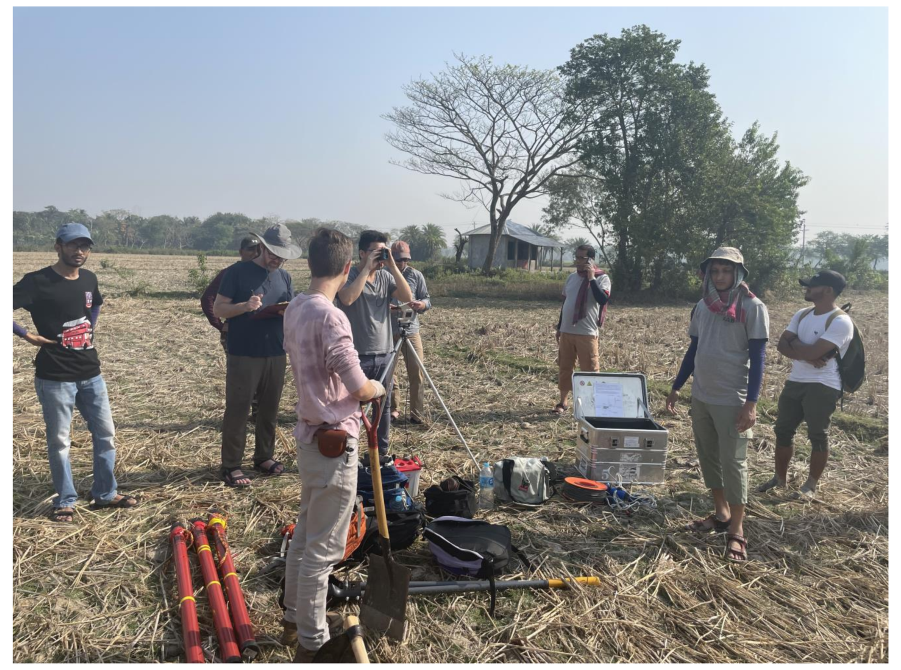
Conclusions

Entrapment of seawater onshore within the Bengal Delta can be explained , in part, by rapid shoreline progradation and the presence of a confining units. This conclusion may apply to other delta systems around the world (e.g. Mississippi delta).

Bangladesh MagnetoTelluric/TEM Field Survey







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