DIGITAL MAPPING TECHNIQUES 2014

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Impacts of sea-level rise on groundwater resources in the Delaware coastal plain: a numerical model perspective

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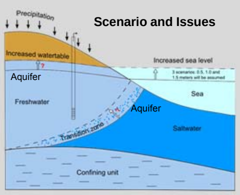
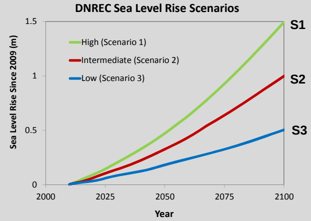
1. Abstract

Groundwater flow in Delaware's surficial aquifer adjacent to the Delaware Estuary is simulated using a 3-D, transient, variable-density groundwater flow model. The model predicts movement of the fresh-water/salt-water interface and changes in water table depth due to sea-level rise through the year 2100. Three scenarios simulate sea level rises of 1.5 (S1), 1.0 (S2), and 0.5 (S3) meters. A representative conceptual model was constructed based on the characteristics of ten selected Delaware watersheds. Results indicate that the salt water intrudes inland up to 4.6 km along the tidal river in scenarios S1 and S2. To estimate effects on Delaware watersheds, modeled changes in water table depth are applied to 18 watersheds by mapping model coordinates to each watershed. Areas potentially impacted by sea level rise are identified by evaluating two critical depths to water, 0 and 0.5m, representing groundwater inundation (waterlogging) and effective rooting depths of major local crops. Land area impacted ranges from 60 hectares for scenario S3 with critical depth 0m to 18,500 hectares for scenario S1 with critical depth 0.5m. For scenario S3, there is minimal impact for the 0m condition (60 ha), but significant impact for the 0.5m condition (4,400 ha). There is 5-9 times more area impacted by waterlogging from a rising water table than from surface water inundation for all scenarios except scenario S3 with the 50cm condition where it is 38 times more area. Over 60% of the impacted area in all scenarios is cropland.

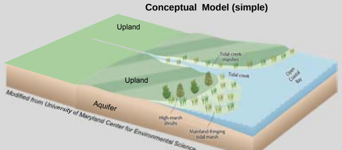




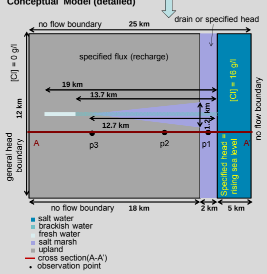
The study focuses on the effect of sea level rise on the water-table aquifers in Delaware Bay watersheds.

2. Modeling Methodology

Conceptual Model (simple)

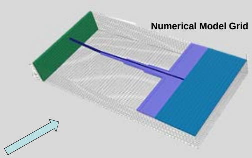


Conceptual Model (detailed)



Conceptual model of a typical tidal creek and watershed in the Delaware Estuary.

Conceptual model is a rectangular domain with an upland (gray), tidal river (blue), bay (turquoise) and, tidal wetlands along the river and bay (purple). As sea level rises, the creek stage increases with time to account for the effect of the encroaching tidal prism. The marsh area is progressively inundated during sea level rise to simulate transgression. Saltwater migrates from the bay up the creek as sea level rises.



SEAWAT simulation code
3-D, transient, variable density

Hydrologic Properties

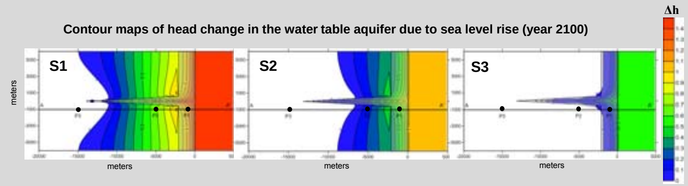
Model Parameter	Value
Cell size	50 to 400 m
Hydraulic Conductivity	25 m/day
Longitudinal dispersivity	1 m
Effective porosity	0.25
Upland recharge	380 mm/year

Initial condition:
1,000-yr ramp-up to steady-state

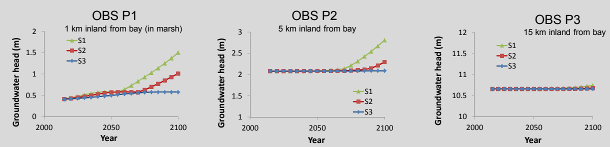
3.1. Water Table

At the upland/marsh boundary (X=2,000 m), the water table rises 0.8, 0.3 and 0.1 m for S1, S2, S3, respectively by year 2100. Head changes propagate 13, 8, and <1 kilometers inland for S1, S2, and S3, respectively by year 2100.

Contour maps of head change in the water table aquifer due to sea level rise (year 2100)

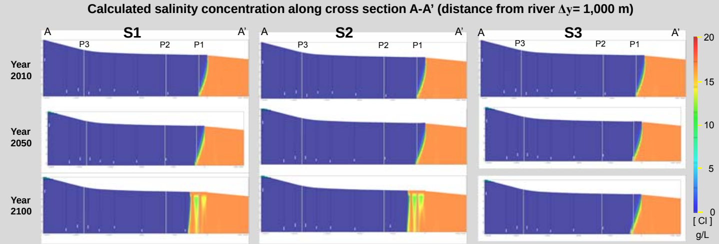


Water table changes over time at observation points P1, P2 and P3 (locations are shown in figure above)

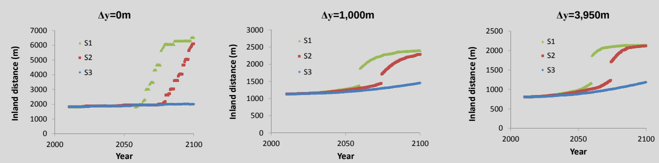


3.2. Salinity

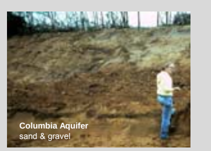
Calculated salinity concentration along cross section A-A' (distance from river Δy= 1,000 m)

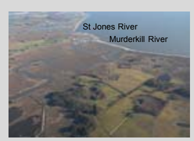


Calculated position of the salt water front in bottom layer for different distances from river (Δy)



By year 2100, in S1 and S2, the toe of the salt water front migrates 4.6 km in the aquifer under the river. The toe does not migrate significantly in S3 at that location. At 3.95 km from the river, the toe migrates 1.5, 1.5 and 0.5 km for S1, S2, and S3, respectively



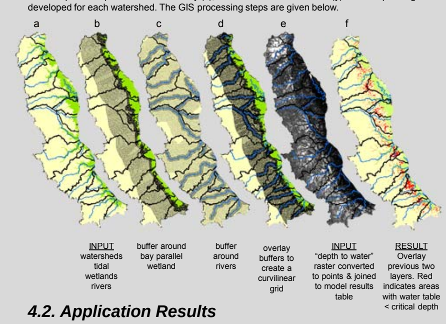


4. Application

Information from the simulation was used to identify areas within these coastal watersheds that would be inundated by the rising sea or become waterlogged due to a rising water table.

4.1. Application Methodology

The predicted change in head (Δh) for each scenario was output from the model into a coordinate system representing distance from the present upland/marsh boundary (x), and distance from the river (y). A corresponding curvilinear coordinate system was developed for each watershed. The GIS processing steps are given below.



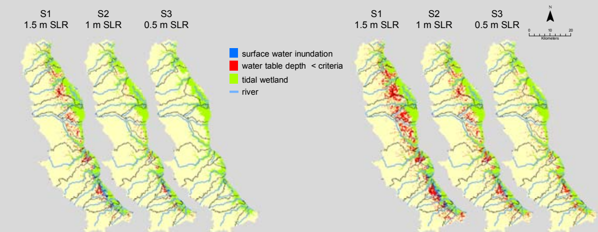
GIS processing steps

a. Input data: tidal wetlands and primary river for each watershed
b. Erase tidal wetlands along primary rivers (long axis quasi-perpendicular to the shoreline) to produce "bay marsh". Calculate multi-ring buffers for distance away from bay marsh (x-coordinate).
c. Calculate multi-ring buffers with distance away from rivers (y-coordinate).
d. Overlay multi-ring buffers to create a grid.
e. Input data: Convert "depth to water table" raster to a vector point layer.
f. Overlay point layer (not shown) with both multi-ring buffer layers. A table of model output from the end of the simulations (2100) with similar coordinate system (distance from marsh and river) is joined to the attribute table and a new depth to water was calculated.

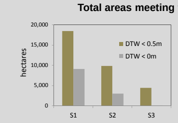
4.2. Application Results

A critical depth to water is defined as the depth where there would be impacts to current land uses. Two critical depths to water were used: 0 m (water at land surface) and 0.5 m. The latter value was chosen as a conservative representation of the effective rooting depths (EFD) of local crops (90% of all crops are corn, soybeans, and winter wheat). Saturated conditions in the root zone inhibit crop growth. The EFDs of corn and winter wheat are 0.9m and 0.6m for soybeans. Areas of tidal and nontidal wetlands were not included in calculations shown below, but tidal wetlands (green in figures below) are fully inundated in year 2100 for all three scenarios, assuming no migration landward or vertical accretion. Areal distributions of areas meeting the depth criteria are shown below in blue (inundated by surface water) and red (waterlogging from rising water table). Most of the areas affected are croplands (> 60% for all scenarios and conditions; see pie chart and photo below).

water table depth < 0 m — **water table depth < 0.5 m**

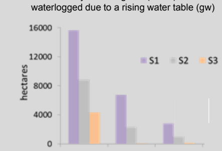


Total areas meeting the depth criteria

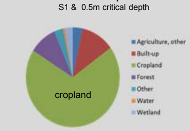


Scenario	hectares DTW <0.5 m	DTW < 0m
S1	18,500	9,100
S2	9,900	3,000
S3	4,400	60

Areas meeting the depth criteria that are inundated by the rising sea (inund) or waterlogged due to a rising water table (gw)



Land use impacted
S1 & 0.5m critical depth



5. Conclusions

Water-table rise and surface-water inundation in year 2100

- Total land area impacted ranges from 60 hectares (ha) for 0.5m SLR with critical depth of 0m to 18,500 ha for 1.5m SLR with critical depth of 0.5m.
- Over 60% of the area impacted in all scenarios is cropland.
- 3 to 9 times more area is impacted by a rising water table than from surface-water inundation for all scenarios except 0.5 m SLR with the 0.5m condition where it is 38 times more area.

Salt-water intrusion in year 2100

- By year 2100, for 1.5m and 1.0m SLR, the salt water in the base of the aquifer migrates 4.6 km inland from the marsh/upland boundary under the river.
- By year 2100, at 4 km from the river, salt water in the base of the aquifer migrates 1.5, 1.5 and 0.5 km for 1.5, 1.0, and 0.5m SLR, respectively.