SUITABLE BOUNDARY LOCATION IDENTIFCATION FOR RAINFALL-RUNOFF AND SURGE MODEL COUPLING TO EVALUATE COMPOUND FLOOD HAZARDS IN COASTAL REGIONS

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INTRODUCTION

Flooding in many coastal regions is exacerbated due to complex interactions of multiple flood drivers such as rainfall-runoff and coastal surge which can occur simultaneously or sequentially during storm events, leading to compound flooding hazards. The Texas Gulf Coasts (USA) are especially vulnerable from compound flooding due to frequent occurrence of tropical storms which bring strong winds to drive storm surge and heavy rainfall to generate inland flooding. Large scale studies {Coastal Texas Restoration and Protection Study (CTX, 2021), Texas General Land Office's Texas River Basin Study, Base Level Engineering Study} are being conducted by state and federal agencies for flood hazard assessment and for development of mitigation and abatement strategies for reducing this risk and increasing community resilience. Traditionally, large scale storm surge models do not account for runoff contributions to water levels in the interior of their domain. Riverine models for their part use either normal depth or mean high water levels to assign downstream boundary conditions within tidally influenced area, thus ignoring effects of storm surge. In this Planning Assistance to States (PAS) study, located in the Lower Clear Creek and Dickinson Bayou watersheds (Texas, USA), we have evaluated rainfall-runoff and storm surge interactions to determine suitable locations to use as model boundary conditions for exchanging data between rainfall-runoff and surge models under compound flooding conditions.

METHODS

Complex interactions of storm surge and rainfall-runoff processes on compound flooding were resolved in this study by performing rainfall-runoff modeling with hydrologic & hydraulic models (e.g., HEC-HMS, HEC-RAS), and storm surge/wave modeling with the Coastal Storm Modeling System (CSTORM-MS, Massey et. al., 2011) coupled surge model Advanced Circulation (ADCIRC) and nearshore wave model Steady-State Waves (STWAVE). This study updated an ADCIRC mesh and STWAVE grids from the Coastal Texas Study (CTX, 2021) to include increased resolution in the study focus areas (see figure 1), and updated bathymetry of the Clear Creek and Dickinson Bayou watersheds using the 2018 Texas Water Development Board Lidar dataset and bathymetric surveys along Dickinson Bayou.

Riverine inflow contributions from major Clear Creek and Dickinson Bayou tributaries were provided by an existing hydrologic model, HEC-HMS which was developed as part

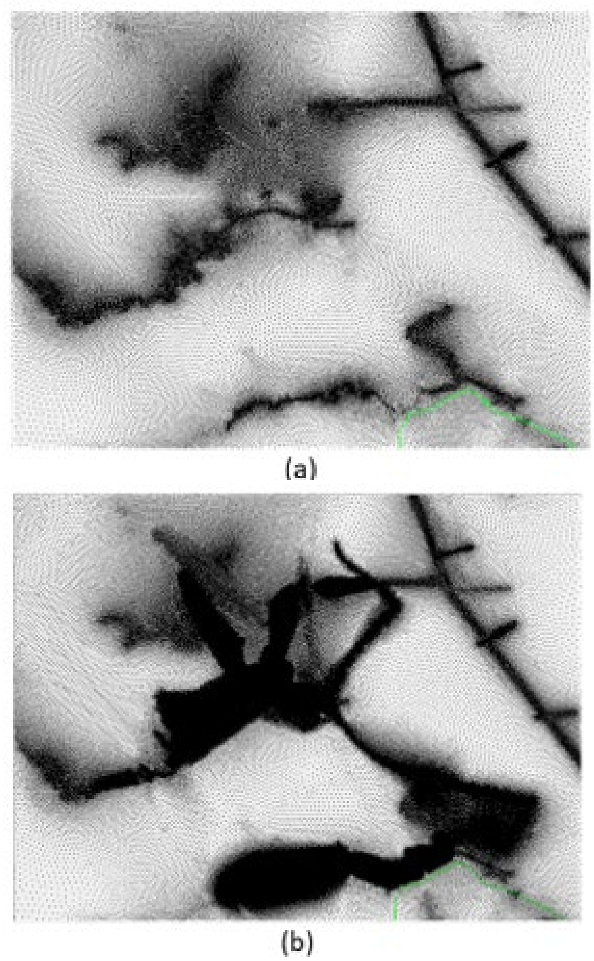

Figure 1- ADCIRC element edges as black lines in the Dickinson Bayou and Clear Creek areas for (a) the CTX ADCIRC mesh and (b) the refined ADCIRC mesh.

of the Lower Clear Creek and Dickinson Bayou Flood Mitigation Plan (Freese & Nichols, 2021), The flows were extracted at the confluence of the tributaries and the main stem for each watershed. Riverine inflow specifications from major Clear Creek and Dickinson Bayou tributaries were inserted by removing three elements per inflow (see Figure 2). Each "hole" in the mesh incorporates a mainland boundary condition for the portion of the element(s) on land and a river flow boundary condition for the portion of the element located within Clear Creek or Dickinson bayou. Figure 3 shows each tributary flow specification locations in both Clear Creek and Dickinson Bayou watersheds as inserted in the ADCIRC mesh. The rainfall-runoff model

(HEC-RAS) downstream boundary condition inputs were assigned by using the surge model simulation results. Both rainfall-runoff and surge model simulation results for a few historical and synthetic events were compared to gain insights on suitable locations for boundary data exchanges for compound flood hazard estimations. Hurricanes Ike (2008) and Harvey (2017), and Tropical Storm (TS) Allison (2001) were selected to provide more meaningful real-world context from recent events affecting the study area.

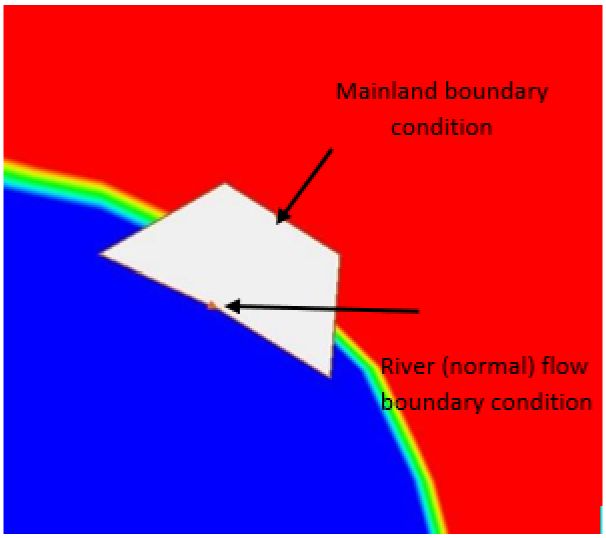

Figure 1- Zoomed in view of tributary flow contribution insertion into the ADCIRC mesh in the Clear Creek and Dickinson Bayou areas with arrows indicating the two boundary conditions used to specify the mainland boundary condition and the tributary flow boundary.

Figure 3- Locations for tributary flow insertions in Clear Creek and Dickinson Bayou, TX (represented as orange triangles).

RESULTS

For the storm events simulated, comparisons between HEC-RAS and ADCIRC results were performed at several locations along the watershed. The comparisons included HEC-RAS simulations and five (5) ADCIRC simulations: (1) a no riverine inflow, (2) a riverine inflow set at the 10-year storm steady state value, (3) a riverine inflow set at the 50-year storm steady state value, (4) a riverine inflow set at the 100-year storm steady state value, and (5) a time varying historical riverine inflows, as computed by HEC-RAS, for the storms. Maximum water surface elevations and time-series

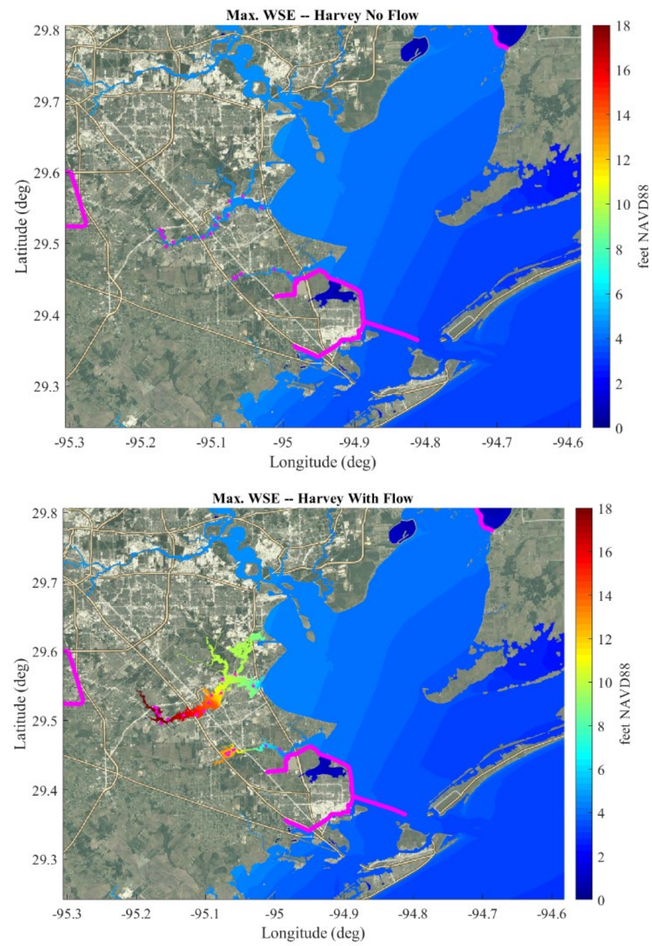

Figure 4- Maximum Water Surface Elevation for Hurricane Harvey simulations {without- (top), and with (bottom) inclusion of riverine flow scenarios}.

of waster surface elevations at selected stations were examined to study the uncertainty in water surface elevation predictions due to omission of the effects of compound flooding. ADCIRC modeling results indicate that omission of the effects of compound flooding due to riverine inflow contributions, results in an under prediction of total water surface elevations, particularly leading up to peak surge values. Figure 4 displays maximum water surface elevation for Hurricane Harvey simulations for without- (top), and with (bottom) inclusion of riverine flow. Figure 6 shows time series hydrographs for Hurricane Harvey simulations at three selected locations (locations are marked as asterisk in figure 5). Depending on location along the watershed

Figure 5- Stations of interests along the Clear Creek (Red-colored asterisks denote the locations where water surface elevation comparisons were made in figure 5).

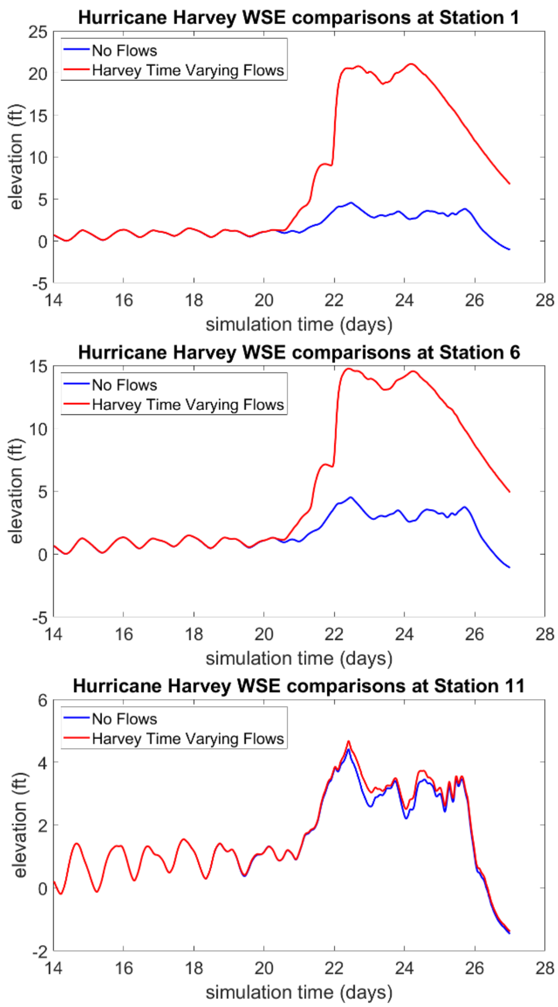

Figure 6- Water surface elevation comparisons for Hurricane Harvey simulations with- and without tributary flow scenarios (station locations are marked in asterisk in figure 4).

relative to the coast, the peak surge values may not be significantly changed by including riverine flows. This is especially true for locations closest to the open coast. For simulations performed using the synthetic storms, as with the simulations performed using Hurricane Ike and tropical storm Allison (results not presented here) shows similar results.

CONCLUSION

Complex interactions of storm surge and rainfall-runoff processes on compound flooding were investigated in this study by performing rainfall-runoff and storm surge/wave modeling. The modeling results indicate that omission of the effects of compound flooding due to riverine inflow contributions results in underprediction of water surface elevation leading up to peak surge values. However, peak surge values themselves may not experience much uncertainty especially for stations located far enough downstream of riverine inflow contributions. Areas further upstream can show larger difference in the ADCIRC water surface elevations and even the flood extents, particularly when the surges are low, for the no river inflows, and the river inflow values are large. However, in these areas, the hydraulic model results are given priority over the ADCIRC model, as they in general are better at resolving the flow features in those areas of the watershed. The analysis performed as part of this study provides critical insights on complex compound flooding hydrodynamics and suitable boundary location criteria for data exchanges between loosely coupled rainfall-runoff and surge models for compound flooding hazard simulations in the low elevation/gradient coastal regions.

REFERENCES

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