Investigating the environmental and socioeconomic impacts of sea level rise in the Galveston Bay, Texas region

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Project Overview

Problem: Given an expected increase in the rate of sea level rise (SLR) in the next decades, the population of the greater Houston area has incomplete information on the extent of projected SLR and its social, economic, and environmental impacts.

Objective: An assessment of the impacts of SLR to provide knowledge to mitigate and adapt to higher sea level during the next 50 to 100 years.

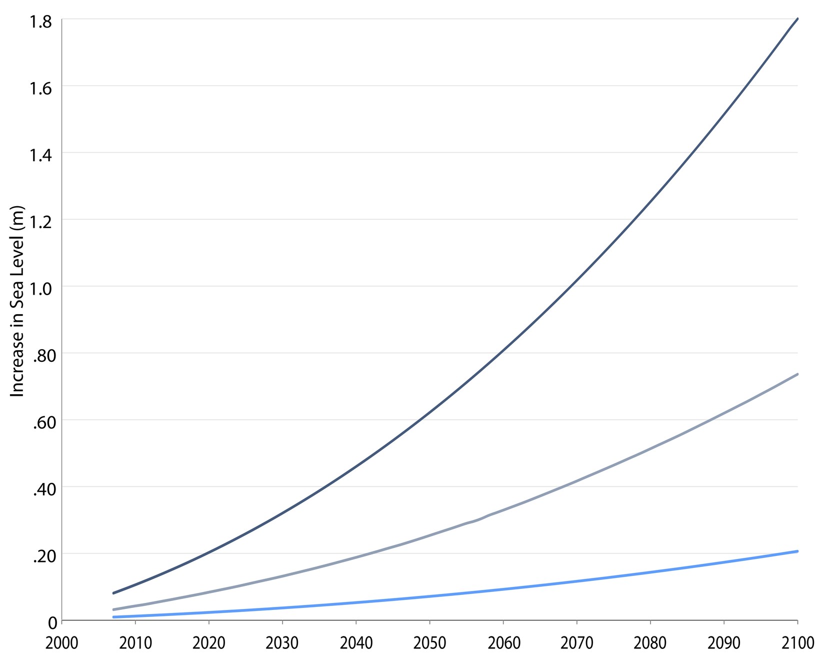
1. Project geographic changes to coastal environments that SLR is expected to cause.
2. Economic impact on the natural and built environments.
3. Analysis of current policies and opportunities for coastal zone management with respect to SLR.

Study Area

Galveston Bay is Texas's largest bay covering about 600 sq. mile located along the upper coast of Texas. The bay is within greater Houston metropolitan area, which is the fifth largest metropolitan area in the US. Four counties border the bay: Brazoria, Chambers, Harris and Galveston County.

The Galveston Bay system is located on a microtidal, wave-dominated coast. The systems of rivers and bayous provide freshwater inflow to the bay, resulting in estuarine and fresh water wetlands fringing the bay shoreline that provide nurseries for many types of marine life.

Sea Level Rise Scenarios



High Scenario - 1.8 m SLR by 2100
From Jevrejeva et al., 2014*. Projection is based on both expert opinion and multiple process studies finding that there is a 95% chance that mean sea levels will not exceed 1.8 m above those at present.

Moderate Scenario - 0.74 m SLR by 2100
From United Nations' IPCC AR5, 2013. The median value of their highest RCP scenario (RCP8.5) was selected for use in model. This curve is used as the base curve to develop high and low scenario curves.

Low Scenario - 0.21 m by 2100
Extrapolation of SLR as measured by TOPEX and Jason series of satellite radar altimeters (1993-2014). Average sea level rate calculated using the 1×1 deg gridded sea level anomaly time series data along the Texas coast.

* Jevrejeva, S., Grinsted, A., Moore, J.C., 2014. Upper limit for sea level projections by 2100. Environ. Res. Lett. 9.

Methods

Subsidence

On the upper Texas coast, SLR has been exacerbated by subsidence due to groundwater withdrawal, oil/gas production and compaction of Holocene sediments. To include the effect of land subsidence in our study area, we developed a subsidence rate grid using GPS Port-A-Measure (PAM) sites, GPS Continuously Operating Reference Station (CORS) sites, extensometers, and National Geodetic Survey releveling sites (Figure 1). These datasets had varying time-span for each site. Since the Harris Galveston Subsidence District adopted a water regulatory plan in 1999, we decided to use data only after 1999 giving different weightage for the datasets based on their temporal resolution.

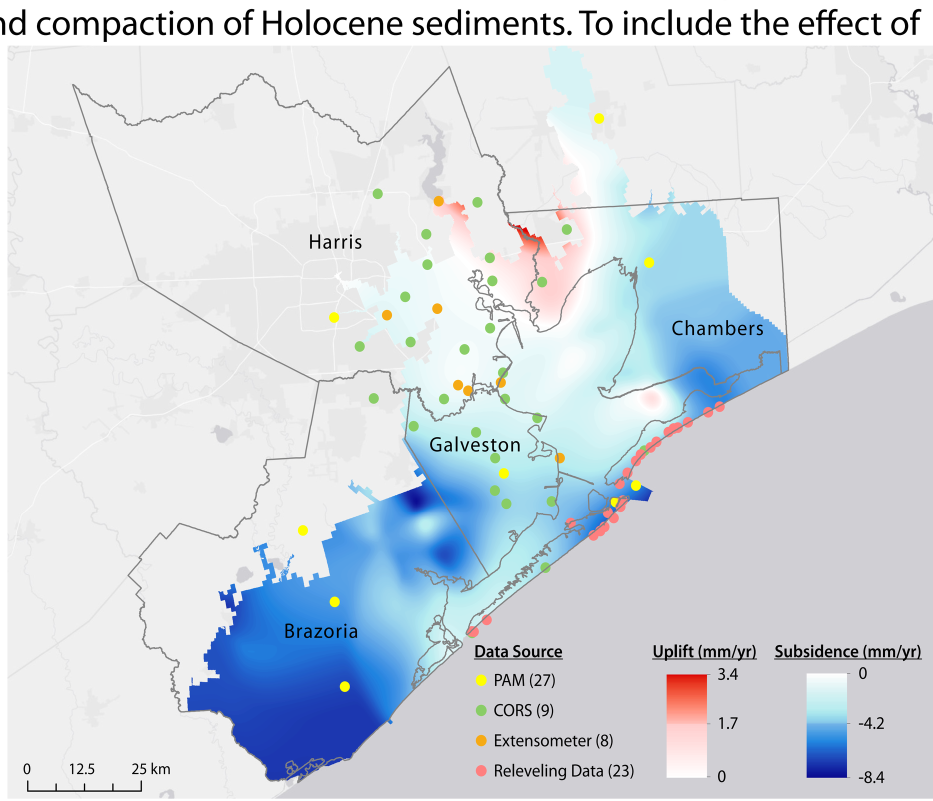


Figure 1: Final interpolated subsidence grid and location of data sources. PAM, CORS, and Extensometer data provided by the Harris Galveston Subsidence District. Releveling data from the National Geodetic Survey.

Models

The **Sea Level Affecting Marshes Model (SLAMM)** is used to predict wetland conversion due to long-term SLR, incorporating the processes of inundation, erosion, accretion, overwash, and soil saturation. **HAZUS-MH** is used to evaluate the property damage to building stocks and the direct business interruption losses due to flooding caused by 100-year flood event scenario with three SLR scenarios.

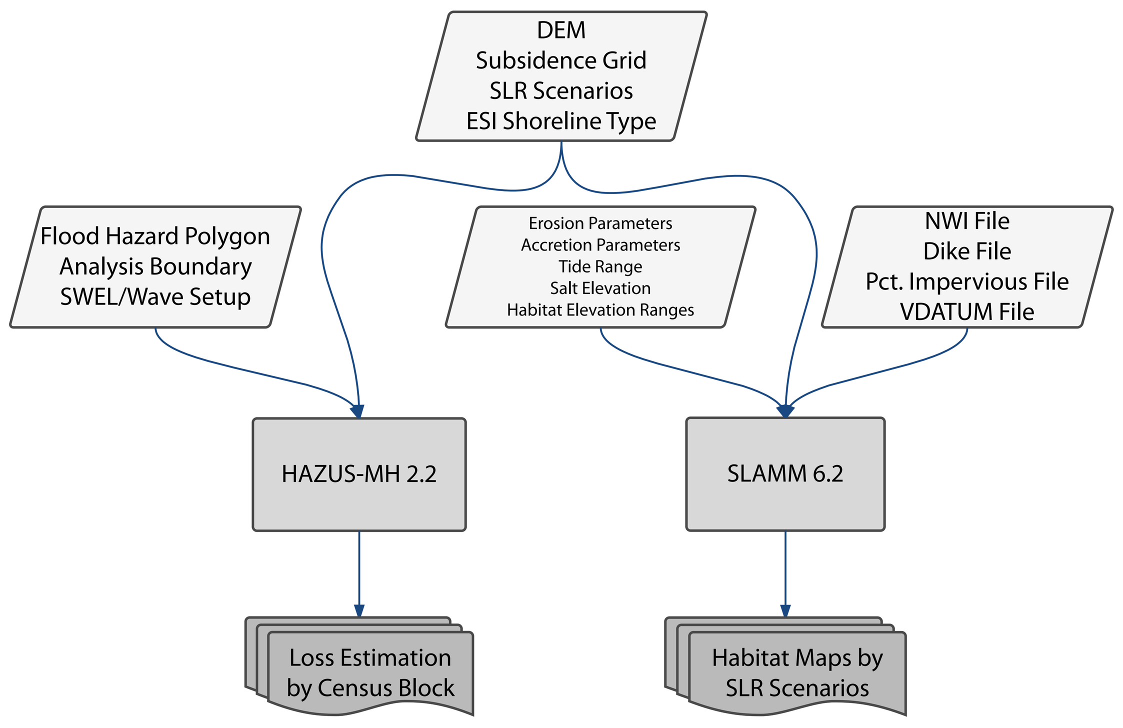


Figure 2: Inputs and outputs of the HAZUS-MH and SLAMM models used in this study.

Results: Socioeconomic Impacts (HAZUS-MH)

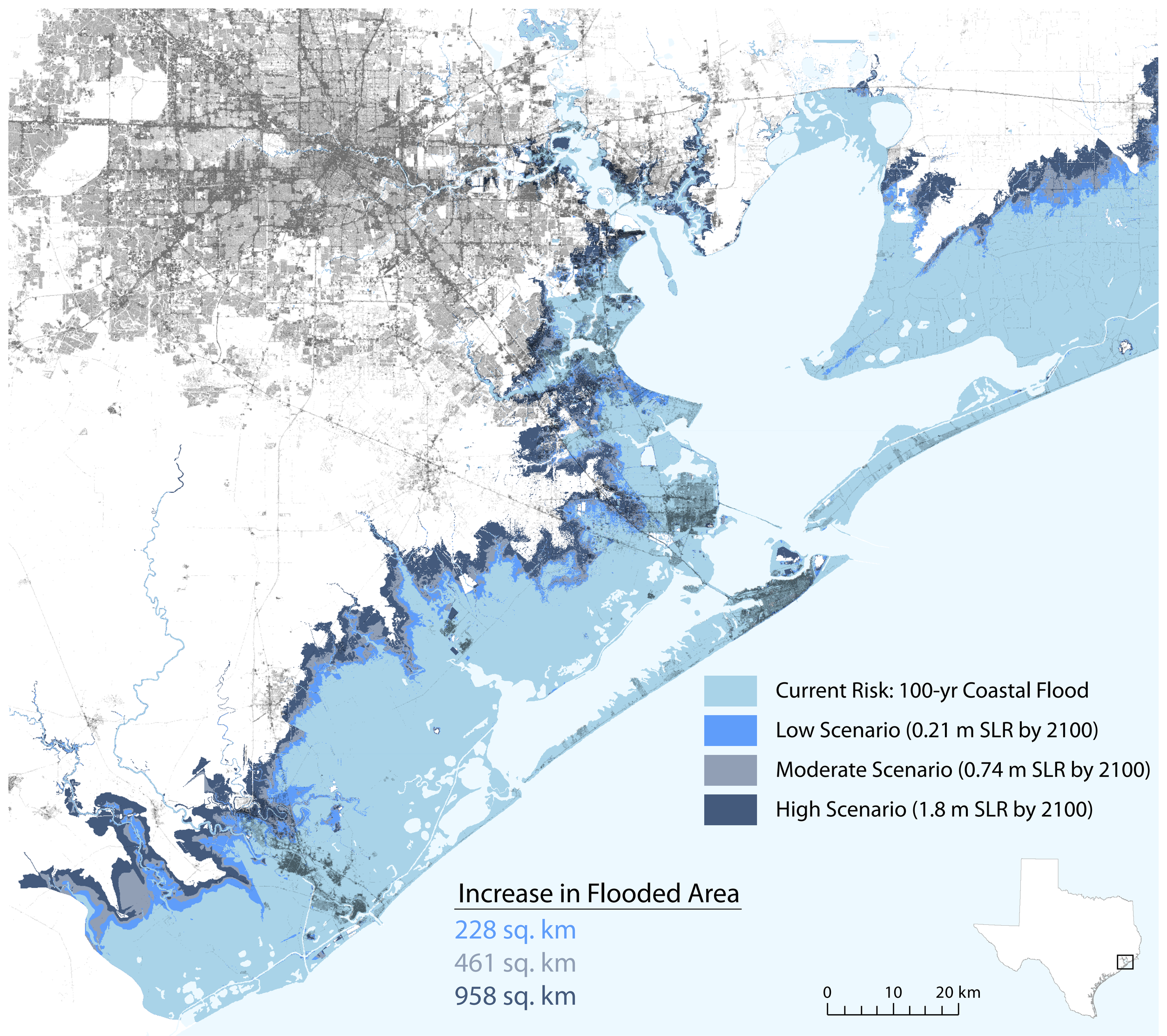


Figure 3: Extent of inundation due to a 100-year coastal flood with present-day sea level (Current Risk) and due to 3 SLR scenarios in 2100 on top of 100-year flood.

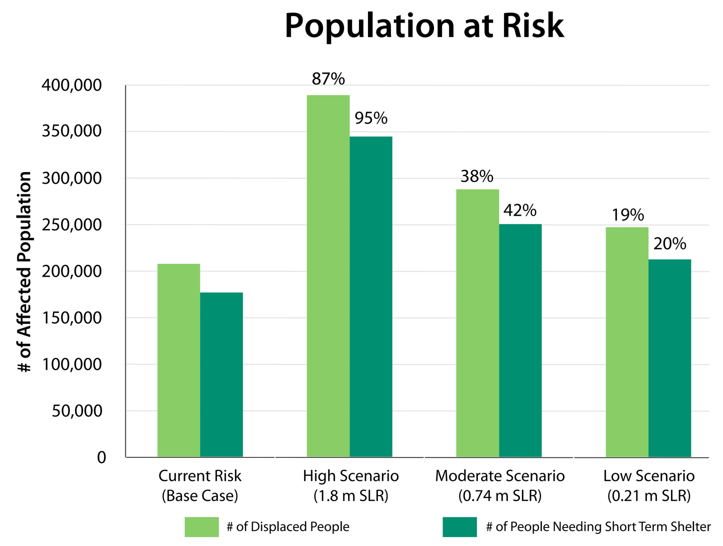


Figure 4: The population affected by a 100-year coastal flood in each SLR scenario. Percent number shows percentage increase from the Current Risk.

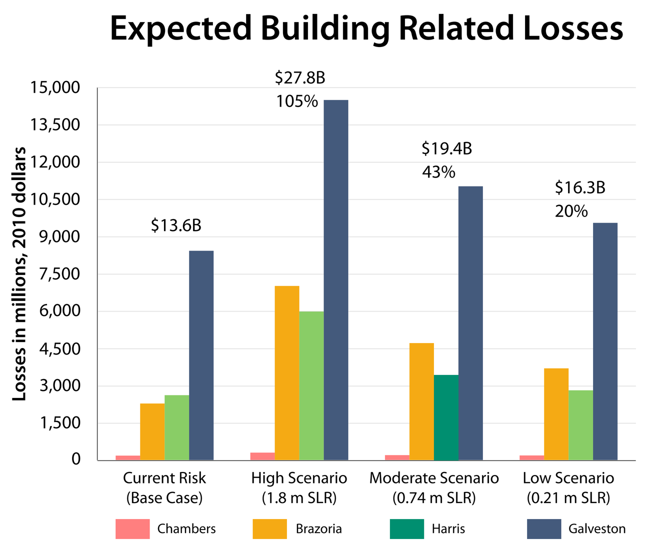


Figure 5: The amount of damage expected from a 100-year coastal flood in each SLR scenario. Percent number shows percentage increase from the Current Risk.

Facility	Current Risk	Risk with sea-level rise in 2100		
		High Scenario	Moderate Scenario	Low Scenario
Fire Stations	14	27 (93%)	24 (71%)	19 (36%)
Hospitals	0	6	4	2
Police Stations	20	37 (85%)	31 (55%)	25 (25%)
Schools	84	147 (75%)	117 (39%)	99 (18%)
Waste Water Treatment Plant	36	53 (47%)	45 (25%)	40 (11%)
Oil Refineries	16	20 (25%)	18 (13%)	18 (13%)
Power Plants	4	9 (125%)	6 (50%)	4 (0%)

Figure 6: Essential facilities and infrastructure at risk. Percent number shows percentage increase from the Current Risk.

Results: Enivronmental Impacts (SLAMM)

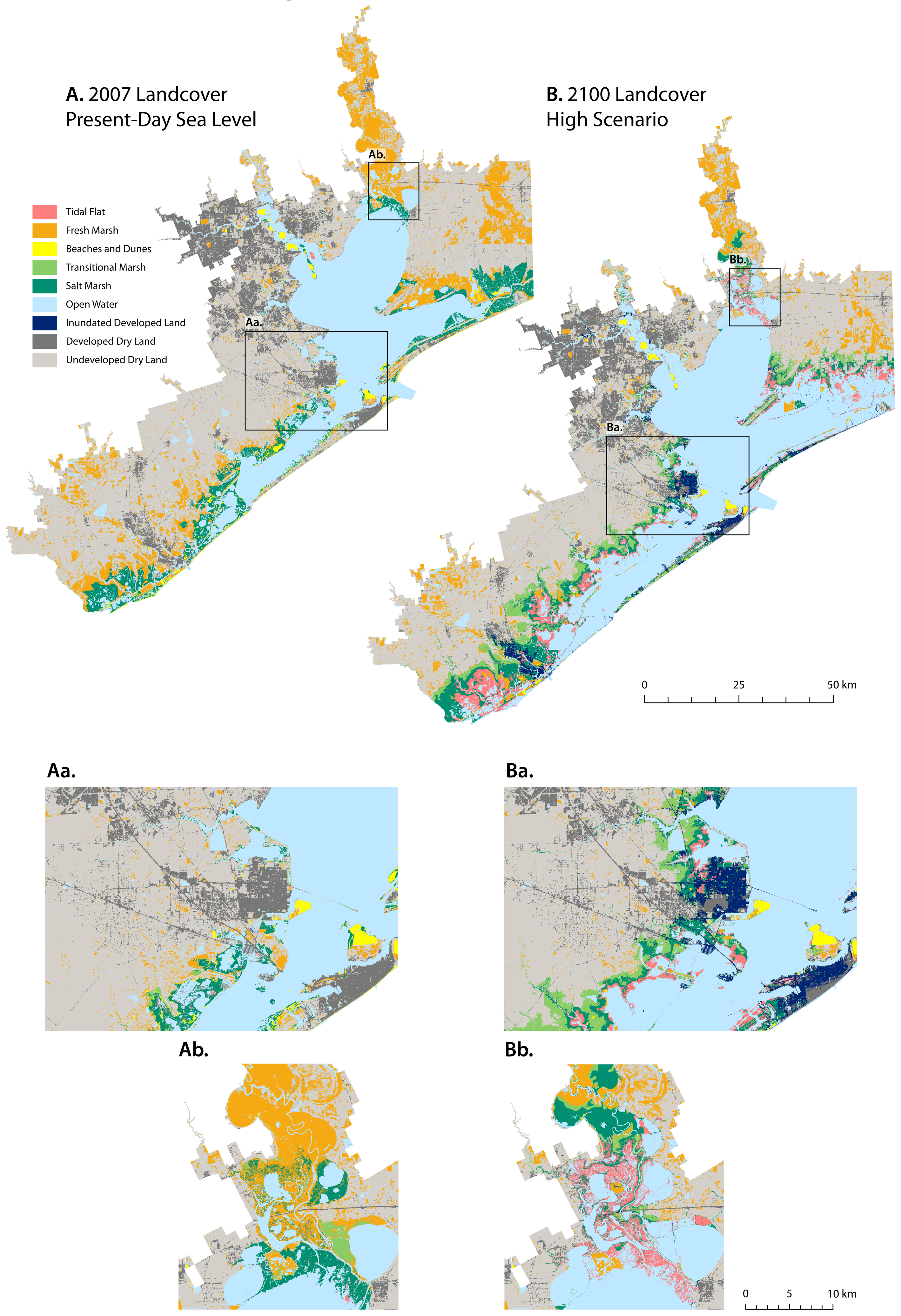


Figure 7: A. Landcover in 2007 **Aa.** Texas City area in 2007 **Ab.** Trinity River area in 2007 **B.** Landcover in 2100 under the High Scenario **Ba.** Texas City in 2100 **Bb.** Trinity River area in 2100

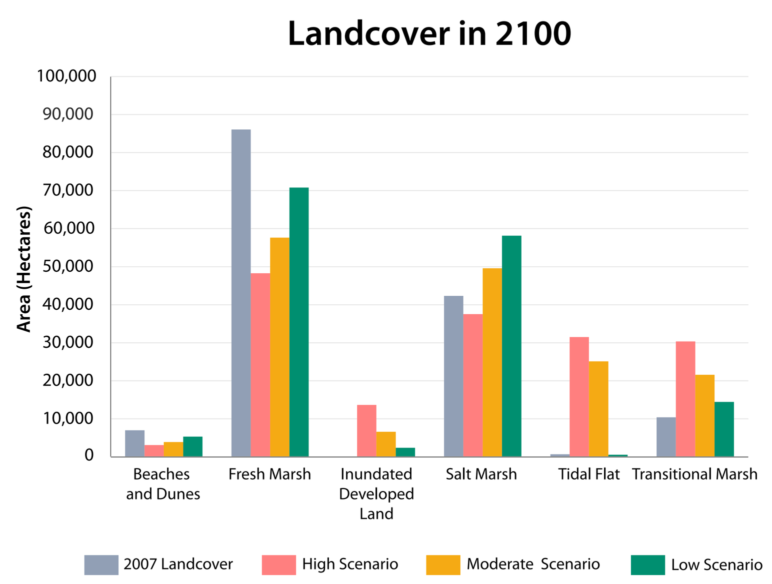


Figure 8: Change in landcover in 2100 for each SLR scenario.

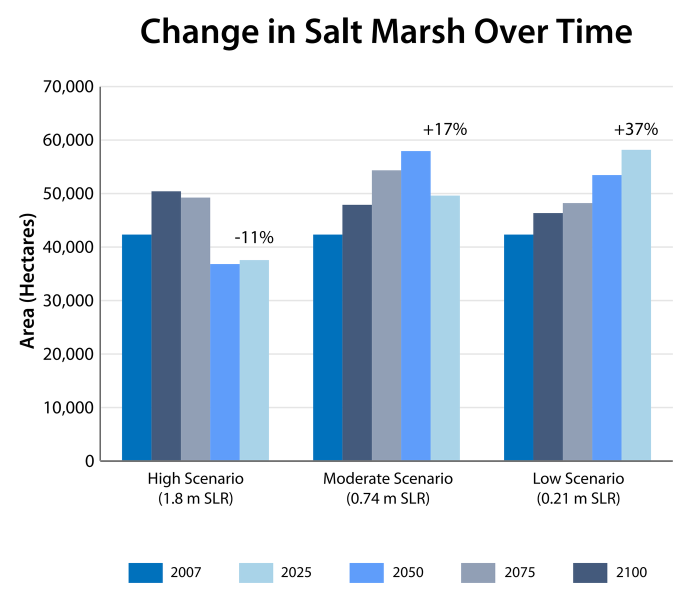


Figure 9: Change in area of salt marsh after each 25-year timestep for all SLR scenarios. Percent number shows change from 2007.

Conclusion: Socioeconomic Impacts (HAZUS-MH)

- SLR significantly increases the risk to population (20% to 87%), property (19% to 105%), essential facilities (23% to 84%), and transportation system (15% to 69%).
- Total building-related losses due to SLR are expected to be $16.3B for our Low SLR, $19.4B for Moderate SLR and 27.8B for High SLR Scenario.
- HAZUS-MH results are based on the current socio-economic environment and are conservative.
- Impacts due to long-term coastal erosion and habitat losses by SLR are not covered on HAZUS-MH results.
- Time is the uncertainty, not the amount of sea level rise!

Conclusion: Environmental Impacts (SLAMM)

- Signficant effects of SLR on natural and built environments are observed in all scenarios.
- Fresh marshes are particularly vulnerable with significant losses in all SLR scenarios (-18% to -44%), converting to transitional marshes, estuarine marshes, or flats.
- In all scenarios salt marshes are initially able to keep up with SLR as the habitat transitions landward to newly inundated, gently sloping upland areas.
- In Moderate and High scenarios, salt marsh is lost after 2050 and 2075 respectively due to increase in rate of SLR, transitioning to flats or open water.
- Losses of undeveloped dry land are observed in all SLR scenarios (-2% to -18%) including economically important agriculutral lands.