SHORELINE RESPONSE TO FUTURE SEA LEVEL RISE

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HISTORICAL FLORIDA SHORELINE CHANGE

Florida (Figure 1), United States, has shoreline change measurements starting in the 1800s with spacing of about every 300 m. In addition, due to extensive shoreline development and tourism, processes causing shoreline change have been studied extensively. The 1160-km east and 275-km southwest shorelines advanced seaward on average from the 1800s even before widespread beach nourishment and despite sea level rise. Shoreline advance despite sea level rise has been noted along other coasts such as the Netherlands central coast (Stive and de Vriend, 1995). In contrast, the 335-km Florida west coast retreated landward on average almost 30 m from 1867 to 2015.

Figure 1. Florida east, southwest, and west coasts

FACTORS CAUSING SHORELINE CHANGE

Dean and Houston (2016) present Equation (1), which has terms representing the processes responsible for shoreline area change along Florida coasts (similar to an equation used by Stive et al,1991, for the Netherlands central coast). Figure 2 defines symbols.

$$L\Delta X = -L\Delta S\left(\frac{W_*}{h_* + B}\right) - \frac{\Delta V_{sink}}{(h_* + B)} + \frac{\Delta V_{source}}{(h_* + B)} - \frac{L\Delta T}{(h_* + B)}\frac{dQ}{dy} + \frac{L\Delta T\phi}{(h_* + B)}$$

Equation (1).

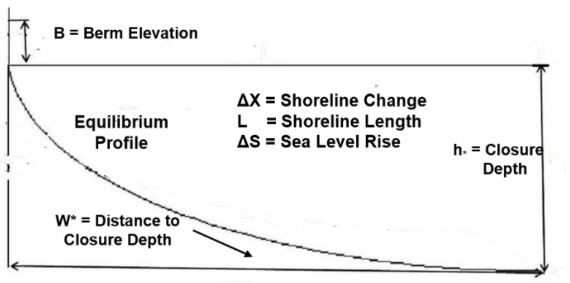

Figure 2. Symbol definition

ΔV_{sink} is the sand volume removed from the littoral system by the primary sink – shoal growth or offshore disposal of dredged sand at inlets cut or modified for navigation; ΔV_{source} is the sand volume added by beach nourishment; ΔT is the time over which the shoreline change occurred; $\frac{dQ}{dy}$ is the longshore sediment transport gradient across the active profile; and ϕ is an onshore transport rate in m^3/m-yr that is determined from the measured shoreline data once other terms have been estimated.

The past must be understood to project the future. Houston and Dean (2014) and Houston (2015) used measured shoreline change and sediment budgets to estimate the effects of processes causing shoreline change on the Florida east and southwest coasts.

The Florida west coast has had an eroding shoreline, making it like many other world coasts. Equation (1) and historical shoreline change data are used to determine the magnitude of past shoreline area change on the west coast caused by each process. Figure 3 shows that sea level rise accounted for less than 20% of the magnitude of shoreline change caused by all processes.

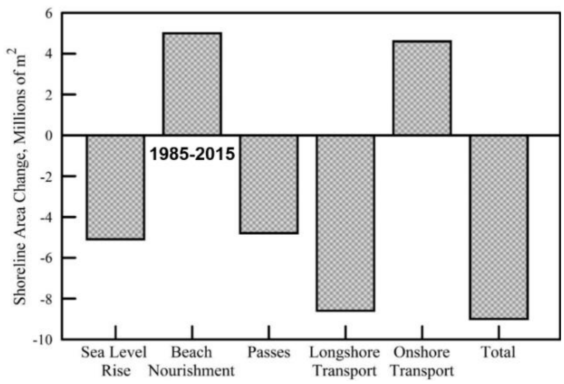

Figure 3. Shoreline area change caused by each process from 1867-2015, except beach nourishment is from 1985-2015 (Houston, 2017).

Figure 4 shows shoreline area change rates for each process (change divided by time over which it occurred). Beach nourishment has dominated shoreline change since 1985, causing shoreline advance. As sea level rise increases, it will contend with beach nourishment.

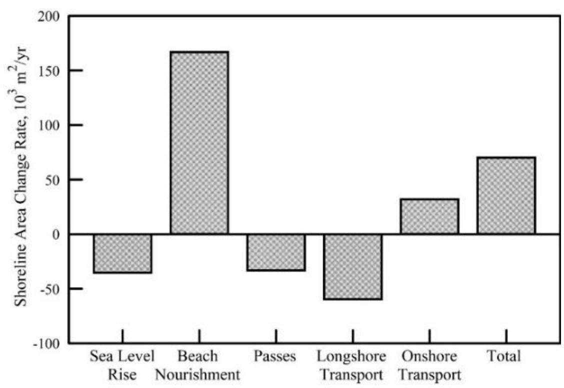

Figure 4. Rate of shoreline area change (Houston, 2017).

PROJECTING FUTURE SHORELINE CHANGE

The effect of future sea level rise on the west Florida shoreline is determined using Equation (1) and sea level rise projections of the Intergovernmental Panel on Climate Change (IPCC 2013). Shoreline change projections are made for each of the four IPCC sea level rise scenarios (IPCC designations 2.6, 4.5, 6.0, 8.5) for 50-years from 2016 - 2065 and for 2016 – 2100. Inlet losses will be lower in the future because new inlets are not being cut, shoals have reached stability, and dredged sand is no longer placed out of the littoral zone but bypassed around Florida inlets. However, it is assumed that existing inlet shoals will rise with sea level rise to remain in equilibrium with tidal hydrodynamics, thereby taking sand out of the littoral system. Beach nourishment is initially assumed to continue at past placement rates, but then varied. Longshore and onshore transport rates are assumed to remain constant (Houston, 2017).

RESULTS

Figure 5 shows shoreline change for each scenario and time frame without and with beach nourishment. The shoreline is stable with the past beach nourishment rate for all scenarios except the upper level rise of the worst scenario (8.5) in 2100, which would require a 20% nourishment increase for stability. Even if scenario 8.5 occurs, there is a 97.5% chance the rise would be less than the upper level rise (IPCC, 2013). Shoreline change rates can be updated every 6 years when IPCC publishes new sea level rise projections.

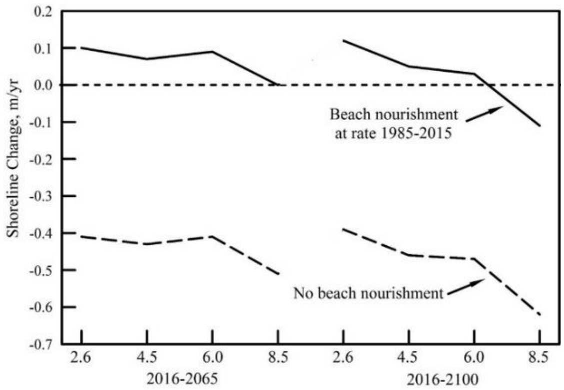

Figure 5. Shoreline change rate on Florida west coast with and without beach nourishment for IPCC scenarios (Houston, 2017).

Shoreline change rates also can be determined for smaller shoreline units (Figure 6).

Figure 6. Counties in west Florida

Figure 6 shows sand volumes that must be placed to attain average shoreline stability (change of 0.0 m/yr) for each of the six counties. Gulf and Franklin counties have only 1.7% of the west coast population, and results discourage development because beach nourishment requirements for stability would be high for this lightly populated coast with little tourism. Walton county needs to increase nourishment to be stable and has a 50-year plan to do so. Okaloosa county could reduce rates except for scenario 8.5 in 2100. Beaches in Escambia/Santa Rosa and Bay counties have widened significantly through beach nourishment, and future nourishment could be reduced and stability maintained.

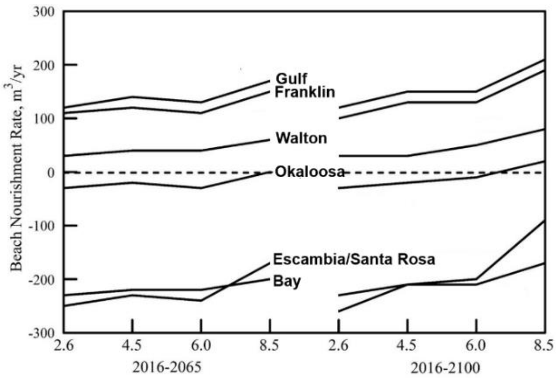

Figure 6. Beach nourishment rates required to attain stability for Florida west coast counties (Houston, 2017).

CONCLUSIONS

All processes causing shoreline change, not just sea level rise, must be considered to project future change. If a shoreline has sufficient information on these processes, beach nourishment volumes required to offset projected sea level rise can be estimated. Beach nourishment is an excellent adaptation strategy for future sea level rise even along a coast like the Florida west coast that has had a long-term eroding shoreline.

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