SURGE SUPPRESSION ACHIEVED BY DIFFERENT COASTAL SPINE (IKE DIKE) ALIGNMENTS

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Abstract

The primary strength of the Ike Dike concept is the regional scope of flood risk reduction benefits that a coastal spine provides. For major surge-producing hurricane events, like the 100-yr and 500-yr proxy storms that were simulated, a 17-ft Ike Dike that extends from south of Freeport, TX to Sabine Pass, TX (see Figure 1), reduces the average peak storm surge throughout Galveston and West Bays, by 8 ft (100-yr proxy) and 9 ft (500-yr proxy). The areas receiving substantial surge reductions are Galveston Island, the north shoreline of West Bay, the Bolivar Peninsula, the western shoreline of Galveston Bay, and the upper reaches of the Houston Ship Channel. No areas behind the coastal spine are omitted from receiving substantial benefits. This is true regardless of whether the area is primarily residential or primarily industrial, and without regard for the economic value of individual properties, structures or residences.

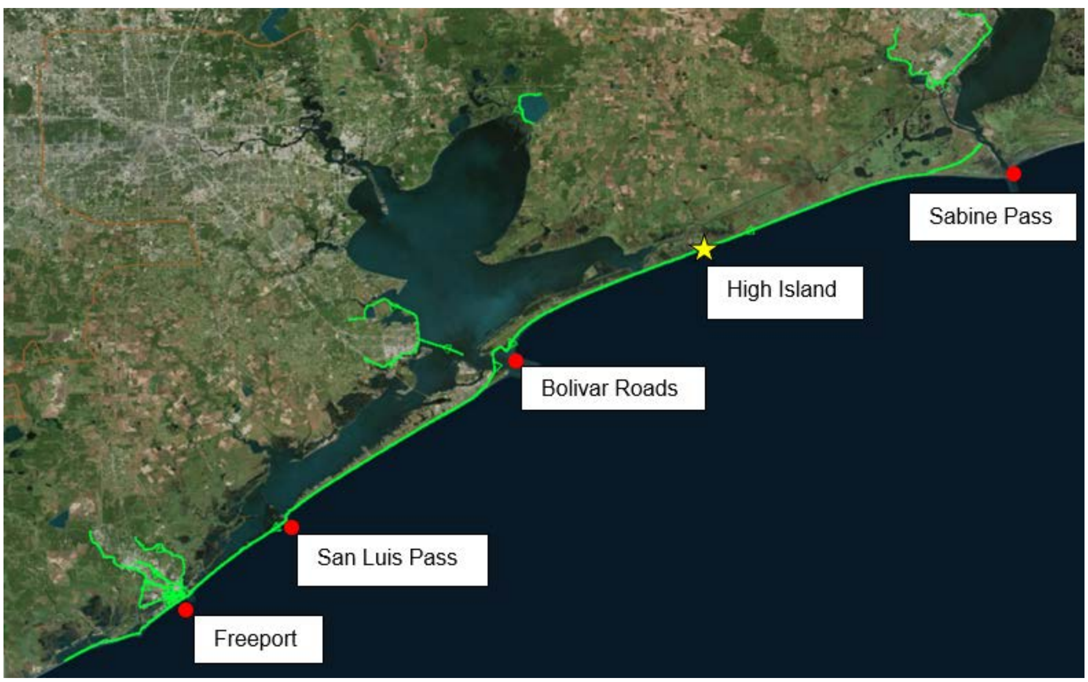

Figure 1. Alignment of the conceptual extended Ike Dike

Dutch partners in the Ike Dike investigation identified several other possible alignments for a long coastal spine. Each alignment involved tying the 17-ft dike into higher ground elevations at different locations on both its eastern and western ends (Van Berchem et al., 2016). Based upon their work, an Alignment 1a was developed, see Figure 2, which included the following: a middle dike section that extends from San Luis Pass to High Island; an eastern termination section that turns inland at High Island and then follows Texas State Highway 124 north to Winnie, TX; and, a coastal western termination section that ends at Freeport. This alignment represents a slightly different version of the extended Ike Dike that is shown in Figure 1.

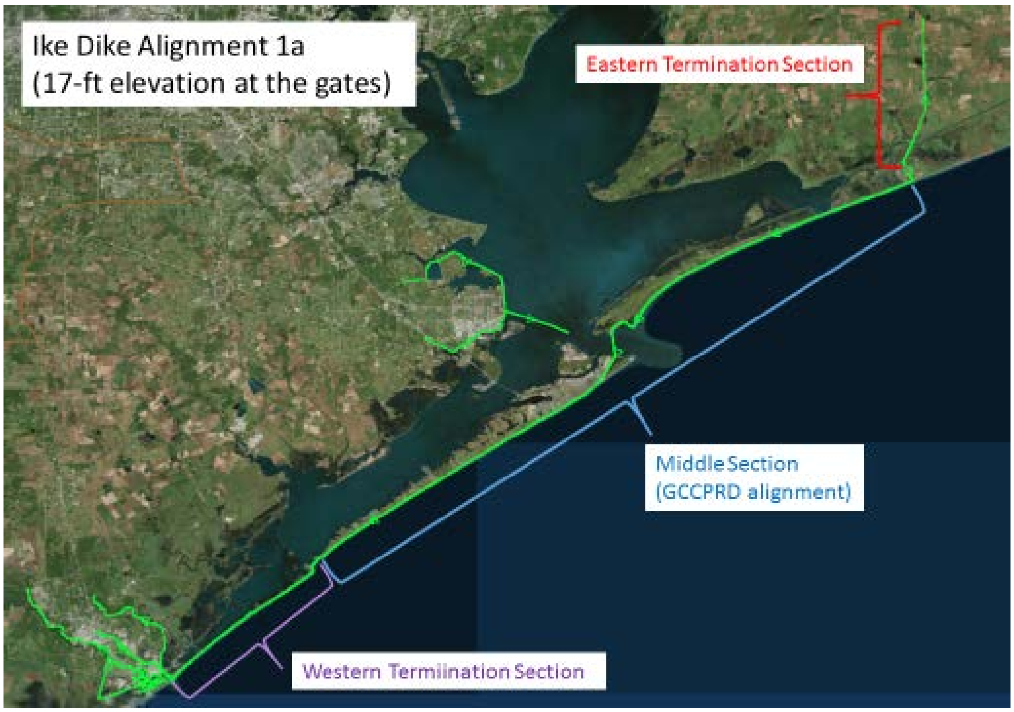

Figure 2. Alternate segments and alignments of the conceptual Ike Dike that were examined.

Preliminary design analyses also were performed by the Dutch partners for gate systems at Bolivar Roads and San Luis Pass (see Jonkman et al., 2015). They developed a preliminary design for both a navigational gate section and an environmental gate section at each pass. Lower crest elevations for the navigation sections were selected in order to reduce their construction cost. Steady flow over the lower gates can occur during major hurricanes. To quantify the influence of overflow on surge levels within the bay, an alternate dike configuration was considered. A second alternate dike configuration, Alignment 1b, was developed in which the 17-ft crest elevation of the dike in Alignment 1a was lowered to 9.8 ft at the locations of both navigation gate sections. The influence was of particular interest at the City of Galveston, which lies immediately adjacent to the

Bolivar Roads gate system and which is vulnerable to flooding from the bay side.

The Gulf Coast Community Protection and Recovery District (2016a and 2016b), GCCPRD, recently completed its own study to investigate measures for reducing hurricane flood risk for the north Texas coast. The coastal spine option considered by the GCCPRD extends from the western end of Galveston Island, across Bolivar Pass, and ends at High Island; it is much shorter in length than either the extended Ike Dike or Alignment 1a that are shown in Figures 1 and 2. In essence their coastal spine option is represented by the middle section in Figure 2.

Alignment 2 closely resembles the coastal spine considered by the GCCPRD. Alignment 2 is only comprised of the middle section shown in Figure 2, without any eastern or western termination sections. However, Alignment 2 differs from the GCCPRD coastal spine in several ways. Alignment 2 has a crest elevation of 17 ft, unlike the crest elevation recommended by GCCPRD which was several feet higher. Also, the alignment of the GCCPRD coastal spine followed the highways on Galveston Island and Bolivar Peninsula. Alignment 2 follows the shoreline, as does the extended Ike Dike and Alignment 1a. The 17-ft crest elevation and the shoreline position of the dike for Alignment 2 were selected to enable a more direct comparison with Alternative 1a and the extended Ike Dike. An Alignment 2 was developed in an attempt to isolate and identify the effects of the eastern termination section shown in Figure 2.

Alternate Alignment 3 was developed to isolate and examine the role of the western termination section on storm surge reduction. It was intended to facilitate examination of the merits/consequences of having/not having a western termination section. Alignment 3 was comprised of Alignment 2 plus the eastern termination section that follows State Highway 124. This alignment had no western termination section. The crest elevation was 17 ft and the alignment followed the shoreline.

Four storm surge simulations were made for each of the four alternate dike alignments, Alignments 1a, 1b, 2 and 3. All simulations were made for a future sea level scenario, which is 2.4 ft higher than present sea level (i.e., a future sea level of 3.31 ft, NAVD88). This future sea level scenario (called SLR1) is the same scenario that was considered previously in the extended Ike Dike analysis. For each dike alignment, simulations were made for the 10-yr, 100-year, and 500-yr proxy storms and for Hurricane Ike, using the same modeling approach that was adopted for the extended Ike Dike simulations.

Merits of an Eastern Termination Section

Results suggest that an eastern termination section might not be cost effective in terms of flood risk reduction benefits to the Houston/Galveston region. This is the case for both of the two eastern section alignments, the State Highway 124 inland alignment and the coastal alignment that extends to Sabine Pass. In terms of peak surges within the Houston/Galveston region, the eastern termination section primarily benefits Bolivar Peninsula, where the potential for flood risk reduction benefits is much lower. An eastern termination section is of relatively little benefit in reducing peak surge at the City of Galveston, along the western shoreline of Galveston Bay and the upper reaches of the Houston Ship Channel, areas that have a much greater potential for damage/loss.

Having no eastern termination section probably means tying the Ike Dike into higher elevation on the south side of High Island. This is the termination location in the coastal spine plan considered by the GCCPRD.

If an eastern section is adopted, costs and benefits should be considered both within and outside the Houston/Galveston region. For example, a coastal alignment for an eastern section which extends all the way to Sabine Pass provides flood risk reduction benefits to the Winnie-to-Port Arthur area which have not been considered heretofore. However those benefits should be accounted for in a complete cost/benefit analysis of an extended Ike Dike alignment. Additionally there are some negative consequences associated with the inland State Highway 124 alignment, which causes local increases in peak surge just outside the dike, due to the “long dike effect.”

Merits of a Western Termination Section

Termination of the coastal spine at the western end of Galveston Island, with no gate system at San Luis Pass, enables propagation of the hurricane surge into West Bay. Without a western termination section the hurricane forerunner surge can propagate through San Luis Pass and into West Bay, and then into Galveston Bay under certain wind and water level conditions, a process that can begin a day or more before the hurricane makes landfall. The absence of a western termination section also allows the peak storm surge associated with a hurricane’s core winds to propagate into West Bay as well; it enables propagation of the peak storm surge through San Luis Pass in addition to flow over the barrier island south of the pass once it becomes inundated.

The peak storm surge results suggest that the western termination section has a much greater positive influence in the Houston-Galveston region than does an eastern termination section, particularly along western and central parts of Galveston Island and along the northern shoreline of West Bay west of Texas City. The western dike section results in greater surge reductions, over a wider geographic area, in areas having higher potential for damage and economic losses.

Another factor that might support inclusion of the western termination section in the Ike Dike concept is the ability to not only prevent the forerunner and peak surge from entering West Bay, but also as a means for controlling the water level inside the bays at the time when the surge gates are closed. It might be advantageous to use the timing of gate closure as a means to minimize the amount of water in the bays, in advance of an approaching hurricane. Such an operational procedure might dictate closing the gates when low astronomical tide creates a minimum water surface inside the bays. Having gates at both San Luis Pass and Bolivar Roads could achieve this operational objective fully; a gate system only at Bolivar Roads can only do this partially. A desire to operationally control the water level inside the bays at the time of gate closure might become increasingly more important as mean sea level rises.

Also, with rising sea level, salinity within West and Galveston Bays is expected to gradually increase, due to the added volume of salt water from the open Gulf that is introduced into the bays. The added volume will be significant in light of the shallowness of the bays. Gate systems at both Bolivar Roads and San Luis Pass might provide an opportunity for managing the salinity within the bays in a beneficial way, by reducing tidal exchange and increasing the residence time for freshwater that is introduced into the bays by the rivers. Operation of the gate systems might provide an opportunity to mitigate, to some degree, negative consequences of a more saline bay system. If there are environmental benefits for having a gate system at San Luis Pass, this would also support inclusion of a western termination section in the Ike Dike concept. Any potential for environmental benefits associated with gate systems at both passes should be explored further.

Influence of Lowered Gates at the Passes

By comparing results for Alignments 1b and 1a, it is evident that the effect of lower gate elevations on peak surge levels behind the dike is relatively small even for the more severe hurricanes. Lower gate elevations lead to slightly higher storm surge levels for the severe hurricanes that were simulated. For less intense hurricane events like the 10-yr proxy storm, which produces little or no overtopping or steady flow over the gates, there are no significant increases to peak storm surge levels behind the dike associated with the lowered gate crest elevations.

These increases in peak surge level, which are relatively small even for the most intense hurricanes, will require a small increase in design elevation for any secondary lines of defense within the bays, such as a ring levee/wall system along the bay side of the City of Galveston.