Chapter 6. Bay Defenses – Other Measures

Introduction

This chapter discusses the other in-bay measures for reducing flood risk and damage that are included in the USACE Plan, aside from the Galveston Ring Barrier (discussed in Chapter 5). In addition, other possible in-bay measures are identified and discussed. All equivalent average annual damage data cited in this chapter were extracted from Table 23 in Appendix E-1 of USACE (2020); data in Table 23 are for the intermediate sea level rise scenario and reflect damage to residential and commercial property. All damage data reflect average annual values computed for a 50-yr period of economic analysis. Cost data for in-bay measures included in the USACE Plan were extracted from the spreadsheets in Annex 22 to Appendix D of USACE (2020). In subsequent text, references are made to reaches that were considered in the USACE economic analyses. Economic reaches are numbered and are shown in Figure 6-1 (the figure is from Figure 2 in Appendix E-1).

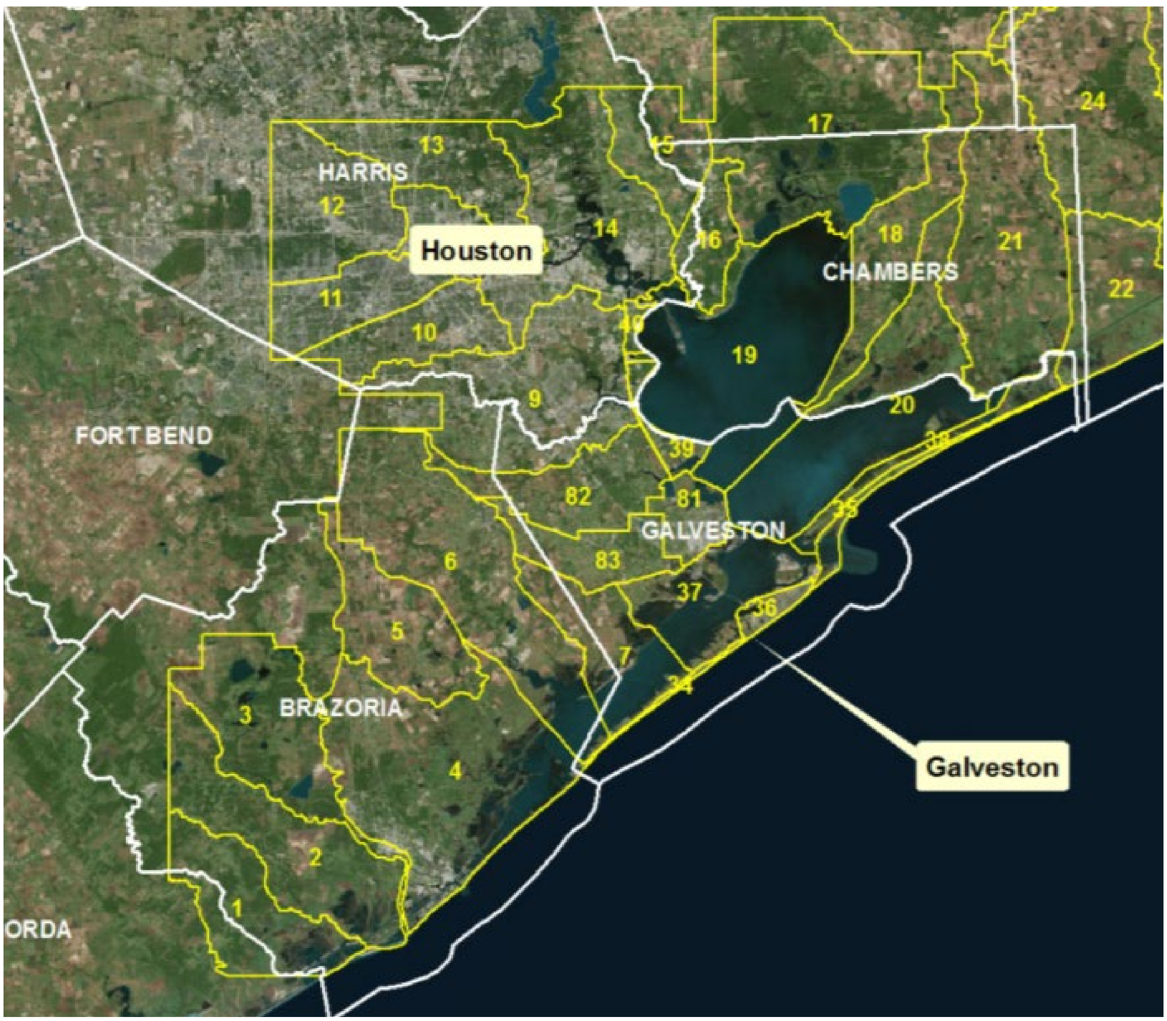

Figure 6-1. Economic analysis reaches considered in USACE (2020).

We concur with a multiple-lines-of-defense approach to reducing flood risk, which is reflected in the USACE Plan. The Plan includes: 1) a long continuous coastal spine situated at the coast, intended to produce the majority of flood risk reduction benefits for the region, 2) shorter, localized second lines of defense where there are strategic opportunities to reduce residual risk further in higher density urban or industrial areas, and 3) non-structural measures implemented at the scale of individual residential and commercial properties in less densely populated and industrialized areas. However, as discussed in previous chapters, the weak land barrier included in the USACE Plan, and omission of a western section of the coastal spine that includes a gate at San Luis Pass and land barrier on Follets Island, allows considerable storm surge to enter both bays. Consequently, the USACE Plan has very high residual damage associated with it. For the intermediate future sea level rise scenario, there are $2.85B of average annual damages for the without-project condition, an average annual damage reduction of $1.70B, and a very high average annual residual damage of $1.15B.

It is unclear what rationale was adopted by USACE for selecting certain areas to receive second lines of defense and nonstructural methods, and not others. Without a clear rationale, choices appear to be arbitrary and illogical, particularly in light of the magnitude and wide distribution of residual damage throughout both bays. The current USACE Plan for in-bay measures appears to only focus on certain areas of Galveston Bay, despite the split in residual damages between Galveston (45%) and West (55%) Bay, with more damage in West Bay. Second lines of defense, short wall/gate systems, are proposed at Clear Lake and Dickinson, but not in other areas with high residual damage. Non-structural methods are only proposed for the western side of Galveston Bay and in a single community adjacent to the Galveston Ring Barrier, and not in other areas where residual damage is even higher.

Because of the very high residual damage associated with the USACE Plan, the need for and desirability of in-bay measures increases along with the likelihood that many measures are cost-effective, more than have been proposed by the USACE. We believe there are other opportunities around the periphery of both Galveston and West Bays to reduce residual risk further. We recommend careful consideration, with analysis of benefits and costs, of potential second-lines-of-defense and non-structural measures in other areas throughout the region. Is does not appear that such a region-wide analysis was done.

Wall/Gate Systems at Dickinson and Clear Lake

Short wall/gate systems are included in the USACE Plan for the entrance channels that lead to both the Clear Lake and Dickinson areas (economic Reaches 9 and 82 in Figure 6-1, respectively). Both second-lines-of-defense take advantage of strategic opportunities to reduce storm surge propagation into a densely populated flood plain by placing a wall/gate system across the conveyance channel that leads to the flood plain. Once closed, the gate system reduces penetration of the storm surge, much like the functionality achieved with the Bolivar Roads gate system, which significantly suppresses surge penetration into Galveston Bay.

We recommend an extensive and detailed examination to identify other possible strategic locations around the periphery of Galveston and West Bay that also might be conducive for a second line of defense. Possible measures include a similar wall gate system, and/or a levee, or other temporary flood defense system that might reduce residual flood risk for industrial or port facilities, or more densely populated communities, further.

The Clear Lake wall/gate system has a first cost of $1.52B and fully funded cost of $2.77B. It helps reduce average annual damages in economic Reach 9 from $558M (without project) to $111M (with project), a benefit of $447M. It appears that significant benefits accrue because of this wall/gate system; although there is insufficient information to isolate its benefits relative to those achieved with the coastal spine, the first line of defense. The Dickinson wall/gate system has a first cost of $ 880M and fully funded cost of $1.65 B. It helps reduce annual average damages in Economic Reach 82 from $155M to $14M, a benefit of $141M. Fewer benefits accrue with the Dickinson wall/gate system compared to the Clear Lake system, but the cost is less.

As a cost-effectiveness metric, an indicative Benefit/Cost ratio (BCR) is defined, where:

> Benefit = the reduction in average annual damage produced by some protective measure, multiplied by 50 yrs to reflect a 50-yr period of analysis
>
> Cost = fully-funded cost of the protective measure over a 50-yr period of analysis

The larger the BCR for a given protective measure, the more cost-effective it is.

For the Clear Lake wall/gate system, the BCR is (0.447B x 50)/2.77B, or **8.07**. For the Dickinson wall/gate system, the BCR is (0.141B x 50)/1.65B, or **4.27**, roughly half as cost effective as the Clear Lake system but still quite favorable. Despite the fact that some, perhaps much, of the damage reduction in both areas is realized because of the coastal spine, the BCR is a reasonable metric for comparing different in-bay measures. All in-bay measures benefit from the coastal spine.

It does not appear that flanking of either short gate/wall system by the storm surge was considered in its design. Based on 2008 LIDAR data, it appears as though terrain elevations adjacent to both gates (8 to 10 ft) are significantly lower than the still water level used to design them (<u>12.8</u> ft at Dickinson Bay and <u>13.5</u> ft at Clear Lake), and the low terrain extends for considerable distances. While high, the wall/gates at both locations are relatively short in length compared to the expanse of terrain that has elevations less than 10 ft. In light of their relatively short length (1.5 miles at Clear Lake and 0.7 miles at Dickinson), and their apparent susceptibility to flanking by a storm surge that is even less than the 1% AEP SWL, we recommend further investigation into the optimal length and height for both of these wall/gate systems. The issue of length for both systems is discussed in Chapter 12 of the Jackson State University, JSU (2018) report. In addition, it does not appear that flanking of the Dickinson and Clear Lake wall/gate was considered in sizing of the pumps. If not, we recommend this investigation be done as well.

Another Pathway for Storm Surge to Enter Clear Lake

Surge model results presented in USACE (2020), and JSU (2018) surge modeling, reveals an apparent overland pathway by which Galveston Bay internal surge can propagate over low-lying terrain and enter the northeast side of the Clear Lake area. This pathway is located near the Shoreacres community. This is a different pathway than that addressed by the proposed wall/gate system at Clear Lake. This pathway appears to be a significant contributor to the high residual damage that remains in the Clear Creek area (Reach 9) even with the second line of defense at the entrance to Clear Lake. The presence of such a vulnerability, and measures to eliminate or reduce the flooding impacts of this pathway, should be carefully investigated. This pathway is described and graphically illustrated in Chapter 12 of the JSU (2018) report.

Non-Structural Measures in the USACE Plan

In the USACE Plan, non-structural improvements are proposed for economic Reaches 39 and 40 on the western side of Galveston Bay, and in a small community in the City of Galveston that is left outside the proposed Ring Barrier. The first cost for these measures is $220M, with a fully funded cost of $420M. The total benefits of the nonstructural measures, in terms of reduced damage, are $38M ($3M in Reach 37, $30M in Reach 39 and $5M in Reach 40). For the full set of nonstructural improvements in the USACE Plan, the BCR is (38M x 50)/420M, or **4.52**, which is comparable to BCR for the Dickinson wall/gate system.

Consideration of Other Areas for in-Bay Measures

In light of the very high residual damage associated with the USACE Plan and its wide spatial distribution, we recommend consideration of, and analysis of, costs and benefits associated with second lines of defense and/or nonstructural methods for other areas around the periphery of both West and Galveston Bays. A focus for other possible second lines of defense should be urban, port and industrial areas where residual damages are highest and/or are concentrated. A focus for non-structural methods should be on these same areas, as well as more sparsely populated areas.

Examination of residual damage in the different economic reaches shown in Figure 6-1 suggests other areas where implementing second lines of defense or non-structural methods might be cost effective. In Table 6-1, the rank-ordered list shows average annual residual damage by economic reach. Only those reaches with average annual residual damage in excess of $10M are shown in the table. There are other areas around the north and east sides of Galveston Bay have smaller levels of residual damage, and are not listed in Table 6-1. These areas also might be candidates for non-structural methods that can be implemented on a property-by-property basis. We recommend this possibility be explored for these areas as well.

In West Bay, two economic reaches, 37 and 4, comprise the bulk of the residual damage. The residual damage in both of these reaches is roughly twice as much as residual damage in any other reach in either West Bay or Galveston Bay. These two reaches should be closely examined to identify the opportunities and potential for cost-effective in-bay measures. Chapter 12 of the JSU (2018) report explored the footprint of some possible second lines of defense (levees, or levees with gates) for Reach 37, which is situated along the easternmost portion of the north shore of West Bay, adjacent to the western portion of the Texas City Levee.

Table 6-1. Residual equivalent average annual damages by economic reach for Galveston and West Bays

Economic Reach	Average Annual Residual Damage	Reach Location – by Bay
Reach 37	$217 M (*214 M)	West Bay (the USACE Plan induces $51 M)
Reach 4	$212 M	West Bay
Reach 9	$111 M	Galveston Bay
Reach 81	$101 M	West Bay
Reach 14	$60 M	Galveston Bay
Reach 39	$60 M (*30 M)	Galveston Bay
Reach 7	$41 M	West Bay
Reach 38	$29 M	Galveston Bay (the USACE Plan induces $11 M)
Reach 83	$28 M	West Bay
Reach 6	$19 M	West Bay
Reach 82	$14 M	Galveston Bay
Reach 34	$13 M	West Bay
Reach 13	$13 M	Galveston Bay
Reach 40	$12 M (*5 M)	Galveston Bay

*These values indicate residual damages associated with implementation of non-structural methods

The USACE Plan actually induces damages in a two reaches, compared to without-project damages; and those areas are indicated in Table 6-1 with underlined text. The USACE Plan induces $51M in average annual damage in reach 37. This is a significant amount. With the exception of one small neighborhood in the City of Galveston, there are no other measures proposed to mitigate the more substantial induced damage throughout this economic reach. The same is true for Reach 38, on the eastern half of Bolivar Peninsula, where the USACE Plan also induces $11M in average annual damage. We recommend consideration of mitigation in these areas where the USACE project induces damage. Mitigation might include structural or non-structural in-bay measures and/or nature-based solutions to reduce wave-induced damage.

Significant residual average annual damages remain in the Texas City economic reach, Reach 81 ($101M). JSU research, see Chapter 12 of the JSU (2018) report, indicates that the southwest termination point of the Texas City Levee can be flanked by severe surge-producing events. This appears to be the source of the residual damage. Model results presented in USACE (2020) also show evidence of this flanking for severe hurricanes. For the weak land barrier included in the USACE Plan, this area is a candidate for a second line of defense. The cost and benefits of an in-bay measure here should be explored, probably via a modification/extension of the Texas City levee at its southwestern terminus. As demonstrated in Chapter 12 of the JSU (2018) report, a robust 17-ft Ike Dike eliminated this flanking even for the 500-yr proxy storm and future sea level rise of +2.4 ft. We expect that a robust 17-ft Ike Dike will completely eliminate this significant residual damage, or nearly so.

Surge modeling by JSU and the USACE both suggest that Reach 14, surrounding the upper Houston ship Channel, will have the highest residual 1% AEP SWLs in all of Galveston Bay, due to in-bay surge generation. Chapter 12 of the JSU (2018) report shows, in a revealing visual way, those industrial areas in Reach 14 that are most vulnerable to residual flooding and damage. We recommend that these industrial areas, and any others in those areas with high residual risk, such as in Reach 4, be examined and evaluated as candidates to receive a second line of defense. Several such areas in Region 4 were identified in Chapter 4.

The listing in Table 6-1 also shows the degree to which non-structural measures reduced residual damage, in those few areas where they are proposed as part of the USACE Plan. The residual damage that remains even with implementation of nonstructural measures is indicated with an asterisk in the table.

The rationale, analysis and evaluation that lead to the selection of economic Reaches 39 and 40 for widespread non-structural measures, and no other areas, is unclear. Residual damages in a number of reaches exceed those in Reach 39, by considerable amounts in some reaches; and all other reaches shown in Table 6-1 exceed the residual damages for Reach 40. Collectively, the reaches around West Bay contain many more structures than those in reaches 39 and 40. Since non-structural measures seem to be implementable on an individual structure by structure basis (raising elevation or flood proofing), it is unclear why other areas around the periphery of West and Galveston Bays are not slated for such measures. We recommend that a system-wide investigation be done, encompassing the entire periphery of both bays, to assess the costs and benefits of implementing non-structural measures throughout the entire region. This is particularly important in light of the poor overall performance of the USACE Plan and the very high residual risk that remains with the Plan.

Relationship between the Coastal Spine and In-Bay Measures

Every contribution to water height in Galveston and West Bays increases the surge in the bays and the need for and height/strength of every single in-bay second line of defense and non-structural measure. For the USACE Plan, the weak land barrier and the absence of a western section to the coastal spine including a gate at San Luis Pass (see Appendix A) lead to significant storm surge entry into both bays, increasing the need for in-bay measures. The size and cost of all in-bay measures is inversely related to the strength of the coastal spine. Improving the coastal spine would help lower water levels everywhere in the bays and should be a priority. A robust 17-ft Ike Dike lowers the 1% SWLs in the bays by 3 to 6 ft, compared to the USACE Plan. With the 17-ft Ike Dike, the elevation and costs for all in-bay measures will be reduced significantly. We expect that many in-bay measures that are cost-effective with the USACE Plan will not be needed with a robust 17-ft Ike Dike.

Nature-Based Solutions

Wherever terrain gradients are lowest, on the bay sides of the barrier islands and other locations around the peripheries of the bays, these areas are highly susceptible to flooding, sensitive to small changes in surge levels, and to rising sea level. Nature-based solutions provide a means for reducing damage caused by storm surge and waves. Even where nature-based solutions cannot significantly reduce storm surge levels, they can reduce wave energy, which can lead to a reduction in wave-induced damage and overtopping. A study by Godfroy et al. (2019) has shown that marshes on the bay side of Galveston Island can lead to a 60% reduction in significant wave heights in 100-year conditions. Nature-based features can reduce wave energy and overtopping potential, leading to reduction in required elevation for more hardened second lines of defense and nonstructural measures.

As part of the ecosystem restoration intervention G28 (Bolivar and West Bay GIWW shoreline and island protection – east) a total of 40 miles of rock breakwater is proposed (section 3.2.1 of the USACE (2020) main report). We recommend an investigation to assess whether or not nature-based features, which will also provide coastline protection and environmental value, can replace portions of these breakwaters, without and with improvements to the USCE coastal spine discussed in previous chapters.

Marshes or other nature-based measures can mitigate, at least partially, for damage induced by the USACE Plan in economic reaches 37 and 38. As part of intervention G28, considerable marsh building is planned along the bay side of Bolivar Peninsula. We recommend investigating the enhancement of the marsh restoration in Reach 38, through additional marsh creation or implementation of other nature-based measures to mitigate for the induced damage in this reach, perhaps in conjunction with second lines of defense or nonstructural measures.

Leaving the “back door” open to surge penetration, by not including a western section to the coastal spine, leads to considerable residual storm surge and wave damage around the periphery of West Bay (see Chapter 4). In addition to consideration of implementing second lines of defense or nonstructural measures to address the high residual damages around West Bay, we recommend investigating use of nature-based measures to reduce damage to communities on western Galveston Island (those outside the Ring Barrier), as well as communities and industrial facilities along the north shore of West Bay.

References

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