Appendix B. Cost-Effectiveness of Implementing the Ike Dike

Introduction

This appendix examines the cost-effectiveness of making two improvements to the coastal spine component of the USACE Plan, in essence adopting the Ike Dike coastal spine concept. The improvements are: 1) implementing a stronger fortified core-enhanced dune as the land barrier on both Galveston Island and Bolivar Peninsula, such as the fortified dune described in Chapter 4, and 2) adding a western section to the coastal spine, which includes a fortified dune on Follets Island and a gate system at San Luis Pass. The elevation of both improvements is 17 ft NAVD88, which is the elevation of the solid core in the fortified dune. Analysis done by Jackson State University (JSU) indicates that, for a 100-yr proxy storm and sea level rise of 2.4 ft, a 17-Ike Dike will reduce 100-yr water levels inside Galveston Bay by another 3 to 4 ft, and by 3 to 6 ft in West Bay, compared to the USACE Plan. This magnitude of peak surge reduction is expected to produce a considerable reduction in residual damage, compared to the USACE Plan, and provide a much higher level of protection for the region.

A wall-in-dune concept was adopted to estimate the cost of a fortified dune. The solid core is an inverted T-wall, which is embedded in a sand dune; this type of dune is illustrated in Figure B-1. This choice for the solid core was made because there were sufficient data provided in the USACE Feasibility Report to make a cost estimate. Cost data were available for inverted T-walls having a crest elevation of 17/18 ft for the Clear Lake and Dickinson wall/gate systems. Other choices for the solid core are possible, and another type of core might be less costly. Other options/combinations of core systems (e.g., clay dike, rubble mound, etc.) would reduce the volume of sand further and thus save costs if sand is assumed the most expensive material.

All equivalent average annual damage data that are cited here were extracted from Table 23 in Appendix E-1 of the USACE Feasibility Report; data in Table 23 are for the intermediate sea level rise scenario, which is consistent with the future sea level considered by JSU. All damage data reflect average annual damage values for residential and commercial properties, computed by USACE for a 50-yr period of economic analysis. Table B-1 shows cost data for the Coastal Storm Risk Management (CSRM) elements of the USACE Plan, and the total cost for all elements. Cost data were extracted from the spreadsheets in Annex 22 to Appendix D of the Feasibility Report.

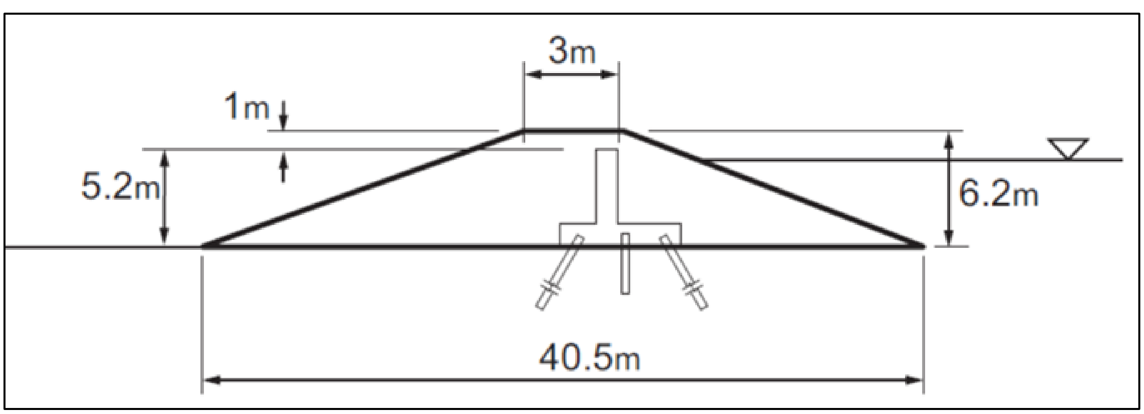

Figure B-1. Cross-section for a fortified dune having an inverted T-wall as the solid core.

Table B-1. Costs for Coastal Storm Risk Management (CSRM) Elements of the USACE Plan

USACE Plan Element	First Cost	Fully Funded Cost
Bolivar Roads gate system	$13.88B	$21.68B
Galveston Ring Barrier	$3.30B	$5.71B
Clear Lake gate	$1.52B	$2.77 B
Dickinson gate	$879M	$1.65B
Bolivar Beach and Dune (initial)	$1.34B	$1.87 B
West Galveston Beach and Dune (initial)	$1.20B	$1.66 B
Bolivar Periodic Renourishment	$671M	$3.13 B (7 renourishments)
West Galveston Renourishment	$359M	$1.70 B (6 renourishments)
Non-structural measures	$220M	$0.422B
Total	$23.37B	$40.59B
Clear Lake inverted T-wall (levees and floodwalls cost line item)		$232M
Dickinson inverted T-wall (levees and floodwalls cost line item)		$109M

Cost of a Fortified Dune Land Barrier

Several assumptions were made to facilitate estimation of the cost for a fortified dune. One is that the volume of sand contained in the dual sand dune system of the USACE Plan is sufficient to cover the solid core of a fortified dune and, if desired, a smaller front dune as is included in the USACE Plan. A second assumption is that the renourishment that is required for the fortified dune will be significantly less than the renourishment estimated for the much lower dual sand dunes n the USACE Plan; a 50% reduction in cost is assumed (thus use of the 0.5 multiplication factor in step 1 below). Compared to the lower dunes in the USACE Plan, the higher fortified dune will experience much less frequent overtopping, erosion and degradation of the dune crest, and subsequent loss of sand volume due to overtopping and overwash.

The cost to build a fortified dune, with an inverted 17-ft high T-wall as its solid core, and with sand cover, is estimated using the following steps:

1) Compute the cost of a mile of beach/dune system in the USACE Plan. $3.53B (1.87B + 1.66B) is the fully funded cost for initial construction of 43 miles of beach/dune on both Bolivar Peninsula and Galveston Island. The per-mile cost for initial construction is $82M per mile. Total renourishment cost for the life of the project is estimated as 0.5 x (3.13B + 1.7B)/ 43 miles = $56M per mile. The total cost for sand in a fortified dune is the sum of initial construction and all renourishment, **$138M per mile.**

2) Compute the cost of a 17-ft inverted T-wall, based on the levees and walls line item cost for the Clear Lake and Dickinson wall/gate systems.

    - Clear Lake - $232M fully funded construction cost x 1.25 factor for other costs = $290M / 1.5 mile length = $193M per mile

- Dickinson - $109M fully funded construction cost x 1.25 for other costs = $136M / 0.7 mile length = $195M per mile

  Use **$195M/mile** for the cost of constructing the inverted T-wall solid core.

3) Compute the total cost to build and renourish a fortified dune as the land barrier, $138M/mile (sand) + $195M/mile (solid core) = **$333M/mile**

Total cost to build and renourish 43 miles of dual sand dune in the USACE Plan is $8.36B.

Total cost to build and renourish 43 miles of fortified dune is $14.32B, an increase of $5.96B.

Total cost to build and renourish 18 miles of dual sand dune on Galveston Island is $3.36B

Total cost to build and renourish 18 miles of fortified dune on Galveston Island is $5.99M, an increase of $2.63B.

Total cost to build and renourish 25 miles of dual sand dune on Bolivar Peninsula is $5.0B

Total cost to build and renourish 25 miles of fortified dune on Bolivar Peninsula is $8.33B, an increase of $3.33B.

Cost of a Western Section to the Coastal Spine

The cost to add 13 miles of fortified dune to Follett's Island is $333M/mile x 13 miles = $4.33B.

The cost for a small gate system at San Luis Pass, a Delft University of Technology (TUDelft) estimate, is $330M. Add 25% for other costs to arrive at a total cost of $413M.

Total cost to add a western section to the coastal spine in the USACE Plan is $4.74B.

Cost-Effectiveness of the USACE Plan

The total fully funded cost for all Coastal Storm Risk Management elements in the USACE Plan is $40.59B (see Table B-1). For the intermediate sea level rise scenario, this investment achieves $1.7B in average annual damage reduction; the average annual residual damage is $1.15B. Note: the amount of damage reduced, which is cited in the USACE Feasibility Report, is overestimated and the residual damage is underestimated because of the flaw in the USACE storm surge modeling discussed in Chapter 2.

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.

Using this metric, the BCR for the entire USACE Plan is ($1.7B x 50)/40.59B or **2.09**. In light of the USACE surge modeling flaw, the BCR for the USACE Plan is likely to be significantly lower than this value.

Damage Reduction from Improvements to the USACE Plan

To assess the cost-effectiveness of improvements to the USACE Plan, the additional cost of making improvements is compared to the further reduction in residual damages that is achieved with the improvements. Costs and damage reduction are then used in calculating the BCR for the improvements.

It is not possible in this review to separate the beneficial effects of implementing a higher fortified dune from benefits attributable to adding a western section. Therefore, for this analysis, it is assumed that improvements made to the coastal spine fronting West Bay only serve to reduce residual damage in West Bay, and the same for Galveston Bay. However, based on information in Appendix A and the JSU (2018) report, the benefit of improvements made in West Bay is also realized in Galveston Bay. Therefore, in this analysis, the cost-effectiveness of improvements made to the spine fronting West Bay is understated, and the value of improvements made to the spine in Galveston Bay is overstated.

Residual damage for the USACE Plan, for the intermediate sea level rise scenario, is $1.15B, distributed as 55% in West Bay ($633M) and 45% in Galveston Bay ($518M). Improvements to the USACE Plan will reduce the residual damage in each bay by a significant, but unknown, amount. In light of the large reductions in 100-yr surge levels expected for the 17-ft Ike Dike, compared to the USACE Plan, cost-effectiveness is examined for two levels of damage reduction, 50% and 75%.

For a 75% reduction in residual damage, damage reduction for West Bay is 0.75 x $633M, or $475M.

For a 50% reduction in residual damage, damage reduction for West Bay is 0.5 x $633M, or $317M.

For a 75% reduction in residual damage, damage reduction for Galveston Bay is 0.75 x $518M, or $389M.

For a 50% reduction in residual damage, damage reduction for Galveston Bay is 0.5 x $518M, or $259M.

Cost-Effectiveness of West Bay Improvements

The cost of improvements in West Bay is calculated as the cost of the western section ($4.74B) plus the added cost to build and renourish 18 miles of fortified dune on Galveston Island, $2.63B. The total cost for West Bay improvements is $7.37B.

Assuming 75% reduction in damages, the BCR for the West Bay improvements is (0.475B x 50)/7.37B = **3.22.**

Assuming 50% reduction in damages, the BCR for the West Bay improvements is (0.317B x 50)/7.37B = **2.15**.

For either percentage of damage reduction, the West Bay improvements appear to be more cost-effective that the USACE Plan in its entirety, particularly in light of the overestimate of damage reduction for the USACE Plan due to the surge modeling flaw, and neglecting the benefit of West Bay improvements to Galveston Bay.

Cost Effectiveness of Galveston Bay Improvements

The cost of improvements in Galveston Bay is calculated as the added cost to build and renourish 25 miles of fortified dune on Bolivar Peninsula. The total added cost for Galveston Bay improvements is $3.33B.

Assuming 75% reduction in damages, the BCR for the Galveston Bay improvements is (0.389B x 50)/3.33B = **5.84**.

Assuming 50% reduction in damages, the BCR for the Galveston Bay improvements is (0.259B x 50)/3.33B = **3.89**.

For either percentage of damage reduction, the Galveston Bay improvements appear to be more cost-effective that the USACE Plan in its entirety, even if the benefit to Galveston Bay is somewhat overstated.

Overall Cost-Effectiveness of Improvements to the USACE Plan

The additional cost to build and renourish 43 miles of fortified dune is $5.96B. The additional cost to add a western section of the coastal spine to the USACE Plan is $4.74B. The total added cost to implement both improvements and implement a robust 17-ft Ike Dike coastal spine is $10.7B.

Average annual residual damages for the USACE Plan are $1.15B.

Assuming 75% reduction in damages (0.75 x $1.15B = $863M), the BCR for all improvements is (0.863B x 50)/10.7B = **4.03**.

Assuming 50% reduction in damages (0.5 x $1.15B = $575M), the BCR for all improvements is (0.575B x 50)/10.7B = **2.69**.

Making both improvements appears to be more cost-effective that the USACE Plan in its entirety.

In addition to direct benefits, in terms of reductions in residual damage derived from improvements to the USACE coastal spine, significant costs are avoided, i.e. saved. One is the reduction in the volume of sand needed to renourish the fortified dune, estimated to be $2.4B. In addition, inside the bays, significant costs are avoided by strengthening the coastal spine. A stronger first line of defense will reduce the need for, or extent, height, strength and cost of all in-bay measures, including the Galveston Ring Barrier, the second lines of defense at Clear Lake and Dickinson, and all non-structural measures. A 10% cost savings for in-bay measures would be $1B, a 25% savings would be $2.5B.

The USACE cost estimate for the Bolivar Roads Storm Surge Barrier is $13.8B. Independent estimates, presented in Chapter 3 suggest a more accurate estimate is $4.6B (and a bandwidth between $2.4B and $6.8B). The added cost to make both improvements and fully implement the 17-ft Ike Dike is $10.7B. This cost increase is roughly offset by the sum of a $7B to $11B overestimate for the cost of the Bolivar

Roads Barrier, $2.4B cost avoidance for renourishment volume, and $1B to $2.5B cost avoidances for in-bay measures. With a more realistic estimate for the Bolivar Roads Barrier, implementing the two improvements to the USACE coastal spine is not expected to change the overall cost estimate by much ($23.37B for the Plan elements shown in Table B-1); however, the improvements will be much more effective in reducing damage for the entire region than the USACE Plan. We are concerned that the high estimate for the Bolivar Roads Barrier adversely skews the overall benefit-cost ratio, leading to limited consideration of other means for reducing damage in the region.