Houston Ship Channel Expansion Channel Improvement Project, Harris, Chambers, and Galveston Counties, Texas

Plan Formulation
Appendix A

U.S. Army Corps of Engineers
Southwestern Division
Galveston District
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PLAN FORMULATION APPENDIX

1.0 PLAN FORMULATION RATIONALE

Plan formulation is the process of building alternative plans that meet the planning objectives of the study within the planning constraints. The planning objectives and planning constraints are listed in the **Main Report (Section 4.0)**. First management measures are formulated. These measures are features that can be implemented at a specific geographic site to address the planning objective(s). A feature can be a structural element that requires construction or a nonstructural action. Then alternative plans are developed, comprising a set of one or more management measures functioning together to address the planning objective.

Preliminary plans are formulated by combining management measures. Each plan must be formulated in consideration of the following four criteria described in the Principles and Guidelines (P&G):

- Completeness: Extent to which the plan provides and accounts for all necessary investments or actions to ensure realization of the planning objective
- Effectiveness: Extent to which the plan contributes to achieving the planning objective
- Efficiency: Extent to which the plan is the most cost-effective means of addressing the specified problems and realizing the specified opportunities, consistent with protecting the nation's environment
- Acceptability: Workability and viability of the alternative plan with respect to acceptance by Federal and non-Federal entities and the public, and compatibility with existing laws, regulations, and public policies

The USACE is required to consider the option of "No Action" as one of the study alternatives in order to comply with the requirements of the National Environmental Policy Act (NEPA). With the No Action Plan (i.e., the Future Without-Project Condition or FWOP Condition), it is assumed that no project would be implemented by the Federal Government or by local interests to achieve these particular planning objectives. In the FWOP Condition, it is assumed that normal operation and maintenance (O&M) activities, along with other probable channel improvements, would be performed over the 50-year period of analysis. The No Action Plan, therefore, forms the basis to which all other alternative plans are measured. Details of the No Action plan are included in FWOP Conditions section of the main report.

Initial study efforts involved a determination of the magnitude and extent of the problems along the Houston Ship Channel (HSC) in order to develop and evaluate an array of alternative solutions that meet the existing and long-range future needs of the non-Federal sponsor (Port of Houston Authority or PHA) and the public. At the initiation of the feasibility phase of the project, lines of communication were opened with Federal, state, and local agencies, private groups, and the affected public. A Notice of Intent (NOI) *to prepare a Draft Environmental Impact Statement (EIS) for the HSC 45-Foot Expansion Channel Improvement Project (HSC ECIP), Harris, and Chambers Counties, Texas* was issued in the Federal Register dated March 29, 2016. An initial agency stakeholder meeting was held in Galveston, Texas on May 3, 2016. A Notice of Public Scoping Meetings was issue on April 18, 2016 to inform the public of the two public scoping meetings held in Houston, Texas and La Porte, Texas on May 17, 2016, and May 19, 2016, respectively. To date, three different meetings (25 July 2016, March 14, 2017, and April 19, 2017) were held with the Houston Pilots to determine which measures would result in lifting pilot restrictions or meeting objectives.

This appendix addresses the feasibility study analysis up to the selection of the Tentatively Selected Plan for Public Review using the information that was available at that date. This includes the formulation of measures and alternative plans, the screening of measures and alternative plans, and the selection of the Tentatively Selected plan (the NED Plan inclusive of measures carried forward for further evaluation. This appendix stops at that point, and picks up in the Final Integrated Feasibility Report and EIS (FIFR-EIS) in Chapter 6.

2.0 MANAGEMENT MEASURES

The main problems with the existing channel are the inefficient vessel utilization of the HSC system due to current channel dimensions (depth and width), including inefficiency of in-channel configurations. The system has constrained vessel sizes, draft restricted areas in the upper channel, inadequate channel configurations for vessels currently using the channel, including the width and size of channel bends and turns. These inefficiencies are contributing to congestion along the waterway, especially with the high volume of barge and deep-draft vessel traffic on the HSC. There are also safety concerns with vessel traffic and congestion and a lack of suitable placement areas (PAs) and beneficial use (BU) sites for the placement of dredged material.

Prior to the development and presentation of measures and subsequently alternatives, the existing Federal channels were divided into six study segments (**Figure 1**). Those segments are as follows:

Segment 1 **Bay Reach (**Bolivar Roads to Boggy Bayou)
Segment 2 **Bayport Ship Channel** (BSC)
Segment 3 **Barbours Cut Channel** (BCC)

Segment 4 **Boggy Bayou to Sims Bayou**
Segment 5 **Sims Bayou to I-610 Bridge**
Segment 6 **I-610 Bridge to Main Turning Basin**

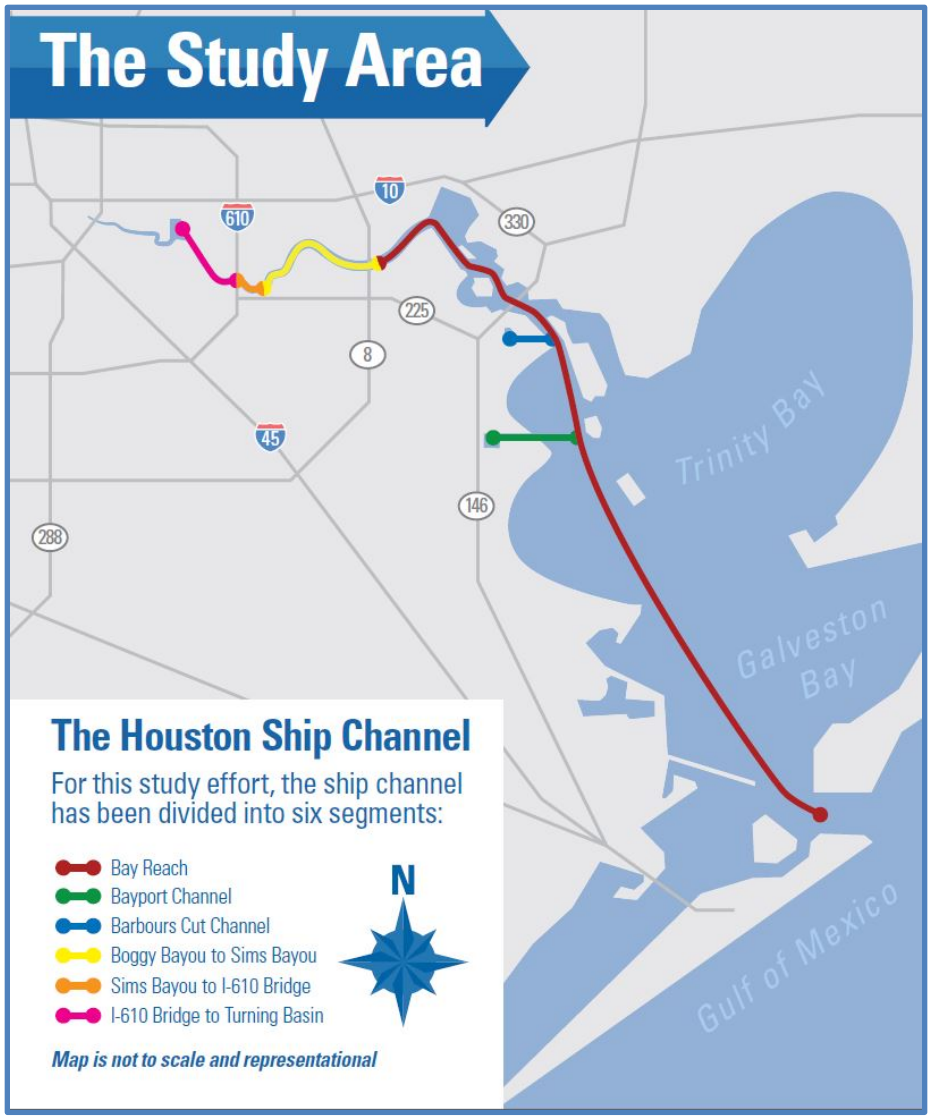

Figure 1 – Study Segments or Reaches for the HSC ECIP Feasibility Study

Nonstructural and structural measures were developed to address the planning objective, alone or in combination with other measures. These measures were later combined to form alternatives to be evaluated in this study process. New measures identified in later phases of the Plan Formulation process were also reviewed and considered in the alternative analysis. Plan formulation involves meeting the study objectives while not violating constraints. The study takes into account all applicable county, state, and Federal laws, permitting requirements, regulations, and environmental guidance. Specific study constraints include:

- Impacts to social, environmental, and cultural resources will be avoided or minimized to the extent practicable;
- Height restrictions due to road/bridge crossings over the HSC limit the air draft of vessels transiting the HSC and pose deepening and cost constraints. Deepening the upper channel (Segments 4-6) would allow the existing vessel fleet to load deeper. Deepening is not being considered for Segment 1 and is not in the scope of this study. Each crossing is listed with the common name underlined, the air draft in parenthesis, and study segment location:
    - Fred Hartman Bridge or Baytown Bridge (175 foot air draft Mean High Water (MHW)) in **Segment 1** – HSC-Bay Reach;
    - Sam Houston Ship Channel Bridge or Beltway 8 Bridge (formerly known as Jesse H. Jones Memorial) (175 foot air draft MHW) in **Segment 4** - Boggy Bayou to Sims Bayou);
    - Sidney Sherman Bridge or I-610 Bridge (135 foot air draft MHW) in **Segment 6** – HSC I-610 Bridge to Main Turning Basin;
- Lynchburg Ferry (owned by Harris County) in **Segment** 1 – HSC-Bay Reach, does not have room for channel improvements; therefore, no improvements in the vicinity of the Lynchburg Ferry are being considered. Ferry landings exist on either side of the HSC;
- Coastal Water Authority (CWA) pipeline crossings (three) are located in vicinity of Lynchburg Ferry in **Segment 1**. These 108-inch diameter pipelines cross under the channel and are just cleared for the current project (with two foot advanced; one foot allowable overdepth). These crossings would be impacted with any channel improvements in this area. No improvements in this area are being considered;
- Washburn Tunnel is located in **Segment 5** – HSC Sims Bayou to I-610 Bridge where the project depth of the HSC is 41.5 feet plus 2 feet advanced maintenance and 1-foot allowable overdepth. At the tunnel crossing, the channel is maintained at 40.5 feet plus 1-foot allowable overdepth. Any improvements in this area would have to avoid impacts to the Washburn Tunnel;
- Other various permitted crossings at 175 foot air draft (power lines);
- Alternative plans should not cause or amplify problems in other areas;
- Due to previous oyster shell mining in the Bay Reach of the HSC **(Segment 1)**, there are geographical constraints for the development of new PAs/BU sites in close proximity to the channel. Previous construction (e.g. Mid Bay PA and Atkinson Island Marsh BU) in this reach has experienced foundation failure issues resulting in substantial cost increases; and
- Hardened development, including major refineries, docks, and other industrial development, situated directly adjacent to the channel limit potential widening opportunities

The study takes into account all applicable county, state, and Federal laws, permitting requirements, regulations, and environmental guidance.

2.1 Nonstructural Measures – Operational Practices

The nonstructural measures considered included:

- Adjust vessel speed – to alleviate maneuverability or meeting issues;
- Increase tug boat assistance – to overcome maneuvering, passing, turning, or other movement restrictions;
- Traffic controls – to schedule/manage channel entry/exit more efficiently;
- Changes to operating procedures (tides, lightering, etc.) – to overcome draft restrictions; and
- Changes to Shipper Association Operating Procedures – to schedule/manage channel entry/exit or berthing more efficiently

Non-structural measures have been employed historically to allow vessel transit of the HSC system; however, they are not sufficient to alleviate the existing inefficiencies and they are already practiced to the greatest extent practicable. Therefore, non-structural measures were not carried forward for further analysis beyond the initial screening of the measures.

2.2 Structural Measures

Structural measures included:

- Channel deepening – deepening to alleviate light-loading of vessels, allow more efficient loading practices, and use of fewer larger ships;
- Channel widening (including meeting areas) – widening to allow more efficient and safe meeting of vessels, alleviate one-way traffic restrictions;
- Other channel configurations (bend easing/flares) – to ease sharp turns and associated vessel slow down, maneuverability issues, and/or tug assist;
- Multipurpose mooring areas – areas to tie up to for temporary harbor for layover (e.g., layberth), or disabled vessels (refuge), reducing anchorage transits to Bolivar Roads or offshore (Sea Buoy);
- Turning basins – to provide more efficient locations and size for vessel(s) to turn around in one-way channels;
- Sediment Barrier/Shoaling attenuation structures – structures (breakwaters/jetty) to alleviate wave energy or excessive shoaling in problem spots and reduce O&M; and

- Offshore crude terminal (LOOP) – terminals for offloading fully loaded vessels in waters deeper than current channels and pipelining product to shore

3.0 SUMMARY OF ALTERNATIVE ANALYSIS

3.1 Initial Screening of Measures Based on Contribution to Objectives

The initial screening of the measures was based on whether a measure would address one or more of the planning objectives alone or in combination with other measures. If a measure could not meet at least one objective, the measure was dropped from further consideration in plan formulation. Screening of structural and non-structural measures is provided in **Table 1**.

Regarding the nonstructural measures previously identified, these measures are already in place and are a regular part of HSC operations. Adjusting (reducing) the speed of vessels any further would affect the maneuverability. Tug use is common and used as needed; however, an increase in tugs will further contribute to an already congested channel. The USCG operated Houston/Galveston Vessel Traffic Services (VTS), was established in 1975 under the authority of the Ports and Waterways Safety Act of 1972. The Houston/Galveston VTS is used to coordinate movement in the channel. Additionally, the Houston Pilots have working rules (non-structural measures) in place to provide for vessel transit in the HSC. The Houston Pilots Association (HPA) Working Rules was updated on October 24th, 2018. The latest full description of the rules is available at the following website: http://houston-pilots.com/workingrules.pdf. Lightering is a common practice on the HSC and tidal fluctuation is small in this region so there really is not a difference shown in time or transit. Ultimately, the VTS, Pilot Rules, and the other non-structural implementations listed above are not sufficient to overcome restrictions, and congestion problems on the HSC and its tributaries. Modifying these practices would not provide transportation cost savings; therefore, these measures were not carried forward for further analysis.

In regards to structural measures, the LOOP Terminal is a lightering area where very large crude carriers and ultra large crude carriers that are typically too large to access a harbor load and unload liquid bulk. These carriers have beams that often exceed 200 feet, LOA of over 1,500 feet, and drafts often exceeding 66 feet. Most tankers of this size are not able to enter the HSC. No measure being considered in this study will allow vessels this size to call at HSC. The remaining structural measures were carried forward.

Table 1 –Initial Screening of Non Structural Measures Based On Contribution to Objectives

Measure	Notes	Contributes to Objective				
		Obj 1*	Obj 2*	Obj 3	Obj 4	Obj 5
		*Primary NED Objectives				
Non-Structural Measures						
Adjust vessel speed	Already at the slowest speed possible without affecting maneuverability	No	No	No	Yes	No
Additional Tug Assist	Standard tug operations are sufficient and additional tugs would not improve transportation efficiency. In some cases, tugs are an interim risk reduction.	No	No	No	No	No
Traffic Management (Vessel Traffic System or VTS)	USCG and Pilots collaborate for effective traffic management. VTS Houston/Galveston exists to prevent groundings, allisions, and collisions by sharing information and implementing appropriate traffic management measures.	No	Yes	No	Yes	No
Use tides, lightering	The tidal range for Galveston Bay at NOAA Pier 21 is diurnal maximum 1.75 feet at MLLW, minimum -0.63 feet MLLW; therefore, it does not really make a difference in time or transit. Lightering is already common practice.	No	No	No	No	No
Terminal improvements	Projected terminal improvements are included in the without-project condition; would not substantially improve transportation efficiency.	No	No	No	No	No
Structural Measures						
Channel Deepening	Inclusive of deepening of berthing areas, projected to improve transportation efficiency.	Yes	Yes	Yes	No	No
Channel Widening	Widening to create meeting area(s) may improve transportation efficiency and safety.	Yes	Yes	Yes	Yes	No
Other Channel Configurations	Bend easing and flares are insufficient to address existing safety concerns and assure safe and efficient maneuverability	Yes	Yes	Yes	Yes	No
Shoaling Attenuation Feature/ Sediment Barrier	Construction of breakwater/jetty to function as shoaling attenuation features to assist in the reduction of shoaling.	No	No	No	No	Yes
Improve existing or create additional turning basins	Reduce inefficiencies created by requiring channel closures or other restrictions while operating vessels in areas without adequate turning opportunities.	Yes	Yes	No	Yes	No
Create multipurpose moorings for layover mooring and disabled vessels	Improve safety and environmental impacts by limiting transits of vessels outside of immediate service area. Ships have to move down channel to Bolivar Roads Anchorage or Sea Buoy Anchorage.	Yes	Yes	No	Yes	No
LOOP	We do not expect that deepening would result in Larger Tankers (70 foot draft) being able to transit HSC.	No	No	No	No	No

Obj 1 - Reduce navigation transportation costs by increasing economies of scale for vessels to and from HSC;
Obj 2 - Increase channel efficiency, and maneuverability in the HSC system for the existing fleet and future vessels;
Obj 3 - Develop environmentally suitable placement for dredged material and maximize use of BU of dredge material;
Obj 4 – Increase channel safety for vessels utilizing the HSC, BSC, and BCC;
Obj 5 - Reduce high shoaling at BSC Flare to reduce dredging frequency.

3.2 Second Screening of Measures

The study scope does not consider deepening beyond 46.5 feet. Deepening greater than 46.5 feet is expected to be cost prohibitive due to the significant environmental and engineering challenges as well as high costs associated with project depth below 46.5 feet. The NFS supports this study scope and is not in support of an expanded analysis of deeper depths.

Without bay deepening and significant channel modifications that would be required for the transit of a VLCC, it is assumed that VLCCs would not enter HSC and current lightering practices at the LOOP would continue. The project makes no change to these practices.

Barge lane relocation is assumed under all widening scenarios. Barge lanes would be replaced to the specifications of P.L. 106-377 as an associated cost of the project.

3.2.1 Secondary Screening of Measures Criteria

All non-structural measures were screened out in the initial screening and the remaining structural measures were further developed. The following criteria were used to evaluate and conduct a second iteration of screening of the structural measures prior to developing alternatives:

1. Environmental issues – a measure that would negatively affect a Wildlife Management Area (WMA) or Bird Rookery will be eliminated from further study.
2. Engineering issues – If it was determine that 1) insufficient space is available for a measure or 2) a measure is already appropriately sized for the design vessel(s) that measures will be eliminated from further study.
3. Infringement on another Federal Project – any measure that would negatively affect or overlap with another Federal project will be eliminated. The HSC is adjacent to the Texas City Ship Channel, Cedar Bayou Navigation Channel, the Gulf Intracoastal Waterway (GIWW), and the Galveston Harbor and Channels.
4. Regulatory Permit issued – if a Department of the Army (DA) Regulatory Permit has been issued for proposed work the expectation is that work will be conducted.
5. Houston Pilots Input – To date, three different meetings (25 July 2016, 14 March 2017, and 19 April 2017) were held with the Houston Pilots to determine which measures would result in lifting pilot restrictions or meet objectives. If a measure is determined to not improve safety or lift a restriction in part or whole, it will be elimated.

3.2.2 Secondary Screening of Measures Per Segment

Segment 1 - Bay Reach

In Segment 1, twenty-two measures to increase safety and efficiency in the Bay reach, from Bolivar Roads to Boggy Bayou, were evaluated and screened (**Table 2**).

Table 2 – Structual Measure for Segment 1 – Bay Reach

#	Measure	Mid-Station Reference	Description - Improvement	Drop or Advance	Reason(s) for Dropping
SEGMENT 1 - BAY REACH (*Bolivar Roads to Boggy Bayou or BR-BB)*					
1	BE1 138+369	138+369	Ease bend below Buoy 18/Bolivar Roads (safety, vessels > 1100 LOA)	Advance	N/A
2	BE1 128+731	128+731	Ease bend near Buoy 18/Bolivar Roads (safety, vessels > 1100 LOA)	Advance	N/A
3	CW1 BR-Redfish	105+000	Widening to allow meeting of bigger container/tanker design vessel	Advance	N/A
4	BE1 78+844	78+844	Ease bend near Redfish (safety; allow vessels > 1100 LOA)	Advance	N/A
5	CW1 Redfish-BSC	54+000	Widening to allow meeting of bigger container/tanker design vessel	Advance	N/A
6	MM1 HSCBay	52+000	Mooring on HSC south of Mid Bay PA	Drop	2,5
7	CW1 Hog	50+000	Widening Hog Island stretch; enable larger 2-way meeting past Hog	Advance	N/A
8	MM1 HSCBSC	33+000	Multipurpose Mooring near 5-Mile Cut	Drop	2,5
9	CW1 BSC-BCC	12+000	Widening to allow meeting of bigger container/tanker design vessel	Advance	N/A
10	CW1 BR-BCC	0+000	Widening to allow meeting of bigger container/tanker design vessel	Advance	N/A
11	MM1 CBNC	10+00	Mooring to providing queuing /refuge, modifications to CBNC	Drop	1,3
12	BE1 28+605	28+605	Ease bend near Bayport, easing beyond Project Deficiency Report width	Advance	N/A
13	BE1 27+48	27+48	Improve safety; two-way traffic	Drop	2
14	BE1 153+06	153+06	Improve safety; two-way traffic upstream of Fred Hartmann Bridge	Advance	N/A
15	BE1 246+54	246+54	Improve safety; two-way traffic around Alexander Island turn	Advance	N/A
16	CN1 AI	309+00	New one-way spur channel around Alexander Island - widebody 2 way	Drop	2
17	MM1 AI	309+00	Alexander Island mooring	Advance	N/A
18	MM1 520+00	520+00	Battleship area mooring to enable tanker design vessel queuing	Advance	N/A
19	TB1 JP	570+00	Turning Basin	Drop	4
20	CM1 595+00	595+00	Meeting in front of Dow Lone Star	Replaced with combined measure (CW1 SJM BB)	
21	CM1 660+00	660+00	Shell Oil Meeting to enable 2-way		
22	CW1 SJM BB	612+90	Widening from San Jacinto Monument to Boggy Bayou	Advance	

1. Environmental Issues – location would impact Wildlife Management Area (WMA) or Bird Rookery

2. Engineering Issues such as insufficient space available, already appropriately sized for design vessel, pipelines, overhead utilities.

3. Infringement on another Federal Project (Cedar Bayou Navigation Channel)

4. Regulatory Permit issued authorizing future work in area

5. Houston Pilot input

Bend easing measures in the Bay (#1, 2, 4, and 12 in **Table 3**) between Bolivar Roads (Buoy 18) to Barbours Cut would allow the design vessels to enter into the HSC. Easing the bends could lift the pilot rule restriction for 1,000-by 138-feet maximum vessel size of all types from Bolivar Roads to Barbours Cut and allow for an LOA increase from 1,000 feet to 1,200 feet.

Measures for widening in the Bay (#3, 5, 9, and 10 in **Table 3**) would allow for increased meeting opportunities of widebody vessels (beam of 120 feet plus). Currently the HSC channel width does not support two-way traffic for vessels with a combined beam of 310 feet or greater below the BSC (Beacons 75/76) or 272 feet combined beam above the BSC to Morgans Point. This results in delay time and waits at the anchorage, increasing transportation costs.

Pilot rules allow a maximum vessel size of 860- by 120 feet from Baytown, Texas to Boggy Bayou. Measures (#7, 14, 15, and 22) for selective widening (including bend easings) of discrete areas would increase the maximum LOA and beam sizes allowed for unrestricted transit. This would permit the meeting of larger vessels and more nighttime transit, leading to an overall drop in channel congestion.

Measures for multipurpose moorings (#6, 8, 11, 17, and 18) would reduce traffic delays and transit times for vessels conducting intraport movements on the HSC by providing vessel-mooring opportunities for chemical tankers. Moorings in the upper channel were considered most beneficial. The measures for mooring near the San Jacinto Monument were carried forward (#17 and 18). The other mooring measures (#6, 8, 11, and 17) were dropped from further consideration.

Five measures were dropped from further consideration in Segment 1. Three of the mooring measures were dropped either because the Houston Pilots felt the measure (#6 and 8) would be in an area too congested to support a multipurpose mooring and the measure (#11) would infringe on another Federal Channel (Cedar Bayou Navigation Channel). One of the bend easing measures (#13) was dropped because the PDT believed this would be better improved with a flare expansion in Segment 3. A spur channel around Alexander Island (#16) was dropped from further consideration as a significant number of pipelines and overhead utilities would be impacted. Additionally, a turning basin measure (#19) considering a location at Jacintoport was dropped because a DA Regulatory Permit for a future dock was issued at this location.

Lastly, two measures (#21 and 22) were combined into one measure (#22) to widen the channel from the San Jacinto Monument to Boggy Bayou to eliminate or reduce an area of concern where the channel necks down from 530 feet to 400 feet.

Segment 2 – BSC

Seven measures were considered for Segment 2, the BSC (**Table 3**).

Table 3 – Structural Measures for Segment 2 – Bayport Ship Channel

#	Measure	Mid-Station Reference	Description - Improvement	Drop or Advance	Reason(s) for Dropping
SEGMENT 2 - BAYPORT SHIP CHANNEL					
1	BE2_BSCFlare	27+000	Expand Flare; enable container vessel to pass BSC, turn into BSC	Advance	N/A
2	TB2 BSCRORO	130+00	New BSC TB at east end of land cut to enable design container vessel	Advance	N/A
3	CW2_BSC	100+00	Widen BSC to AOM width and wider	Advance	N/A
4	CD2_BSC	100+00	BSC AOM Deepening	Advance	N/A
5	SA2 BSCFlare	221+00	Sedimentation Attenuation Feature to reduce heavy shoaling	Advance	N/A
6	TB2_BSCTB	25+59	Expand existing BSC TB to enable design container vessel	Drop	2
7	MM2 BSC	135+00	Multipurpose mooring to reduce anchorage transits	Advance	N/A

1. Environmental Issues – location would impact Wildlife Management Area (WMA) or Bird Rookery
2. Engineering Issues such as insufficient space available, already appropriately sized for design vessel, pipelines, overhead utilities.
3. Infringement on another Federal Project (Cedar Bayou Navigation Channel)
4. Regulatory Permit issued authorizing future work in area
5. Houston Pilot input

In Segment 2, seven measures were considered for the BSC. One measure (#1) would be to address residual navigation concerns remaining after the construction of the recommended plan from the *Houston Ship Channel Project Deficiency Report (Flare at the Intersection of the Houston Ship Channel and Bayport Ship Channel), Houston-Galveston Navigation Channels, Texas* (March 2016) report (HSC PDR). The recommended plan was an approved interim corrective action for container design vessels turning into the BSC. The PDR plan authorized increasing the flare radius from 3,000 to 4,000 feet and widening on the east side of the HSC by 235 feet near Beacon 75/76. The Pilot Working Rules (updated 25 May 2016) state:

> *"Effective upon completion of the dredging project to increase the radius of the Bayport flare from 3000' to 4000' and to widen the east side of the Houston Ship Channel in the vicinity of B-75/76, the maximum size of vessels permitted to transit the Bayport Ship Channel is 1160'x150'x45'. Vessel traffic management protocols to be developed. 09.02.15"*

This measure would further expand the existing flare to allow for safe and efficient transit of the design container vessel into the BSC.

The other measures considered for the BSC are a measure (#2) for a new turning basin at the east end of the land cut to reduce restrictions for design container vessels entering into the BSC.

Currently the BSC is limited to 1,000- by 138-feet maximum vessel size with three tugs. Another measure (#3) would widen the BSC to increase the maximum vessel size from 138-feet beam up to the design container vessel and allow 24-hour transit for the container design vessels.

A measure for a shoaling attenuation structure (#5) was considered to reduce the dredging frequency around the flare. The high shoaling within the BSC flare area results in increased maintenance dredging, strains placement area capacity, and increases maintenance costs. One measure (#7) introduces a multipurpose mooring to address the lack of a dedicated waiting area results in increased transit time and cost inefficiencies because vessels (Tankers and Chemical Tankers at BSC) are required to go to the anchorages located at Bolivar Roads and Sea Buoy.

Lastly, one measure (#6) to expand the existing BSC turning basin was dropped from further consideration because the existing turning basin is already designed to accommodate the longest containership design vessel LOA.

Segment 3 – BCC

In Segment 3, five structural measures were considered for the BCC (**Table 4**).

Table 4 – Structural Measures for Segment 3 – Barbours Cut Channel

#	Measure	Mid-Station Reference	Description - Improvement	Drop or Advance	Reason(s) for Dropping
SEGMENT 3 – BARBOURS CUT CHANNEL					
1	BE3_BCCFlare	10+00	Expand existing Flare to enable design container vessel entry	Replaced with combined measure (BETB3_BCCFlare)	
2	TB3_BCCMouth	15+00	New TB at BCC mouth so container vessel can back into Dock 1		
3	CW3_BCC	45+00	Widen BCC to enable design container vessel transit	Advance	N/A
4	CD3_BCC	45+00	BCC AOM Deepening	Advance	N/A
5	BETB3_BCCFlare	10+00	Ease flare and create new turning basin	Advance	N/A

1. Environmental Issues – location would impact Wildlife Management Area (WMA) or Bird Rookery
2. Engineering Issues such as insufficient space available, already appropriately sized for design vessel, pipelines, overhead utilities.
3. Infringement on another Federal Project (Cedar Bayou Navigation Channel)
4. Regulatory Permit issued authorizing future work in area
5. Houston Pilot input

Initially, four measures (#1, 2, 3, and 4) were considered in Segment 3. Two measures (#1 and 2) were later combined to form a new measure (#5) that would address both an easing of the flare and a turning basin at the mouth, allowing container design vessels to safely enter the BCC and successfully turn around. A measure to widen beyond the current 300 foot width (#3) would allow maximum vessel sizes beyond the current 1,000- by 138-foot maximum vessel size restriction and ease congestion when large vessels are at berth.

Segment 4 – Boggy Bayou and Sims Bayou

In Segment 4, six structural measures were considered (**Table 5**).

Table 5 – Structural Measures for Segment 4 – Boggy Bayou to Sims Bayou

#	Measure	Mid-Station Reference	Description - Improvement	Drop or Advance	Reason(s) for Dropping
SEGMENT 4 - BOGGY BAYOU TO SIMS BAYOU					
1	CW4_BB-GB	750+00	Widen from BB to Greens Bayou to enable 2-way design tanker traffic	Advance	N/A
2	TB4_775+00	775+00	New TB at Pasadena Docks	Advance	
3	TB4_845+00	845+00	Old Brown & Root TB	Drop	Future Barge Fleet area planned
4	CD4_Whole	890+00	Deepen from 41.5 feet as much as possible up to 46.5 feet	Advance	N/A
5	TB4_Hunting	920+00	Expand Hunting TB to accommodate design vessel turning	Advance	N/A
6	TB4_Sims	1070+00	Expand existing Sims Bayou TB to accommodate turning in reach	Drop	2

1. Environmental Issues – location would impact Wildlife Management Area (WMA) or Bird Rookery
2. Engineering Issues such as insufficient space available, already appropriately sized for design vessel, pipelines, overhead utilities.
3. Infringement on another Federal Project (Cedar Bayou Navigation Channel)
4. Regulatory Permit issued authorizing future work in area
5. Houston Pilot input

In Segment 4, six measures were considered. Current Pilot Rules restrict the maximum vessel size from Boggy Bayou to Sims Bayou to 750- by 116-feet. With this restriction, the design vessels are restricted in daylight, beam, and LOA. A widening measure (#1) from Boggy Bayou to Greens Bayou would increase the maximum vessel size to 850- by 138-feet at least to Greens Bayou. This would allow Aframax Tankers to call/transit up to Greens Bayou without restriction and improve meeting opportunities in this segment.

One measure (#4) would deepen the entire segment from 41.5 feet deep as much as possible up to 46.5 feet deep. This would result in an increase of vessel loading efficiencies.

Turning basins (#2, 3, 5, and 6) were considered in Segment 4 to provide for turning opportunities for Aframax Tankers in the Boggy Bayou to Greens Bayou segment. One measure (#2) would create a new turning basin while a second measure (#5) would expand the existing Hunting Turning Basin. Two measures (#3 and 6) were dropped from further consideration. The first ended up being the location of a future barge fleet area and the second measure evaluation concluded that under the current regime the design vessel would fit; however, under the higher current regime the is not enough room to expand the existing basin to meet design vessel requirements.

Segment 5 –Sims Bayou to I-610 Bridge

In Segment 5, three structural measures were considered (**Table 6**).

Table 6 – Structural Measure for Segment 5 – Sims Bayou to I-610 Bridge

#	Measure	Mid-Station Reference	Description - Improvement	Drop or Advance	Reason(s) for Dropping
SEGMENT 5- SIMS BAYOU TO I-610 BRIDGE					
1	TB5_1105+00	1105+00	New TB to accommodate turning of design vessel in that reach	Drop	2
2	CD5_Whole	1120+00	Deep from 37.5 feet as much as possible up to 41.5 feet	Advance	N/A
3	TB5_1137+00	1137+00	New TB in front of USCG Station to accommodate turning	Drop	2

1. Environmental Issues – location would impact Wildlife Management Area (WMA) or Bird Rookery
2. Engineering Issues such as insufficient space available, already appropriately sized for design vessel, pipelines, overhead utilities.
3. Infringement on another Federal Project (Cedar Bayou Navigation Channel)
4. Regulatory Permit issued authorizing future work in area
5. Houston Pilot input

Three measures were considered in Segment 5. The turning basin measures (#1 and #2) were dropped due to insufficient space. The first would have conflicted with existing docks at the Sims Metal Management facility and the second measure with Valero Marketing, and Cargill Food docks.

The remaining measure (#2) would deepen the channel from Sims Bayou to the I-610 Bridge from the existing 37.5 feet depth as much as possible up to 41.5 feet deep. This would result in increased loading efficiencies.

Segment 6 – I-610 Bridge to Main Turning Basin

In Segment 6, two structural measures were considered (**Table 7**).

Table 7 – Structural Measures for Segment 6 – I-610 Bridge to Main Turning Basin

#	Measure	Mid-Station Reference	Description - Improvement	Drop or Advance	Reason(s) for Dropping
SEGMENT 6 - I-610 BRIDGE TO MAIN TURNING BASIN					
1	TB6_Brady	1195+00	Expand existing Brady Island TB to accommodate turning	Advance	N/A
2	CD6_Whole	1230+00	Deepen from 37.5 feet by at least 2 feet but as much as possible	Advance	N/A

1. Environmental Issues – location would impact Wildlife Management Area (WMA) or Bird Rookery
2. Engineering Issues such as insufficient space available, already appropriately sized for design vessel, pipelines, overhead utilities.
3. Infringement on another Federal Project (Cedar Bayou Navigation Channel)
4. Regulatory Permit issued authorizing future work in area
5. Houston Pilot input

In Segment 6 a measure for a turning basin (#1) and a deepening measure (#2) were considered and advanced. The turning basin measure would result in the expansion of an existing turning basin to alleviate the Pilot Rule restriction that will not allow the design vessel to turn at Brady Island Turning Basin.

Currently, in this segment, channel dimensions limit loading and the channel is draft restricted. To increase loading efficiencies by deepening, reduce restriction of 750- by 106-feet maximum vessel size, and reduce daylight restriction for Bulk Carrier vessels greater than 700 feet LOA, the channel would be deepened from 37.5 feet deep as much as possible (at least two feet) from the I-610 Bridge to the Main Turning Basin.

Of the 45 measures considered, 15 were either dropped from further consideration or combined with another alternative. The remaining 30 measures were forwarded and combined into alternatives.

4.0 BASIS FOR CHOICE

The measures identified above were screened to determine if they adequately addressed the problems with HSC system. As stated previously, measures that did not meet one of the objectives for this study were dropped from further consideration. The remaining measures were then formed into arrays of alternatives plans, which were screened to determine the most effective alternatives. The screening consisted of three levels:

- Initial Array of Alternatives;
- Evaluation Array of Alternatives; and
- Final Array of Alternatives

Each level consisted of a more detailed analysis when compared to the previous level. The Initial Array was screened on a qualitative level, using screening criteria, scientific judgment from use of mapping and alternative footprints, as well as the professional expertise of a multidisciplinary Project Delivery Team (PDT) to identify the implications of each alternative. Professional judgment was used to provide qualitative assessments of environmental and economic conditions. No detailed environmental and economic analysis was included at this level. With the Evaluation Array, a screening matrix was developed, which included quantitative criteria such as quantities, costs, net excess benefits, environmental impacts and Benefit-to-Cost Ratios (BCRs). During analysis of the Final Array of alternatives, a preliminary economic analysis was performed to calculate the net excess benefits and BCRs for each of the alternative plans. The Final Array of

alternatives will be evaluated based on calculations for BCRs and on how effectively they meet the four criteria in the P&G.

The following are the methodology and evaluations that were used to develop the criteria used for screening the three separate arrays of alternatives.

4.1 Methodology to Develop Technical Criteria

Technical criteria require adequate project dimensions to provide safe and efficient passage of design vessels while minimizing environmental impacts. These criteria require plans to be compatible with navigation needs and consistent with the requirements of the navigational equipment using this portion of the waterway and to provide a long-term plan for the placement of dredged materials in order to continue maintenance of the waterway in the future.

The plans must consider specific environmental conditions of the area including soil conditions, topography, and terrestrial and aquatic ecosystems. Formulation of alternative alignments and dredged material placement alternatives and their evaluation are accomplished by analysis of historical and projected shoaling rates in cubic yards per year (cy/yr) and general structural and nonstructural alternatives applicable for conditions in the study area. Initial screening of the alternatives was completed using basic screening criteria, use of mapping and alternative footprints, and professional expertise and scientific judgment of the PDT. More detailed technical information (both historical data and specific information and analyses prepared for this project), will be used during screening of the Evaluation and the Final Arrays of alternatives.

Under the new SMART planning requirement to limit Feasibility Study scope and duration, engineering analyses of any specific placement or potential uses of dredged material will occur during the development of the DMMP during the feasibility-level analysis phase of the study. This is when most modeling efforts will conducted, during the feasibility-level analysis phase of the study. Technical information and the corresponding screening level in which this information was used include, but are not limited to, the following:

- Aerial photography (all arrays);
- Historical dredging records (all arrays);
- Previously published scientific reports related to the study area (all arrays);
- Marine and estuarine resource investigations (all arrays);
- HarborSym Modeling (Evaluation and Final Arrays);
- Hydrodynamic Modeling of past studies (BSC Flare, HSC, etc.) (Final Array)
- Relative Sea Level Change (Final Array only)
- Threatened and Endangered Species Considerations (Final Array), and

- Mapping and analysis of oyster reef impacts (all arrays)
- 50-year Dredged Material Management Plan (DMMP) (Final Array)
- Draft HSC DMMP study analysis (Final Array)

Modeling results will not be available for the hydrodynamic modeling, storm surge modeling, and sediment and water quality analysis until the feasibility-level analysis phase of the study and some additional modeling will likely be performed during Pre-Construction Engineering and Design (PED) for the navigation project.

4.2 Methodology to Develop Economic Criteria

The economic criteria require that tangible benefits attributable to projects exceed project costs. Project benefits and costs are reduced to average annual equivalent (AAEQ) values and related in a BCR. This ratio must exceed unity (1) to meet the NED objective. Selected plans, whether structural, nonstructural, or a combination of both, should maximize excess benefits over costs; however, unquantifiable features must be addressed subjectively. These criteria are used to develop plans that achieve the objective of NED and provide a base condition for consideration of economically unquantifiable factors, which may affect project proposals.

The USACE planning guidelines require that the alternative that most reasonably maximizes net economic benefits, consistent with protecting the Nation's environment, be identified as the NED Plan. This NED Plan may be selected as the Recommended Plan. However, for a navigation project, if a plan with lesser benefits is preferred by the sponsor due to financial constraints, guidance allows for a categorical exemption to be granted and this lesser plan, referred to as the Locally Preferred Plan or LPP, would be selected as the Recommended Plan.

All structural and nonstructural measures for navigation projects would be evaluated using the appropriate 50-year period of analysis and the applicable interest rate at the time of analysis. Total annual costs should include amounts for operation, maintenance, major replacements, and mitigation, as well as amortization and interest on the investment.

HarborSym, a planning level, general-purpose model developed by the USACE Institute for Water Resources (IWR), will be used to analyze transportation costs of various waterway modifications. HarborSym is a Monte Carlo simulation model of vessel movements at a port for use in economic analysis. While many harbor simulation models focus on landside operations, such as detailed terminal management, HarborSym instead concentrates on specific vessel movements and transit rules on the waterway, fleet and loading changes, as well as incorporating calculations for both within harbor costs and costs associated with the ocean voyage. A more detailed discussion of HarborSym is included in the **Appendix B, Economic Appendix**.

4.3 Methodology to Develop Environmental Criteria

The general environmental criteria for navigation projects are identified in Federal environmental statutes, executive orders (EOs), and planning guidelines. It is national policy that fish and wildlife resource conservation be given equal consideration with other study purposes in the formulation and evaluation of alternative plans. Care must be taken to preserve and protect significant ecological, aesthetic, and cultural values, and to conserve natural resources. These efforts also should provide the means to maintain and restore, as applicable, the desirable qualities of the human and natural environments. Alternative plans formulated to improve navigation should avoid damaging the environment to the extent practicable and contain measures to minimize or mitigate unavoidable environmental damages.

The USACE Environmental Operating Principles (EOPs) ensure our missions include totally integrated sustainable environmental practices. These principles are available at the following webpage: http://www.usace.army.mil/Missions/Environmental/Environmental-Operating-Principles/. The seven re-energized EOP principles (July 2012) and how they are being addressed in study are as follows:

Foster sustainability as a way of life throughout the organization. Planning for the project is considering the sustainability of the channel improvements in regards to maintenance, through the dredged material management planning process. This includes a beneficial use planning process that will seek to address the sustainability of degraded ecological resources and employ beneficial use and placement methods that will enable a project that can be maintained in the long term. The Galveston Bay Beneficial Uses Group (BUG) that has a long-standing history of addressing sustainable, ecological beneficial placement for the HSC is being involved in the planning process.

Proactively consider environmental consequences of all USACE activities and act accordingly. The planning process has examined the impact of the significant ecological resources that would be significantly impacted by the TSP. Oyster reef impacts have been analyzed in detail using the most current available mapping and employing a certified habitat model to determine functional losses and required mitigation. Planning after the TSP will include investigation of portions of the TSP that did not have existing reef mapping but still have potential to contain reef due to sufficient salinity, bathymetry, and undredged conditions. These areas are upstream of Morgans Point and are relatively minor, but have been identified. Other resources have

been assessed, such as tidal wetlands, but will not be impacted. A comprehensive EIS that addresses a full suite of physical, biological, and human environment resources is being prepared for integration with the feasibility report to comply with NEPA.

Create mutually supporting economic and environmentally sustainable solutions. The planning has resulted in identifying the beneficial use of new work dredged material to help build oyster reef mitigation and significantly reduce costs to the project to aid in project economic benefits and justification. Beneficial use planning for long-term maintenance placement will continue with the approved TSP to ensure operation and maintenance of the proposed channel improvements are economically and environmentally sustainable.

Continue to meet our corporate responsibility and accountability under the law for activities undertaken by the USACE, which may impact human and natural environments. The NEPA process (**Chapters 2, 3, and 7 of the Main Report**) and environmental documentation (addressed in **Chapter 6 of the Main Report and Appendix E-Q**) will include a comprehensive array of environmental statutes being addressed for T&E species, EFH, marine species, coastal consistency, water quality, environmental justice and many others. This includes a thorough accounting of acts, statutes and executive orders that will be ruled out, such as prime and unique farmlands and soils, in addition to those directly relevant to the project setting and potential impacts (such as the Marine Mammal Protection Act). The Fish and Wildlife Act coordination has commenced, and informal consultation for Essential Fish Habitat initiated. A Draft Biological Assessment is being prepared. Section 404(b)(1) compliance checklists and Section 401 State Water Quality Certification forms will be initiated and continued through the detailed DMMP planning process after the TSP is approved.

Consider the environment in employing a risk management and systems approach throughout life cycles of projects and programs. Oyster mitigation planning will consider the results of project salinity modeling in the next phase of planning to incorporate the potential project effects to Bay system salinity, and revise mitigation modeling and adjust the mitigation plan accordingly. Significant project change is not expected, but it is being considered and analyzed. Relative sea level change has been analyzed for the project area, and results will be used in the post-TSP phase during dredged material placement planning to ensure placement areas consider and incorporate the risk of forecasted sea level rise over 50 and 100-year periods. The beneficial use planning for dredged material placement will inherently consider risk-based factors for constructability, weather and climate exposure, and stable foundation

conditions. This will include additional geotechnical investigation to address uncertainties and risks for successful placement feature construction. Design during PED will take climatic factors in to account for the design of shore protection.

- **Leverage scientific, economic, and social knowledge to understand the environmental context and effects of USACE actions in a collaborative manner.** The coordination process is involving the scientific input of pertinent resource agencies, and the public and stakeholder involvement has targeted the economic interests of navigation and the affected public.

  Employ an open, transparent process that respects views of individuals and groups interested in USACE activities. The Scoping Meeting solicited and considered all comments received regarding the planning process and concerns. Further public meetings and coordination is planned for the TSP resulting from further analysis conducted during the feasibility-level analysis phase of the study.

4.4 Methodology to Develop Social and Other Criteria

Plans proposed for implementation should have an overall favorable impact on the social well-being of affected interests and have overall public acceptance. Structural and nonstructural alternatives must reflect close coordination with interested Federal and state agencies and the affected public. The effects of these alternatives on the environment must be carefully identified and compared with technical, economic, and social considerations and evaluated in light of public input.

4.5 USACE Campaign Plan

In August 2006, as a result of lessons learned from hurricanes Katrina and Rita, the USACE Chief of Engineers initiated the "Actions for Change" in an effort to transform the USACE planning, design, construction, and operation and maintenance principles and decision-making processes. These initiatives were developed to ensure USACE success in the future by improving the current practices and decision-making process of the USACE organization. The goals and objectives outlined in the refreshed Campaign Plan (FY 15-19, May 2015) are available on the internet at: http://www.usace.army.mil/About/CampaignPlan.aspx. The Goals and Objectives include:

Goal 1: Support National Security – Deliver innovative, resilient, and sustainable solutions to Department of Defense (DoD) and the Nation.

Goal 2: Transform Civil Works – Deliver enduring and essential water resource solutions using effective transformation strategies.

Goal 3: Reduce Disaster Risks – Deliver support that responds to, recovers from, and mitigates disaster impacts to the Nation.

Goal 4: Prepare for Tomorrow – Build resilient People, Teams, Systems, and Processes to sustain a diverse culture of collaboration, innovation, and participation to shape and deliver strategic solutions.

Campaign Plan Goals 1 and 3 do not apply directly to the USACE Planning process; therefore, they are not discussed in detail. Goals 2 and 4, which pertain to water resources planning and directly to the HSC ECIP study, are described in more detail below.

Goal 2: Transform Civil Works

With Goal 2 USACE will focus its talents and energy on comprehensive, sustainable, and integrated solutions to the nation's water resources and related challenges through collaboration with stakeholders. Implementable solutions for the Nation's water resource priorities will be based on transparent, risk-informed decisions developed in close collaboration with stakeholders and partners. USACE will deliver timely, cost effective, and high quality products.

Goal 4: Prepare for Tomorrow

Goal 4 emphasizes that a USACE will employ a workforce with proven capability to consistently, and reliably deliver the highest quality solutions to the Nation's public engineering challenges today. The HSC ECIP PDT can be relied upon to provide innovative concepts for building strong into our future. The Campaign Plan results are discussed in **Section 8.6 of the Main Report**.

4.6 Key Uncertainties (PDT)

The key uncertainties for this study are highlighted below:

Navigation Channel Effectiveness and Efficiency (add net benefits)

- Ship simulations will be conducted during the feasibility-level phase of the study to identify optimal navigation channel configurations for design vessels and mitigate the risks for vessels operations.
- The hydrodynamic and sediment modeling would provide additional information for ship simulation studies, shoaling estimates, and environmental impacts.
- Lack of information about container services in the Gulf of Mexico; utilize other gulf port analysis with additional specific HSC adaptions assisting in the formulation effectives.

National Environmental Policy Act (NEPA) Compliance

- Water and sediment testing is needed for contaminants in the upper project area (Boggy Bayou and the Main Terminal Basin). The channel is situated within a highly industrialized area for which very little data is available. This part of the project area is in close proximity, but upstream, to two superfund sites.

Alternative Plan Formulation and Design

- Geotechnical exploration needed to fill data gaps to complement existing data to increase level of confidence in engineering analysis and preliminary design for screened alternatives.
- Results of water/sediment testing can affect the type and location of a PA and affect whether the material can be used beneficially; the District's extensive historical testing data on maintenance material will be used to extrapolate future risk.
- Pipeline information will be retrieved from Sponsors pipeline database. Conservative assumptions will be made on location and density of pipelines.
-

<u>Placement Area/Beneficial Use Considerations</u>

- Long-term sediment chemistry data suggests that there are no chemicals of concern (COCs) at levels requiring special handling; however, there is a possibility there may be areas in need of remediation or special handling. Upland PA design allows for some levels of

contaminants; however, decant water monitoring methods would be adapted to address any concerns.

- BU PA s may not be used if COCs above ecologic thresholds are found.
- Site-specific information regarding new PAs, (upland confined or BU) has not been evaluated.
- Special remediation or mitigation has not been identified for new PAs.
- Dredging and placement costs assume that the PA will be within 5 miles to 7.5 miles from the channel.
- PA locations are currently unknown. Assumptions have made based on historical methods for PA construction for the HSC and may not reflect unique problems due to material strength or foundation stability.
- Existing hydrographic survey data was used to determine material quantities. Typically, channel surveys do not extend beyond the existing channel toes. National Oceanic and Atmospheric Administration (NOAA) data was used to supplement hydrographic survey data. Because the data is not current, material quantities may be overestimated.
- Ship simulation is required and will be conducted during the feasibility-level analysis phase of the study and PED to affirm and refine the channel design assumptions.
- Oyster Mitigation costs have assumed that the elevations needed for oyster productivity can be achieved using dredged materials with a thin veneer of cultch. While contrary to the previous project mitigation, the possibility of functionality has been demonstrated on other projects and the overall required relief elevations have been reduced on other projects in Galveston Bay with success.

Cost Contingencies for the Draft Report - Risk contingency markups were developed by the PDT using the USACE Abbreviated Risk Analysis (Excel) for all construction features. The PDT determined concerns and risk levels to arrive at contingency markups for each measure in the alternatives (**Table 8**).

Table 8 –Abbreviated Risk Analysis Results for Estimated Cost Contingencies

Cost Account	Features of Work	Percent Contingency (%)
01 Lands and Damages	Real Estate	25%
02 Relocations	Pipeline Relocations	34%
06 Fish and Wildlife (Mitigation)	Oyster Reefs	29%
12 Navigation, Ports and Harbors	Mob/Demob	20%
12 Navigation, Ports and Harbors	Bay Pipeline Dredging Contracts	23%
12 Navigation, Ports and Harbors	Bayou Pipeline Dredging Contracts	31%
12 Navigation, Ports and Harbors	Bayou PAs	57%
12 Navigation, Ports and Harbors	Bay PAs	52%
12 Navigation, Ports and Harbors	Bayou BU Sites	50%
12 Navigation, Ports and Harbors	Bay BU Sites	50%
12 Navigation, Ports and Harbors	Bank Stabilization (Sheet-pile Walls)	28%
12 Navigation, Ports and Harbors	Shoaling Attenuation Feature	44%
12 Navigation, Ports and Harbors	Mooring Facilities	23%
30 Planning, Engineering and Design	Planning, Engineering, and Design	2%
31 Construction Management	Construction Management	2%

As the Study progresses, the team will continue to evaluate dredging and placement methods to arrive at the optimum design. Dredging methods and placement area features may differ for the Open Bay sections as opposed to the Bayou sections of the project. Risk Contingency markups will be re-evaluated to match the specific methods and features in the final design. However, at the screening phase of the project, an average contingency of 27 percent was used for dredging in both Open Bay and Bayou areas (Average of 23 percent for dredging contracts in the Bay and 31 percent for dredging contracts in the Bayou).

The Dredged Material Management Plan (DMMP) has not yet been developed. Placement options and costs vary widely between Upland PA and Beneficial Use sites, and it is not feasible to develop specific placement plans for all measures during this phase of the study. Specific placement area locations and construction details will be designed for the Preferred Plan. For the screening process, placement costs were estimated based on the historical average cost of all placement area related work in the HSC project area since the last deepening and widening of the channel. To account for the possible cost variation, a risk contingency of 52 percent was applied to the historical cost. Likewise, a 32 percent contingency markup was applied to the structural costs included in the alternatives evaluated. Structural costs were estimated for bank stabilization, mooring facilities, and jetty construction.

5.0 INITIAL ARRAY OF ALTERNATIVE PLANS

Individual measures were previously developed and screened to satisfy the four planning objectives. Alternative plans were then formulated through combinations of remaining management measures to target the needs of specific design vessels and study segments.

In this phase, comprehensive alternative plans were formulated for the HSC system and specific needs for different design vessels used within the system. The alternatives are meant to be standalone plans that can be directly compared to one another. Some alternatives were intended to provide all-inclusive plans and others were drafted to focus more closely on specific problems. Based on the measures previously identified, eight structural alternatives and a no-action alternative were included in the initial array. A range of widths and depths for the structural alternatives were evaluated using HarborSym.

5.1 Design Vessels for the Study Segments

Eight design vessels were identified within the six study segments. The alternatives target improvements for those different design vessels throughout the HSC system. **Table 9** below provides the design vessels and study segments they are associated with.

Table 9 – Design Vessels per Study Segment

Segment	Type	Class	LOA	Beam	Draft
1,2,3	Containership	Gen II +	1,100	158	49
1,2,3	Containership	Gen II +	1,200	140	49
1,2	Tanker	Suezmax	935	164	54
3,4	Tanker	Aframax	850	138	54
4	Bulk Carrier	Panamax	810	106	44
5	Tanker	Panamax size	610	106	44
5	Vehicle Carrier	Ro-Ro	640	106	34
6	Bulk Carrier	70k-110k Bulker	750	106	45

5.2 Initial Alternatives

Based on the measures previously identified and screened, eight structural alternatives were formulated through combinations of remaining management measures and included in the Initial Array. Additionally, USACE is required to consider the option of No Action or Future Without-Project (FWOP) Condition as one of the alternatives in order to comply with Engineer Regulation (ER) 1105-2-100 and the requirements of NEPA. The FWOP Condition forms the basis against which all other alternative plans are measured.

5.2.1 Initial Array of Alternatives

The HSC is a massive and highly complex navigation system. The 52 mile-long channel is the destination for over 10 percent of all calls made by oceangoing vessels of 10,000 deadweight tons (DWT) or greater at U.S. ports (26 percent more calls than the second busiest port). It handles the most foreign tonnage of any port in the U.S. (21 percent more than the second largest port), and it is the sixth largest container port in the U.S. by twenty-foot equivalent units (TEUs). The density of vessel calls, diversity of traffic, and limited channel capacity lead to high levels of congestion throughout the system.

Alternative plans were developed to address congestion, vessel delays, and inefficient vessel loading issues throughout the channel. Alternatives targeted different segments of the system. However, the ultimate goal of the study is to increase navigation efficiencies throughout the entire HSC system. To that end, the alternatives became additive in nature in that a combination of alternatives best meets the study planning objectives for the HSC system. A combination of plans maximizes the net Nation Economic Development (NED) benefits.

Initial Assumptions used in the Development of Alternatives

Channel Width in Segment 1 up to Morgans Point – During the development of the alternatives, the PDT asked the Houston Pilots to use their best professional judgment (without verification through ship simulation) to identify an absolute minimum additional channel width below Morgans Point that they considered necessary for two-way traffic of wide-body vessels (120-feet beam and over). The minimum width below Morgans Point being considered in the alternatives is 650 feet. Currently the HSC has authorized width of 530 feet throughout the Bay in Segment 1.

Channel Width Range below Morgans Point for Public and Agency Coordination – Because ship simulation does not occur until after the concurrent review period for the DIFR-EIS, the PDT determined the need to use channel width range for the lower portion of Segment 1 up to Morgans Point. In this way, the full range of potential impacts would be covered during the Concurrent Review Process (Policy, Public Review, Agency Technical Review (ATR), and Independent External Peer Review (IEPR)) and the ultimate channel width would be dialed down to the dimensions determined to be necessary for safe, efficient navigation of the design vessels through ship simulations.

Possibility of Additional Features – A concern during the formulation of alternatives was the need to verify all impacts were sufficiently coordinated during the Concurrent Review Process. The PDT determined that some measures such as Turning Basins, or minimal widening or bend easing to alleviate pinch points that might not necessarily be economically justified but are necessary for

safety would have to be verified through ship simulation. To be most transparent and timely, some measures identified as problem areas by the Houston Pilots might be carried forward for further analysis by ship simulation. However, if ship simulation determined any additional features as not necessary for safe, efficient transit then those features would be eliminated from the TSP, unless the Non-Federal Sponsor elected to pursue an LPP.

Summary of Alternatives Considered - The following paragraph provides a brief summary of alternative plans evaluated by this study followed by a more expansive narrative. The study first evaluated the No Action Alternative. Then the study evaluated a minimum system-wide plan (Segments 1-6) in that is attempts to accommodate the study's design vessels, but does not address the existing or future congestion in the channel (Alternative 1). The study then evaluated alternatives (Alternatives 2 and 3) that specifically address Galveston Bay (Segments 1-3); Alternative 2 focused on the containership design vessel while maintaining two-way traffic in Galveston Bay. Alternative 3 similarly focused on maintaining two way but specifically for measures benefitting the Suezmax tanker calling on BSC. Alternative 4 consisted of improvements in Segment 4 to accommodate the transit of the Aframax taker while Alternative 5 focused on measures to improve bulker, tanker and vehicle carrier traffic in Segments 4-6. Alternatives 6 and 7 evaluated the system-wide impact of adding a mooring facility; Alternative 6 specifically evaluated the benefits of a mooring facility located in in the BSC (Segment 2) and Alternative 7 looked at a mooring facility located in the upper bayou (Segment 1) where there are significantly different impacts, costs, and benefits than in the BSC. Lastly, Alternative 8 was a compilation of planning objectives across the entire HSC system. It builds on Alternative 1 with the most beneficial measures from Alternatives 2 through 7. It is the plan, which most completely and efficiently meets the planning objectives of the study and maximizes the NED benefits.

Future Without-Project Condition (No Action Alternative)

The No Action Alternative retains the existing depths and widths of the HSC and its tributary channels (**Table 1-1, Main Report**). The FWOP condition is described in more detail in **Section 3 of the Main report.** The entire HSC system will face increased inefficiencies as total vessel traffic approaches the estimated capacity of the channel, channel constraints limit optimal fleet usage and loading, and limited meeting areas, and lack of mooring facilities creates high levels of channel congestion. In Segment 1, vessels will continue to face various meeting restrictions and nighttime transit rules due to the constraints of the current channel design. Vessels, especially large tankers and containerships, will face delays ranging from one hour to over 12 hours. Without the channel improvements, Segments 2 and 3 will face increased transit inefficiencies as the containership fleet shifts to Post-Panamax Generation II vessels. Segments 4, 5, and 6 all face congestion issues as total traffic is expected to grow over the study period. Lastly, an established safety issue in the vicinity of the HSC/BSC intersection would not be addressed beyond an interim

corrective action. A final corrective action was recommended in the HSC PDR, referenced in the Section 1.9 of the **Main Report under Prior Studies, Reports, and Existing Water Projects**. This alternative would result in no environmental impacts.

ALTERNATIVE 1 – Minimum System Wide Plan (No Bay Widening)

This alternative focused on modifications in the lower portion of Segment 1 (south of BCC) and Segments 4, 5, and 6. It is the minimum system-wide plan in that it attempts to accommodate the study's design vessels, but does not address the existing or future congestion in the channel.

In Segment 1, four bend easings would be constructed to allow the design vessels to transit into the Bay Reach beyond the four undersized bends. Modifications to Segment 2 and 3 (flare modification/turning basin, widening) would allow maximum vessels sizes in the BSC and BCC beyond the current 1,000- by 138-foot maximum vessel size restriction and ease congestion when large vessels are at berth. This would provide for larger Containerships (1100x158 and 1200x140) to enter the BSC and BCC channels to call on the associated terminals. Additionally, widening the BSC and BCC channels would allow smaller vessels to continue transiting the channel once larger vessels are at berth instead of halting traffic in the channel. The flare modification at the BSC could also provide for a final corrective action to alleviate residual safety issues remaining after construction of the interim corrective action recommended by the HSC PDR. A shoaling attenuation structure would reduce the dredging frequency around the flare; high shoaling within the BSC flare area results in increased maintenance dredging, strains placement area capacity, and increases maintenance costs. A multipurpose Bay mooring would address the lack of a dedicated waiting area that results in increased transit time and cost inefficiencies because vessels (Tankers and Chemical Tankers at BSC) are required to go to the anchorages located at Bolivar Roads and Sea Buoy. Lastly, deepening Segments 4-6 would allow for an increased efficiency in loading practices for all design vessels except the vehicle carrier that drafts 34 feet when calling on the upper channel. This could also relieve channel congestion due resulting from a drop in total calls due to increase in draft. Alternative 1 is illustrated in **Figure 2**, and includes:

- Four bend easings on the main HSC channel in the Bay reach with associated relocation of barge lanes (**Segment 1**);
- New turning basin/flare expansion on BSC near the entrance of the land cut (**Segment 2**);
- Widen BSC from existing 300-400 feet to 455 feet (**Segment 2**);
- Shoaling attenuation structure around BSC Flare (**Segment 2**);
- Bay multipurpose mooring at BSC (**Segment 2**);
- Combination flare and turning basin on BCC near the entrance (**Segment 3**);
- Widen BCC from existing 300 feet to 455 feet (**Segment 3**); and

- Channel deepening from the existing channel depth of 41.5 feet to a maximum depth of 46.5 feet as much as possible upstream of Boggy Bayou (**Segment 4**); and
- Channel deepening from the existing channel depth of 37.5 feet to a maximum depth of 41.5 feet as much as possible upstream of Boggy Bayou (**Segments 5, and 6**)

Specific pilot rules and restrictions from the Houston Pilots Working Rules (Updated May 25, 2016) that were targeted are as follows:

- Maximum Vessel Size is 1000x138 from Bolivar Roads to Barbour Cut (all vessel types);
- Maximum 41.5-feet draft above Boggy Bayou to Sims Bayou; and
- Maximum 37.5-feet draft from Sims Bayou to Main Turning Basin

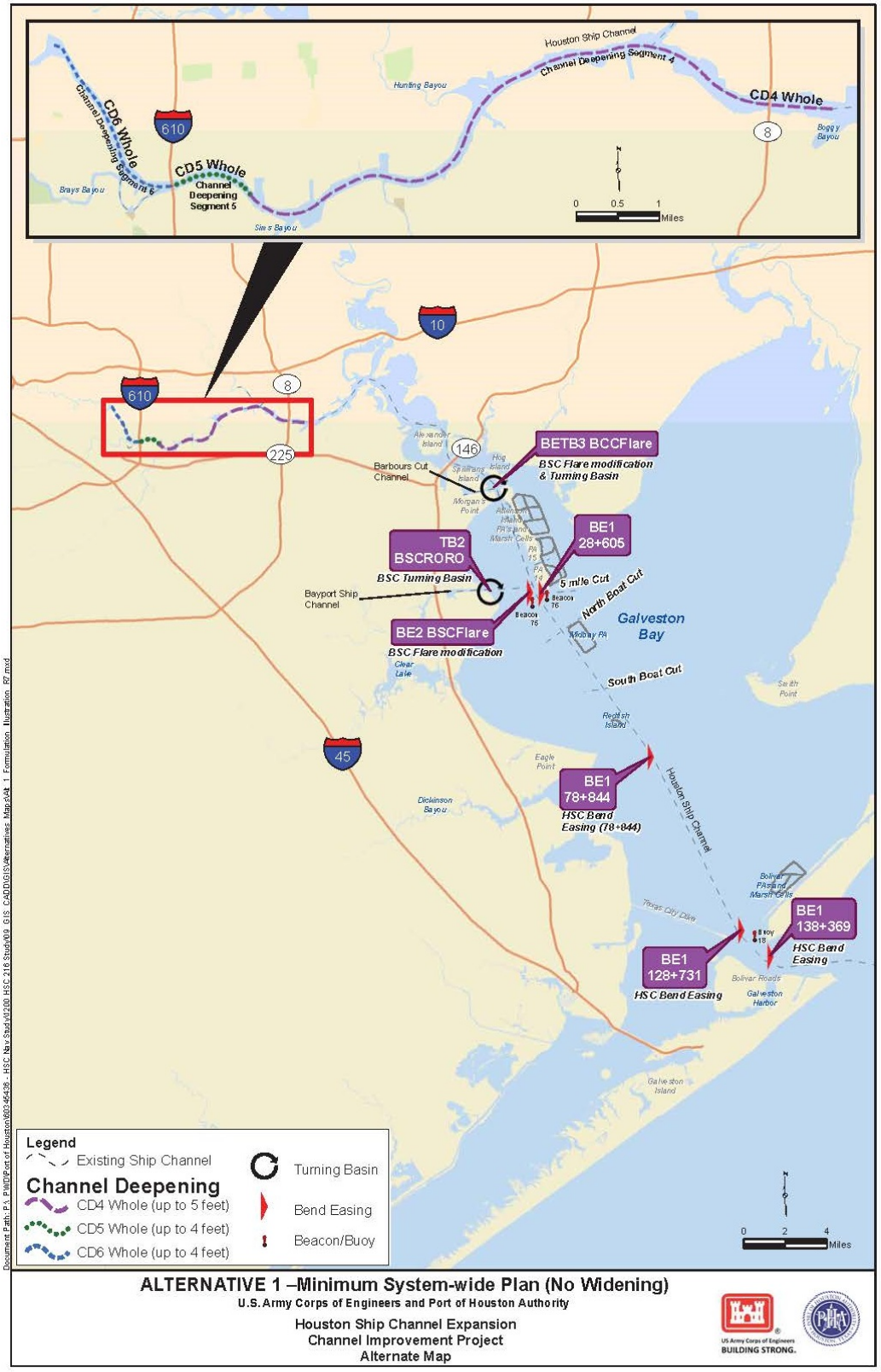

Figure 2 – Alternative 1 – Minimum System-Wide Plan (No <u>Bay</u> Widening)

ALTERNATIVE 2 – Bay Plan

The intention of Alternative 2 is to allow transit of the containership design vessel while alleviating one-way traffic in Galveston Bay. This alternative does not include any improvements to Segments 4, 5, and 6. This alternative focused on modifications in Segment 1 to get the design vessels into the Bay Reach beyond the four undersized bends and channel widening increments between Bolivar Roads and BCC to alleviate one-way traffic in and out of the HSC system and lift daylight restrictions. Modifications in Segments 1, 2, and 3 would provide for Generation II+ design vessel Containerships (1100x158 and 1200x140) to enter the BSC and BCC channels and pass the berths with other ships moored to call on the associated terminals. Flare modifications could result in a final corrective action to alleviate residual safety issues remaining after construction of the interim corrective action recommended by the HSC PDR. Alternative 2, illustrated in **Figure 3**, includes:

- Four bend easings on the main HSC channel with associated relocation of barge lanes (**Segment 1**);
- Widen (in whole or in part) the HSC main channel for meeting between Bolivar Roads and BCC between the existing 530 foot width to between 650 to 900 feet (**Segment 1**);
- New turning basin with flare expansion on BSC (**Segment 2**);
- Widen BSC from existing 300 feet to 455 feet (**Segment 2**);
- Shoaling attenuation structure near the BSC Flare to reduce heavy shoaling (**Segment 2**);
- Combination flare and turning basin on BCC (**Segment 3**); and
- Widen BCC from existing 300 feet to 455 feet (**Segment 3**)

Specific pilot rules and restrictions from the Houston Pilots Working Rules (Updated May 25, 2016) that were targeted are as follows:

- No vessel meeting in BSC;
- Containerships with dimensions equal to or greater than 1160 x 150 x 45 feet will transit Bayport Ship Channel and make berth at Dock 1;
- Maximum vessel size permitted to transit to Barbours Cut Number 1 is 1158 x 142 feet. When this vessel is at berth, no vessel transits the channel; and
- The maximum vessel size of 1158 LOA x 142 feet beam and above docked at Barbours Cut Number 1 will restrict all movement of vessels with beams greater than 106 feet

Measures were evaluated and screened by the study team. Consistent with new SMART Planning concepts this effort included was based on existing information. Results of modeling efforts will not be available until the feasibility-level analysis phase of the study. In the evaluation of the

Initial Array, Eight alternative plans were developed to address issues such as congestion, vessel delays, and inefficient vessel loading issues throughout the channel. Alternatives targeted different segments of the HSC system. However, the ultimate goal of the study is the increase navigation efficiencies throughout the entire HSC system. To that end, the alternatives became additive in nature in that a combination of alternatives best meets the study planning objectives for the HSC system.

The study team evaluated the need of selectively widening the existing 530-foot wide HSC to facilitate two-way traffic meeting by large vessels as well as the easing of the channel bends and turns associated with transit restrictions, slowdowns, and additional tug assist. The study team established the range of widths for widening the channel using recommendations from the Engineer Manual (EM) 1110-2-1613, *Hydraulic Design of Deep-Draft Navigation Projects,* and from information based on discussions with the Houston Pilots Association (HPA). The EM recommended a 902-foot (rounded down to 900 feet) channel to allow two Suezmax design vessels to meet in the Bay. A 900-foot channel was considered very costly in regards to impacts to the environment and quantities of material. Using a standard pilot rule of thumb of "2.5 times the combined beam width" would allow for a smaller channel widening of 820 feet. Discussions with the HPA indicated that a bare minimum of an additional 100 feet of channel width, for a total 650-foot width, would be necessary for two-way traffic of wide-body vessel meeting opportunities in the Bay Reach below Morgans Point and/or to revise the current vessel transit conditions. Therefore, an assumption was made that a channel at some dimension between 650 and 820-feet would allow for safe, efficient meeting opportunities. This will be confirmed during ship simulations that occur after concurrent review of the DIFR-EIS; therefore, the widening component will be treated as a range until the dimension for safe, efficient transit is verified. In this way, the maximum possible environmental impacts can be coordinated and the actual impacts dialed down once the true dimension is established.

The analysis additionally considered reduced risk of accidents along the lower reaches of the HSC and construction of a multipurpose mooring area in or near Galveston Bay to reduce congestion from multi-anchorage transits to and from Bolivar Roads or offshore (Sea Buoy) while a vessel is waiting between facilities. Widening in the side channels (BSC and BCC) was considered in addition to flare modifications and turning basins. Additional bend easing and widening was investigated and deepening of the upper channel segments beyond Boggy Bayou, the limit of the 46.5-foot channel.

The measures within each alternatives were assessed for environmental impacts (bay bottom and oysters) to assess mitigation costs, pipeline relocation costs, estimated quantities of new work dredging, shoaling, estimated placement costs using historical information from the HSC system, and maintenance dredging costs to estimated costs for Project First Costs and Operation and

Maintenance. This was in turn used to assess the economic benefits for each of the alternative plans and look at combination of plans to maximize the net benefits.

However, as addressed previously, there are uncertainties without the use of ship simulations at this phase. Therefore, in the alternatives there were components the study team determined needed to be carried forward regardless for purposes of safety in the HSC system. Once these components are further evaluated and simulated, the results of the TSP will be refined. In regards to those components carried forward for further evaluation, if economic justification does not support the need for those components they will be eliminated from the TSP

Figure 3 – Alternative 2 – Bay Plan

ALTERNATIVE 3 – Suezmax Plan

This alternative, similar to Alternative 2, focused on modifications in Segment 1 to get the design vessels into the Bay Reach beyond the four undersized bends and channel widening increments between Bolivar Roads and BCC to alleviate one-way traffic in and out of the HSC system. Additional bend easings and selective widening would provide opportunities between Morgans Point and Boggy Bayou for design vessel meeting in the Bayou portion of the Bay Reach and would alleviate one-way traffic restrictions for widebody vessels, particularly the Suezmax vessels (935x164). Widening the BSC would allow Generation II+ design vessel Containerships (1100x158 and 1200x140) and the Suezmax Tanker to enter the BSC and pass the berths with other ships moored to call on the terminals. Lastly, a shoaling attenuation structure would reduce the dredging frequency around the flare; high shoaling within the BSC flare area results in increased maintenance dredging, strains placement area capacity, and increases maintenance costs. Alternative 3, illustrated in **Figure 4**, includes:

- Four bend easings on the main HSC channel with associated relocation of barge lanes (**Segment 1**);
- Widen (in whole or in part) the HSC main channel for meeting between Bolivar Roads and BCC between the existing 530 foot width to between 650 to 900 feet (**Segment 1**);
- Two bend easings in the Bayou Portion of the HSC main channel above Morgans Point. The first easing near Fred Hartman Bend and the second easing near Alexander Island Turn (**Segment 1**);
- Minor widening of the channel in the Bayou portion of the HSC main channel in the Hog Island Stretch and from the San Jacinto Monument to Boggy Bayou from the existing 400 foot width to 530 feet for approximately 1.3 miles (**Segment 1**);
- Widen BSC from existing 300-400 feet to 455 feet (**Segment 2**);and
- A shoaling attenuation structure located near the BSC Flare to reduce heavy shoaling (**Segment 2**)

Specific pilot rules and restrictions from the Houston Pilots Working Rules (Updated May 25, 2016) that were targeted are as follows:

- No vessel meeting in BSC;
- Two widebodies meeting in the HSC between Buoy 18 and Beacons 75/76 restricted to 310 combined beam and 85’ combined draft; and
- Any widebody tanker proceeding with cargo will be daylight restricted above Buoy 18

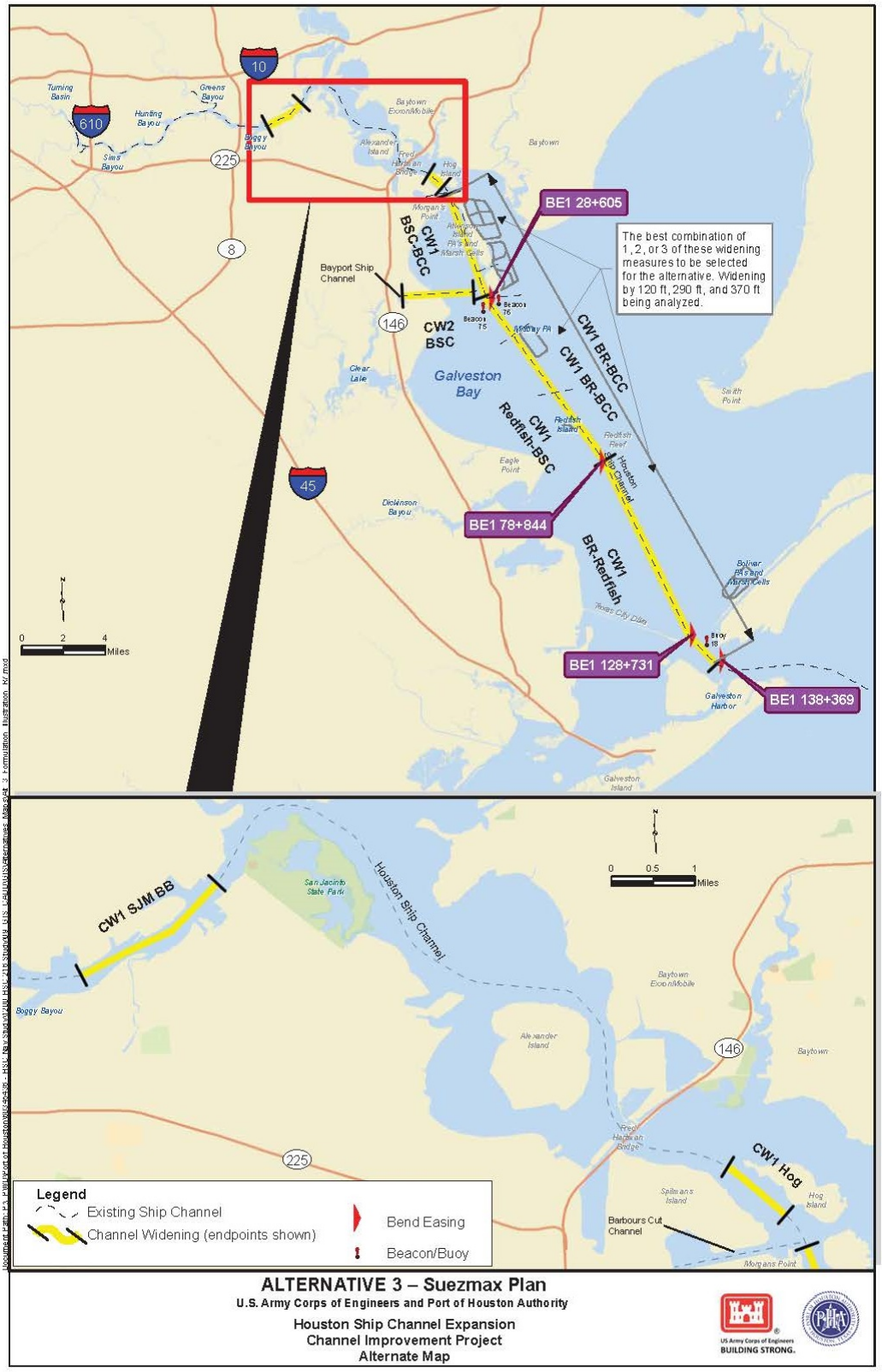

Figure 4 – Alternative 3 – Suezmax Plan

ALTERNATIVE 4 – Aframax Plan

This alternative focused on modifications to allow vessels larger than the pilot rules maximum vessel size (750x116) and up to the design vessel for this segment to allow from efficient use of the channel by the tanker fleet. The modifications in Segment 4 are to allow for the Aframax design vessel (850x138). Deepening the channel in Segment 4 would allow for increased loading efficiencies and widening would allow vessel meeting for beams wider than the current guideline. A new turning basin and the expansion of an existing turning basin would provide future Aframax vessels going further up in this segment a turning basin of sufficient size to turn. Additionally, this would provide for more turning opportunities for smaller vessels such as tankers and bulk carriers, alleviating the need to transit all the way to the Main Turning Basin. Alternative 4, illustrated in **Figure 5**, includes:

- Minor widening of the channel in the Bayou portion of the HSC main channel in the Hog Island Stretch and from the San Jacinto Monument to Boggy Bayou from the existing 400-foot width to 530 feet approximately 1.3 miles to remove a neck-down in the channel (**Segment 1**);
- Deepen the HSC main channel from Boggy Bayou to Sims Bayou beyond 41.5 feet as much as possible up to 46.5 feet deep (**Segment 4**);
- Widen the HSC main channel from Boggy Bayou to Greens Bayou from the existing 400-foot width up to 530 feet (**Segment 4**);
- New turning basin in the Boggy Bayou to Greens Bayou Segment near Pasadena docks (**Segment 4**); and
- Expand Hunting Bayou Turning Basin (**Segment 4**)

Specific pilot rules and restrictions from the Houston Pilots Working Rules (Updated May 25, 2016) that were targeted are as follows:

- Maximum draft above Boggy Bayou to Sims Bayou is 41.5 feet;
- Maximum vessel size from Boggy to Simms Bayou is 750 LOA x 116-feet beam and draft restricted to 41.5 feet;
- Vessels with > 105-feet beam shall not meet any ship vessel of any size above Boggy Bayou;
- All vessels > 750-feet LOA and a draft > 39 feet are daylight restricted above the Beltway 8 Bridge.

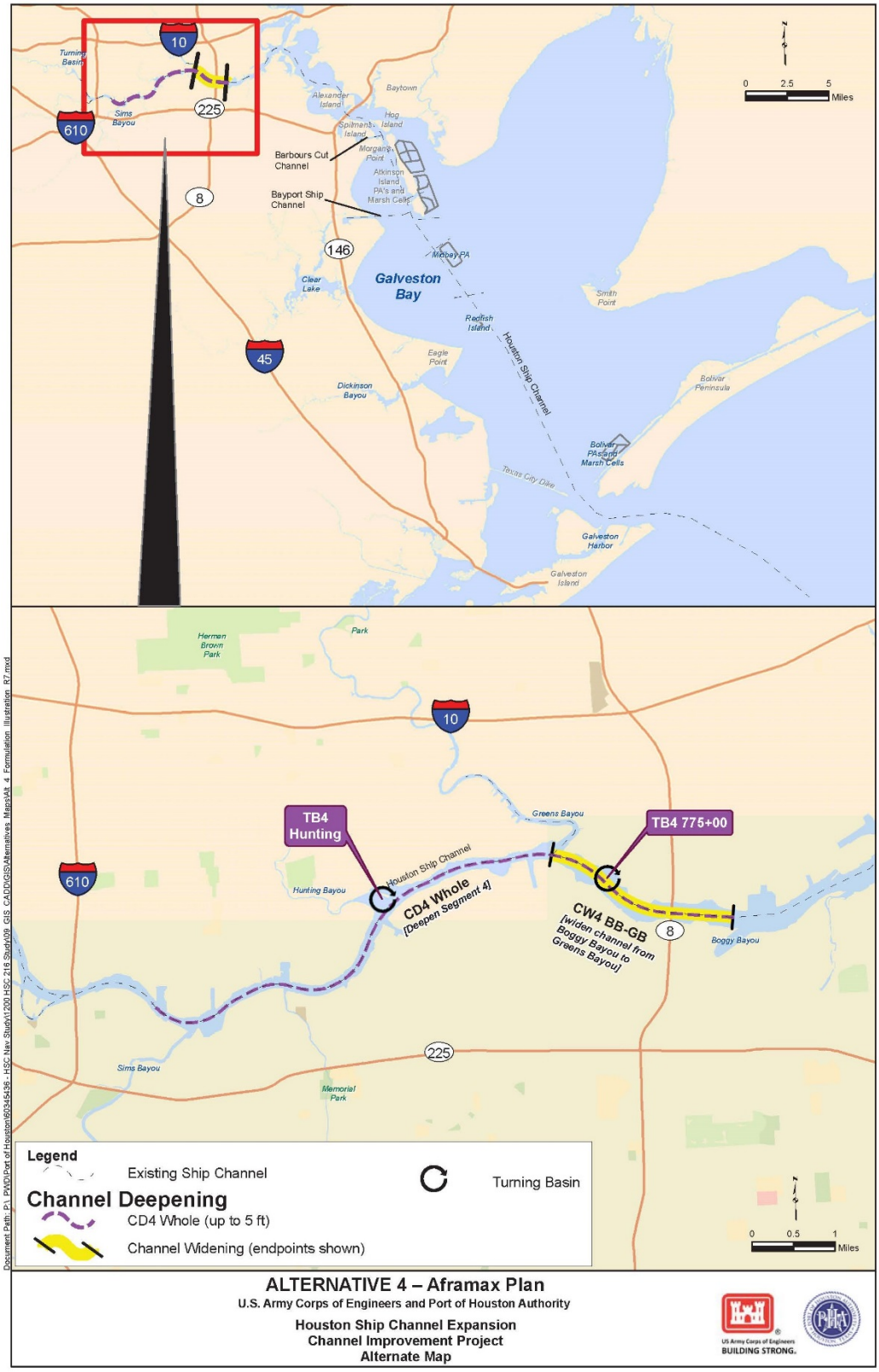

Figure 5 - Alternative 4 – Aframax Plan

ALTERNATIVE 5 – Bulkers, Tankers, and Vehicle Carriers Plan

This alternative focused on modifications to enable tanker vessels larger than the current guideline and up to the design vessel for this segment to allow from efficient use of the channel by the tanker fleet. Deepening the channel in Segments 4, 5, and 6, would allow for increased loading efficiencies and widening would allow vessel meeting for beams wider than the 105-feet in Segment 4. Expansion of existing turning basins would provide for more turning opportunities for smaller vessels such as tankers and bulk carriers, alleviating the need to transit all the way to the Main Turning Basin. Alternative 5, illustrated in **Figure 6**, includes:

- Deepen the HSC main channel from Boggy Bayou to Sims Bayou from the existing 41.5-foot depth up to 46.5 feet (**Segment 4**);
- Expand Hunting Bayou Turning Basin (**Segment 4**)
- Deepen the HSC main channel from Sims Bayou to I-610 Bridge from the existing 37.5-foot depth up to 41.5 feet (**Segment 5**);
- Expand Brady Island Turning Basin (**Segment 6**); and
- Deepen the HSC main channel from I-610 Bridge to Main Turning Basin from the existing 37.5-foot depth up to 41.5 feet (**Segment 6**);

Specific pilot rules and restrictions from the Houston Pilots Working Rules (Updated May 25, 2016) that were targeted are as follows:

- Maximum draft from Sims Bayou to Turning Basin is 37.5 feet.

Figure 6– Alternative 5 – Bulkers, Tankers, and Vehicle Carriers Plan

ALTERNATIVE 6 – Bay Mooring Plan

This alternative focused on reducing congestion in the channel caused by multiple inter-channel vessel movements between facilities out to the anchorage while waiting to transit between docks. These transits result in increased transportation costs. Alternative 6, illustrated in **Figure 7**, includes:

- The addition of a new multipurpose mooring in the BSC to be located just outside the land cut (Segment 2).

There are no specific pilot rules targeted for this alternative. A lack of sufficient layberthing space (e.g. sitting at someone's dock) leads to the need for anchorage transits to Bolivar Roads or offshore (Sea Buoy) until a berth comes available.

ALTERNATIVE 7 – Bayou Mooring Plan

This alternative focused on reducing congestion in the channel caused by multiple inter-channel vessel movements between facilities out to the anchorage while waiting to transit between docks. These transits result in additional transportation costs. Alternative 7, illustrated in **Figure 8,** includes:

- Two new multipurpose moorings in the HSC upper channel; one mooring would be located near Alexander Island and the other mooring would be located near the San Jacinto Monument (Segment 1).

There are no specific pilot rules targeted for this alternative. This alternative is to address a lack of sufficient layberthing space (e.g. sitting at someone's dock) for vessels when a berth is not available. This lack of layberthing for vessels leads to the need for anchorage transits to Bolivar Roads or offshore (Sea Buoy) until a berth comes available, contributing to increased transportation costs and congestion in the channel.

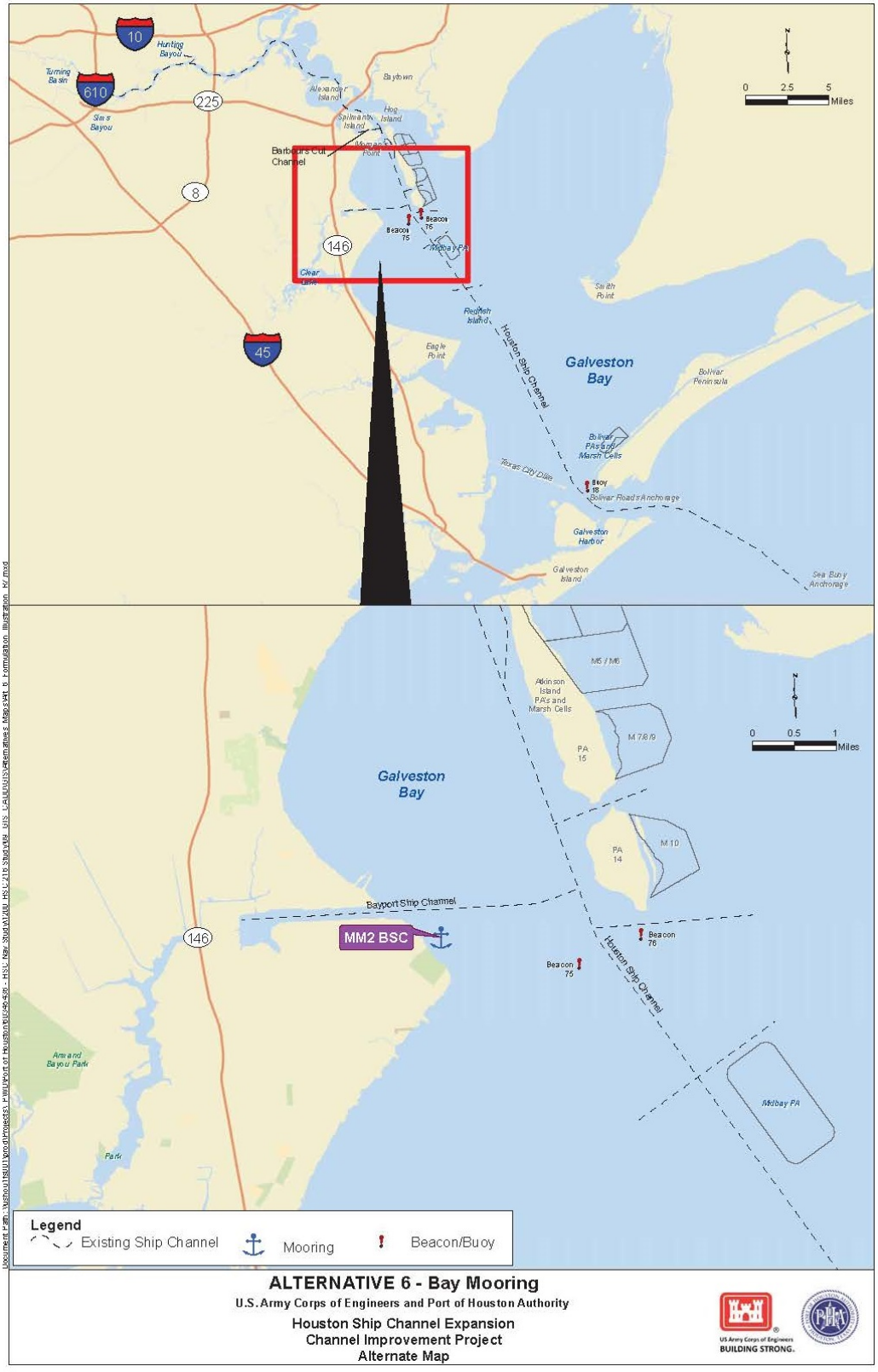

Figure 7 – Alternative 6 – Bay Mooring

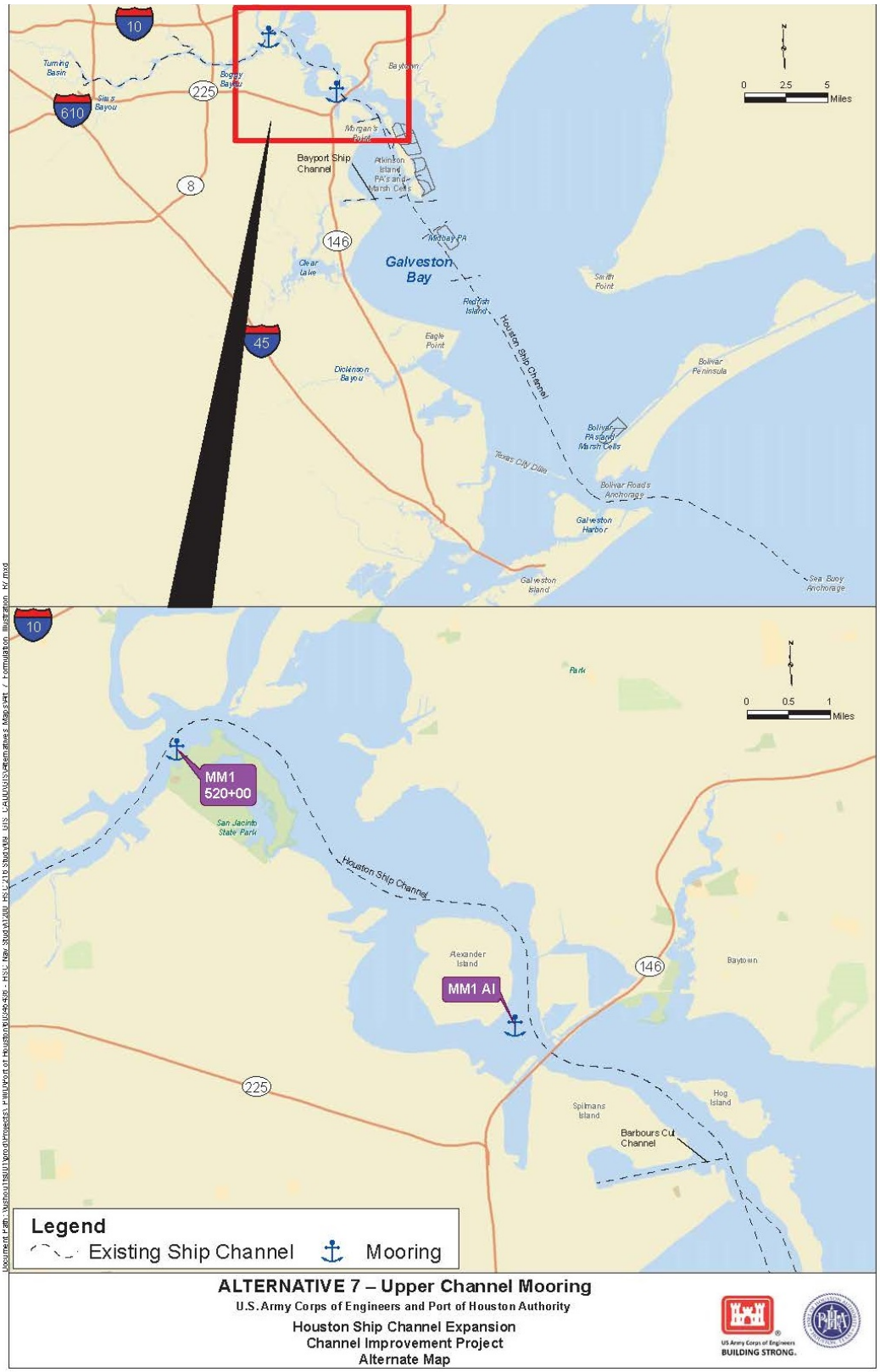

Figure 8 – Alternative 7 – Upper Channel Mooring

ALTERNATIVE 8 – The Comprehensive Plan

This alternative focused on modifications in Segment 1 to allow the design vessels into the Bay Reach beyond the four undersized bends. Channel widening increments between Bolivar Roads and BCC would alleviate one-way traffic in and out of the HSC system for Gen II + Container vessel transits and meeting of two-way wide body vessels such as the Suezmax (935x164), reduce combined beam and draft restrictions, and lift daylight restrictions. Bend easings and selective widening would provide opportunities between Morgans Point and Boggy Bayou for design vessel meeting in the Bayou portion of the Bay Reach and would alleviate one-way traffic restrictions for widebody vessels. Multi-purpose moorings would reduce congestion in the channel caused by multiple inter-channel vessel movements between facilities out to the anchorage while waiting to transit between docks. These transits result in additional transportation costs and time. Modifications in Segments 1, 2, and 3 would provide for Generation II+ design vessel Containerships (1100x158 and 1200x140) and Suezmax to enter the BSC and BCC channels and pass moored vessels to call on the associated terminals. Note that residual safety issues remaining after construction of the interim corrective action recommended by the HSC PDR need a final corrective action. Widening the BSC and BCC channels would allow maximum vessel sizes beyond the current 1,000- by 138-foot maximum vessel size restriction and ease congestion when large vessels are at berth.

A shoaling attenuation structure would reduce the dredging frequency around the flare; high shoaling within the BSC flare area results in increased maintenance dredging, strains placement area capacity, and increases maintenance costs. A mooring would help reduce congestion in the channel caused by multiple inter-channel vessel movements between facilities out to the anchorage while waiting to transit between docks. These transits result in increased transportation costs. Deepening the channel in Segments 4, 5, and 6, would allow for increased loading efficiencies and widening in Segment 4 would allow vessel meeting for beams wider than the current pilot's guideline of 105 feet. New turning basins and the expansion of existing turning basins would reduce the distance future vessels are required to transit before reaching a turning basin of sufficient size to turn and provide more turning opportunities for smaller vessels such as tankers and bulk carriers, alleviating the need to transit all the way to the Main Turning Basin. Alternative 8, illustrated in **Figure 9**, includes:

- Four bend easings on the main HSC channel with associated relocation of barge lanes (**Segment 1**);
- Widening (in whole or in part) the HSC main channel for meeting between Bolivar Roads and BCC from the existing 530-foot width to between 650 to 900 feet (**Segment 1**);

- Two bend easings in the Bayou Portion of the HSC main channel above Morgans Point. The first easing near Fred Hartman Bend and the second easing near Alexander Island Turn (**Segment 1**);
- Minor widening of the channel in the Bayou portion of the HSC main channel in the Hog Island Stretch and from the San Jacinto Monument to Boggy Bayou from the existing 400-foot width to 530 feet approximately 1.3 miles (Segment 1);
- Two new multipurpose moorings in the HSC upper channel with one mooring located near Alexander Island and the other mooring located near the San Jacinto Monument (**Segment 1**);.
- New turning basin with flare expansion on BSC (**Segment 2**);
- Widen BSC from existing 300 feet to 455 feet (**Segment 2**);
- Shoaling attenuation structure near the BSC Flare (**Segment 2**);
- A new multipurpose mooring in the BSC just outside the land cut (**Segment 2**)
- Combination flare and turning basin on BCC (**Segment 3**);
- Widen BCC from existing 300 feet to 455 feet (**Segment 3**);
- Deepen the HSC main channel from Boggy Bayou to Sims Bayou from the existing 41.5-foot depth up to 46.5 feet (**Segment 4**);
- Widen the HSC main channel from Boggy Bayou to Greens Bayou from the existing 400-foot wide channel up to 530 feet (**Segment 4**);
- New turning basin in the Boggy Bayou to Greens Bayou Segment near Pasadena docks (**Segment 4**);
- Expand Hunting Bayou Turning Basin (**Segment 4)**
- Deepen the HSC main channel from Sims Bayou to I-610 Bridge from the existing 37.5-foot depth up to 41.5 feet (**Segment 5**);
- Expand Brady Island Turning Basin (**Segment 6**); and
- Deepen the HSC main channel from I-610 Bridge to Main Turning Basin from the existing 37.5-foot depth up to 41.5 feet deep (**Segment 6**)

Specific pilot rules and restrictions from the Houston Pilots Working Rules (Updated May 25, 2016) that were targeted are as follows:

- Maximum vessel size 1000x138 Bolivar Road to Barbours Cut;
- Two widebodies meeting in the HSC between Buoy 18 and Beacons 75/76 restricted to 310 combined beam and 85-feet combined draft;
- Any widebody tanker proceeding with cargo will be daylight restricted above Buoy 18;
- Two widebodies meeting in the HSC between Beacons 75/76 and Boggy Bayou restricted to combined beam of 272 feet and combined draft of 77 feet;

- Containerships with dimensions equal to or greater than 1150x141 will not be met by any vessel in HSC;
- Loaded Suezmax tankers will not meet any vessel with a beam above 106 above Beacon 18;
- Loaded Aframax tankers (approximately 135 x 850 feet) will not meet a larger, loaded vessel;
- No vessel meeting in Bayport Ship Channel;
- Containerships with dimensions equal to or greater than 1160 x150 x 45 feet will transit Bayport Ship Channel and make berth at Dock 1;
- Maximum vessel size permitted to transit to Barbours Cut Number 1 is 1158 x 142 feet. When this vessel is at berth, no vessel transits the channel;
- The maximum vessel size of 1158 LOA x 142-feet beam and above docked at Barbours Cut Number 1 will restrict all movement of vessels with beams greater than 106 feet;
- Maximum draft above Boggy Bayou to Sims Bayou is 41.5 feet;
- Maximum vessel size from Boggy to Simms Bayou is 750 LOA x 116 feet beam and draft restricted to 41.5 feet;
- Vessels with > 105 feet beam shall not meet any ship vessel of any size above Boggy Bayou;
- All vessels > 750 feet LOA and a draft > 39 feet are daylight restricted above the Beltway 8 Bridge;
- Maximum draft from Sims Bayou to Turning Basin is 37.5 feet; and
- No car carrier of any size or any other vessel of 325 LOA or longer will arrive/depart City Docks #20-32 when required to turn at Brady Island Turning Basin when there is a vessel docked or encroached into City Dock #27. No vessel 580 LOA or longer loaded to more than 30 feet draft when required to turn at Brady Island Turning Basin will arrive/depart City Dock #20-32 when there is a vessel docked or encroached into City Dock # 27.

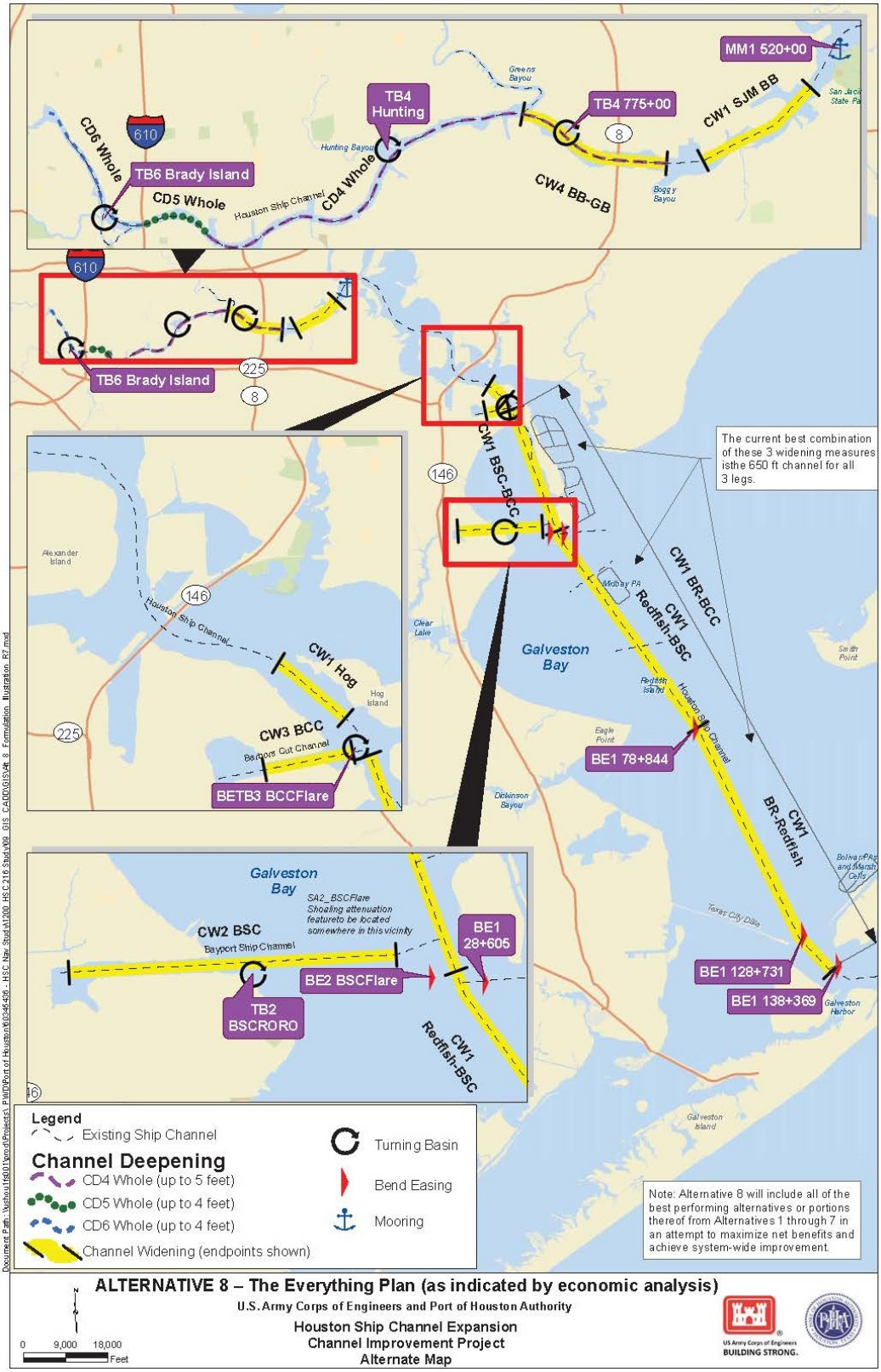

Figure 9 – Alternative 8 – The Comprehensive Plan

5.3 Initial Screening Criteria

To evaluate and screen the initial array of alternative plans to determine those that best meet the study objectives and avoid the study constraints, an initial screening matrix was developed.

The following information was assessed to provide the cost of each measure within the alternatives: New work dredging construction costs, PA construction costs, impacted oyster area (acreage) and its associated mitigation unit costs, real estate costs, relocation costs, mooring structure construction costs, sheet pile wall construction costs, shoaling attenuation feature costs, and contingencies. Additionally, the 50- year incremental maintenance costs were evaluated and a total cost inclusive of Project First Cost and Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) cost was evaluated to determine the economic benefits. These criteria are shown in **Table 10**.

Table 10 – Criteria for Screening Initial Array

Criteria	Metric	Inventory
Costs	Dollars	New work dredging construction costs, placement area construction costs, impacted oyster area (acreage), mitigation unit costs, real estate costs, relocation costs, mooring structure construction costs, sheet pile wall construction costs, shoaling attenuation feature costs, and contingencies and 50-year maintenance.
Economic Benefits	Dollars	Assessment of transportation cost savings/HarborSym

Evaluation Array of Alternative Plans

Once the alternatives were developed, the PDT evaluated the impacts, and estimated costs for the measures within the alternatives. The first screening of the eight alternatives resulted in the elimination of the measures that were not economically justified (benefits greater than costs). **Tables 11 through 18** summarize the results of the economic cost benefit analysis using the following color-coding:

- Gray highlighting (gray) indicates measures that were not economically justified;
- Gray highlighting with an asterisk (*gray) indicates measures that were not economically justified; however, will be carried forward for engineering safety concerns. Note, any of these measures that are carried forward for ship simulation would be dropped from the TSP if not validated by the ship simulation as necessary for safety;
- White highlighting (white) indicates measures that were economically justified but did not produce the highest net benefits (another measure produced higher net benefits);and
- Green highlighting (green) indicates the economically justified measures that produced the highest net benefits

The final summation in each table includes only those alternatives with the highest net benefits. The tables also provide the following economic information: 1) Average Annual Equivalent (AAEQ) Costs; 2) Average Annual Equivalent (AAEQ) Benefits; 3), Net Benefits; and 4) Benefit Cost Ratio (BCR). .

In Alternative 1 (**Table 11**), one measure shown in gray was not economically justified; however, it was carried forward for further engineering safety evaluation. That measure was the Turning Basin/Flare. The remaining measures for the design vessel transit and the Bayou Deepening (Segment 4-6) shown in green are economically justified and those measures were carried forward as Alternative 1 to the final screening of alternatives. Refer back to **Table 9** for a listing of the design vessels per study reach.

Table 11 – Alternative 1 – Minimum System-Wide Plan (No Bay Widening) ($000)

Measure	Measure	Description of Measure	Project First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
			October 2016 Price Level, 2.875 Discount Rate					
Measures for Design Vessel Transit	BE1_138+369_530	Bend easing in Bay	$5,200	$5,200	$21,600	$21,500	$(100)	1.00
	BE1_128+731_530	Bend easing in Bay	$5,500	$7,600				
	BE1_078+844_530	Bend easing in Bay	$24,600	$58,800				
	BE1_028+605_530	Bend easing in Bay	$23,000	$36,200				
	BE2_BSCFlare	Flare Expansion post HSC PDR plan	$21,600	$139,900				
	SA2_BSCFlare	Shoaling attenuation structure near BSC Flare	$22,300	$22,300				
	CW2_BSC_455	Widen BSC up to 455 feet wide	$153,800	$254,100				
	CW3_BCC_455	Widen BCC up to 455 feet wide	$104,200	$109,500				
	TB3_BCCFlare_1800NS	Ease flare and create turning basin	$24,900	$44,000				
BSC TB	*TB2_BSCRORO_1800	Turning Basin/Flare at BSC	$50,800	$93,400	$2,900	$1,400	$(1,500)	0.5
Bayou Deepening	CD4_Whole	Deepen beyond 41.5 feet up to 46.5 feet.	$45,400	$45,400	$1,900	$25,400	$23,500	13.4
	CD5_Whole + CD6_Whole	Deepen beyond 37.5 feet up to 41.5 feet.	$19,900	$19,900	$800	$11,400	$10,600	14.3
		Total[1,2]	**$513,900**	**$848,900**	**$27,700**	**$59,700**	**$32,000**	**2.2**

[1] *Totals include measures that are economically justified (green) plus measures requiring safety validation via ship simulation (*gray). Total excludes measures without economic justification or that do not maximize net benefits in comparison to an alternative measure (white)*
[2] *Total include costs associated with pipeline relocations and real estate costs*

Table 12 provides the analysis for Alternative 2 – Bay Plan. Alternative 2 considered increments of widening in the Bay to provide for vessel meeting opportunities. Three widths (650, 820, and 900 feet) were evaluated in different combinations for the Bay widening as follows:

1. Widening from Bolivar Roads to Redfish Reef;
2. Widening from Redfish Reef to BSC;
3. Widening from BSC to BCC; and
4. Widening from Bolivar Roads to BCC

Although the 820-foot width is economically justified from Bolivar Roads to Redfish Reef, the evaluation showed channel widening to be economically justified at the 650-foot width from Bolivar Roads to the BCC. Additionally, though the increments are economically justified

individually at 650 feet, they have a higher net benefit for the combined widening from Bolivar Roads to the BCC. The measures for design vessel transit were also carried forward.

Table 11 - Alternative 2 - Bay Plan ($000)

Measure	Measure	Description of Measure	Project First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
			October 2016 Price Level, 2.875 Discount Rate					
Bay Widening for Widebody Meeting (900 foot width)	CW1_BR-Redfish_900	Widen to 900 feet from Bolivar Roads to Redfish Reef	$281,200	$311,400	$12,100	$8,600	$(3,500)	0.7
	CW1_Redfish-BSC_900	Widen to 900 feet from Redfish Reef to BSC	$463,800	$973,200	$29,100	$7,800	$(21,300)	0.3
	CW1_BSC-BCC_900	Widen to 900 feet from BSC to BCC	$310,200	$585,800	$18,200	$2,500	$(15,700)	0.1
	CW1_BR-Redfish_900 CW1_Redfish-BSC_900	Widen to 900 feet from Bolivar Roads to BSC	$745,000	$1,284,600	$41,200	$17,900	$(23,300)	0.4
	CW1_BR-Redfish_900 CW1_Redfish-BSC_900 CW1_BSC-BCC_900	Widen to 900 feet from Bolivar Roads to BCC	$1,055,200	$1,870,400	$59,400	$24,800	$(34,600)	0.4
Bay Widening for Widebody Meeting (820 foot width)	CW1_BR-Redfish_820	Widen to 820 feet from Bolivar Roads to Redfish Reef	$186,200	$210,000	$8,100	$8,600	$500	1.1
	CW1_Redfish-BSC_820	Widen to 820 feet from Redfish Reef to BSC	$343,500	$742,400	$22,000	$7,800	$(14,200)	0.4
	CW1_BSC-BCC_820	Widen to 820 feet from BSC to BCC	$242,400	$458,200	$13,600	$2,500	$(11,100)	0.2
	CW1_BR-Redfish_820 CW1_Redfish-BSC_820	Widen to 820 feet from Bolivar Roads to BSC	$529,700	$952,500	$30,100	$17,900	$(12,200)	0.6
	*CW1_BR-Redfish_820 *CW1_Redfish-BSC_820 *CW1_BSC-BCC_820	Widen to 820 feet from Bolivar Roads to BCC	$772,100	$1,410,700	$43,700	$24,800	$(18,900)	0.6
Bay Widening for Widebody Meeting (650 foot width)	CW1_BR-Redfish_650	Widen to 650 feet Bolivar Roads to Redfish Reef	$44,600	$54,300	$2,000	$8,600	$6,600	4.3
	CW1_Redfish-BSC_650	Widen to 650 feet from Redfish Reef to BSC	$119,500	$283,700	$8,200	$7,800	$(400)	1.0
	CW1_BSC-BCC_650	Widen to 650 feet from BSC to BCC	$106,200	$195,200	$6,100	$2,500	$(3,600)	0.4
	CW1_BR-Redfish_650 CW1_Redfish-BSC_650	Widen to 650 feet from Bolivar Roads to BSC	$164,100	$338,000	$10,200	$17,900	$7,700	1.8
	CW1_BR-Redfish_650 CW1_Redfish-BSC_650 CW1_BSC-BCC_650	Widen to 650 feet from Bolivar Roads to BCC	$270,300	$533,200	$16,300	$24,800	$8,500	1.5
Measures for Design Vessel Transit	BE1_138+369_530	Bend easings (530 feet) between Bolivar Roads and BCC	$5,200	$5,200	$21,600	$21,500	$(100)	1.0
	BE1_128+731_530		$5,500	$7,600				
	BE1_078+844_530		$24,600	$58,800				
	BE1_028+605_530		$23,000	$36,200				
	BE2_BSCFlare	Expansion of Flare post HSC PDR plan	$21,600	$139,900				
	SA2_BSCFlare	Shoaling attenuation structure near BSC Flare	$22,300	$22,300				
	CW2_BSC_455	Widen BSC up to 455 feet wide	$153,800	$254,100				
	CW3_BCC_455	Widen BCC up to 455 feet wide	$104,200	$109,500				
	BETB3_BCCFlare_1800NS	Ease flare and create turning basin	$24,900	$44,000				
BSC TB	*TB_BSCRORO_1800	Turning Basin at BSC	$50,800	$93,400	$2,900	$1,400	$(1,500)	0.5
		Total[1, 2]	**$706,300**	**$1,304,300**	**$40,800**	**$47,700**	**$6,900**	**1.2**

[1] *Totals include measures that are economically justified (green) plus measures requiring safety validation via ship simulation (*gray). Total excludes measures without economic justification or that do not maximize net benefits in comparison to an alternative measure (white)*

[2] *Total include costs associated with pipeline relocations and real estate costs*

Table 13 showed increments of widening in the Bay to provide for vessel meeting opportunities at 650 feet, to be economically justified. The other measures under Bay and Upper Bay Bend Easing, Widening from the San Jacinto Monument to Boggy Bayou and BSC, would be carried forward for engineering safety evaluation.

Table 12 - Alternative 3 – Suezmax Plan ($000)

Measure	Measure	Description of Measure	Project First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
			October 2016 Price Level, 2.875 Discount Rate					
Bay Widening for Widebody Meeting (900 foot width)	CW1_BR-Redfish_900	Widen to 900 feet from Bolivar Roads to Redfish Reef	$281,200	$311,400	$12,100	$8,600	$(3,500)	0.7
	CW1_Redfish-BSC_900	Widen to 900 feet from Redfish Reef to BSC	$463,800	$973,200	$29,100	$7,800	$(21,300)	0.3
	CW1_BSC-BCC_900	Widen to 900 feet from BSC to BCC	$310,200	$585,800	$18,200	$2,500	$(15,700)	0.1
	CW1_BR-Redfish_900 CW1_Redfish-BSC_900	Widen to 900 feet from Bolivar Roads to BSC	$745,000	$1,284,600	$41,200	$17,900	$(23,300)	0.4
	CW1_BR-Redfish_900 CW1_Redfish-BSC_900 CW1_BSC-BCC_900	Widen to 900 feet from Bolivar Roads to BCC	$1,055,200	$1,870,400	$59,400	$24,800	$(34,600)	0.4
Bay Widening for Widebody Meeting (820 foot width)	CW1_BR-Redfish_820	Widen to 820 feet from Bolivar Roads to Redfish Reef	$186,200	$210,000	$8,100	$8,600	$500	1.1
	CW1_Redfish-BSC_820	Widen to 820 feet from Redfish Reef to BSC	$343,500	$742,400	$22,000	$7,800	$(14,200)	0.4
	CW1_BSC-BCC_820	Widen to 820 feet from BSC to BCC	$242,400	$458,200	$13,600	$2,500	$(11,100)	0.2
	CW1_BR-Redfish_820 CW1_Redfish-BSC_820	Widen to 820 feet from Bolivar Roads to BSC	$529,700	$952,500	$30,100	$17,900	$(12,200)	0.6
	*CW1_BR-Redfish_820 *CW1_Redfish-BSC_820 *CW1_BSC-BCC_820	Widen to 820 feet from Bolivar Roads to BCC	$772,100	$1,410,700	$43,700	$24,800	$(18,900)	0.6
Bay Widening for Widebody Meeting (650 foot width)	CW1_BR-Redfish_650	Widen to 650 feet from Bolivar Roads to Redfish Reef	$44,600	$54,300	$2,000	$8,600	$6,600	4.3
	CW1_Redfish-BSC_650	Widen to 650 feet from Redfish Reef to BSC	$119,500	$283,700	$8,200	$7,800	$(400)	1.0
	CW1_BSC-BCC_650	Widen to 650 feet from BSC to BCC	$106,200	$195,200	$6,100	$2,500	$(3,600)	0.4
	CW1_BR-Redfish_650 CW1_Redfish-BSC_650	Widen to 650 feet from Bolivar Roads to BSC	$164,100	$338,000	$10,200	$17,900	$7,700	1.8
	CW1_BR-Redfish_650 CW1_Redfish-BSC_650 CW1_BSC-BCC_650	Widen to 650 feet from Bolivar Roads to BCC	$270,300	$533,200	$16,300	$24,800	$8,500	1.5
Bay Bend Easing	*BE1_138+369_530	Bend easing (530 feet) between Bolivar Roads and BCC	$5,200	$5,400	$3,400	N/A	N/A	N/A
	*BE1_128+731_530	Bend easing (530 feet) between Bolivar Roads and BCC	$5,500	$7,600				
	*BE1_078+844_530	Bend easing (530 feet) between Bolivar Roads and BCC	$24,600	$58,800				
	*BE1_028+605_530	Bend easing (530 feet) between Bolivar Roads and BCC	$23,000	$36,200				
Upper Bay Bend Easing	*CW1_HOG_600	Widen Hog Island reach	$10,300	$21,700	$1,900	N/A	N/A	N/A
	*BE1_153+06	Bend easing at Fred Hartman Bend	$10,500	$30,400				
	*BE1_246+54	Bend easing Alexander Island	$6,000	$14,200				
SJM-BB Widening	*CW3_SJM-BB	Widening at transition from 400 to 530 feet.	$17,800	$56,400	$1,500	$200	$(1,300)	0.1
BSC Widening	*CW2_BSC_455	Bayport Ship Channel Widening for Suezmax Transit	$153,800	$254,100	$8,300	$1,100	$(7,200)	0.1
		Total[1,2]	**$527,000**	**$1,018,300**	**$31,300**	**$26,100**	**$(5,200)**	**0.8**

[1] *Totals include measures that are economically justified (green) plus measures requiring safety validation via ship simulation (*gray). Total excludes measures without economic justification or that do not maximize net benefits in comparison to an alternative measure (white)*

[2] *Total include costs associated with pipeline relocations and real estate costs*

Table 14 provides the analysis for Alternative 4 – Aframax Plan. Deepening of Segment 4 and widening from Boggy Bayou to Greens Bayou in Segment 4 were economically justified. The turning basin measures were carried forward for engineering safety evaluation.

Table 13 - Alternative 4 – Aframax Plan ($000)

Measure	Measure	Description of Measure	Project First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
			October 2016 Price Level, 2.875 Discount Rate					
To Accommodate Aframax Design Vessel	CD4_Whole	Deepen beyond 41.5 feet up to 46.5 feet	$45,400	$45,400	$1,900	$25,400	$23,500	13.4
	CW4_BB-GB_530	Widen Boggy Bayou to Greens Bayou to 530 feet	$22,900	$112,600	$2,700	$35,100	$32,400	13.0
	*TB4_775+00	Create new turning Basin for Aframax	$30,300	$67,100	$2,000	$-	$(2,000)	0.0
	*TB4_Hunting	Expand existing Hunting Bayou Turning Basin	$900	$17,900	$400	$-	$(400)	0.0
SJM-BB Widening	*CW3_SJM-BB	Widening at transition from 400 to 530 feet.	$17,800	$56,400	$1,500	$200	$(1,300)	0.1
		Total[1,2]	**$129,900**	**$312,900**	**$8,500**	**$60,700**	**$52,200**	**7.1**

[1] *Totals include measures that are economically justified (green) plus measures requiring safety validation via ship simulation (*gray). Total excludes measures without economic justification or that do not maximize net benefits in comparison to an alternative measure (white)*
[2] *Total include costs associated with pipeline relocations and real estate costs*

Table 15 provides the analysis for Alternative 5 – Bulkers, Tankers, and Vehicle Carriers Plan. Deepening of Segments 4, 5, and 6 was determined to be economically justified. The turning basin measures would be carried forward for engineering safety evaluation.

Table 14 – Alternative 5 – Bulkers, Tankers, and Vehicle Carriers Plan ($000)

Measure	Measure	Description of Measure	Project First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
			October 2016 Price Level, 2.875 Discount Rate					
To Accommodate Bulker, Tanker, and Vehicle Carrier Design Vessel	CD4_Whole	Deepen beyond 41.5 feet up to 46.5 feet	$45,400	$45,400	$2,200	$25,400	$33,600	16.3
	*TB4_Hunting	Expand Hunting Bayou Turning Basin	$900	$17,900	$300	$ -	$(300)	0.0
	CD5_Whole + CD6_Whole	Deepen beyond 37.5 feet up to 41.5 feet	$19,900	$19,900	$800	$11,400	$15,900	20.9
	*TB6_Brady_900	Expand Brady Island Turning Basin	$19,600	$30,900	$1,000	$ -	$(1,000)	0.0
		Total[1]	**$98,400**	**$126,700**	**$4,600**	**$36,800**	**$32,200**	**8.0**

[1] *Totals include measures that are economically justified (green) plus measures requiring safety validation via ship simulation (*gray). Total excludes measures without economic justification or that do not maximize net benefits in comparison to an alternative measure (white)*
[2] *Total include costs associated with pipeline relocations and real estate costs*

Table 16 provides the analysis for Alternative 6 –Bay Mooring, which is not economically justified nor carried forward for engineering safety evaluation.

Table 15 – Alternative 6 - Bay Mooring ($000)

Measure	Measure	Description of Measure	Project First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
			October 2016 Price Level, 2.875 Discount Rate					
Bay Mooring	MM2_BSC_1800	Multipurpose mooring outside BSC land cut	$94,600	$164,100	**$5,200**	**$2,100**	**$(3.100)**	**0.4**
		Total[1]	-	-	**-**	**-**	**-**	**-**

[1]*Measure was not economically justified, nor was it carried forward for safety validation via ship simulation*

Table 17 provides the analysis for Alternative 7 –Upper Channel Moorings, one of which is economically justified while the other was eliminated.

Table 16 – Alternative 7 - Upper Channel Moorings ($000)

Measure	Measure	Description of Measure	Project First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
			October 2016 Price Level, 2.875 Discount Rate					
Bay Mooring	MM1_AI(d)	Multipurpose mooring near Alexander Island	$124,900	$212,500	$6,800	$3,000	$(3,800)	0.4
	MM1_520+00*	Multipurpose mooring near San Jacinto Monument	$47,600	$116,200	$3,300	$3,300	$-	1.0
		Total[1,2]	$47,600	$116,200	$3,300	$3,300	$-	1.0

[1] *Totals include measures that are economically justified (green) plus measures requiring safety validation via ship simulation (*gray). Total excludes measures without economic justification or that do not maximize net benefits in comparison to an alternative measure (white)*
[2] *Total include costs associated with pipeline relocations and real estate costs*

Table 18 provides the analysis for Alternative 8 – The Comprehensive Plan. In Alternative 8, the measures for the design vessels transits were economically justified, as was bayou deepening. The increments of widening in the Bay to provide for vessel meeting opportunities were considered most economical for 650 feet, although the 820 feet width is economically justified from Bolivar Roads to Redfish Reef. Channel widening in Segment 4 from Boggy Bayou to Greens Bayou is economically justified. One bayou mooring is economically justified while the bay mooring and one bayou mooring were not and will be eliminated. Measures that were not economically justified but would be carried forward for further evaluation as engineering safety concerns include the turning basin at BSC, widening from the San Jacinto Monument to Boggy Bayou where the channel necks down, limited widening and bend easing in the bayou portion of Segment 1, and the three turning basins in Segments 4-6.

Table 17 – Alternative 8 – The Comprehensive Plan ($000)

Alt	Alternative	Measure	Project First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
			October 2016 Price Level, 2.875 Discount Rate					
1, 2	Measures for Design Vessel Transit	BE1_138+369_530	$5,200	$5,200	$21,600	$21,500	$(100)	1.0
		BE1_128+731_530	$5,500	$7,600				
		BE1_078+844_530	$24,600	$58,800				
		BE1_028+605_530	$23,000	$36,200				
		BE2_BSCFlare	$21,600	$139,900				
		SA2_BSCFlare	$22,300	$22,300				
		CW2_BSC_455	$153,800	$254,100				
		CW3_BCC_455	$104,200	$109,500				
		BETB3_BCCFlare_1800NS	$24,900	$44,000				
1	*BSC TB	TB2_BSCRORO_1800	$50,800	$93,400	$2,900	$1,400	$(1,500)	0.5
1, 2, 6	Bay Mooring	MM2_BSC_1800	$89,700	$159,300	$5,200	$2,100	$(3,100)	0.4
1, 4, 5	Bayou Deepening	CD4_Whole	$45,400	$45,400	$1,900	$25,400	$23,500	13.4
		CD5_Whole + CD6_Whole	$19,900	$19,900	$800	$11,400	$10,600	14.3
2, 3	Bay Widening_900	CW1_BR-Redfish_900	$281,200	$311,400	$12,100	$8,600	$(3,500)	0.7
		CW1_Redfish-BSC_900	$463,800	$973,200	$29,100	$7,800	$(21,300)	0.3
		CW1_BSC-BCC_900	$310,200	$585,800	$18,200	$2,500	$(15,700)	0.1
		CW1_BR-Redfish_900 CW1_Redfish-BSC_900	$745,000	$1,284,600	$41,200	$17,900	$(23,300)	0.4
		CW1_BR-Redfish_900 CW1_Redfish-BSC_900 CW1_BSC-BCC_900	$1,055,200	$1,870,400	$59,400	$24,800	$(34,600)	0.4
2, 3	Bay Widening_820	CW1_BR-Redfish_820	$186,200	$210,000	$8,100	$8,600	$500	1.1
		CW1_Redfish-BSC_820	$343,500	$742,400	$22,000	$7,800	$(14,200)	0.4
		CW1_BSC-BCC_820	$242,400	$458,200	$13,600	$2,500	$(11,100)	0.2
		CW1_BR-Redfish_820 CW1_Redfish-BSC_820	$529,700	$952,500	$30,100	$17,900	$(12,200)	0.6
		*CW1_BR-Redfish_820 *CW1_Redfish-BSC_820 *CW1_BSC-BCC_820	$772,100	$1,410,700	$43,700	$24,800	$(18,900)	0.6
2, 3	Bay Widening_650	CW1_BR-Redfish_650	$44,600	$54,300	$2,000	$8,600	$6,600	4.3
		CW1_Redfish-BSC_650	$119,500	$283,700	$8,200	$7,800	$(400)	1.0
		CW1_BSC-BCC_650	$106,200	$195,200	$6,100	$2,500	$(3,600)	0.4
		CW1_BR-Redfish_650 CW1_Redfish-BSC_650	$164,100	$338,000	$10,200	$17,900	$7,700	1.8
		CW1_BR-Redfish_650 CW1_Redfish-BSC_650 CW1_BSC-BCC_650	$270,300	$533,200	$16,300	$24,800	$8,500	1.5
3	SJM-BB Widening	*CW1_SJM-BB_530	$17,800	$56,400	$1,500	$200	$(1,300)	0.13
3	Upper Bay BE Suezmax	*CW1_HOG_600	$10,300	$21,700	$1,900	$-	$-	0.0
		*BE1_153+06	$10,500	$30,400				
		*BE1_246+54	$6,000	$14,200				
4	Aframax Widening	CW4_BB-GB_530	$22,900	$112,600	$2,700	$35,100	$32,400	13.0
4, 5	Bayou TB	*TB4_775+00	$30,300	$67,100	$2,000	$-	$(2,000)	0.0
		*TB4_Hunting	$900	$17,900	$400	$-	$(400)	0.0
5	Brady Island TB	*TB6_Brady_900	$19,600	$30,900	$1,000	$-	$(1,000)	0.0
7	Bayou Mooring	MM1_AI(d)	$120,000	$207,600	$6,800	$3,000	$(3,800)	0.4
		MM1_520+00*	$47,600	$116,200	$3,300	$3,300	$-	1.0
Total (650')			**$950,000**	**$1,849,700**	**$56,800**	**$123,100**	**$66,300**	**2.2**
Total (820')			**$1,451,800**	**$2,727,200**	**$84,700**	**$123,100**	**$38,400**	**1.5**

[1] *Totals include measures that are economically justified (green) plus measures requiring safety validation via ship simulation (*gray). Total excludes measures without economic justification or that do not maximize net benefits in comparison to an alternative measure (white)*

[2] *Total include costs associated with pipeline relocations and real estate costs*

6.0 EVALUATION OF FINAL ARRAY OF ALTERNATIVE PLANS

6.1 Final Screening of Alternative Plans

The final array was screened based on the economic benefits of each alternative. As shown in **Table 19**, Alternative 8 provides the highest net benefits (benefits minus costs) of all the alternatives and best meets the study objectives.

Table 18 – Final Screening of Alternative Plans ($000)

Alt	First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
	October 2016 Price Level, 2.875 Discount Rate					
No Action	This alternative does not meet the study objectives. This alternative forms the baseline to which all other alternatives are compared. The No-Action Alternative would not result in additional costs for construction and O&M nor would it provide additional benefits; however, it would not result in environmental impacts.					
1	$513,900	$848,900	$27,700	$59,700	$32,000	2.2
2	$706,300	$1,304,300	$40,800	$47,700	$6,900	1.2
3	$527,000	$1,018,300	$31,300	$26,100	$(5,200)	0.8
4	$129,900	$312,900	$8,500	$60,700	$52,200	7.1
5	$98,400	$126,700	$4,600	$36,800	$32,200	8.0
6	$94,600	$164,100	$5,200	$2,100	$(3,100)	0.4
7	$47,600	$116,200	$3,300	$3,300	$-	1.0
8 (650')	$950,000	$1,849,700	$56,800	$123,100	$66,300	2.2
8 (820')	$1,451,800	$2,727,200	$84,700	$123,100	$38,400	1.5

6.2 Additional Features for Inclusion into the TSP for Further Evaluation and Ship Simulation

Bay Widening for Meeting - The PDT evaluated three methods to determine the range of widths that would be considered for widening the channel in the bay and elected a lesser width than recommended by EM 1110-2-1613. The bay widening was considered in three increments: Bolivar Roads to Redfish, Redfish to BSC, and BSC to BCC. These widths were determined to be of adequate length for meeting and passing of the design vessels in the bay reach. Because limited ship simulation would not possible until after pubic review, the PDT determined that Alternative 8 would be evaluated for a width ranging from 650-feet to 820-feet. This would allow for maximum impacts to be coordinated through the NEPA process. It was agreed that once the limited ship simulations were conducted to establish the necessary dimensions of width required for the meeting and passing of the design vessels in the bay reach, that width would be carried forward and impacts would be reduced while project design was further refined. To assess the range, the impacts were presented for the 650-foot and 820-foot widths.

Further Evaluation of TSP Measures – A limited number of measures listed below were added to Alternative 8as part of the TSP to provide for the safe and efficient transit of the design vessels.

1. Minor widening of the channel in the bayou portion of the HSC main channel in the Hog Island stretch and two bend easings for maneuverability (**Segment 1);**
2. A turning basin requested by the pilots to provide for additional turning opportunities at the BSC at the mouth of the BSC land-cut (**Segment 2)**;
3. Turning Basin at Station 775+00 would be the most upstream location for Aframax vessels to turn (**Segment 4)**;
4. Hunting Turning Basin to ensure continued Federal maintenance (**Segment 4)**;
5. The alleviation of a channel restriction by widening from the existing 400-feet to 530-feet for a distance of approximately 1.3 miles from just west of the San Jacinto Monument and Boggy Bayou (**Segment 4)**; and
6. Improvement of and consideration of federalizing an existing turning basin located near Brady's Landing (**Segment 6)**

Further engineering and environmental evaluation will be conducted during the feasibility-level analysis phase of the study to determine whether these features remain, or are eliminated from the TSP. As per Planning Bulletin (PB) 2017-01, paragraph 6.e., there is typically not enough detailed information to conclude that the TSP will ultimately be the NED Plan. Once ship simulations are conducted, a determination of which features and their dimensions that will provide for the safe and efficient navigation of vessels in the channel can be established.

Table 20 provides the estimated range of costs for the features included in the TSP. First Cost of the TSP is estimated to range between $950,000,000 and $1,451,800,000.

Table 19 – TSP (inclusive of Features to be Further Evaluated) ($000)

Alt	First Cost	O&M	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits*	Net Benefits*	BCR*
	October 2016 Price Level, 2.875 Discount Rate						
8(650)[1]	$950,000	$899,700	$1,849,700	$56,800	$123,100	$66,300	2.2
8(820)[2]	$1,451,800	$1,275,400	$2,781,600	$84,700	$123,100	$38,400	1.5

[1] Alternative 8 includes bay widening to 650 feet plus measures for further evaluation; lower range.

[2] Alternative 8 includes bay widening to 820 feet plus measures for further evaluation; higher range.

Alt	First Cost	O&M	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits*	Net Benefits*	BCR*
	October 2016 Price Level, 2.875 Discount Rate						
8(650)[1]	$950,000	$899,700	$1,849,700	$56,800	$123,100	$66,300	2.2
8(820)[2]	$1,451,800	$1,275,400	$2,781,600	$84,700	$123,100	$38,400	1.5

[1] Alternative 8 includes bay widening to 650 feet plus measures for further evaluation; lower range.

[2] Alternative 8 includes bay widening to 820 feet plus measures for further evaluation; higher range.

6.3 Final Comparison of Alternatives

Tables 21 - 22 provide a list of the pilot rules the PDT has targeted for the study. The alternatives are identified with a Y where a rule could be eliminated or reduced in theory. Ship simulations to be performed subsequent to the Agency Decision Milestone and will be used to define the future with-project footprint to provide the dimensions for safe and efficiency transit of vessels. In this comparison, Alternative 8 either reduces or alleviates all target Pilot Rules.

Table 20 - Pilot Rules Targeted by Each Alternative

Comparison of Alternatives and How they Change Pilot Rules and Practices									
Current Working Rules and Practices (530 foot Channel)	**Anticipated Change to Working Rules and Practices**	**Alternatives**							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Maximum vessel size 1000x138 Bolivar Road to Barbours Cut.	Increase vessel LOA to 1200 feet.	**Y**	**Y**	**Y**					**Y**
Two widebodies meeting in the HSC between Buoy 18 and Beacons 75/76 restricted to 310 combined beam and 85' combined draft	Eliminate restriction by widening channel.		**Y**	**Y**					**Y**
Any widebody tanker proceeding with cargo will be daylight restricted above Buoy 18	Eliminate restriction to Beacon 75/76 (Bayport) by widening.		**Y**	**Y**					
	Eliminate restriction to Morgans Point by widening								**Y**
Two widebodies meeting in the HSC between Beacons 75/76 and Boggy Bayou restricted to combined beam of 272 feet and combined draft of 77 feet	No combined beam restriction or combined draft restriction in the widened channel from Beacons 75/76 to Morgans Point. Extend the outbound sailing restriction from the upper reaches by 2 hours.								**Y**
Containerships with dimensions equal to or greater than 1150x141 will not be met by any vessel in HSC	Eliminate restriction by widening channel.								**Y**
Loaded Suezmax tankers will not meet any vessel with a beam above 106 above Beacon 18	Loaded Suezmax tankers will meet vessels greater than 106' beam in the widened channel to from Beacon 18 to Morgan's Point.								**Y**
Loaded Aframax tankers (approximately 135 x 850 feet) will not meet a larger, loaded vessel	Loaded Aframax tankers will meet larger vessels from Beacon 18 to Morgan's Point.								**Y**
No vessel meeting in Bayport Ship Channel	Combined beam restriction of approximately 212 feet		**Y**						**Y**
Containerships with dimensions equal to or greater than 1160 x150 x45 feet will transit Bayport Ship Channel and make berth at Dock 1	Containerships with dimensions equal to or greater than 1160 x150 x 45 feet will		**Y**						**Y**

	berth at all Bayport Container Terminal Docks								
Maximum vessel size permitted to transit to Barbours Cut Number 1 is 1158 x 142 feet. When this vessel is at berth, no vessel transits the channel.	The design containership will berth at all Barbours Cut Docks		**Y**						**Y**

Table 21 - Pilot Rules Targeted by Each Alternative (continued)

Comparison of Alternatives and How they Change Pilot Rules and Practices (Continued)									
Current Working Rules and Practices (530 foot Channel)	**Anticipated Change to Working Rules and Practices**	**Alternatives**							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
The maximum vessel size of 1158 LOA x 142' beam and above docked at Barbours Cut Number 1 will restrict all movement of vessels with beams greater than 106 feet.	All vessels transit the channel when the maximum vessel size (1158 LOA x 142' beam and above) is berthed at Docks 1-6.		**Y**						**Y**
Maximum draft above Boggy Bayou to Simms Bayou is 41.5'.	Maximum draft increased up to 46.5'.	**Y**			**Y**				**Y**
Maximum vessel size from Boggy to Simms Bayou is 750 LOA x 116' beam and draft restricted to 41.5'.	Increase maximum vessel size to 850 LOA x 138' beam and draft up to of 46.5'.				**Y**				**Y**
Vessels with > 105' beam shall not meet any ship vessel of any size above Boggy Bayou.	Allowable meeting of vessels with >105' beam from Boggy to Greens Bayou.				**Y**				**Y**
All vessels > 750' LOA and a draft > 39' are daylight restricted above the Beltway 8 Bridge.	Allow for vessels of 850 LOA x 138' beam feet and draft up to 46.5' to move from (Shell) to Greens Bayou without daylight restriction. (Needs widening from CW1_SJM-BB_530)				**Y**				**Y**
Maximum draft from Simms Bayou to Turning Basin is 37.5'.	Maximum draft from Simms Bayou to Turning Basin up to 41.5'.	**Y**				**Y**			**Y**
No car carrier of any size or any other vessel of 325 LOA or longer will arrive/depart City Docks #20-32 when required to turn at Brady Island Turning Basin when there is a vessel docked or encroached into City Dock #27. No vessel 580 LOA or longer loaded to more than 30' draft when required to turn at Brady Island Turning Basin will arrive/depart City Dock #20-32 when there is a vessel docked or encroached into City Dock # 27.	Lift part of all restriction for turning at Brady Island Turning Basin and allow for use of City Dock #27. (Measure TB6_Brady_900 needs further evaluation.					**Y**			**Y**

Each Alternative was formulated in consideration of the four criteria in the P&G: completeness, effectiveness, efficiency, and acceptability as presented in **Table 23** and **Table 24**. With the exception of the No-Action Alternative, each alternative in the Final Array is considered acceptable. While all of the alternatives which improve the channel in some fashion while avoiding and minimizing environmental impacts to the greatest extent possible during the 50-year period of analysis, only two alternatives (Alternative 1 and 8) would provide system-wide benefits. The plan with the greatest net excess benefits is considered the most complete, efficient, and effective plan. Therefore, Alternative 8 is the plan that best meets the four P&G criteria.

Table 22 - Comparison of P&G Evaluation Criteria (Part 1)

Alternative #	No Action	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8
Criteria	**FWOP**	**Minimum System Wide Plan**	**Bay Plan**	**Suezmax Plan**	**Aframax Plan**	**Bulkers, Tankers, and Vehicle Carriers Plan**	**Bay Mooring Plan**	**Upper Channel Mooring Plan**	**The Comprehensive Plan**
Acceptability (meets all laws, regulations and guidance)	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
Completeness (provides and accounts for all necessary investments or other actions to ensure the realization of the planning objective)	● No Action is an Incomplete solution to all planning objectives	● Minimally complete solution; does not address congestion. ● Provides second most improvement in navigation efficiency over No Action ● Does not maximize transportation benefits throughout the entire HSC System	● Incomplete solution ● Provides improvement in navigation efficiency over No Action ● Does not maximize transportation benefits throughout the entire HSC System.	● Incomplete solution ● Provides improvement in navigation efficiency over No Action ● Does not maximize transportation benefits throughout the entire HSC System	● Incomplete solution ● Provides improvement in navigation efficiency over No Action ● Does not maximize transportation benefits throughout the entire HSC System.	● Incomplete solution ● Provides improvement in navigation efficiency over No Action ● Does not maximize transportation benefits throughout the entire HSC System.	● Incomplete solution ● Provides improvement in navigation efficiency over No Action ● Does not maximize transportation benefits throughout the entire HSC System.	● Incomplete solution ● Provides improvement in navigation efficiency over No Action ● Does not maximize transportation benefits throughout the entire HSC System.	● Most complete solution ● Provides most improvement in navigation efficiency over all other alternatives ● Maximizes transportation benefits throughout entire HSC System.

Table 23 - Comparison of P&G Evaluation Criteria (Part 2)

Alternative #	No Action	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8
Efficiency (extent to which an alternative plan is the most cost effective means of achieving the objective)	● No Action does not address the planning objective	● Less costly than TSP ● Does not address objective as effectively ● Net excess benefits not maximized and are less than the TSP	● Less costly than TSP ● Does not address objective as effectively ● Net excess benefits not maximized and are less than the TSP	● Less costly than TSP ● Does not address objective as effectively ● Net excess benefits not maximized and are less than the TSP	● Less costly than TSP ● Does not address objective as effectively ● Net excess benefits not maximized and are less than the TSP	● Less costly than TSP ● Does not address objective as effectively ● Net excess benefits not maximized and are less than the TSP	● Less costly than TSP ● Does not address objective as effectively ● Net excess benefits not maximized and are less than the TSP	● Less costly than TSP ● Does not address objective as effectively ● Net excess benefits not maximized and are less than the TSP	● Most costly alternative ● Addresses objectives most effectively ● Highest net excess benefits
Effectiveness (extent to which the alternative plans contribute to achieve the planning objective)	● Ineffective for improving navigational efficiencies	● Second most effective plan for improving navigation efficiency ● This is a minimally system wide improvement	● Not effective as TSP for improving navigation efficiency ● Not a system wide improvement	● Not effective as TSP for improving navigation efficiency ● Not a system wide improvement	● Not effective as TSP for improving navigation efficiency ● Not a system wide improvement	● Not effective as TSP for improving navigation efficiency ● Not a system wide improvement	● Not effective as TSP for improving navigation efficiency ● Not a system wide improvement	● Not effective as TSP for improving navigation efficiency ● Not a system wide improvement	● Most effective alternative for improving navigation efficiency ● This is a system wide improvement

7.0 TENTATIVELY SELECTED PLAN

The TSP was selected based upon limited detailed information; the general understanding of the transit restrictions that could be reduced by channel improvements to increase transportation cost savings; the current vessel fleet forecast; historical information regarding environmental conditions requiring mitigation; generalized type of dredged material placement; and general assumptions regarding channel improvement design. Additional economic, engineering, and environmental evaluation, including ship simulations were performed during the feasibility-level analysis phase to confirm the TSP and engineering assumptions.

The TSP includes the following features, inclusive of additional features (denoted with an asterisk (*)) the PDT believes are necessary for safe and efficient navigation in the HSC. Additionally, non-Federal sponsor improvements addressed in the text following **Figure 4**, are being recommended for federalization.

- Four bend easings on main HSC channel with associated relocation of barge lanes (**Segment 1**);
- Widening (in whole or in part) the HSC main channel between Bolivar Roads and BCC from the existing 530-foot width to somewhere between 650-feet to 820 feet (**Segment 1**);
- Addition of a new multipurpose mooring on the HSC near the San Jacinto Monument (**Segment 1**);
- *Minor widening of the channel in the bayou portion of the HSC main channel in the Hog Island stretch (**Segment 1)** ,
- *The alleviation of a channel restriction in Segment 4 by widening from the existing 400-feet to 530-feet for a distance of approximately 1.3 miles from just west of the San Jacinto Monument and Boggy Bayou (**Segment 1)**;
- Flare expansion on BSC (**Segment 2**);
- Shoaling attenuation structure near the BSC Flare (**Segment 2**);
- *A turning basin requested by the pilots to provide for additional turning opportunities at the BSC in Segment 2 at the mouth of the BSC land-cut (**Segment 2**);
- Widen BSC from existing 300-400 feet to 455 feet (**Segment 2**);
- Widen BCC from existing 300 feet to 455 feet (**Segment 3**);
- Combination flare and turning basin on BCC (**Segment 3**); and
- Deepen the HSC main channel from Boggy Bayou to Sims Bayou from the existing 41.5-foot depth up to 46.5 feet (**Segment 4**);
- Widen the HSC main channel from Boggy Bayou to Greens Bayou from the existing 400-foot wide channel up to 530 feet (**Segment 4**);

- *Turning Basin at Station 775+00 would be the most upstream location for Aframax vessels to turn (**Segment 4)**;
- *Hunting Turning Basin to ensure continued Federal maintenance (**Segment 4)**;
- Deepen the HSC main channel from Sims Bayou to I-610 Bridge from the existing 37.5-foot depth up to 41.5 feet (**Segment 5**);
- Deepen the HSC main channel from I-610 Bridge to Main Turning Basin from the existing 37.5-foot depth up to 41.5 feet deep (**Segment 6**); and
- *Improvement of and consideration of federalizing an existing turning basin located near Brady's Landing in Segment 6 (**Segment 6)**;

The TSP is shown in **Figure 10.** Concurrent with the development of the TSP, project specific 33 U.S.C Section 408 Reports and Environmental Assessments (EAs) for the BSC, BCC, Greens Bayou Channel, and Jacintoport Channel were reviewed. The purpose was to verifying the non-Federal improvements and making a determination of whether it is in the Federal interest to include the dimensions as part of this recommendation for federal authorization. Note, as part of this feasibility study, the improvements of these AOMs were assumed to be in place in the FWOP condition.

Federal assumption of maintenance of these improvements (BSC, BCC, Greens Bayou Channel, and Jacintoport Channel) is recommended to the dimensions shown below and on the page following **Figure 10**. For the BSC and BCC, the additional modifications recommended under the TSP are noted in the second bullets.

Bayport Ship Channel (**Segment 2**)

- The non-Federal sponsor improvements resulted in a channel 46.5-feet deep by 400-feet wide from the HSC to the Land Cut and 350-feet wide from the Land Cut to Turning Basin; and
- The TSP recommends further modification to widen the entire BSC 46.5-feet deep channel from 400 feet wide to 455- feet wide.

Barbours Cut Channel (**Segment 3**)

- The non-Federal sponsor improvements resulted in a channel 46.5-feet deep by 300-feet wide; and
- The TSP recommends further modification to widen the BCC 46.5-feet deep channel from 300 feet wide to 455- feet wide.

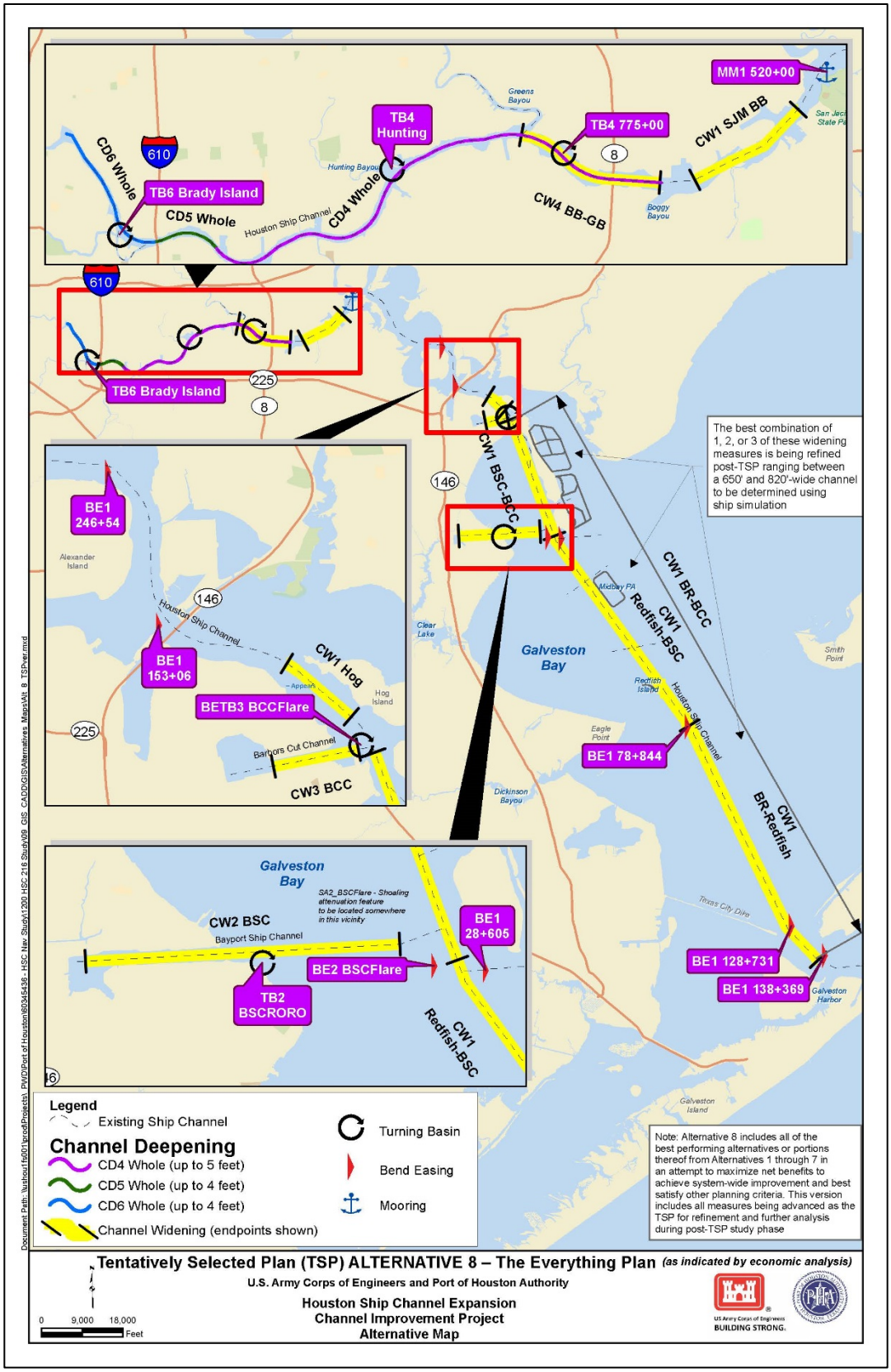

Figure 10 – Tentatively Selected Plan

Greens Bayou Channel is 1.6-mile long combination deep (41.5 feet) and shallow draft (16.5 feet) that serves multiple facilities adjacent to the HSC. This study includes Greens Bayou Channel and confirms the economic benefits of maintaining this channel at the aforementioned depths (**Segment 4)**.

Jacintoport: This study also recommends federalization of the Jacintoport channel (a side channel of the Houston-Galveston Navigation Channels, Texas Federal navigation project) to a depth of 41.5 feet. The analysis completed under Section 5001 of Water Resources Development Act (WRDA) of 2007 confirmed the Federal interest of this channel (**Segment 1)**.

This appendix only addresses information up to the selection of the Tentatively Selected Plan for public review. Further refinement of the Tentatively Selected Plan along with subsequent analysis is included Chapter 6 of the Main Report.

7.1 Project Costs.

Per Engineer Regulation (ER) 1110-2-1302, *Civil Works Cost Engineering* (USACE, 2016b), cost estimates for the TSP phase of the Feasibility Study must be a minimum of a Class 4 parametric estimate. A Class 4 Level Estimate was performed for the Measures included in Alternatives 1 through 8, due to the substantial lack of technical information and scope clarity at this phase in the study. Major estimate assumptions were made, with reliance on cost engineering judgment, parametric modeling, and historical averages. **Table 25** provides the Class 4 estimate performed for the TSP See **Engineering Appendix, Section 11** for more detailed information regarding costs.

Table 24 – TSP Cost Summary (October 2016 Price Levels)

	Difference in cost addresses range in width of bay widening component (650 feet and 820 feet range)		
	Construction Item	Cost (with 650-Foot)	Cost (with 820-Foot)
01	Lands and Damages	$179	$179
02	Relocations	$12,462	$12,462
06	Fish & Wildlife Mitigation	$39,400	$45,200
12	Navigation		
	Dredging	$407,500	$726,100
	Placement Areas	$112,800	$213,600
	Structures	$234,700	$234,700
	Navigation (12) Subtotal	**$755,000**	**$1,174,400**
30	Engineering and Design	$79,400	$122,000
31	Construction Management	$63,600	$97,600
	Project First Cost Total	**$950,000**	**$1,451,800**
	HTRW Remedial Action*	N/A	N/A

**Associated financial costs that are not part of the recommended Federal project but are a necessary non-Federal responsibility.*

7.2 Equivalent Annual Costs and Benefits.

The Tentatively Selected Plan for this study is the plan that maximizes NED benefits over costs. **Table 26** provides a detailed benefit cost analysis for Alternative 8 for both 650 and 820 foot widening.

Table 25 – HSC ECIP Equivalent Annual Costs and Benefits

2017 Price Level, 50 Year Period of Analysis, 2.875 Percent Discount Rate *Difference in cost addresses range in width of bay widening component (650 feet and 820 feet range)*		
	TSP with widening to 650	TSP with widening to 820
Investment Costs		
Total Project Construction Costs	$950,000	$1,452,000
Interest During Construction	$69,000	$108,000
Total Investment Cost	**$1,019,000**	**$1,560,000**
Average Annual Costs		
Construction Average Annual Costs	$38,700	$59,200
OMRR&R	$18,000	$25,500
Total Average Annual Costs	**$56,800**	**$84,700**
Average Annual Benefits	$123,100	$123,100
Net Annual Benefits	$66,300	$38,400
Benefit-Cost Ratio	**2.2**	**1.5**

7.3 Least Cost Disposal Plan

Engineering analysis of any specific placement or BU of dredge material was postponed until feasibility design and analysis phase. Additional formal engineering of the DMMP will occur during PED phase after the project is authorized by congress. Some discussion of potential options for dredged material placement recommended during the initial public scoping meetings held in May 2016, and discussions with various environmental agencies are included in **Section 13 of Appendix C.**

Construction of the TSP would generate an approximate range of 27.6-52.5 million cubic yards (mcy) of dredged material. The 50-year incremental O&M quantity would generate an approximate range of 79.3-116.9 mcy of dredged material. The formulation of the DMMP for construction and O&M will require a programmatic approach to determine the least cost disposal plan, the most cost-efficient methods to dredge and place the material from each reach. A

generalized approach to how this may be developed during the feasibility-level design and analysis phase of the study. Parametric cost estimation utilizing historic data from the previous HGNC Deepening and Widening Construction and Maintenance was used to determine the project costs for the TSP in the DIFR-EIS. Dredged material placement ranged from upland confined PAs, BU for intertidal marsh creation, bird island creation, island restoration, benthic habitat creation/restoration, bay bottom restoration, and offshore placement for habitat creation for the HGNC Project.

To develop the least cost placement plan, the most cost-efficient methods to dredge and place the material from each reach will need to be determined. The availability of multiple disposal areas near the channels and spaced throughout the project area allows significant flexibility and efficiency New placement areas that may be developed are generally desired to be within five miles of the HSC, BSC, and BCC but may range up to 7.5 miles or greater depending on the need.

For the formulation of the TSP, only general navigation features (GNF) were considered to determine the Federal Interest in the project. However, the need to efficiently accommodate future maintenance dredging from LSF would also be considered. Further analysis of the dredging and placement requirements of the LSF for DMMP analysis will be considered post TSP. The costs for dredging and any PA capacity for LSF O&M is a non-Federal responsibility.

General Navigation Features (GNFs) are cost shared between USACE and the NFS during the construction of project. *GNFs include channels, jetties or breakwaters, locks, basins or water areas for vessel maneuvering, turning, passing, mooring or anchoring incidental to transit of the channels and locks, and dredge material placement areas (*except the Gulf Intracoastal Water (GIWW) and Atlantic Intracoastal Waterway*).

Oversimplification: If the vessel is coming into the dock, all the facilities needed to get it from open water to the dock are GNF.

LSFs are features fully funded by non-Federal interests. *LSFs might include such things as piers, wharves, berthing, and mooring.

Oversimplification: Once the vessel stops, everything it touches are the LSF.

*List of features is not all-inclusive
ER 1105-2-100 Planning guidance notebook and oversimplification provided at http://www.iwr.usace.army.mil/Missions/Training/Planning-Associates-Program/PA-Program-2013-Course-Schedule/2013-Deep-Draft-Navigation-Course/

7.3.1 Beneficial Use Opportunities

The Federal Government has placed considerable emphasis on using dredged material in a beneficial manner. Statutes such as the WRDAs of 1992, 1996, 2000, and 2007, demonstrate that BU has been a Congressional priority. The USACE has emphasized the use of dredged material for BU through such regulations as 33 Code of Federal Regulations (CFR) Part 335, ER 1105-2-100, and ER 1130-2-520 and by Policy Guidance Letter (PGL) 56. ER 1105-2-100 states that "all dredged material management studies include an assessment of potential BUs for environmental purposes including fish and wildlife habitat creation, ecosystem restoration and enhancement and/or hurricane and storm damage reduction" (USACE 2000, E-69). In accordance with ER 1105-2-100, the USACE is considering BU of dredged material as a part of the project. Opportunities for BU of dredged material exist in the project vicinity. Many BU options were identified in previous studies and meetings with the resource agencies as further described in **Appendix C, Section 13**. The Beneficial Uses Group (BUG), consisting of Federal and state agencies (EPA, NFMS, NRCS, USFWS, TCEQ, TXGLO, and TPWD) will be coordinated with regularly throughout the development of the DMMP for the HSC ECIP.

During further analysis conducted prior to the final report, options for BUs that are cost-effective and meet regulatory and environmental protection requires will be developed. However, if a plan were considered that would result in additional cost, above the least cost placement plan (environmentally acceptable, with sound engineering techniques, and economically justified), the additional increment of cost over the least cost plan would likely be at a 100 percent non-Federal cost.

From this point forward, please refer to the Final Integrated Feasibility Report. This appendix provides formulation up to the selection of the TSP that went forward for public review. This was the NED plan with inclusion of additional benefits for further evaluation.