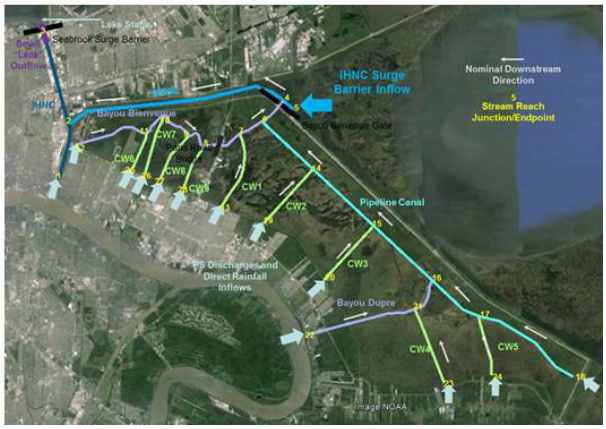
Part IV.
Evaluation of
Compartmentalization Alternatives



Upper right photo: USACE, Management Measures Digital Library—
Floodwalls, Levees, and Dams, Local Flood Risk Management: Closure Structures
Lower left photo: http://www.nola.com/environment/index.ssf/2014/01/corps_awards_74_million_contra.html

Part IV screens the 36 compartmentalization alternatives identified in Part II and modeled in Part III, yielding five remaining priority projects. Part IV then presents a feasibility evaluation of engineering, risk reduction, and costs for these five projects.

13. Initial Screening of Compartmentalization Alternatives

This section presents an initial screening of the 36 compartmentalization alternatives identified in Section 9, including the two IHNC Basin projects—the IHNC Basin Levee/Floodwall and IHNC Basin Operational Modification. *The purpose of the initial screening for this Report is to identify those clear priority alternatives which may warrant accelerated investment*. The 36 alternatives are therefore examined for Class D inundation reduction on the basis of the flooded area/footprint for the applicable breach locations presented in Section 12. The screening considers potential improvements—such as elevating the feature and closing cross drainage.

The 36 alternatives are ranked Good, Fair, or Poor for

- Class D Inundation Risk Reduction. An overall risk reduction rank is assigned to the alternative based on a review of the breach scenario results presented in Section 12. The ranking considers inundation probability due to local HSDRRS vulnerability to overtopping and breaching (see Table 10.1) plus the flood consequences both inside and outside the compartmentalization feature associated with potential upgrades. As discussed in Section 6.1, for purposes of this Report residual hurricane surge risks do ***not*** include the polder population and assume that comprehensive evacuation is implemented whenever there is a threat of inundation. Residual risks encompass uninsured damages to public and private assets and the associated economic, cultural, and personal losses. Upgrades that have no impact on the Class D inundation scenarios, or that have significant net adverse flood risks are ranked Poor for the purposes of this Report. Significant adverse flood impacts can require expensive mitigation, diminishing the risk reduction benefits of a project.
- Upgrade General Feasibility. An overall general feasibility rank is assigned to improving the feature taking into account major issues with construction complexity, cost uncertainties, impacts to polder drainage, and challenges with property owners. Upgrades that require multiple cross drainage closures and involve significant drainage and/or property owner impacts are ranked Poor for the purposes of this Report.

Alternatives ranked Good in both categories are deemed a priority for further evaluation. Table 13.1 summarizes the initial screening and identifies six priority alternatives. The first, Ormond Ring Levee, is located in St. Charles Parish and therefore further assessment of this priority alternative falls to the PLD and St. Charles Parish. Five priority compartmentalization alternatives are identified for further investigation in this Report for SLFPA-E (see Section 14). They are

1. EJ/SC Parish-Line Levee/Floodwall
2. Maxent Levee
3. 40 Arpent/Violet Canal Levee/Floodwall
4. IHNC Basin Levee/Floodwall
5. IHNC Basin Operational Modification

It is important to note that many compartmentalization alternatives not deemed a priority for purposes of this Report could be reconsidered in feasibility analysis addressing Class E inundation hazards.

Table 13.1. Summary of Initial Screening of 36 East-Bank Compartmentalization Alternatives

Alternative	Class D Inundation Risk Reduction	Upgrade General Feasibility
Metro Polder, St. Charles		
1. Airline Hwy	Fair	Poor
2. KCS Railroad	Fair	Poor
3. CN Railroad (north of River Road)	Poor	Poor
4. Ormond Ring Levee (*for further evaluation by PLD*)	***Good***	***Good***
Metro Polder, Jefferson		
5. Interstate 10	Poor	Poor
6. Sauve-Metairie Ridge	Good	Fair
7. Airline Hwy	Poor	Poor
8. KCS/CN Railroad.	Poor	Poor
9. Causeway Boulevard	Fair	Fair
10. Bonnabel Ridge	Fair	Fair
11. EJ/SC Parish-Line Levee/Floodwall	***Good (for Jefferson)***	***Good***
12. EJ/O Parish-Line Monticello Levee/Floodwall	Poor	Good
Metro Polder, Orleans		
13. Gentilly Ridge	Good	Poor
14. NS Railroad to St. Bernard	Good	Poor
15. CSX Railroad to NO East	Good	Poor
16. Bayou St. John Banks	Fair	Good
17. NS Railroad North to Lakefront and NO East	Poor	Poor
18. Carrollton Ridge	Poor	Fair
19. Pontchartrain Expressway Corridor	Poor	Fair
20. Lafitte Street Embankment	Poor	Fair
21. Esplanade Ridge	Poor	Good
22. NS Railroad South to Mississippi River	Poor	Poor
NO East Polder		
23. Maxent Levee	***Good***	***Good***
24. BSNWR Levee	Fair	Good
25. Interstate 10	Good	Poor
26. Sauvage Ridge with Chef Menteur Hwy/CSX RR	Good	Fair
27. Downman Road		
28. Paris Road.		
St. Bernard Polder		
29. 40 Arpent Levee/Floodwall	***Good***	***Good***
30. NS Railroad Spur in Arabi	Poor	Poor
31. Paris Road Ridge	Poor	Fair
32. Violet Canal Levee—*combine with 40 Arpent Levee*	***Good***	***Good***
33. Louisiana Hwy 46	Poor	Poor
34. Bayou Road Ridge	Good	Fair
IHNC Basin		
35. IHNC Basin Levee/Floodwall	***Good***	***Good***
36. IHNC Basin Operational Modifications	***Good***	***Good***

13.1. Metro Polder

The three Metro parishes—St. Charles, Jefferson, and Orleans—include 22 potential alternatives for compartmentalization—including ten parallel and twelve perpendicular barriers.

St. Charles Parish
St. Charles Parish includes four compartmentalization alternatives.

- Airline Hwy (Parallel)
- KCS Railroad (Parallel)
- CN Railroad (north of River Road) (Parallel)
- Ormond Ring Levee (Perpendicular)

Table 13.2 summarizes the screening of the St. Charles Parish alternatives.

The three breach scenarios in St. Charles Parish showed the existing Airline Hwy and KCS Railroad barriers to be insufficient in reducing inundation. An increase in elevation and elimination of cross drainage pathways for these two features would allow them to provide compartmentalization benefit for Class D inundation. The CN Railroad, further to the south in the parish, provides inundation reduction, protecting developed areas south of the CN Railroad. The Ormond Ring Levee provides a inundation reduction from the easternmost breach (MSC-3), and would provide a similar benefit for the western breaches (MSC-1 and 2) if it were elevated by a few feet (the model used an elevation just under 5 ft NAVD88).

The St. Charles levee has a Major level of breach vulnerability (see Section 5.2). Improved Airline Hwy and KCS Railroad barriers would increase risk in a small area north of these features at the eastern end of the parish, and an improved CN Railroad would increase risks north of the railroad throughout the parish. Airline Hwy and the KCS Railroad are ranked Moderate for risk reduction, and the CN Railroad is ranked Poor. The Ormond Ring Levee is ranked Good for risk reduction because the adverse impact outside the levee would probably be small relative to the positive benefits inside levee.

Because of complex elevation and multiple drainage closure requirements, and associated cost uncertainties and drainage impacts, the general feasibility for improving Airline Hwy, KCS Railroad, and CN Railroad improvement is ranked Poor. The Ormond Ring Levee has a Good ranking for general feasibility, with raising the elevation likely to be most achievable with the installation of a supplemental I-Wall.

The Ormond Ring Levee is the only St. Charles barrier with overall rankings of Good for both risk reduction and general feasibility. However, the alternative falls under the jurisdiction of the PLD and St. Charles Parish, and not SLFPA-E, and will not be evaluated further in this Report. Improvement of the Ormond Ring Levee appears to be a priority internal barrier option for the PLD and St. Charles Parish to pursue. However, improvement of the HSDRRS levees in St. Charles Parish are likely to be a far more cost-effective alternative.

Table 13.2. Screening of Metro Polder-St. Charles Compartmentalization Alternatives

Alternative	Class D Inundation Risk Reduction			
	Breach Scenario	Reach Vulnerability	Consequence Reduction	Adverse Consequences
Airline Hwy	MSC-1 MSC-2 MSC-3	Major	Reduces flood risk south of Airline Hwy	Improvements would increase flood risk north of Airline Hwy in eastern part of parish
		Overall Rank: Fair		
KCS Railroad	MSC-1 MSC-2 MSC-3	Major	Reduces flood risk south of KCS RR	Improvements would increase flood risk north of KCS RR in eastern part of parish
		Overall Rank: Fair		
CN Railroad	MSC-1 MSC-2 MSC-3	Major	Reduces flood risk south of CN RR	Improvements would increase flood risk north of CN RR, i.e. throughout much of parish
		Overall Rank: Poor		
Ormond Ring Levee	MSC-1 MSC-2 MSC-3	Major	Reduces flood damage risk in Ormond area	Improvements might cause small increase in flood risk
		Overall Rank: Good		

Alternative	Upgrade General Feasibility		
	Construction Complexity	Cost Uncertainties	Other Impacts
Airline Hwy	Significant elevation & multiple cross drainage closures	Moderate	Major drainage impacts
		Overall Rank: Poor	
KCS Railroad	Significant elevation & multiple cross drainage closures	Moderate	Major drainage impacts; railroad cooperation
		Overall Rank: Poor	
CN Railroad	Some elevation & multiple cross drainage closures	Minimal	Major drainage impacts; railroad cooperation
		Overall Rank: Poor	
Ormond Ring Levee	Modest elevation	Minimal	No drainage impacts (forced drainage already in place)
		Overall Rank: Good	

Jefferson Parish
Jefferson Parish includes eight compartmentalization alternatives.

- Interstate 10 (Parallel)
- Sauve-Metairie Ridge (Parallel)
- Airline Hwy (Parallel)
- KCS/CN Railroad (Parallel)
- Causeway Boulevard (Perpendicular)
- Bonnabel Ridge (Perpendicular)
- EJ/SC Parish-Line Levee/Floodwall (Perpendicular)
- EJ/O Parish-Line Monticello Levee/Floodwall (Perpendicular)

Tables 13.3, 13.4, and 13.5 summarize the screening of these alternatives.

With the breach inflow scenarios along the Lakefront and West Return Wall, the compartmentalization effect of the four parallel barriers in the parish declines north to south. Interstate 10 would require some elevation (median dividers could be upgraded) and multiple closure gates for several north-south drainage canal crossings. Much of the potential effectiveness of the interstate is due to the large amount of storage in the terrain bowl north of the interstate.

The Jefferson Parish HSDRRS reaches have Minor breach vulnerability. The risk reduction is ranked Good for the Metairie Ridge. Upgrading the interstate as a parallel barrier would of course worsen the inundation risk in the northern part of the parish. Therefore the interstate is ranked Poor for risk reduction. Airline Hwy and the KCS/CN Railroad are ranked Poor for risk reduction as the scenarios show that these barriers are too far south to impact the Class D inundation hazard.

While the western Sauve Ridge is too far south to impact the two western-most breaches, the eastern Metairie Ridge north of Airline Hwy contains inundation for breaches along the eastern Lakefront (MJ-3 and 4). The Sauve-Metairie Ridge is ranked Good for risk reduction.

Given the complexities and costs of multiple drainage closures and associated drainage impacts, the general feasibility of improving Interstate 10 as an inundation barrier is considered Poor. Airline Hwy and the KCS/CN Railroad would involve multiple cross drainage closures and therefore have a Poor general feasibility.

Potential upgrade of the Metairie Ridge would require raising Metairie Road uniformly along the ridge and is ranked Fair for general feasibility.

The four breach scenarios show that improving the two perpendicular barriers across northern Jefferson Parish—Causeway Boulevard and Bonnabel Ridge—do not currently influence Class D inundation from the western side of the Parish (MJ-1 and MJ-2). With substantial elevation and closure gates for east-west drainage canals either feature could restrict inundation from inundation further east (MJ-3 and MJ-4). These two perpendicular barriers would not unfairly affect inundation risks, as the probability of breaching could be considered equal for either east or west of the barriers. Both features have an overall risk reduction rank of Good.

Table 13.3. Screening of Metro Polder-Jefferson Parallel Compartmentalization Alternatives

Alternative	Class D Inundation Risk Reduction			
	Breach Scenario	Reach Vulnerability	Consequence Reduction	Adverse Consequences
Interstate 10	MJ-1 MJ-2 MJ-3 MJ-4	Minor	Reduces flood risk south of I-10	Improvements would increases flood risk north of I-10
		Overall Rank: Poor		
Sauve-Metairie Ridge	MJ-1 MJ-2 MJ-3 MJ-4	Minor	Reduces flood risk south of ridge in eastern part of the parish	None
		Overall Rank: Good (for Metairie Ridge)		
Airline Hwy	MJ-1 MJ-2 MJ-3 MJ-4	Minor	Doesn't reduce flood risk	None
		Overall Rank: Poor		
KCS/CN Railroad	MJ-1 MJ-2 MJ-3 MJ-4	Minor	Doesn't reduce flood risk	None
		Overall Rank: Poor		

Alternative	Upgrade General Feasibility		
	Construction Complexity	Cost Uncertainties	Other Impacts
Interstate 10`	Some elevation; multiple cross drainage closures	Major	Major drainage impacts
		Overall Rank: Poor	
Sauve-Metairie Ridge	Elevation of Metairie Rd.	Major	No drainage impacts
		Overall Rank: Fair	
Airline Hwy	Significant elevation & multiple cross drainage closures	Major	Major drainage impacts
		Overall Rank: Poor	
KCS/CN Railroad	Significant elevation & multiple cross drainage closures	None	Major drainage impacts. Railroad cooperation
		Overall Rank: Poor	

Improvements face complexities for elevation and closure gates for at least one east-west drainage canal. The closure gages would impede drainage during hurricanes. The general feasibility of these two perpendicular barriers is ranked Poor.

The easternmost St. Charles breach scenario (MSC-3)—at both 30,000 and 60,000 acre-ft—shows that an improved EJ/SC Parish-Line Levee/Floodwall would be an effective barrier to further eastward Class D inundation into Jefferson Parish. (Note that the model may under-represent the current EJ/SC Levee/Floodwall inundation reduction). Given the major vulnerability of St. Charles Parish levees, the risk reduction rank is therefore Good for Jefferson Parish. However, there is no similar protection of St. Charles Parish for a West Return Wall breach scenario (MJ-1). Given the lower vulnerability of the East Jefferson HSDRRS and the very low terrain bowl of northern Jefferson Parish and the higher general ground elevation of St. Charles Parish, the risk reduction is ranked Poor for St. Charles Parish.

Table 13.4. Screening of Metro Polder-Jefferson Perpendicular Compartmentalization Alternatives

Alternative	Class D Inundation Risk Reduction			
	Breach Scenarios	Reach Vulnerability	Consequence Reduction	Adverse Consequences
Causeway Boulevard	MJ-1 MJ-2		No impact	No impact
	MJ-3	Moderate	Reduces flood risk east of Causeway	Increases flood risk west of Causeway
	MJ-4		Reduce flood risk west of Causeway	Increases flood risk east of Causeway
			Overall Rank: Fair	
Bonnabel Ridge	MJ-1 MJ-2		No impact	No impact
	MJ-3	Moderate	Reduces flood risk east of Bonnabel	Increases flood risk west of Bonnabel
	MJ-4		Reduce flood risk west of Bonnabel	Increases flood risk east of Bonnabel
			Overall Rank: Fair	

Alternative	Upgrade General Feasibility		
	Construction Complexity	Cost Uncertainties	Other Impacts
Causeway Boulevard	Significant elevation & cross drainage closures	Major	Major drainage impacts
		Overall Rank: Fair	
Bonnabel Ridge	Elevation & cross drainage closure	Major	Major drainage impacts
		Overall Rank: Fair	

Some upgrading of the EJ/SC Levee/Floodwall could be achieved without significant construction complexities or cost uncertainties. Closure gates would be required for the northern CN Railroad and Airline Hwy crossings. (Airline Hwy is a major evacuation route and a gate could only be closed under an imminent threat of inundation.) Minor gravity drainage improvements may be required for a small area south of Airline Hwy. The EJ/SC Levee/Floodwall has an overall general feasibility ranking of Good. A substantial inundation risk disparity for St. Charles versus Jefferson Parish exists with the current EJ/SC Levee/Floodwall for breach scenarios along the eastern St. Charles Parish HSDRRS. Upgrade of the barrier to address greater breach volumes would exacerbate the risk disparity, but nonetheless would be prudent for SLFPA-E and Jefferson Parish to consider absent plans to upgrade the St. Charles Parish HSDRRS.

The easternmost Jefferson and westernmost Orleans Lakefront breach scenarios (MJ-4 and MO-1)) show that the EJ/O Parish-Line Monticello Levee/Floodwall has no compartmentalization benefit for Class D inundation. The rank for Monticello Levee risk reduction is therefore Poor.

Within Jefferson Parish, the EJ/SC Parish-Line Levee/Floodwall is considered a priority for further evaluation in Section 14.

Table 13.5. Screening of Metro Polder-Jefferson Compartmentalization Alternatives, Two Parish-Line Levee/Floodwall Barriers

Alternative	Class D Inundation Risk Reduction			
	Breach Scenarios	Reach Vulnerability	Consequence Reduction	Adverse Consequences
EJ/SC Levee/Floodwall	MSC-3	High	Reduces flood risk in western Jefferson Parish	Increases flood risk in St. Charles Parish
Monticello Levee/Floodwall	MJ-1	Moderate	None	None
		Overall Rank: Good (Jefferson Parish)		
	MJ-4	Moderate	None	None
	MO-1	Moderate	None	None
		Overall Rank: Poor		

Alternative	Upgrade General Feasibility		
	Construction Complexity	Cost Uncertainties	Other Impacts
EJ/SC Levee/Floodwall	Levee/floodwall upgrade and crossing closures	Depend on level of upgrade	Gravity drainage for small area south of Airline Hwy
		Overall Rank: Good	
Monticello Levee/Floodwall	No upgrade required.	None	None
		Overall Rank: Good	

Orleans Parish

Orleans Parish includes ten compartmentalization alternatives.

- Gentilly Ridge (Parallel)
- NS Railroad to St. Bernard (Parallel)
- CSX Railroad to NO East (Parallel)
- Bayou St. John Banks (Perpendicular)
- NS Railroad North to Lakefront and NO East (Perpendicular)
- Carrollton Ridge (Perpendicular)
- Pontchartrain Expressway Corridor (Perpendicular)
- Lafitte Street Embankment (Perpendicular)
- Esplanade Ridge (Perpendicular)
- NS Railroad South to Mississippi River (Perpendicular)

Tables 13.6, 13.7, and 13.8 summarize the screening of these alternatives.

Upgrading the three Orleans Parish parallel barriers would provide some compartmentalization benefit for Class D inundation scenarios. In the western portion of the parish the NS Railroad is the northernmost feature and it reduces southward inundation from the western breaches (MO-1 and MO-2), with the Gentilly Ridge providing a secondary barrier. In the eastern portion of the parish, the Gentilly Ridge—along with the CSX Railroad (east of Peoples Avenue) reduce southward inundation for the eastern Lakefront breach (MO-3), as well as the northern IHNC breach (MO-4), with the NS Railroad a secondary barrier. For an IHNC breach south of Gentilly Ridge (MO-5) the eastern Gentilly Ridge and western NS Railroad both provide effective barriers. Closure structures for underpasses and drainage conveyances would improve the effectiveness of the railroad embankments, while closure structures for roads and drainage features would improve the effectiveness of the Gentilly Ridge.

Table 13.6. Screening of Metro Polder-Orleans Parallel Compartmentalization Alternatives

Alternative	Class D Inundation Risk Reduction			
	Breach Scenarios	Reach Vulnerability	Consequence Reduction	Adverse Consequences
Gentilly Ridge	MO-1 MO-2 MO-3 MO-4	Minor	Reduces southward flooding	Increases flooding north of ridge
	MO-5	Major	Reduces northward flooding	Increases flooding south of ridge
		Overall Rank: Good		
NS RR (to St. Bernard)	MO-1 MO-2 MO-3 MO-4	Minor	Reduces southward flooding	Increases flooding north of NS RR
	MO-5	Minor	Reduces northward flooding	Increases flooding south of NS RR
		Overall Rank: Good		
CSX Railroad	MO-1 MO-2	Minor	None	None
	MO-3 MO-4		Reduces southward flooding	Increases flooding north of CSX RR
	MO-5	Minor	Reduces northward flooding	Increases flooding south of CSX RR
		Overall Rank: Good		

Alternative	Upgrade General Feasibility		
	Construction Complexity	Cost Uncertainties	Other Impacts
Gentilly Ridge	Multiple roadway & cross drainage closure	Major	Major drainage impacts
		Overall Rank: Poor	
NS RR (to St. Bernard)	Multiple underpass & cross drainage closure	Major	Major drainage impacts. Railroad cooperation
		Overall Rank: Poor	
CSX Railroad	Multiple underpass & cross drainage closure	Major	Major drainage impacts. Railroad cooperation
		Overall Rank: Poor	

Improving the parallel barriers has a disparate inundation risk impact with respect to Lakefront breach scenarios,-increasing risk to the north and reducing risk to the south. However, with respect to the IHNC breaches, the probability of breaches north and south of the features can be considered roughly equal, meaning there is not disparate risk impact for the IHNC breach scenarios. Given the IHNC floodwalls have a higher vulnerability than the Lakefront HSDRRS, the three parallel barriers are ranked as Good for risk reduction. Construction complexities, cost issues, drainage impacts, and property challenges associated with all three features cause them to be ranked Poor for general feasibility.

Of the two perpendicular barriers north of Gentilly Ridge, Bayou St. John and the NS Railroad North to Lakefront, the latter has a more distinctive effect on inundation—associate with the IHNC breach scenarios. However, the latter has disparate impacts east and west of the barrier. Bayou St. John is ranked Fair for providing some risk reduction, while the NS Railroad North to Lakefront is ranked Poor.

Table 13.7. Screening of Metro Polder-Orleans Perpendicular Compartmentalization Alternatives North of NS Railroad

Alternative	Class D Inundation Risk Reduction			
	Breach Scenarios	Reach Vulnerability	Consequence Reduction	Adverse Consequences
Bayou St. John Banks	MO-1	Minor	Reduces some flooding east of bayou	Increases some flooding west of bayou
	MO-2		None	None
	MO-3		None	None
	MO-4		None	None
	MO-5	Major	Reduces some flooding west of bayou	Increases some flooding east of bayou
		Overall Rank: Fair		
NS RR North to Lakefront	MO-1	Minor	None	None
	MO-2		None	None
	MO-3		None	None
	MO-4	Major	Reduces flooding west of NS RR	Increases flooding east of NS RR
	MO-5			
		Overall Rank: Poor		

Alternative	Upgrade General Feasibility		
	Construction Complexity	Cost Uncertainties	Other Impacts
Bayou St. John Banks	Some elevation of banks	Minor	None
		Overall Rank: Good	
NS RR North to Lakefront	Multiple underpass & cross drainage closures	Major	Major drainage impacts. Railroad cooperation
		Overall Rank: Poor	

Raising the Bayou St. John Banks would not involve major construction complexities and cost uncertainties and is therefore ranked Good for general feasibility. The NS Railroad North to Lakefront is ranked Poor for general feasibility due issues with underpasses, drainage crossings, drainage impacts.

The five perpendicular barriers south of the NS Railroad (to St. Bernard), have risk reduction ranks of Poor for the Class D inundation breach scenarios. With improved cross drainage closure, the three westernmost features, the Carrollton Ridge, the Pontchartrain Expressway Corridor, and the Lafitte St. Embankment could reduce inundation footprint under some Lakefront breach scenarios where some flood water manages to penetrate south of the NS Railroad and Gentilly Ridge. Blocking drainage crossings for these three features would also have a similar impact for the south IHNC breach, MO-5. However, upgrading these three features would have some disparate flooding impact: protecting areas to the west comes at the expense of increasing risk to the east. With significant elevation at their northern end, the NS South spur and Esplanade Ridge could reduce westward inundation for the south IHNC breach, MO-5, but would increase inundation to the east. The general feasibility is ranked Good for upgrading the Esplanade Ridge, Poor for the NS South Spur, and Fair for the other three barriers.

None of the ten Orleans Parish interior compartmentalization barriers are ranked Good for both criteria and therefore none are deemed a priority for further evaluation in Section 14.

Table 13.8. Screening of Metro Polder-Orleans Perpendicular Compartmentalization Alternatives South of NS Railroad

Alternative	Class D Inundation Risk Reduction			
	Breach Scenarios	Reach Vulnerability	Consequence Reduction	Adverse Consequences
Carrollton Ridge	MO-1	Minor	Reduces flooding to the west	Increases flooding to the east
	MO-2			
	MO-3		None	None
	MO-4			
	MO-5	Major	Reduces flooding to the west	Increases flooding to the east
		Overall Rank: Poor		
Pontchartrain Expwy	MO-1	Minor	Reduces flooding to the west	Increases flooding to the east
	MO-2			
	MO-3		None	None
	MO-4			
	MO-5	Major	Reduces flooding to the west	Increases flooding to the east
		Overall Rank: Poor		
Lafitte St Embankment	MO-1		None	None
	MO-2	Minor	Reduces flooding to the west	Increases flooding to the east
	MO-3		None	None
	MO-4			
	MO-5	Major	Reduces flooding to the west	Increases flooding to the east
		Overall Rank: Poor		
Esplanade Ridge	MO-1	Minor	None	None
	MO-2			
	MO-3			
	MO-4			
	MO-5	Major	Reduces flooding to the west	Increases flooding to the east
		Overall Rank: Poor		
NS Spur (South to River)	MO-1	Minor	None	None
	MO-2			
	MO-3			
	MO-4			
	MO-5	Major	Reduces flooding to the west	Increases flooding to the east
		Overall Rank: Poor		

Alternative	Upgrade General Feasibility		
	Construction Complexity	Cost Uncertainties	Other Impacts
Carrollton Ridge	Cross drainage closure	Major.	Major drainage impacts
		Overall Rank: Fair	
Pontchartrain Expwy	Cross drainage closure	Major	Major drainage impacts
		Overall Rank: Fair	
Lafitte St Embankment	Elevation & cross drainage closure	Minor	Major drainage impacts; railroad cooperation
		Overall Rank: Fair	
Esplanade Ridge	Elevation at northern end	Minor	None
		Overall Rank: Good	
NS Spur (South to River)	Elevation at northern end	Minor	Railroad cooperation
		Overall Rank: Poor	

13.2. NO East Polder

The NO East Polder has six potential compartmentalization alternatives. These include the Maxent Levee and BSNWR Levee and four internal features. Both levees are inside the HSDRRS but outside the main developed portion of the polder (see Sections 7.2).

As previously noted in Section 9.2, SLFPA-E has conducted engineering investigations of the Maxent Levee in support of NFIP accreditation for non-surge flooding. The Maxent Levee can also provide redundant surge protection from surge overtopping and breaching which might occur along the HSDRRS east of the Maxent Levee. The Maxent Levee—given that the largely undeveloped area east of the levee (including the BSNWR) is about 20,000 acres—does not require major improvements to provide Class D inundation risk reduction. As discussed in Section 10, the Class D inundation scenario modeling for the NO East Polder used the Maxent Levee as part of the model boundary.

Minor upgrades to the Maxent Levee could be considered to enhance Class D inundation risk reduction, such as armoring with enhanced turf or HPTRM, particularly at any points subject to higher erosion. Upgrades would have minimal adverse flood impacts east of the levee. Upgrading the Maxent Levee would pose minor construction issues and cost uncertainties, and no drainage or property impacts. The Maxent Levee has an overall rank of Good for both risk reduction and general feasibility.

The BSNWR Levee parallels a large portion of the Maxent Levee and may slightly enhance wave reduction in the event of HSDRRS overtopping/breaching. Upgrading this barrier might modestly add to Class D inundation risk reduction of the Maxent Levee and is ranked Fair. The barrier could be upgraded with elevation and/or resiliency, or possibly enhancing heavy forest-type vegetation. The general feasibility of upgrading the BSNWR Levee is Good.

In addition to these two levees, there are four potential compartmentalization features inside the Maxent Levee depicted in the NO East polder inundation model:

- Interstate 10 (Parallel)
- Sauvage Ridge with Chef Menteur Hwy and/or CSX Railroad (Parallel)
- Downman Road (Perpendicular)
- Paris Road (Perpendicular)

Table 13.9 summarizes the screening of these four interior alternatives.

The two parallel features—Interstate 10 and Sauvage Ridge—have different flood risk impacts north and south of the barriers, depending on the breach location. Higher vulnerability IHNC Basin I wall segments (NOE-5, NOE-7, and NOE-8) are present both north and south of the two features—indicating that improvement of these features may not benefit one area more than another. The risk reduction rank for these two features is Good. Interstate 10 would require elevation (perhaps using upgraded median dividers) and multiple closure gates for several north-south drainage canal crossings. Sauvage Ridge would likely require raising Chef Menteur uniformly along the ridge. The two features are ranked Poor and Fair, respectively, for general feasibility.

Table 13.9. Screening of NO East Polder Interior Compartmentalization Alternatives

Alternative	Class D Inundation Risk Reduction			
	Breach Scenario	Reach Vulnerability	Consequence Reduction	Adverse Consequences
Interstate 10	NOE-1 NOE-2 NOE-3 NOE-4	Minor	Reduces flood risk south of I-10	Increases flood risk north of I-10
	NOE-5 NOE-6	Moderate	Reduces flood risk north of I-10	Increases flood risk south of I-10
	NOE-7 NOE-8	Major		
		Overall Rank: Good		
Sauvage Ridge	NOE-1 NOE-2 NOE-3 NOE-4	Minor	Reduces flood risk south of ridge	Increases flood risk north of ridge
	NOE-5 NOE-6 NOE-7	Moderate	Reduces flood risk north of I-10	Increases flood risk south of I-10
	NOE-8	Major	Reduces flood risk south of ridge	Increases flood risk north of ridge
		Overall Rank: Good		
Downman Road	NOE-1 NOE-2 NOE-3 NOE-4	Minor	Reduces flood risk west of road	Increases flood risk east of road
	NOE-5 NOE-6 NOE-7	Moderate		
	NOE-8	Major	Reduces flood risk east of road	Increases flood risk west of road
		Overall Rank: Poor		
Paris Road	NOE-1 NOE-2 NOE-3	Minor	Reduces flood risk east of road	Increases flood risk west of road
	NOE-4 NOE-5 NOE-6	Moderate	Reduces flood risk west of road	Increases flood risk east of road
	NOE-7 NOE-8	Major	Reduces flood risk east of road	Increases flood risk west of road
		Overall Rank: Poor		

Alternative	Upgrade General Feasibility		
	Construction Complexity	Cost Uncertainties	Other Impacts
Interstate 10`	Some elevation; multiple cross drainage closures	Major	Major drainage impacts
		Overall Rank: Poor	
Sauvage Ridge	Elevation of Chef Menteur Hwy	Major	No drainage impacts
		Overall Rank: Fair	
Downman Road	Elevation; cross drainage closure	None	Some drainage impact
		Overall Rank: Poor	
Paris Road	Elevation	None	No drainage impact
		Overall Rank: Fair	

Downman Road, lying near the west end of the polder, reduces flood risk in the developed area of NO East, east of the road, for only one scenario—a breach along the IHNC north of Chef Menteur Hwy (NOE-8). For the other scenarios Downmad Road increase flood risk east of the road. Paris Road protects the developed area west of the road for only two of the eight scenarios NOE-4 and NOE-5, and increases flood risks for the other scenarios. Downman Road and Paris Road are both ranked Poor for risk reduction.

Upgrading both Downman and Paris Road as compartmentalization features would involve elevation. For Downman Road it would also require cross drainage closure. Upgrading the two roads are ranked Poor and Fair, respectively, for general feasibility.

The Maxent Levee feature in NO East is deemed a priority for further evaluation.

13.3. St. Bernard Polder

The St. Bernard Polder has six potential compartmentalization alternatives. These include the 40 Arpent Levee/Floodwall and five internal features. The 40 Arpent Levee/Floodwall is inside the HSDRRS but outside the developed portion of the polder (see Sections 7.3). As previously noted in Section 9.3, SLFPA-E has conducted engineering investigations of the 40 Arpent Levee/Floodwall in support of NFIP accreditation for non-surge flooding. The 40 Arpent Levee/Floodwall can also provide redundant surge protection from surge overtopping and breaching which might occur along the HSDRRS. The 40 Arpent Levee/Floodwall—given that the Central Wetlands outside the levee comprise about 29,000 acres—does not require major improvements to provide Class D inundation risk reduction. As discussed in Section 10, the Class D inundation scenario modeling for the St. Bernard Polder used the 40 Arpent Levee/Floodwall as part of the model boundary.

Minor upgrades to the 40 Arpent Levee/Floodwall could be considered to enhance Class D inundation risk reduction, such as armoring with enhanced turf or HPTRM, particularly at any points subject to higher erosion. Upgrades would have minimal adverse flood impacts outside of the levee. Limited upgrades to the 40 Arpent Levee/Floodwall would pose minor construction issues and cost uncertainties, and no drainage or property impacts. The 40 Arpent Levee/Floodwall has an overall rank of Good for both risk reduction and general feasibility.

The additional five compartmentalization alternatives inside the 40 Arpent Levee/Floodwall represented in the St. Bernard polder inundation model are:

- NS Railroad Spur in Arabi (Perpendicular)
- Paris Road Ridge (Perpendicular)
- Violet Canal Levee (Perpendicular)
- Louisiana Hwy 46 (Parallel)
- Bayou Road Ridge (Parallel)

Table 13.10 summarizes the screening of these five interior alternatives.

Table 13.10. Screening of St. Bernard Polder Interior Compartmentalization Alternatives

Alternative	Class D Inundation Risk Reduction			
	Breach Scenario	Reach Vulnerability	Consequence Reduction	Adverse Consequences
NS Railroad Spur in Arabi	USB-1	Major	**Reduces flooding east of RR**	**Increases flooding west of RR**
	USB-2			
	USB-3			
	USB-4	Minor	**Reduces flooding west of RR**	**Increases flooding east of RR**
	USB-5			
	USB-6			
		Overall Rank: Poor		
Paris Road Ridge	USB-1	Major	**Reduces flooding east of Paris Rd**	**Increases flooding west of Paris Rd**
	USB-2			
	USB-3			
	USB-4	Minor	**Reduces flooding west of Paris Rd**	**Increases flooding east of Paris Rd**
	USB-5			
	USB-6			
		Overall Rank: Poor		
Violet Canal Levee	USB-1	Major		
	USB-2		**None**	**None**
	USB-3			
	USB-4			
	USB-5		**Reduces flooding in LSB**	**Increases flooding in USB**
	USB-6	Minor		
	LSB1			
	LSB-2			
	LSB-3		**Reduces flooding in USB**	**Increases flooding in LSB**
	LSB-4			
	LSB-5	Moderate		
		Overall Rank: Good		
Louisiana Hwy 46	LSB1			
	LSB-2	Minor		
	LSB-3			
	LSB-4			
	LSB-5	Moderate		
		Overall Rank: Poor		
Bayou Road Ridge	LSB1			
	LSB-2	Minor		
	LSB-3			
	LSB-4			
	LSB-5	Moderate		
		Overall Rank: Good		

Alternative	Upgrade General Feasibility		
	Construction Complexity	Cost Uncertainties	Other Impacts
NS Railroad Spur in Arabi	Elevation	Moderate	Railroad cooperation
		Overall Rank: Poor	
Paris Road Ridge	Elevation of Paris Rd.	Moderate	No drainage impacts
		Overall Rank: Fair	
Violet Canal Levee	Armoring	Minor	None
		Overall Rank: Good	
Louisiana Hwy 46	Significant elevation	Major	No drainage impact
		Overall Rank: Poor	
Bayou Road Ridge	Culvert closures	Minor	Drainage impacts
		Overall Rank: Fair	

The Violet Canal Levee, which divides Upper and Lower St. Bernard, can be considered part of the 40 Arpent Levee system and is included in the non-surge flood levee NFIP accreditation. SLFPA-E has addressed the Violet Canal Levee in the NFIP engineering evaluations and upgrades. As demonstrated in the Class D breach scenario modeling results, the Violet Canal Levee is also an effective barrier to surge inundation from the Upper to the Lower portion of the polder, and vice versa. Further upgrades to the Violet Canal Levee similar to those mentioned for the 40 Arpent Levee/Floodwall could be considered—e.g., armoring. The Violet Canal Levee ranks Good for both risk reduction and general feasibility and is deemed a priority for further evaluation—as part of the 40 Arpent Levee/Floodwall.

The six Upper St. Bernard inundation scenarios (USB-1, 2, 3, 4, 5, and 6) show that an elevated NS Railroad Spur and/or Paris Road could reduce flooding east and west of the barriers, depending on the scenario (and raise flooding on the opposite side of the barrier). Given that inundation from the IHNC has a higher probability than from the 40 Arpent Levee, the barriers would have disparate flood risk impacts and they are both barriers are ranked Poor for risk reduction. Upgrading the two features would primarily involve elevation, which would likely involve more issues for the NS Railroad Spur than Paris Rd. The features are ranked Poor and Fair respectively for general feasibility.

The five Lower St. Bernard inundation scenarios (LSB-1, 2, 3, 4, and 5) show that further elevation and closure of cross drainage conveyances for Louisiana Hwy 46 or Bayou Road could reduce inundation north or south of the roads, depending on the scenario (and raise flooding on the opposite side of the road). Given the greater elevation associated with surrounding terrain, Bayou Road appears to have better risk reduction potential. The probability of breaching on either side can be considered roughly equal so the two features could be considered to have no disparate risk impact. Louisiana Hwy 46 and Bayou Road are ranked Fair and Good for risk reduction. The two barriers are ranked Poor and Fair for general feasibility, with the former requiring extensive elevation and both requiring many drainage culvert closures.

13.4. IHNC Basin

As noted in Section 9.4, the IHNC Basin includes two compartmentalization alternatives:

- IHNC Basin Levee/Floodwall.
- IHNC Basin Operational Modification. Stakeholders identified two key elements for potential improvement, including a) requirements for mooring barges and large vessels and securing potentially buoyant structures to their foundations; and b) using the Bayou Bienvenue Sector Gate to divert IHNC Basin surge to the Central Wetlands.

Both alternatives affect Class D inundation associated with breaching along the IHNC—including breach scenarios MO-4, MO-5, NOE-8, and USB-1. Table 13.11 summarizes the screening of these two alternatives. Both alternatives are ranked Good for risk reduction based on the vulnerability of these reaches and the reduction of consequences of Class D inundation breaches at these locations. Both alternatives would benefit all three polders

Table 13.11. Screening of IHNC Basin Compartmentalization Alternatives

Alternative	Risk Reduction			
	Breach Scenario	Reach Vulnerability	Consequence Reduction	Adverse Consequences
IHNC Basin Levee/Floodwall	MO-4 MO-5 NOE-8 USB-1	Major	Benefits large areas within all three polders.	No aggravation of risk to any polder.
		Overall Rank: Good		
IHNC Basin Operational Modifications	MO-4 MO-5 NOE-8 USB-1	Major	Benefits large areas within all three polders.	No aggravation of risk to any polder.
		Overall Rank: Good		
Alternative	**General Feasibility**			
	Construction Complexity	**Cost Uncertainties**	**Other Impacts**	
IHNC Basin Levee/Floodwall	Standard upgrade technologies. Some locations may have batter pile issues. Consider twin vertical pile design.	Relocations. Twin pile design.	No polder drainage/property impacts.	
		Overall Rank: Good		
IHNC Basin Operational Modifications	Minimal construction required.	Minimal	No polder drainage/property impacts. Potential environmental impact of surge water salinity on Central Wetland.	
		Overall Rank: Good		

In addition, both alternatives are ranked Good for general feasibility. Upgrading the IHNC Basin Levee/Floodwall could be achieved by improving soils, buttressing the protected side of the wall or upgrading the embankment, converting I-Walls to L-Walls, or full replacement with T-Walls; and adding floodwalls to low levee reaches. The upgrade would likely make use of the existing ROW. Some advanced upgrade options could require some extensive relocations. Upgrades could be phased according to reach elevation needs. The upgrades employ standard technology practices which were used extensively in the HSDRRS construction and have well-established costs. Bayou Bienvenue Gate Operational Modification also has minimal construction complexities and cost uncertainties. A possible adverse impact is the effect of surge salinity on the Central Wetlands.

Both IHNC Basin alternatives—Upgrading IHNC Basin Levee/Floodwall and IHNC Operational Modification—are a priority for further evaluation in Section 14. Upgrading the IHNC Basin Levee/Floodwall and Operational Modification can be considered as partial alternatives to each other for reducing inundation risk from an IHNC Basin Levee/Floodwall breach.

14. Engineering Assessment of Priority Compartmentalization Alternatives

This section presents a technical description of current conditions and potential upgrades for the five priority compartmentalization alternatives to improve East-Bank Class D surge inundation risk reduction:

1. EJ/SC Parish-Line Levee/Floodwall
2. Maxent Levee
3. 40 Arpent/Violet Canal Levee/Floodwall
4. IHNC Basin Levee/Floodwall
5. IHNC Basin Operational Modifications

A *baseline* Option 0 upgrade for surge residual risk reduction is presented for each of the five alternatives. One additional risk reduction upgrade option—Option 1—is presented for the Maxent Levee and 40 Arpent/Violet Canal Levee/Floodwall. Two additional risk reduction upgrade options—Options 1 and 2—are presented for the EJ/SC Parish-Line and IHNC Basin Levee/Floodwall alternatives. Table 14.1 summarizes the upgrade options for the five priority compartmentalization alternatives.

This section provides basic design aspects for potential upgrades—along with technical issues and possible adverse impacts—consistent with a reconnaissance-level feasibility evaluation of compartmentalization alternatives. Crucial engineering investigations required for upgrade options are also described. The upgrade descriptions facilitate the assessment of risk reduction and costs for the alternative upgrades in Sections 17 and 18. The feasibility evaluation encompassed by Sections 16, 17, and 18 provides the basis for recommendations—presented in the *Executive Summary*—for proceeding to the next phase of developing priority compartmentalization alternatives.[1]

14.1. East Jefferson/St. Charles Parish-Line Levee/Floodwall

Current Condition

Figure 14.1 shows the major elements of the EJ/SC Parish-Line Levee/Floodwall. The current general profile of the EJ/SC Parish-Line from the HSDRRS to the Mississippi River Levee is depicted in Figures 14.2.a and b.[2] The profile—about 10,100 ft in total length—is comprised of 11 major segments, including seven constructed Levee/Floodwall reaches, three openings, and the Private Property/River Road segment. Levees and steel sheet pile floodwalls make up about 1 and 0.6 miles, respectively. Additional photographs of the Levee/Floodwall (see Figure 7.4 in Part II) are provided in Figure 14.3. The length and range in elevation for each segment is summarized in Table 14.2. Five of the seven Levee/Floodwall reaches (over 8,400 ft) are generally above 7.5 ft NAVD88. The 117 ft HESCO Bag reach has a minimum elevation of 5 ft NAVD88. The short 52 ft Levee 4 transition is at about 7 ft NAVD88.

[1] The next phase of engineering, flood risk reduction and adverse impacts, flood impact mitigation requirements, environmental impact assessments and mitigation requirements, and design/construction/O&M costs—requires development of engineering details to the preliminary (30 percent) design level. Preliminary designs and further feasibility assessments would be undertaken in the next phase if SLFPA-E chooses to move forward with any of the projects.

[2] The profile elevations were surveyed by J. Anthony Cavell PLS, and Bob Jacobsen PE LLC in October 2014.

Table 14.1. Upgrade Options for Five Priority Compartmentalization Alternatives*

Option 0 (Baseline)	Option 1	Option 2
1. EJ/SC Parish-Line Levee/ Floodwall		
Improve two temporary barriers to provide continuous containment at current SWL Safe Limit & close the E-W Ditch, assume 6 ft NAVD88.	Improve segments to raise SWL Safe Limit to 8 ft NAVD88; install resiliency measures. Additional and higher temporary barriers and closures for continuous containment.	Upgrade the EJ/SC Parish-Line Levee/Floodwall to contain a Class D 30,000-acre-ft breach at St. Rose with a T-Wall and gates to 14 ft NAVD88.
2. Maxent Levee		
Install resiliency measures along lower elevation points north of Interstate 10.	Improve Levee north of Interstate 10 and install additional resiliency measures.	
3. 40 Arpent/Violet Canal Levee/ Floodwall		
Improve temporary barriers at openings to 7.0 ft NAVD88.	Improve a few segments to raise SWL Safe Limit to 8.0 ft NAVD88, and install additional resiliency measures.	
4. IHNC Basin Levee/ Floodwall		
Implement resiliency measures to improve I-Wall SWL Safe Limits and FOSs (e.g., deep soil mixing, buttresses, etc.).	Upgrade the IHNC Basin Levee/Floodwall for major impact loading at 8.0 ft NAVD88. 8.2 mi of I-Wall upgraded to L-Wall.	Upgrade the IHNC Basin Levee/Floodwall for major impact loading at 11.0 ft NAVD88. 13.1 mi of I-Wall upgraded to T-Wall.
5. IHNC Basin Operational Modifications		
Finalize the plan for using the Bayou Bienvenue Sector Gate to divert IHNC Basin surge into the Central Wetlands and modify the *Master Water Control Manual* for the IHNC Basin and *OLD EOP Manual*. Install remote monitoring & controls. Also, support a CPRA-led detailed review of the current and best practices for mooring barges and large vessels and securing potentially buoyant structures, and expedited implementation of recommendations to ensure best practices are being followed.		

* All upgrade designs will be defined on the basis of **residual *surge risk management purposes—<u>not</u> NFIP purposes***—including SWL Safe Limit and FOS.

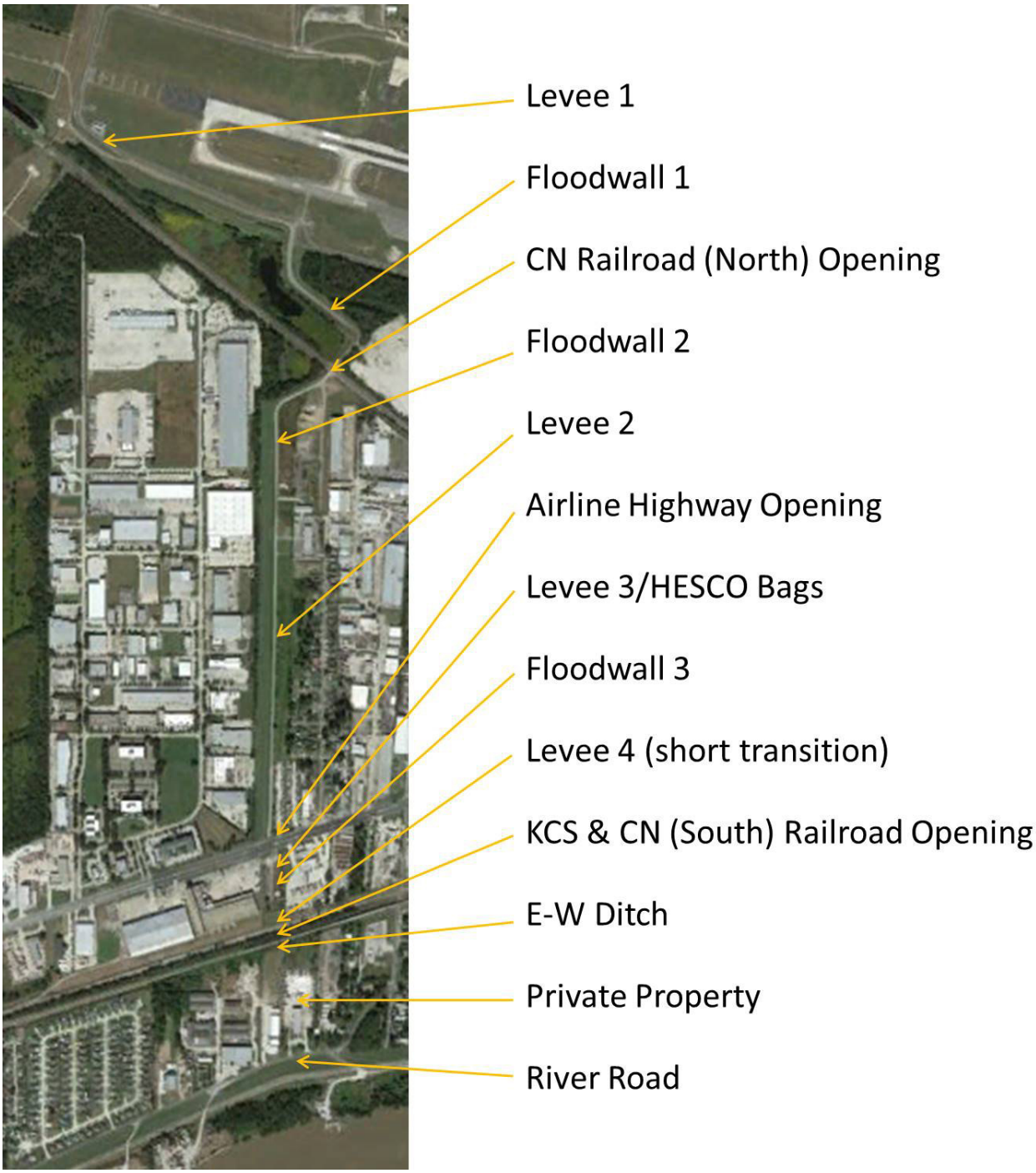
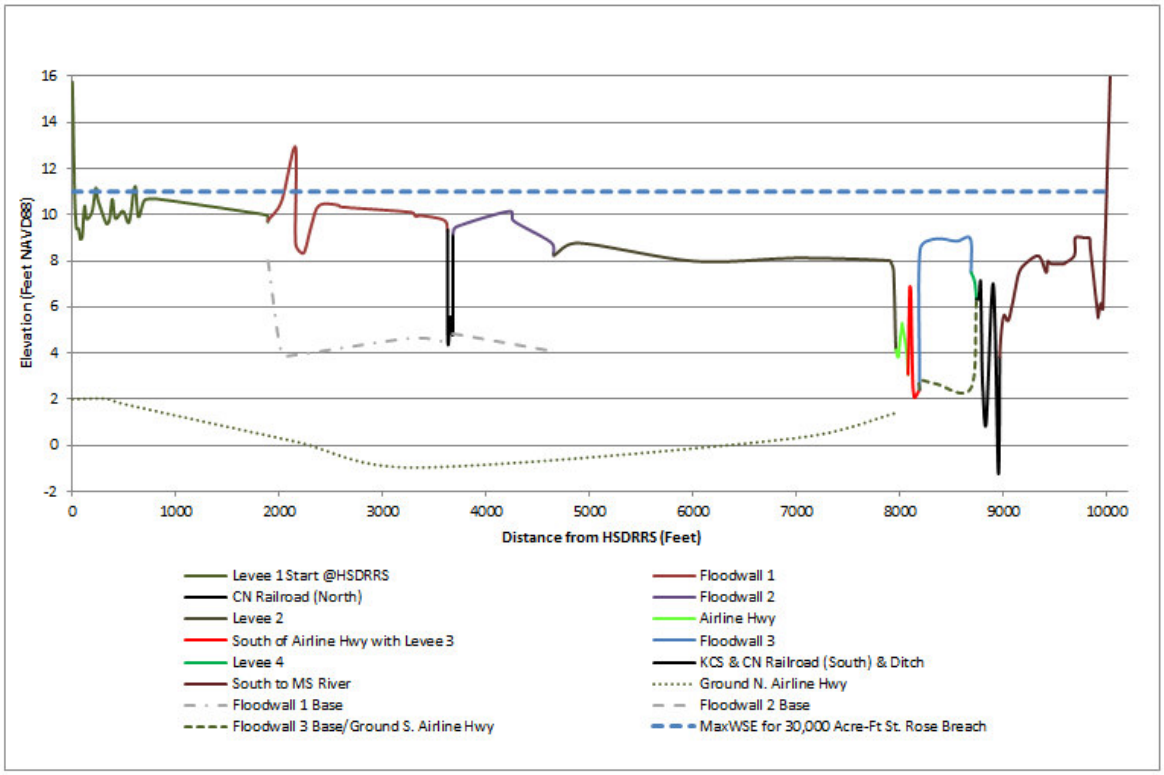
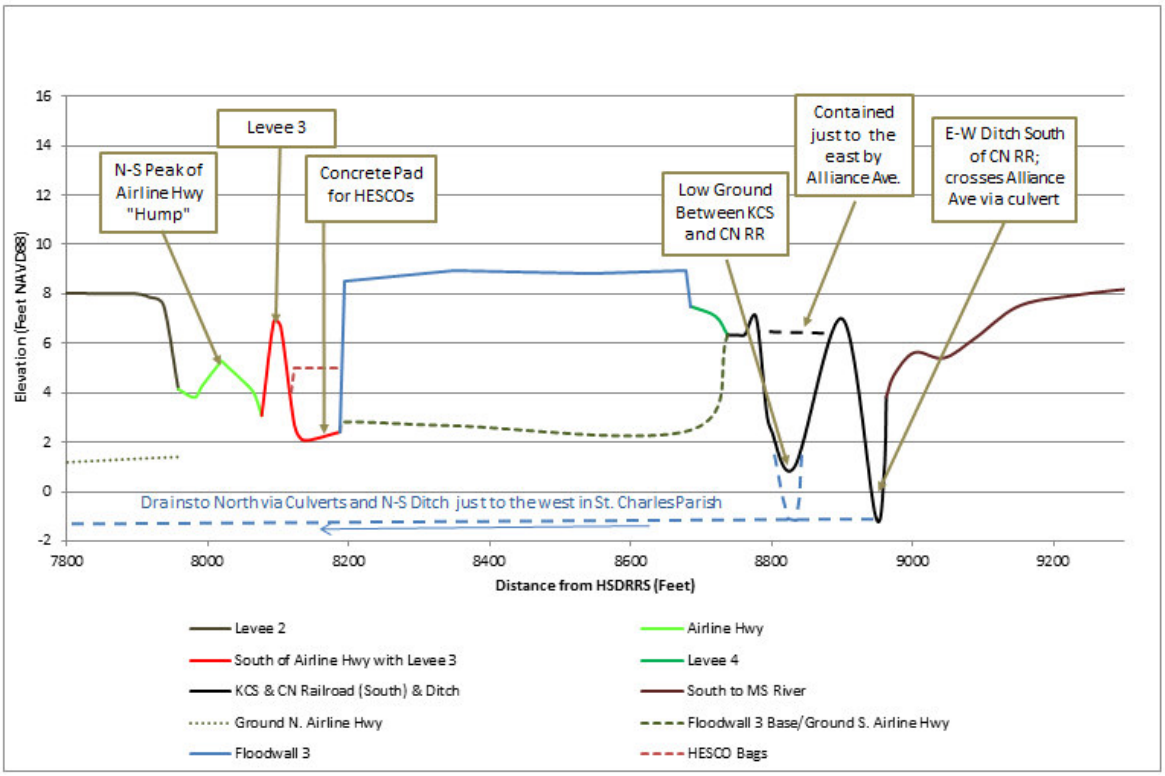


Figure 14.1. Major Elements of the EJ/SC Parish-Line Levee/Floodwall



a) From HSDRRS to Mississippi River



b) Detail of Southern Portion

Figure 14.2. Profile of the EJ/SC Parish-Line Levee/Floodwall

a. Floodwall 1, Note transition of floodwall heights; portion may have been lifted.

b. CN Railroad (North) Opening

c. Floodwall 3

Figure 14.3 Additional Photographs of the EJ/SC Parish-Line Levee/Floodwall
(see Figure 7.4 in Part II)

d. Levee 4

e. KCS Railroad and Low Area between KCS and CN Railroads

f. CN Railroad (South), culvert is at Parish-Line; E-W Ditch is obscured by heavy brush.

Figure 14.3. Additional Photographs of the EJ/SC Parish-Line Levee/Floodwall, Cont'd
(see Figure 7.4 in Part II)

Table 14.2. Jefferson/St. Charles Parish-Line Segments

Segment	Length	Elevation ft NAVD88	
	Ft	Existing Crown	Current SWL Safe Limit*
Levee 1	1,890	8.9 - 11.2	6
Floodwall 1	1,737	8.3 - 12.9	6
CN Railroad (North) Opening	52	4.5 - 5.6	6, with sand bagging
Floodwall 2	976	8.2 - 10.2	6
Levee 2	3,326	7.6 - 8.8	6
Airline Hwy Opening	95	3.1 - 5.3	6, with sand bagging and bump
Levee 3/HESCO Bags	117	5.0 - 6.9	6, with sand bagging
Floodwall 3	492	7.5 - 9.0	6
Levee 4 (short transition)	52	7.1 - 7.1	6
KCS & CN (South) Railroad Opening and E-W Ditch	222	-1.0 - 7.1	-1
Private Property/River Road	1,140	3.8 - 9.0	4

*Working assumption for purposes of this Report.

Components of the "West Return Levee" were initiated by Jefferson Parish well before the middle of the 20th Century, at which time the USACE became involved in the project. All elements of the current Levee/Floodwall were installed prior to 2000—many probably before 1990. (Past engineering and construction information on the Levee/Floodwall segments—as well as what, if any, elements remain authorized as a federal project—were not available for this Report.) Floodwalls 1 and 2 were installed at levee segments which have a crown elevation of about 4 ft NAVD88. These two floodwall segments have exposed sheet pile heights as high as about 9 ft and 6 ft above the levee crown, respectively. Photographs of Floodwall 1 indicate that the sheet piles may have been lifted at some point to provide a greater crown height.

Table 14.2 includes a *working assumption* for the current inundation containment, or SWL Safe Limit, for each of the 11 segments. With the inclusion of some minor upgrades and emergency sand bagging practices, the table shows that the entire Parish-Line currently provides containment to 6.0 ft NAVD88.

No detailed geotechnical engineering analyses have been identified which establish the *SWL Safe Limit* for each reach. The SWL Safe Limit is the estimated maximum water level that can be withstood without *collapse breach*, at a reasonable FOS. The SWL Safe Limit may exceed the segment crown in which case overtopping occurs and there would be an increasing chance of erosion breaching. A *working assumption* of this Report is that the SWL Safe Limit for six of the seven raised Levee/Floodwall reaches is 6.0 ft NAVD88 (all but Levee 3)—i.e., they have an adequate FOS against failing with a SWL up to 6.0 ft NAVD88, including the presence of associated waves. The seventh reach, Levee 3, would provide the same containment with either larger HESCO Bags or additional sand bagging. ***A detailed geotechnical engineering study of all reaches of the EJ/SC Parish-Line Levee/Floodwall is required to actually determine the SWL Safe Limit.*** Such a study entails extensive subsurface investigations and examining a variety of potential failure mechanisms, including those seen during Hurricane Katrina. Such a study is beyond the scope of this Report and is strongly recommended if SLFPA-E and/or Jefferson Parish intend to rely on the EJ/SC Parish-Line Levee/Floodwall for surge risk management.

Containment to 6.0 ft NAVD88 can also be readily established for the three openings. When hurricane forecasters indicate a possible threat of St. Charles Parish surge inundation, Jefferson Parish already has a practice of placing sand bags across the CN Railroad (North).

The Louisiana DOTD recently repaved Airline Hwy and added a small hump at the Parish-Line, raising the interior traffic lane elevations to 5.0 ft NAVD88. Ground elevations near the shoulders still remain closer to 3.0 ft NAVD88. SLFPA-E (through the East Jefferson Levee District, EJLD) has a current practice of sand bagging the shoulders but has agreed to keep the four traffic lanes open for evacuation and emergency response vehicles. (Note: DOTD drawings indicate that there is no subsurface drainage across the Parish-Line at the Airline Hwy opening.)

At the KCS & CN (South) Railroad Opening the railroad tracks themselves are at about 7.0 ft NAVD88 and would provide containment for 6.0 ft NAVD88 inundation—other than seepage through track ballast. The land between the two tracks is fairly low (1.0 ft NAVD88) but is blocked on the east by Alliance Ave to 6.0 ft NAVD88. The eastward flow of inundation in the KCS & CN right of way can be contained at 6.0 ft NAVD88 by reducing seepage through track ballast (with grout injection) and sand bagging as needed along Alliance Avenue, or in between the tracks at the Parish-Line if desirable.

There is a continuous East-West (E-W) Ditch along the south side of the KCS & CN right-of way (at the north end of the Private Property) with an invert approaching -1.0 ft NAVD88. This E-W Ditch connects to a north-south St. Charles Parish-Line Canal—which lies just to the west of the Levee/Floodwall—but the E-W Ditch also continues eastward into Jefferson Parish, with a culvert crossing Alliance Avenue. Drainage to the east across Alliance Avenue ultimately runs to Butler Canal and the pump station north of Armstrong Airport along the West Return Wall. Within 100 ft south of the E-W Ditch, the elevation of the Private Property rises to above 6.0 ft NAVD88 and stays above this elevation to the Mississippi River Levee. Thus, full containment at 6.0 ft NAVD88 requires closure of the E-W Ditch at the Parish-Line, along with sand bagging over a short distance to the south on the Private Property.

Upgrade to Reduce Surge Inundation Risk
As discussed in Section 13.1 upgrading the EJ/SC Parish-Line Levee/Floodwall is a priority compartmentalization alternative for reducing surge inundation risk, particularly an HSDRRS breach near St. Rose. Three upgrade options have been defined:

- Option 0 — Improve temporary barriers to provide continuous containment at current SWL Safe Limit and close the E-W Ditch, assume 6 ft NAVD88.
- Option 1 — Improve segments to raise SWL Safe Limit to 8 ft NAVD88; install resiliency measures. Further improve temporary barriers and closures for continuous containment.
- Option 2 — Upgrade the Levee/Floodwall to contain a Class D 30,000-acre-ft breach at St. Rose with a T-Wall to 14 ft NAVD88.

The three options yield greater inundation risk reduction in East Jefferson but greater risk increases in St. Charles Parish. The next feasibility-level analysis and preliminary engineering would be required to better define net benefits, as well as any necessary mitigation measures, including whether the options are justifiable relative to greater investment in St. Charles Parish HSDRRS levee design and resiliency.

Option 0

The baseline Option 0 includes reviewing available design and construction information for the Levee/Floodwall, and new detailed geotechnical engineering investigation of all segments. This geotechnical engineering analysis will determine the SWL Safe Limits under existing conditions—*addressing* FOS *suitable for residual surge risk management*. The *working assumption* of this Report is the geotechnical analysis will show that Option 0 can achieve a SWL Safe Limit of 6.0 ft NAVD88 and no improvements will be needed to levee and floodwall reaches for this SWL Safe Limit. However, the engineering analyses could determine that specific reaches have higher and lower SWL Safe Limits. The analysis will refine an Option 1 modestly higher SWL Safe Limit, including the basic measures for levee and floodwall improvements, and resiliency measures. Finally, the analysis will refine upgrade and resiliency measures for Option 2. The Option 0 analysis will identify further investigations necessary to evaluate Option 1 and 2 measures.

The analysis will include determining any remaining federal authorizations and the path forward for coordinating with the USACE, CPRA, and PLD. The analysis will also include a) further defining inundation risk reductions and increases in East Jefferson and St. Charles Parishes under all three options; b) any required flood risk—as well as environmental—mitigation measures; and c) whether upgrading the St. Charles HSDRRS Levee is a more cost-effective risk reduction approach than upgrading the EJ/SC Parish-Line Levee/Floodwall.

The Parish-Line survey shows that for a SWL Safe Limit of 6.0 ft NAVD88 openings must be addressed at CN Railroad (North), Airline Hwy, the E-W Ditch, and southward on the Private Property. The EJLD currently relies sand and HESCO bags at the CN (North) and Airline Hwy shoulder openings. EJLD could continue and expand the use of bags to achieve containment at 6.0 ft NAVD88. This could include re-instituting sand-bagging the Airline Hwy traffic lanes and median as part of careful coordination with GOHSEP, CPRA, DOTD, and the parish emergency management offices— ***in the event a surge forecast indicates potential inundation of eastern St. Charles.***

An alternative to sand and HESCO bags is an erectable flood barrier shown in Figure 14.4—with removable vertical posts (with pre-installed receiver footings) horizontal stoplogs, and buttresses (depending on the height). The CN (North) railroad opening would require a concrete pads to provide a foundation for the barrier. In addition, some grouting of the ballast at the railroad track may be considered. An erectable barrier could also be used to replace the HESCO bags south of Airline Hwy. To be preferable to current sand bag practices, erectable barriers would have to be affordable and quicker and easier to install, with reasonable manpower and equipment requirements. HESCO bags may continue to be preferable at some locations. Sand bags would likely still be needed to transition between erectable barriers and levees and floodwalls.

Under Option 0, the E-W Ditch requires closure to 6.0 ft NAVD88 SWL Safe Limit. The ground elevation just south of the Ditch must also be raised for a short distance. A drainage study is required to determine if permanent closure or a gated structure should be installed in the E-W Ditch. The latter—with a gate normally open except in the event of a severe surge forecast—would allow continued eastward and/or westward flow in the ditch if needed to maintain the current normal drainage. If St. Charles Parish property does not drain eastward in the E-W Ditch to Jefferson Parish but is conveyed to the north via the Parish-Line Canal—then St. Charles Parish drainage would be unaffected by the E-W Ditch closure. On the other hand, if St. Charles Parish drainage is affected, the Parish-Line Canal would require improvements. If Jefferson Parish property drains westward into St. Charles and its Parish-Line Canal, then closure of the E-W Ditch would require improvements in Jefferson Parish's drainage.

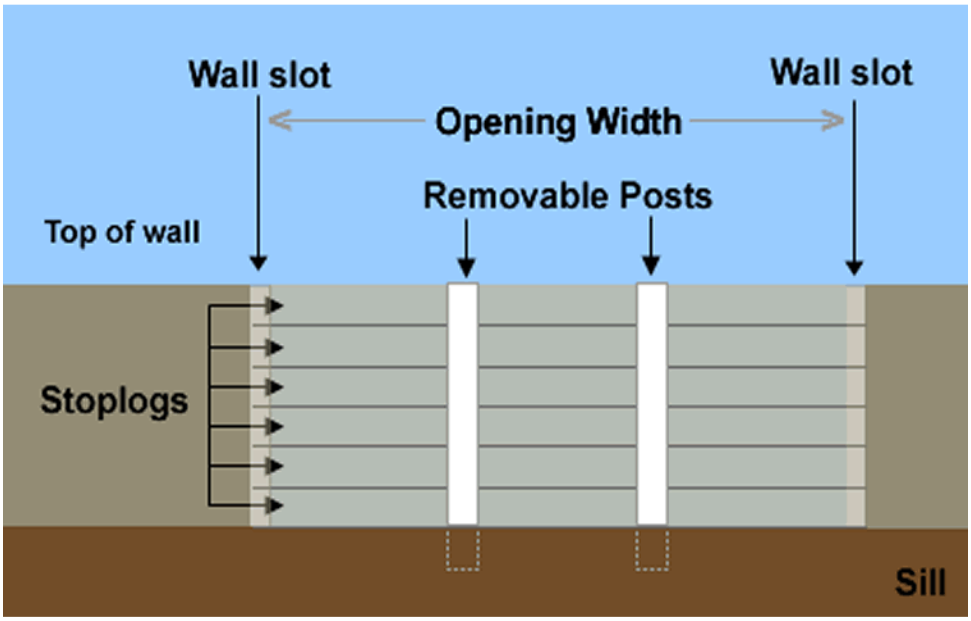


Figure 14.4 Temporary Erectable Barriers With Removable Posts and Horizontal Stoplogs
USACE, http://library.water-resources.us/docs/MMDL/FLD/Feature.cfm?ID=19

Option 1

For purposes of this Report it is assumed that the geotechnical analysis will show that Option 1 can achieve a SWL Safe Limit of 8.0 ft NAVD88. A SWL Safe Limit of 8.0 ft NAVD88 requires that the Option 0 temporary barriers, the E-W Ditch Closure, and the elevation along the parish line on the Private Property south of the E-W ditch must all be raised. A new I-Wall will replace the short Levee 4 section and will extend to south of the CN (South) Railroad. New temporary barriers will be required at the KCS and CN (South) Railroad as well as at the River Road openings.

In addition, the resiliency of the existing sheet pile walls will be improved. For the purposes of this Report, Option 1 resiliency measures are assumed to include deep soil mixing for 2,000 ft of sheet pile wall and improvement of the protected-side berm along 3,200 ft of sheet pile walls. 3,400 feet of levee will be raised to provide a crown elevation of 9.0 ft NAVD88 and HPTRM installed on the protected-side of 5,200 ft of levee.

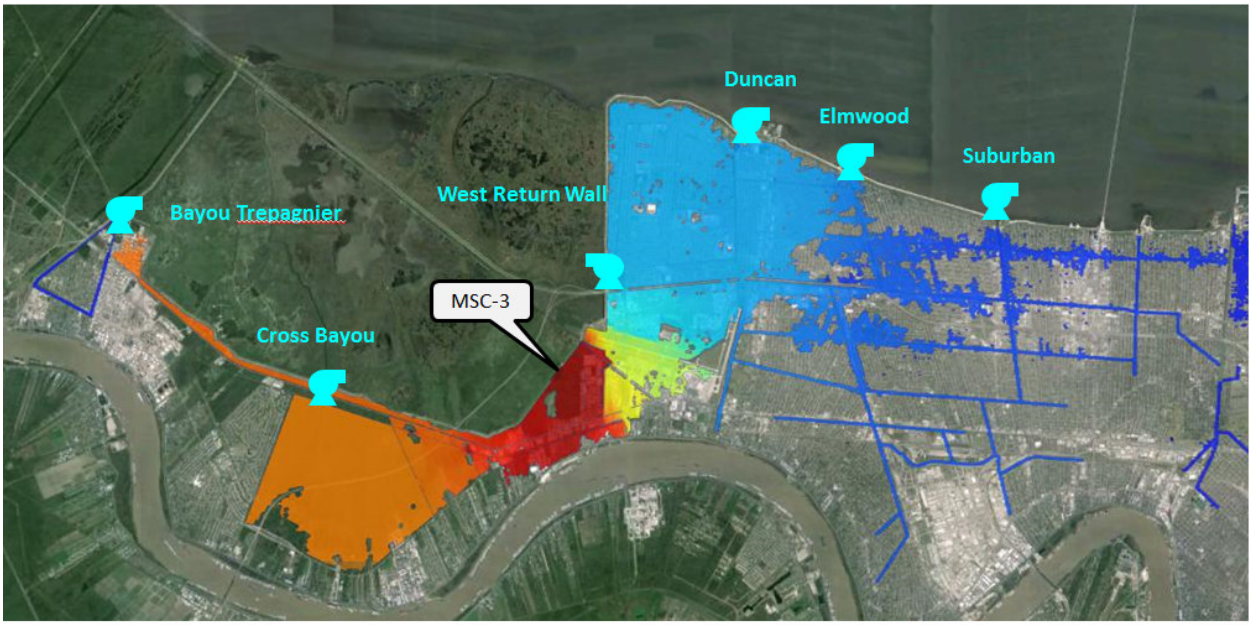
Option 2

Figure 14.5.a reproduces the 30,000 acre-ft St. Rose breach scenario (MSC-3a) previously depicted in Figures 12.1.c. (As discussed in Section 12.1, the current Levee/Floodwall containment in Figure 14.5.a may be slightly under-represented.) A full containment of the breach inundation in St. Charles Parish was simulated with the Metro Polder model (previously described in Section 11). Hourly WSE figures for this simulation are included in Appendix H.7. The resulting MaxWSE is illustrated in Figure 14.5.b and shows that the inundation would reach 11.0 ft NAVD88 along a barrier sufficient to prevent flow into Jefferson Parish.

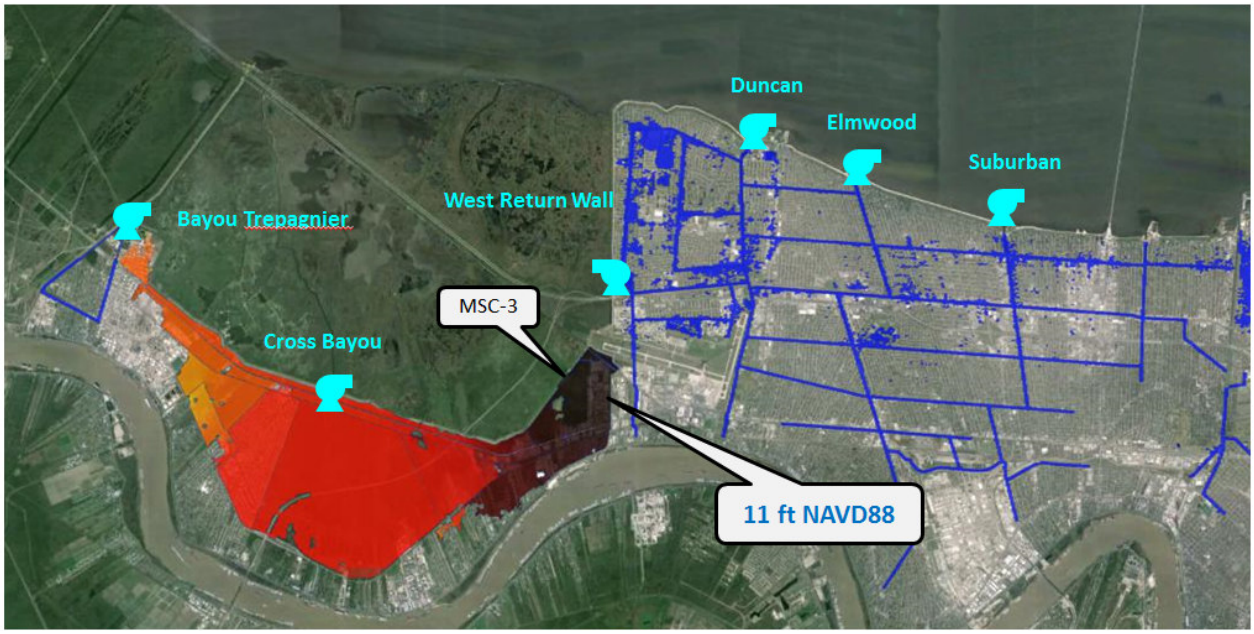
The entire Parish-Line profile shown in Figure 14.2—with the exception of a short section of Floodwall 1—is well below 11.0 ft NAVD88. Using the working assumption that the current Levee/Floodwall has a design SWL of 6.0 ft NAVD88, an effective Class D inundation barrier would need to raise the design limit by five feet. It is unlikely that minor modifications to the current levees and floodwalls could be employed to achieve a Class D inundation barrier.

For purposes of this Report, an Option 1 design requirement can be met with a new T-Walls—with crown elevation of 14.0 ft NAVD88 (providing 3 ft of freeboard)—installed the length of the Parish-Line from the HSDRRS to the Mississippi River, with gates at the CN Railroad (North), Airline Hwy, the KCS & CN Railroad (South), and River Road. (A future Feasibility Study might determine that raised levees or L-Walls could be a cheaper upgrade for some portions of the feature.) Additional right-of-way may be required for the T-Walls south of Airline Hwy, as well as all four gates. The upgrade for Class D inundation would not impose any new drainage impacts beyond those for the minor upgrade of current conditions.

Figure 14.6.a reproduces the more extreme 60,000 acre-ft St. Rose breach scenario (MSC-3b) previously depicted in Figures 12.1.d. A full containment of this larger breach inundation in St. Charles Parish was simulated with the Metro Polder model and hourly snapshots for this simulation are included in Appendix H.7. The resulting MaxWSE is illustrated in Figure 14.6.b and shows that the inundation would reach 13.5 ft NAVD88 along a barrier sufficient to prevent flow into Jefferson Parish. If the Option 1 design provided a 14.0 ft NAVD88 SWL Safe Limit it would limit inundation to wave overtopping.

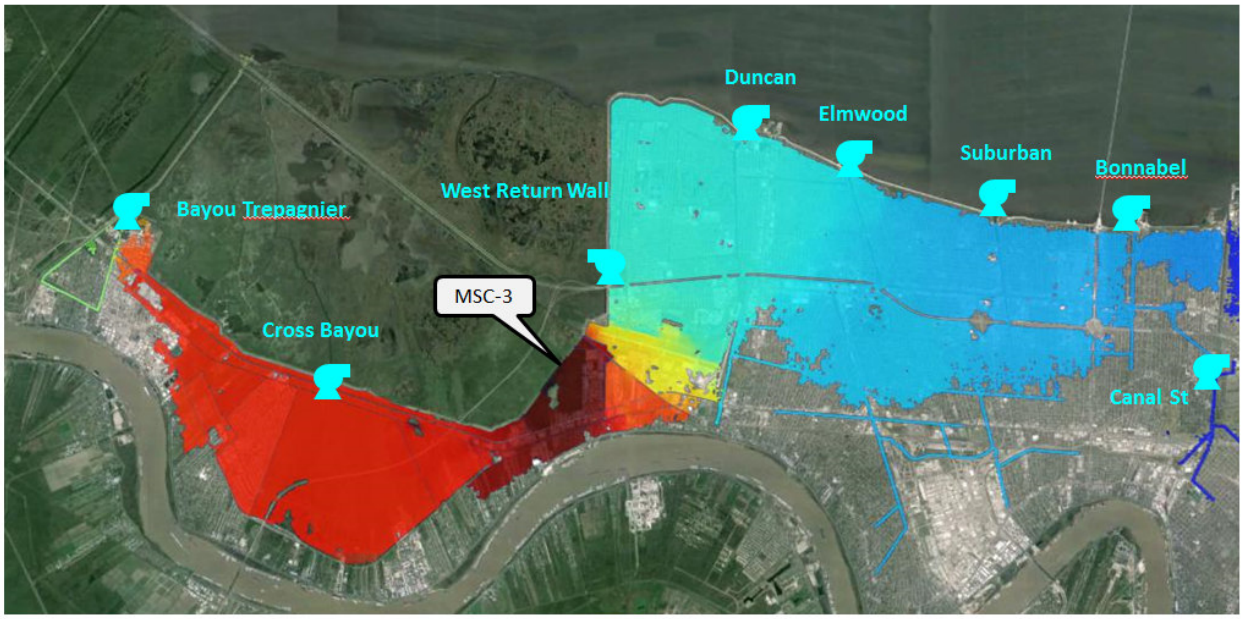


a) Without Levee/Floodwall Upgrade (Reproduction of Figure 12.1.c)

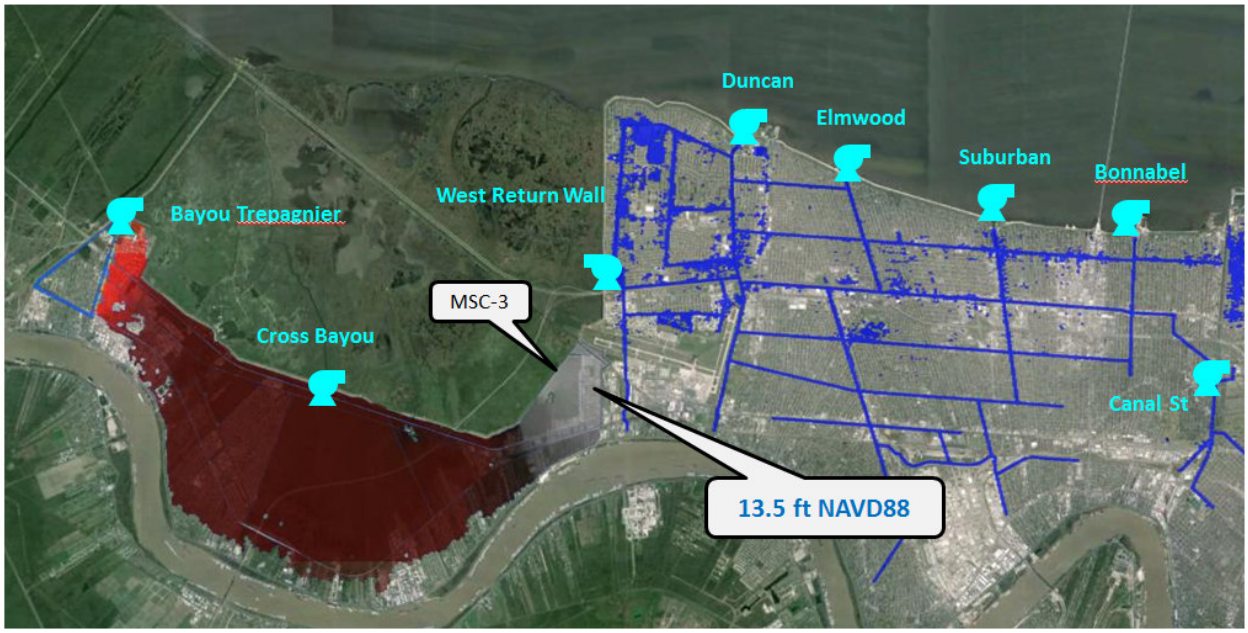


b) With Levee/Floodwall Upgrade

Figure 14.5. MaxWSE for Upgrade of EJ/SC Parish-Line Levee/Floodwall St. Rose Class D Inundation Scenario (30,000 acre-ft)



a) Without Levee/Floodwall Upgrade (Reproduction of Figure 12.1.d)



b) With Levee/Floodwall Upgrade

Figure 14.6. MaxWSE for Upgrade of EJ/SC Parish-Line Levee/Floodwall More Extreme Class D Inundation Scenario (60,000 acre-ft)

14.2. Maxent Levee

Current Condition
As described in Section 7.2, the 4.79-mi Maxent Levee is a key barrier in the NO East Polder, separating the largely developed portion of the polder on the west, from the largely undeveloped portion to the east, which includes the BSNWR. Rainfall drainage channels and storage areas east of the Maxent Levee have higher 100-yr water levels than those west of the Levee and therefore the Maxent Levee is a recognized interior flood barrier. SLFPA-E recently undertook engineering investigations to obtain NFIP accreditation for the Maxent Levee. A final 2015 certification report by Tetra Tech includes a geotechnical engineering analysis and profiles.

The Maxent Levee provides significant surge risk reduction for potential breaching along 21 miles of the HSDRRS east of the Levee—from Lake Pontchartrain to the northern tip of the Michoud Canal on the GIWW. The portion of the HSDRRS that lies outside the Maxent Levee and the IHNC Surge Barrier constitutes over 75 percent of NO East's surge exposure, not including the IHNC Basin.

The Maxent Levee, shown in Figure 14.7, includes two nearly equal length reaches, both of which are comprised entirely of earthen embankments:

- Maxant Reach—a 2.46-mi levee extending from the Michoud Canal (Station 10+00 on the Tetra Tech 2015 profile) to Paris Road (140+10). This levee is crossed by the CSX Railroad, Chef Menteur Hwy, Michoud Blvd, and Lake Forest Blvd. The Maxent Pump Station drains the area west of the Levee and east of Paris Road and discharges across the levee via two buried 42-in steel pipes. An additional buried 54-in corrugated metal pipe is located at the pump station and includes a closure gate.
- Parish Road Reach—a 2.33-mi levee paralleling Paris Road on the east (from 140+10) and terminating at the HSDRRS Lake Pontchartrain floodwall (263+09). This levee is crossed by Interstate 10 between 197+00 and 200+00.

On the undeveloped (flood) side of the Maxent Levee the NFIP 100-yr SWL50 increases south to north:

- -5.0 ft NAVD88 from Michoud Canal to Michoud Boulevard (10+00 to 115+00).
- -4.0 ft NAVD88 from Michoud Boulevard to Interstate 10 (115+00 to 197+00).
- +1.0 ft NAVD88 from Interstate 10 to Lake Pontchartrain HSDRRS (197+00 to 263+09)

The NFIP 100-yr SWL50 is lower south of Interstate 10 due to the presence further east of the BSNWR Levee and forced drainage of the area bounded by the BSNWR and Maxent Levees. The Maxent Levee is certified as both a) having 3 ft of freeboard above these 100-yr SWL50s, and b) providing an adequate ***NFIP*** FOS for a SWL Safe Limit at 3 ft above these 100-yr SWL50.

The crown elevations of the two Maxent Levee reaches are:

- Maxant Reach—above 3.0 ft NAVD88, except near 60+50, 65+00, and 74+50 and a roughly one mile stretch between 90+00 to 140+00 which are above 2.0 ft NAVD88.

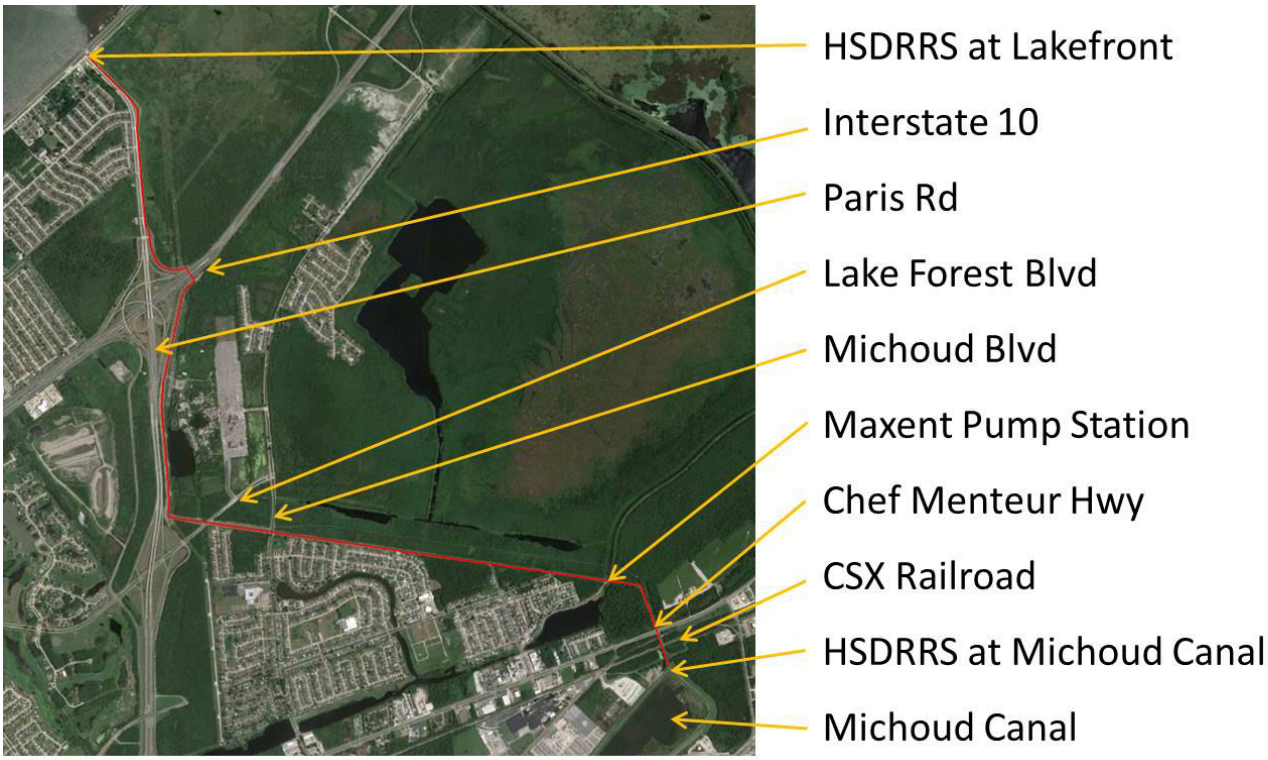


Figure 14.7. Maxent Levee

- Paris Road Reach—the southern portion (to 166+00) is above 3.0 ft NAVD88 except for one point (around 161+50) that is above 2.0 ft NAVD88. North of 166+00 the levee is mostly above 5.0 ft NAVD88, with the exception of a few areas (193+50, 218+00 to 223+00, 244+00, 246+50, 254+00, 260+00) that are only above 4.0 ft NAVD88.

The area east of the Maxent Levee within the HSDRRS encompasses over 19,900 acres. Given this size and the NFIP freeboard—plus potential additional freeboard associated with the higher crown elevations—this area east of the Maxent Levee has the capacity to contain a Class D 30,000-acre-ft inundation from a breach of the HSDRRS. However, an HSDRRS breach along Lake Pontchartrain just east of the Maxent Levee could result in a rapid rise in water levels north of Interstate 10 prior to flood waters equalizing throughout the undeveloped area. A Class D 30,000 acre-ft breach at this location might result in some overtopping at the Maxent Levee north of Interstate 10. Figure 14.8 shows the far northern portion of the Maxent Levee at its intersection with the HSDRRS.

Upgrade to Reduce Surge Inundation Risk
As discussed in Section 13.2 upgrading the Maxent Levee is a priority compartmentalization alternative for reducing inundation risk for the NO East Polder. Two upgrade options have been defined:

Option 0 Install resiliency measures along lower elevation points north of Interstate 10.

Option 1 Improve the Levee north of Interstate 10 and install additional resiliency measures.

Option 0

The baseline Option 0 includes re-analysis of the SWL Safe Limits along the entire Maxent Levee. This re-analysis will determine the SWL Safe Limits under existing conditions—*addressing FOSs suitable for residual surge risk management*. The re-analysis will review the information for the recent NFIP certification—as well as conduct additional geotechnical engineering investigations as needed. The re-analysis will refine Option 0 resiliency measures for the 6,500-ft portion of the Maxent Levee north of Interstate 10. For purposes of this Report, a *working assumption* is that HPTRM will be installed along the protected-side slopes of 1,000 ft of Levee where the crown is below 5.0 ft NAVD88.

The re-analysis will also refine Levee upgrade and resiliency measures for Option 1 and identify further investigations necessary to evaluate these measures. To support the evaluation of improvements and resiliency measures, estimates of flood-side inundation and Maxent Levee overtopping hazards associated with an HSDRRS breach will be developed.

Option 1

Option 1—upgrade the 6,500-ft portion of the Maxent Levee north of Interstate 10—may be modified as a result of the re-analysis. The *working assumption* for Option 1, consistent with the purposes of this Report, is that this stretch of Levee will be improved to provide a crown elevation of 6.0 ft NAVD88 (assumed to provide a SWL Safe Limit of 5.0 ft with a FOS suitable for residual surge risk management)—requiring that about 2,500 ft of levee be raised by 2 feet—and that the entire portion north of Interstate 10 will be armored on the protected side slope with HPTRM.

Figure 14.8. Northern Maxent Levee Near Intersection with HSDRRS

14.3. 40 Arpent/Violet Canal Levee/Floodwall

Current Condition

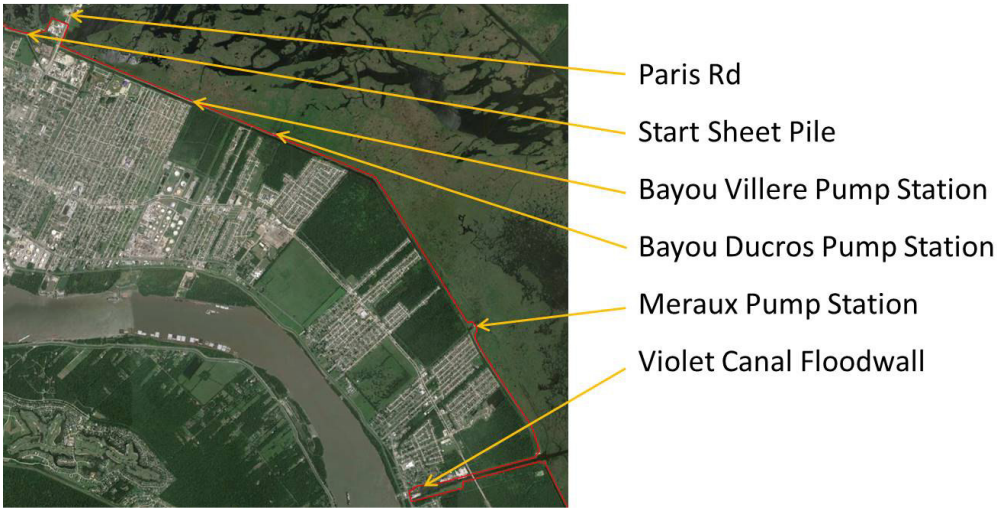
As described in Section 7.3, the 23.17-mi 40 Arpent/Violet Canal Levee/Floodwall comprises a key barrier in the St. Bernard Polder, separating the largely developed portion of the polder on the south, from the Central Wetlands to the north. 100-yr rainfall storage levels in the Central Wetlands—as well as tidally influenced water levels—are higher than those south of the Levee and therefore the 40 Arpent/Violet Canal Levee is a recognized interior flood barrier. SLFPA-E is currently undertaking engineering investigations to obtain NFIP accreditation for the 40 Arpent/Violet Canal Levee. A *draft* 2015 certification report by Tetra Tech includes a geotechnical engineering analysis and profiles.

The 40 Arpent/Violet Canal Levee/Floodwall provides significant surge risk reduction for the St. Bernard Polder. The Levee provides redundant protection from potential breaching along a) 14.5 miles of the HSDRRS from the IHNC Surge Barrier to Verret, or about 64 percent of the HSDRRS outside the IHNC Basin, and b) 7.5 miles of IHNC Basin Levee/Floodwall, or about 85 percent of the St. Bernard's Polder's IHNC Basin exposure. Altogether, the 40 Arpent/Violet Canal Levee/Floodwall provide redundant protection for about 70 percent of the Polder's HSDRRS exposure.

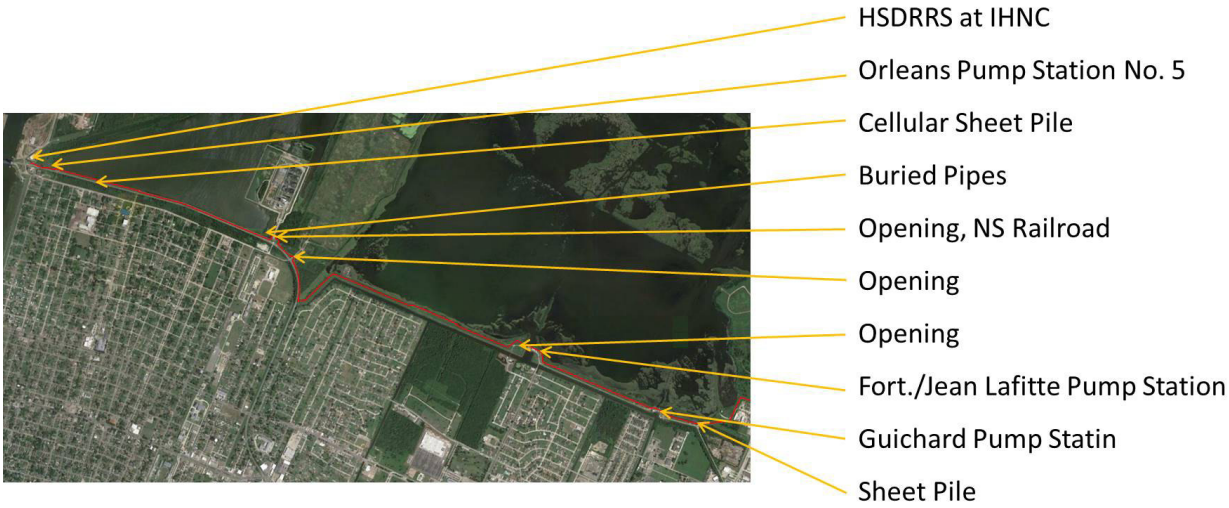
The 40 Arpent/Violet Canal Levee/Floodwall, shown in Figure 14.9, can be considered in three reaches:

- The Lower St. Bernard Reach—a 10.61-mi levee extending from the HSDRRS south of Verret (Station 10+00 on the Tetra Tech 2015 profile) to LA Hwy 46, East St. Bernard Hwy, in Violet (570+00). This portion encircles Lower St. Bernard, including the area along Bayou Rd. This levee has openings at Bayou Rd and LA Hwy 46 at the far eastern end, and at LA Hwy 46 in Violet. The LA Hwy 39 overpasses crosses the levee at Violet Canal. The E J Gore Pump Station discharges across the levee via six buried 42-in steel pipes (409+00).
- The Chalmette-Meraux Reach—a 8.33-mi levee extending from LA Hwy 46 in Violet to about 2,500 ft west of Paris Rd (1009+95). This section includes three segments of sheet pile wall totaling about 600 ft along the north bank of the Violet Canal that are being upgraded for NFIP accreditation. Paris Road crosses over this levee section near the west end (985+00). At the Meraux (716+00), Bayou Ducros (856+00), and Bayou Villere (899+00) Pump Stations the levee is replaced with the pump station concrete head walls.
- The Lower 9th Ward-Arabi Reach—a 4.23-mi sheet pile wall extending from just east of Paris Rd (1009+95) to the IHNC Floodwall (1233+29). The sheet pile wall has breaks at the St. Bernard Guichard (1022+00), and Fortification/Jean Lafitte (1063+00), and Orleans No. 5 (1230+00) pump station concrete head walls. There is an access road opening just west of the Fortification/Jean Lafitte Pump Station at 1070+30 which includes a stoplog closure operated by the LBBLD (see Figure 14.10). The Orleans/St. Bernard Parish-Line is at about station 1145+00. An access road crosses over the sheet pile wall at 1151+00. At 1160+00 there is a crossover road and NS railroad spur to the New Orleans Sewerage and Water Board (NOS&WB) treatment plant located north of the Levee/Floodwall in the Central Wetlands. Four buried 48-in corrugated metal pipes equipped with closure gates are located near 1160+00. A 2,400-ft section (roughly from 1202+00 to 1226+00) is made up of celluar sheet pile.

a. Lower St. Bernard Reach



b. Chalmette-Meraux Reach



c. Lower 9th Ward-Arabi Reach

Figure 14.9. 40 Arpent/Violet Canal Levee/Floodwall

Figure 14.10. Stoplog Closure at Access Road Opening

The NFIP 100-yr SWL50 throughout the whole Central Wetlands outside the 40 Arpent/Violet Canal Levee/Floodwall is 4.0 ft NAVD88. Final engineering investigations are expected to support certifying the Levee/Floodwall as both a) having 3 ft of freeboard above the 100-yr SWL50, and b) providing an adequate ***NFIP*** FOS for a SWL Safe Limit at 3 ft above the 100-yr SWL50, i.e. at 7.0 ft NAVD88.
The crown elevations of the three 40 Arpent/Violet Canal Levee reaches are:

- The Lower St. Bernard Reach—generally above 10.0 ft NAVD88 to station 90+00 except for openings at Bayou Rd (about 5.0 ft NAVD88) and La Hwy 46 (about 7.0 ft NAVD88). The LBBLD installs sand and HESCO bags on Bayou Rd if overtopping is threatened. The remainder of the levee to Violet is generally above 9.0 ft NAVD88. LA Hwy 46 in Violet dips to just below 7.0 ft.
- The Chalmette-Meraux Reach—generally above 9.0 ft NAVD88. The section along the north bank of the Violet Canal is currently being addressed as part of the NFIP certification. About 150 feet dips below 8.0 ft NAVD88 near 902+00
- The Lower 9th Ward-Arabi Reach—from the eastern end at 1009+95 to the access road opening near 1151+00 the 2.65-mi floodwall crown varies between 11.0 and 14.0 ft. West of this point, the remaining 1.58 mi (from 1151+00 to 1233+29) sheet pile crown varies between 9.0 and 13.0 ft NAVD88. Ground elevations adjacent to the sheet piles are generally above 5.0 ft NAVD88. The ground elevation at the 1070+30 opening equipped with the stoplog closure (Figure 14.10) is 5.5 ft NAVD88. An approximately 1,100 ft section (1085+00 to 1096+00) is at close to 4.0 ft NAVD88. The ground elevation at the NOS&WB crossover road is 9.0 ft NAVD88, while the spur opening equipped with the gate is 2.0 ft NAVD88. The 2,400 ft of cellular sheet piles have crown, adjacent exterior ground, and interior soil elevations of 11.5 to 12.5 ft, 0.0 to 2.0 ft, and 4.0 to 6.0 ft NAVD88, respectively.

The Central Wetlands area outside the 40 Arpent/Violet Canal Levee encompasses over 29,400 acres, including 24,300 acres east of Paris Road. Given this size and the NFIP freeboard—plus potential additional freeboard associated with the higher crown elevations—the Central Wetlands has ample capacity to contain a Class D 30,000-acre-ft inundation from a breach of the HSDRRS, including a breach outside the IHNC Surge Barrier entering the Central Wetlands east of Parish Road.

Upgrade to Reduce Surge Inundation Risk
As discussed in Section 13.3 upgrading the 40 Arpent/Violet Canal Levee/Floodwall is a priority compartmentalization alternative for further reducing inundation risk for the St. Bernard Polder. Two upgrade options have been defined:

Option 0 Improve temporary barriers at openings to 7.0 ft NAVD88.

Option 1 Improve a few segments to raise SWL Safe Limit to 8.0 ft NAVD88, and install additional resiliency measures as indicated in the re-analysis.

Option 0
The baseline Option 0 includes a re-analysis of the SWL Safe Limits along the entire 40 Arpent/Violet Canal Levee/Floodwall Levee. This re-analysis will determine the SWL Safe Limits under existing conditions—*addressing FOSs suitable for residual surge risk management*. The re-analysis will review the information for the NFIP certification—as well as conduct additional geotechnical engineering investigations as needed.

The Option 0 re-analysis will define improvements to the two LBBLD temporary barriers consistent with the SWL Safe Limit and *residual surge risk management*. For purposes of this Report, a working assumption is that the temporary barriers will have a SWL Safe Limit of 7.0 ft NAVD88. For temporary barriers LBBLD currently relies on sand and HESCO bags at Bayou Rd and the stoplog closure for the access road just west of the Fortification/Jean Lafitte Pump Station. For purposes of this Report, Option 0 includes the operational upgrade to use of HESCO Bags for the full Bayou Rd closure, as well as for a new closure at LA Hwy 46 in Violet. As an alternative to HESCO bags, erectable flood barriers—as discussed in Section 14.1 Option 0 and shown in Figure 14.4—can be considered.

The re-analysis will also refine 40 Arpent/Violet Canal Levee/Floodwall upgrade and resiliency elements for Option 1 and identify further investigations necessary to evaluate these elements. To support the evaluation of improvements and resiliency measures, estimates of HSDRRS breach and Central Wetlands inundation hazard, and Levee/Floodwall overtopping hazard and will be re-examined in greater detail.

Option 1
Option 1—improve sections to provide a higher SWL Safe Limit and install resiliency measures—will be defined in the re-analysis. The *working assumption* for Option 1 is that the entire Levee/Floodwall will be upgraded to provide a SWL Safe Limit of 8.0 ft with a suitable FOS for residual surge risk management. For the purposes of this Report, to achieve this it is further assumed that

- The 150-ft portion near 902+00 that dips below 8.0 ft NAVD88 will be raised to 9.0 ft NAVD88.
- 3,500 ft (one-third) of sheet pile wall will require upgrading— improvement of the protected-side embankments and construction of buttresses. (The re-analysis will determine if deep soil mixing is also needed; the working assumption is that no deep soil mixing will be required.)
- HPTRM will be installed on the protected-side of the 5,200 feet of levee most vulnerable to erosion from wave overtopping (e.g., due to lower crown, steeper/longer slopes, difficulty in turf maintenance, etc.).

14.4. IHNC Basin Levee/Floodwall

Current Condition

The construction of the current IHNC Basin Levee/Floodwall configuration dates to the post-Hurricane Betsy (1965) surge protection project with elements undergoing improvements all through the 1970s, 80s, and 90s. IHNC Basin perimeter surge protection features are part of the USACE NFIP HSDRRS. The USACE's post-Katrina repairs and final HSDRRS construction have included geotechnical engineering investigations throughout the perimeter and several upgrades, such as:

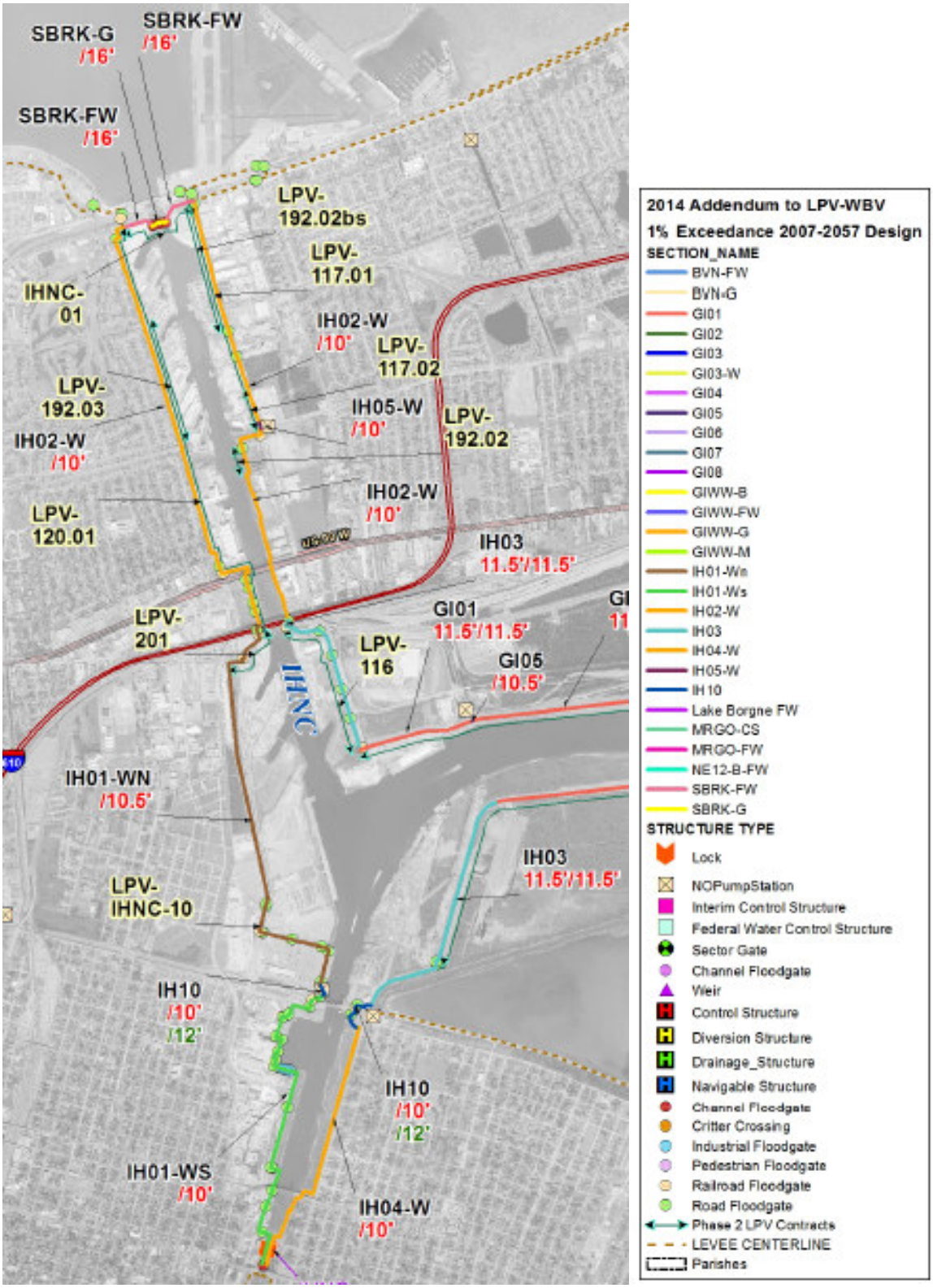
- About 12,000 ft of L- and T-Wall upgrades.
- Paving of the protected-side embankment along a 6,000-ft of west-bank I-Wall south of I-10.
- Deep-soil mixing along 1,800-ft of IHNC west-bank I-Wall south of Seabrook.
- Installation of relief wells along 5,000-ft of IHNC east-bank I-Wall south of Seabrook.
- Reconstruction of some levee segments with better clay material.

The 28.7 mile perimeter, excluding the IHNC and Seabrook Surge Barriers, is broken down into 16 design segments. Figure 14.11 shows the 16 segments of the IHNC Basin Levee/Floodwall—as presented by the USACE in the most recent HSDRRS design (December 2014 *DER*). Table 14.3 lists these segments further broken down into 36 reaches by polder designated. The Metro, NO East, and St. Bernard Polders include 6, 19, and 11 reaches with 5.67, 14.04, and 8.96 miles, respectively:

- The Metro portion stretches along the west-bank of IHNC from the IHNC Lock to the Seabrook Surge Barrier and is largely comprised of floodwalls. About 3,400 ft near Pump Station 19 north of Florida Avenue was upgraded to L-Wall following Hurricane Katrina. The Metro portion includes gates for the CXS (to NO East) and NS (to St. Bernard) Railroads, three railroad spur gates (New Orleans Public Belt), plus close to 30 road gates.
- The NOE portion includes 2.75 and 11.29 miles along the IHNC east-bank and GIWW north-bank, with 4 and 15 reaches, respectively. The IHNC and GIWW portions have 3 and 9 floodwalls at 1.96 and 5.71 miles. About 2,800 ft of floodwall near the Elaine Pump Station along the GIWW is L-Wall. The IHNC portion includes a CSX gate, one spur gate, and 9 road gates, while the GIWW portion includes one spur gate (at the far west end) and about 20 road gates.
- The St. Bernard portion includes 2.61 and 6.35 miles along the IHNC east-bank and GIWW south-bank, with 4 and 7 reaches, respectively. The IHNC and GIWW portions both have 3 floodwalls at 1.47 and 0.37 miles. Approximately 4,300 ft of the IHNC floodwall south of Pump Station No. 5 has been upgraded to T-Wall. About 400 ft at the Bayou Bienvenue Gate was also upgraded to T-Wall. The IHNC portion includes the NS railroad gate and three road gates, while the GIWW portion includes two road gates.

The USACE 2014 *DER* specified minimum hydraulic design elevations for each reach based on limiting the 100-yr Q50 and Q90 to 0.01 and 0.1 cfs/ft. The estimated Q50 and Q90 are in turn based on the USACE 2014 *DER* estimated *interior* 100-yr SWL50s of 6.3 and 6.6 ft NAVD88 for the 2007 and 2057 design cases,[3] a 100-yr SWLσ of 0.8 ft, and interior waves—which are larger for reaches facing a longer fetch. The USACE 2014 *DER* estimated interior 2007 and 2057 500-yr SWL50s at 7.5 and 8.9 ft NAVD88.

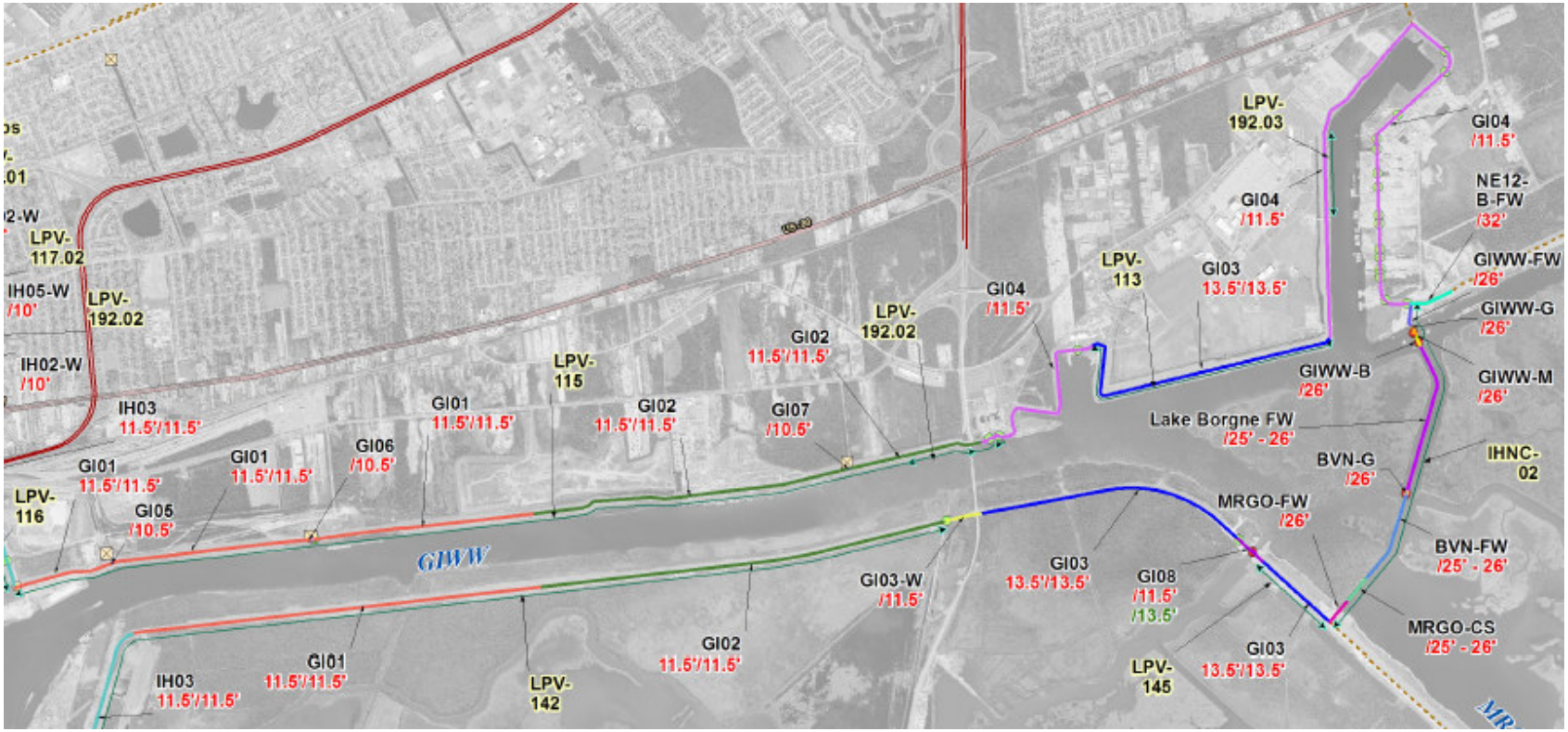
[3] The USACE's October 2013 *Master Water Control Manual for the IHNC Basin* used an earlier, preliminary estimate of the Basin 2057 100-yr SWL at 7.8 ft NAVD88.



a. Along the IHNC

Figure 14.11. Major Elements of the IHNC Basin Levee/Floodwall

USACE 2014



b. Along the GIWW

Figure 14.11. Major Elements of the IHNC Basin Levee/Floodwall, Cont'd

USACE 2014

(LPV designations represent specific HSDRRS projects.)

Table 14.3. IHNC Basin Levee/Floodwall Reach Information

Reach	Description	Primary Type[4]	Length ft[5]	Elevation ft NAVD88	
				2014 DER	Existing Crown[6]
Metro Polder (Seabrook Barrier to Lock)					
IH01-WS	IHNC South of I-10	I-Wall	8,328	10.0	12.1 – 12.8
		L-Wall	200	10.0	12.0
IH10	Orleans PS#5 to PS#19	I-Wall	363	12.0	12.1
IH01-WN	IHNC South of I-10	L-Wall	4,000	10.5	12.0 – 14.8[7]
		I-Wall	6,266	10.5	12.4 – 14.9
IH02-W	IHNC North of I-10	I-Wall	10,794	10.0	11.8 – 13.1
NO East Polder (Seabrook Barrier to IHNC Barrier)					
IH02-W	IHNC North of I-10	I-Wall	5,061	10.0	10.9 – 12.5
IH05-W	Dwyer Pump Station	I-Wall	200	10.0	12.6
IH02-W	IHNC North of I-10	I-Wall	5,105	10.0	12.6 – 13.3
IH03	IHNC Levee South from I-10	Levee	4,138	11.5	13.1 – 14.8
GI01	Levee Section GI02 to IHNC	Levee	2,644	11.5	12.0 – 14.4
GI05	Amid Pump Station (PS#20)	I-Wall	52	10.5	13.6
GI01	Section GI02 to IHNC	I-Wall	1,400	11.5	13.6
		Levee	3,103	11.5	12.7 – 14.0
		I-Wall	300	11.5	NA
		L-Wall	500	11.5	14.5
GI06	Elaine Pump Station	I-Wall	133	10.5	12.9
GI01	Section GI02 to IHNC	L-Wall	2,300	11.5	14.3 – 14.5
		Levee	3,572	11.5	14.4 – 14.6
GI02	Paris Road to levee section GI02	Levee	8,584	11.5	13.8 – 15.0
GI07	Grant Pump Station	I-Wall	23	10.5	13.3
GI02	Paris Road to levee section GI02	Levee	3,572	11.5	14.0 – 15.7
GI04	Michoud Canal and Slip	I-Wall	5,475	11.5	16.0 – 16.8
GI03	Michoud Canal to Michoud Slip	Levee	7,999	13.5	18.9 – 19.7
GI04	Michoud Canal and Slip	I-Wall	19,952	11.5	17.0 – 20.3
St. Bernard Polder (Lock to IHNC Barrier)					
IH04-W	IHNC Lock to Pump Station (PS5)	I-Wall	2,410	10.0	12.2 – 13.0
		T-Wall	4,300	10.0	14.7– 14.8
IH10	Orleans PS5 to PS19	I-Wall	1,063	12.0	10.0 – 12.6
IH03	IHNC Levee South from I-10	Levee	5,994	11.5	14.3 – 14.8
GI01	Levee Section GI02 to IHNC	Levee	10,998	11.5	14.0 – 15.0
GI02	Paris Road to levee section GI02	Levee	10,883	11.5	14.4 – 15.7
GI03-W	Floodwall under Paris Rd Bridge	I-Wall	1,004	11.5	12.0
GI03	Michoud Canal to Michoud Slip	Levee	7,285	13.5	16.9 – 17.8
GI08	Bienvenue Floodgate	T-Wall	400	13.5	16.9
		I-Wall	527	13.5	15.2 – 18.3
GI03	Michoud Canal to Michoud Slip	Levee	2,426	13.5	18.3 – 18.5

[4] The predominant structure type was estimated from profiles (see USACE 2013).

[5] Segment length taken from USACE spreadsheet listing hydraulic reaches.

[6] Based on survey data provided by CPRA, Stanley Consultants 2013.

[7] SLFPA-E (2010) shows a 500-ft portion of the IH01-WN L-Wall just north of Pump Station No. 19—bounded by two CPRA survey points both at 12.1 ft NAVD88—dips below 12 ft NAVD88, to as low as 11.4 ft NAVD88.

The Basin surge SWL reflects a combination of six conditions (USACE, *IHNC Basin Systems Analysis* 2013):

1. The Basin SWL following closure of the surge barriers, which has been assumed for the 100-yr Basin event to be at 3 ft NAVD88 but could vary.
2. The volume of direct rainfall into the Basin. For a 100-yr Basin event this was assumed to be a 10-yr, 24-hr rainfall, at nearly 9 in.
3. The volume of discharge into the Basin from six pump stations. For a 100-yr Basin event this was assumed to be 10-yr, 24-hr regional rainfall, producing nearly 5,140 acre-ft of discharge into the IHNC Basin.
4. Overtopping volume along the Seabrook Barrier. The Seabrook Barrier—consistent with the other HSDRRS floodwalls—was designed for negligible overtopping, according to NFIP overtopping analysis for *2057* Q50 and Q90 (targeted at less than 0.01 and 0.1 cfs, respectively). Thus the 2007 100-yr Q50 and Q90 and associated overtopping volumes are negligible under the NFIP overtopping analysis.
5. Overtopping volume along the IHNC Barrier. Unlike the Seabrook Barrier, the IHNC Barrier was not designed to keep 100-yr Q50 and Q90 below overtopping limits but rather to allow some overtopping consistent with the storage capacity of the Basin. The USACE's NFIP overtopping analysis estimated that 100-yr overtopping volumes (based on Q50 and Q90) are minor.
6. Interior wind setup.

The USACE estimated the 2007 Basin 100-yr SWL50 at 6.3 ft NAVD88 using a combination of Nos. 1, 2, and 3—which equals 5.8 ft NAVD88 according to Basin stage-storage curves—and an additional 0.5 ft for Nos. 4, 5, and 6. A more rigorous estimate of extreme Basin SWL hazard levels and their uncertainties actually requires a complex joint probability analysis encompassing all six independent factors.

Table 14.3 lists the USACE 2014 *DER* minimum hydraulic design elevations for each Basin reach. Floodwall design elevations are based on 2057 100-yr conditions. The 2014 *DER* design elevations range from 10.0 ft in the IHNC to 13.5 at the east end of the GIWW.

Table 14.3 also provides existing crown elevation of each reach based on a limited survey conducted by CPRA (Stanley Consultants January 2013). The CPRA survey did not address the elevation of the various railroad and road gates in the IHNC Basin. The survey included 232 crown locations—42, 122, and 68 in the respective polders. The CPRA survey points show:

- All 12 levee reaches, both T-Wall reaches, and the two L-Wall reaches on the GIWW are above 14 ft NAVD88 with the exception of a few isolated points, which are above 12 ft NAVD88. These reaches are all above their respective 2014 *DER* HSDRRS design elevation.
- All 18 I-Wall reaches, and the two L-Wall reaches on the IHNC west-bank, exceed elevation 11.5 ft NAVD88—except for three localized points:
  - A 150-ft portion of the new IH01-WN L-Wall north of Pump Station No. 19 dips to as low as 11.4 ft NAVD88. This location is above the USACE 2014 *DER* design elevation of 10.5 ft.
  - The very northern point of NOE reach IH02-W at the intersection with the Lakefront floodwall, at the road gate, dips to 10.9 ft NAVD88. This location is above the USACE 2014 *DER* design elevation of 10.0 ft.
  - The corner of the IH10 floodwall just north of the NS Railroad gate in the St. Bernard polder dips to 10.0 ft NAVD88. This location is *below* the 2014 *DER* design elevation of 12.0 ft

> NAVD88. (The CPRA survey showed that the west-bank IH10 I-Wall in the Metro Polder—on the other side of the IHNC from the IH10 reach in the St. Bernard polder—is barely above the design elevation of 12.0 ft NAVD88.)

Partially Revised Estimates for IHNC Basin 100- and 500-yr SWL

It is important to recognize that the USACE IHNC Basin 100- and 500-yr SWL50 and SWLσ estimates rely on approaches suitable for the ***NFIP***. As discussed in the Supplement, *Hurricane Surge Hazard Primer,* these estimates should be redone for purposes of comprehensive surge risk management. Part I (Section 4.3) described the *partial* revision of HSDRRS NFIP overtopping to address several priority issues (see Appendix C). Comprehensive risk management also dictates that estimates should be further updated in the near future to address other outdated elements (see Section 2.2).

Appendix I, Evaluation of Two IHNB Basin Hydrology Issues, includes a re-examination of Seabrook and IHNC Surge Barrier overtopping rates similar to the partial revision of the 20 HSDRRS levee overtopping rates discussed in Section 4.3—incorporating increases to exterior 100- and 500-yr SWL50 (per correction of a USACE FORTRAN code) and SWLσ (using a reasonably conservative approach to all uncertainties), plus the IHNC and Seabrook Surge Barrier overtopping rates, Q50 and Q90. Based on this examination, *partially revised IHNC SWL hazards for comprehensive risk management purposes are*:

- A 2057 100-yr SWL50 of 8.0 ft NAVD88, rather than the 2014 *DER* value of 6.6 ft NAVD88.
- A 2057 100-yr SWLσ of 2.0 ft (consistent with a SWLσ of 25 percent), rather than the 2014 *DER* value of 0.8 ft. A 2057 100-yr SWL90 is then 10.6 ft NAVD88, rounded to 11.0 ft NAVD88.
- A 2057 500-yr SWL50 of 11.0 ft NAVD88, rather than the 2014 *DER* value of 8.9 ft NAVD.

As most IHNC Basin Levee/Floodwall reach crowns are well above the 2014 *DER* elevation design, the increases in the 2057 100-yr Q50 associated with partially revised 2057 100-yr SWL50 and SWLσ are not as drastic as for the 20 levee locations reviewed in Section 4.2. For example, a 12.0 ft NAVD88 floodwall and H_S at 30 percent of the 8ft SWL50, the Q50 is still below 0.01 cfs/ft design criteria. However, the Q90 exceeds the 0.1 cfs/ft criteria (FOS) by a multiple of two. Increases in 500-yr SWL50 and SWLσ result in high 500-yr Q50 and Q90, on the order of 0.5 and 10 cfs/ft.

IHNC Basin SWL Safe Limit Without Major Impacts to I-Walls

As part of preparing the *Master Water Control Manual for the IHNC Basin* (October 2013) the USACE analyzed the IHNC Basin SWL Safe Limits, including waves and debris loading. The *Manual* states:

> The I-walls were analyzed and found to be stable at the 100-yr still water elevation of 7.8 ft. The loading included a *debris* loading." (Note the 2014 *DER* revised the 100-yr SWL to 6.3 and 6.6 ft NAVD88 for 2007 and 2057.)

Note that debris loading does not include major impacts from barges and large vessels and floating structures. The *Manual* also states:

> The basin is designed to contain water up to an elevation of 8 ft. . . . floodwalls can hold water to the top of wall, but overtopping due to wind and waves may start to occur as the water surface exceeds 8 ft.

These two statements taken together indicate that ***for NFIP purposes*** the existing IHNC Basin Levee/Floodwall can be considered to have ***two SWL Safe Limits***:

A. For waves and debris—a SWL of 8.0 ft NAVD88—which is equivalent to the partially revised 2057 100-yr SWL50.
B. For waves but without debris—a SWL of 11.0 ft NAVD88—which is equivalent to the partially revised 2057 100-yr SWL90 and 500-yr SWL50—with the exception of the two localized points noted previously at 10.9 and 10.0 ft NAVD88. Safe Limit B may actually require minor improvements at these two locations. As both locations appear to be very isolated, upgrading erosion protection from overtopping could be considered.

The IHNC Basin NFIP Safe Limits A and B are primarily controlled by I-Walls conditions. A key factor is the elevation for the embankment crown relative the wall crown (i.e., the exposed wall heights for a given SWL) and/or at the embankment toe, including the presence of drainage ditches. The 2013 USACE profiles show that four of the 18 I-Wall reaches—all along the IHNC and three in the Metro Polder—have significant portions with the adjacent ground below elevation below 5.0 Ft NAVD88:

- IH01-WS (Metro Polder), north of Claiborne Avenue, 4,000 out of 8,328 ft; 2,400 is continuously below 3 ft NAVD88 but above 0 ft NAVD88. A typical location is shown in Figure 14.12.
- IH10 (Metro Polder), at Pump Station No. 19, nearly all of the 363 ft (above 3 ft NAVD88).
- IH02-W (Metro Polder), IHNC North of I-10, a short 700 ft segment (above 3 ft NAVD88).
- IH10 (St. Bernard Polder), at Pump Station No. 5, about 300 ft (a portion is below 0 ft NAVD88).

Figure 14.12. IH01-WS I-Wall, Metro Polder North of Claiborne Avenue
(at North Galvez Street; I-Wall crown is at 12.3 ft NAVD88; man is about 6 ft tall; note the ditch)

In addition, there are segments such as IH02-W with elevations at the toe of the I-Wall embankment several feet below 0 ft NAVD88.

In addition to ground elevation, I-Wall SWL Safe Limits are affected by weaknesses in the adjacent and nearby subsurface foundation supporting the wall—such as low strength soils, seepage layers, slippage planes, voids, buried pipelines and ditches, etc.—and insufficiently deep sheet piles or weaknesses in the sheet piles themselves.

Presumably the analysis referenced in the first *Manual* statement includes reach-specific, detailed geotechnical engineering investigations, including analyses associated with recent improvements.[8] Such analyses would typically entail extensive subsurface investigations and examine a variety of potential failure mechanisms, including those seen during Hurricane Katrina. The analyses presumably evaluated additional impacts from floating debris in order to support SWL Safe Limit A. The analyses also presumably addressed a FOS for NFIP purposes—*which would not be sufficient for residual risk management*. A review of the USACE's geotechnical engineering analyses for the various IHNC Basin perimeter components (I-, L-, and T-Walls, levees, gates, and the IHNC Lock) and the reach-by-reach SWL Safe Limits with and without debris, as well as the FOS, is beyond the scope of this Report.

<u>IHNC Basin SWL Safe Limit With Major Impacts to I-Walls</u>

The USACE, *Hurricane and Storm Damage Reduction System Design Guidelines*, June 2012 recommend the use of T-Walls and L-Walls where there is the potential for major impact loading from barges or large vessels. With regard to SWL Safe Limits for I-Walls the *Guidelines* states:

> Typically, I-walls shall not be used on navigable waterways or where there is the potential for barge/boat impact loading unless measures . . . are taken to protect the wall.

Suitable measures include foreshore barriers such as permanent grounding berms, walls, pile fender systems, pile clusters, etc., and some temporary barriers that are rated to withstand major impacts. Some portions of IHNC Basin I-Wall reaches do have foreshore berms, pilings, and walls that may serve as impact barriers. However, there is no comprehensive barrier network for the IHNC Basin I-Walls and the partial barriers have not been evaluated for impact loading. Therefore, the USACE's HSDRRS NFIP accreditation document, the *LSER,* indicates that ***the I-Walls do <u>not</u> have a SWL Safe Limit for major impact*** and that operations with the Basin are managed to reduce the risk of such impacts ***sufficient for NFIP purposes***. Section 15.7.1 states:

> Floodwalls within the GIWW-IHNC Corridor largely consist of I-walls. System planning and design rely upon barge evacuation as part of contingency operations during a hurricane event. Responsibility for planning and actions is shared at the federal, state and local levels with overall command and control residing with the United States Coast Guard. Successful operations are dependent upon actions taken by individual vessel operators or owners in accordance with requirements specified in the Code of Federal Regulations and USCG's Operational Contingency Plan. The Captain of the Port, USCG possesses broad authorities to take emergency actions should they be necessary to secure or sink barges under emergency conditions to negate the potential for catastrophic failure. . . . Risk reduction is maximized through evacuation of the GIWW-IHNC.

Section 15.7.2 goes on to state:

[8] During 2008 Hurricane Gustav the IHNC Basin SWL approached some I-Wall crowns (see Figure 3.7). This was prior to some I-Wall improvements and HESCO bags were used to reinforce the stability of some I-Wall reaches, as shown in Figure 3.8. While the physical evidence of Hurricane Gustav suggests that reinforced Basin I-Walls could be stable for a SWL of 11.0 ft NAVD88, subsoils may have weakened and SWL Safe Limits can only be determined by detailed geotechnical engineering investigations.

Business facilities located within the IHNC corridor typically conduct operations within the corridor. Objects such as boats, tanks, drydocks and recreational trailers could float and become wind driven. As water elevation rises within the closed system, there exist potential for such floating objects to impact the I-walls. Historically, there are no recorded instances where these types of items have seriously damaged a floodwall. However, risk reduction could be substantially improved through improvements in the permitting and enforcement process and designation of a responsible entity for hurricane planning, operations and emergency actions.

Upgrade to Reduce Surge Inundation Risk
As discussed in Section 13.4 upgrading the IHNC Basin Levee/Floodwall is a priority compartmentalization alternative for reducing Class D inundation risk to all three polders. Given the partially revised 2057 100-yr SWL50 (8.0 ft NAVD88) and SWL90/500-yr SWL50 (11.0 ft NAVD88) and existing SWL Safe Limits, three upgrade options have been defined.

Option 0 Implement resiliency measures to improve I-Wall SWL Safe Limits and FOSs.

Option 1 Upgrade the IHNC Basin Levee/Floodwall for major impact loading at 8.0 ft NAVD88.

Option 2 Upgrade the IHNC Basin Levee/Floodwall for major impact loading at 11.0 ft NAVD88.

<u>Option 0</u>
Option 0 is a baseline option and includes a re-analysis of the SWL Safe Limits along the entire Levee/Floodwall. This re-analysis will determine all three SWL Safe Limits—with waves, plus debris loading, and plus major impact loading—under existing conditions at all 36 reaches *addressing FOSs suitable for residual surge risk management*. The re-analysis will review available USACE post-Katrina geotechnical investigations, design, and construction information for all Levee/Floodwall reaches—including the foreshore structures—and will conduct additional geotechnical engineering investigations as needed. The re-analysis will refine potential additional upgrade options and identify further investigations necessary to evaluate those options.

For the purposes of this Report, the *working assumption* is that the re-analysis will show that all 12 levee (13.48 mi) reaches, the six L/T-Wall (2.06 mi) reaches, and the three I-Wall reaches east of Paris Rd (Michoud Slip, Michoud Canal, and Bayou Bienvenue, 4.92 miles) have an acceptable FOS with no need for an Option 0 upgrade. The re-analysis will define Option 0 I-Wall stability and/or foreshore structure improvements to raise SWL Safe Limits. I-wall improvements include three measures (see Figure 14.13), with associated *working assumptions* for the upgrade scope:

- I-Wall foundation improvements—10,000 ft deep soil mixing, (approximately 23 percent of the I-Wall west of Paris Rd).
- Enlargement, strengthening, and paving of I-Wall embankments and embankment toe ground conditions, over 22,000 ft (approximately half the I-Wall west of Paris Rd), or.
- The addition of buttresses (counterforts).

I-Wall strength and stability are an essential part of HSDRRS resiliency. Thus, Option 0 (Baseline) upgrades may be suited for the USACE- Resiliency Program.

In addition to resiliency measures, Option 0 will address the IH10 east-bank I-Wall location at 10.0 ft NAVD88, two feet below the USACE 1014 *DER* design elevation.

a. Buttresses (Counterforts)

b. Embankment Enlargement and Paving

Figure 14.13. I-Wall Improvements

<u>Option 1</u>

Option 1—upgrade the IHNC Basin Levee/Floodwall for major impact loading at 8.0 ft NAVD88—may be modified as a result of the re-analysis of IHNC Basin SWL Safe Limits. The following are *working assumptions* for basic approaches to upgrade Option 1, consistent with the purposes of this Report:

- All 12 levee (13.48 mi) reaches, the six L/T-Wall (2.06 mi) reaches, and the three I-Wall reaches east of Paris Rd (Michoud Slip, Michoud Canal, and Bayou Bienvenue, 4.92 miles) are assumed to have an acceptable FOS with no need for further upgrade. (Detailed investigations may show that some segments require flood-side impact barriers or other upgrades.)

- The remaining 15 I-Wall reaches (8.2 mi) will be upgraded to L-Walls with kicker piles plus buttresses (counterforts). Detailed investigations may show that some reaches require no or minimal upgrade, only an upgrade of foreshore barriers, or some additional foundation improvements such as grout injection and/or deep soil mixing. Other reaches may require total replacement with T-Walls. Construction access and other issues for some segments could dictate the use of impact barriers in place of I-Wall upgrade.
- The flood-side of the nine railroad and 29 road gates will be equipped to allow placement of temporary barriers. Detailed investigations may show that some gates do not require flood-side impact barriers, or that complete replacement of the existing gate and adjacent floodwall is more appropriate for some gates.

Further planning for Option 1 would involve finalizing the reach-by-reach design approach; right-of-way, construction access, and relocation requirements; and O&M requirements.

<u>Option 2</u>
Option 2—upgrade the IHNC Basin Levee/Floodwall for major impact loading at 11.0 ft NAVD88—may be modified as a result of the re-analysis of IHNC Basin SWL Safe Limits. The following are *working assumptions* for basic approaches to upgrade Option 2, consistent with the purposes of this Report:

- Most of the 12 levee (13.48 mi) and six L/T-Wall (2.06 mi) reaches are assumed to have an acceptable FOS with no need for further upgrade. However, a contingency is included the installation of a parallel impact barrier for three miles.
- All 18 I-Wall reaches (13.12 mi) will be upgrade to T-Wall. (Detailed investigations may show that some reaches can be cost-effectively addressed with other approaches, such as upgrade to L-Wall with buttresses; foundation improvements—e.g., grout injection and/or deep soil mixing; use of impact barriers; etc.)
- The flood-side of the nine railroad and 29 road gates will be equipped to allow placement of temporary barriers. (Detailed investigations may show that some gates do not require flood-side impact barriers, or that complete replacement of the existing gate and adjacent floodwall is more appropriate for some gates.)

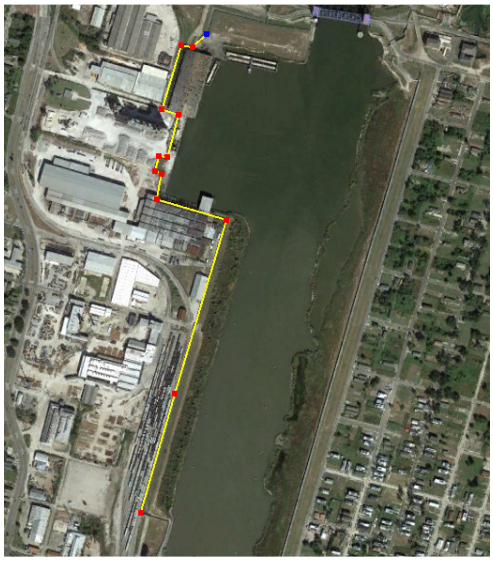
Further planning for Option 2 would involve finalizing the reach-by-reach design approach; right-of-way, construction access, and relocation requirements; and O&M requirements

IHNC Basin Levee/Floodwall improvements under Options 0, 1, and 2 are assumed to not modify the current drainage. If further studies show the need to relocate an I-Wall reach, then the potential drainage impacts will need to be evaluated.

Many portions of the current I-Wall lie in close proximity to existing buildings, overhead power lines, pipelines, pipe racks, and bridges. I-Wall improvements under Options 0, 1, and 2 will need to address complex design and construction challenges at these locations. Figure 14.14 shows 15 example locations totaling close to three miles—over 20 percent of the overall IHNC Basin I-Walls.

a) South of Clairborne Avenue, 500 ft

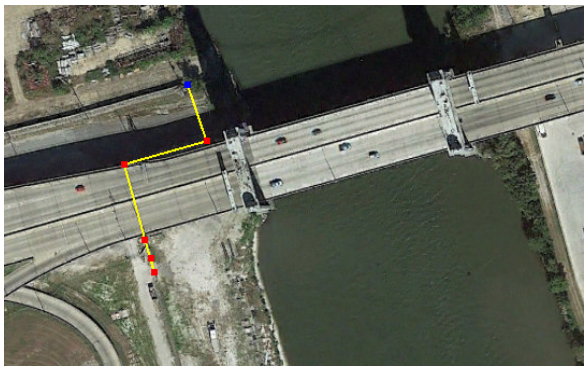
b) Clairborne Avenue, 300 ft



c) Between Clairborne and Florida Avenues, 4,400 ft

Figure 14.14. Example IHNC Basin I-Wall Locations with Existing Structures in Close Proximity

d) At Interstate 10, 500 ft

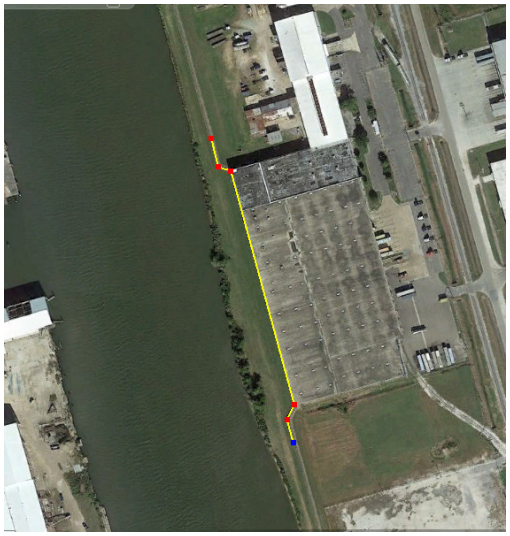


e) At Chef Menteur Hwy, 400 ft

f) East of Seabrook, 2,400 ft

Figure 14.14. Example IHNC Basin I-Wall Locations with Existing Structures in Close Proximity

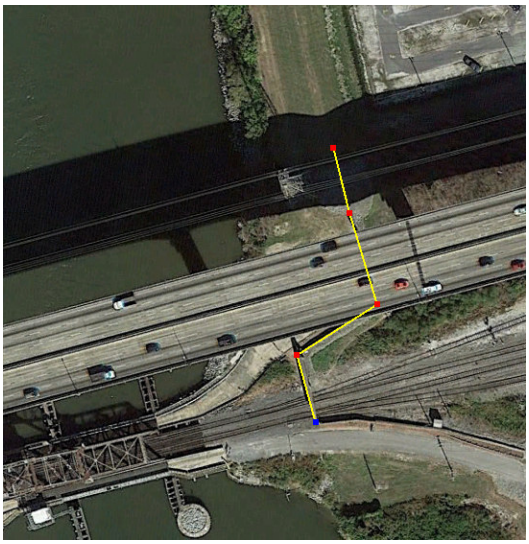
g) NO East South of Seabrook, 600 ft



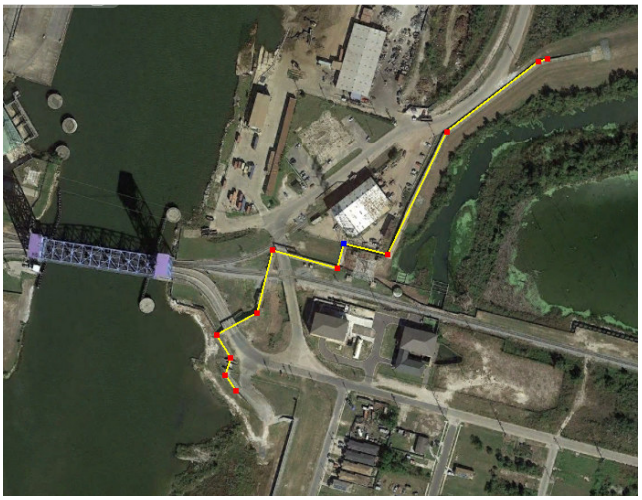
h) Between Dwyer Canal and Chef Menteur Hwy, 850 ft

i) Near Chef Menteur Hwy, 1,000 ft

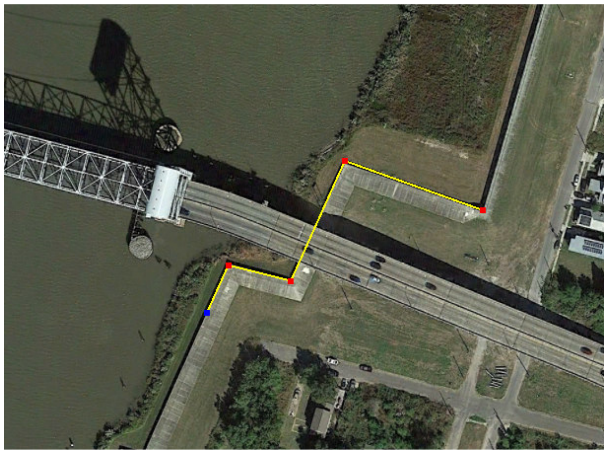
Figure 14.14. Example IHNC Basin I-Wall Locations with Existing Structures in Close Proximity



j) At Interstate 10, 350 ft

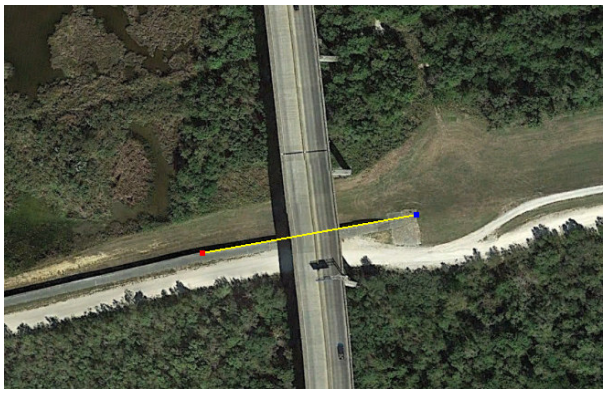


k) Near Florida Avenue, 1,700 ft



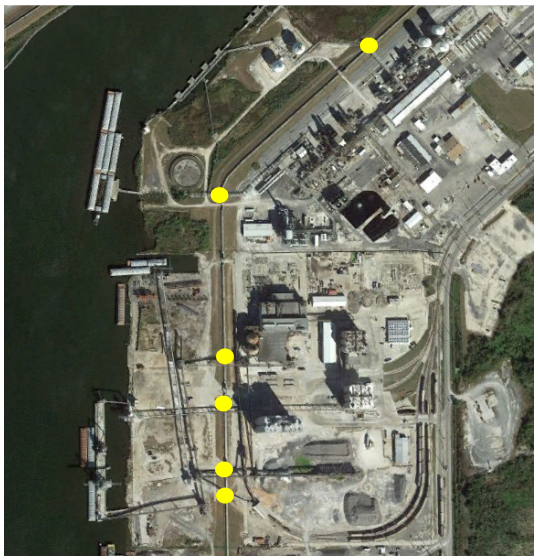
l) Clairborne Avenue, 600 ft

Figure 14.14. Example IHNC Basin I-Wall Locations with Existing Structures in Close Proximity



m) Paris Road, 300 ft

n) Michoud Canal, 300 ft



o) Michoud Canal, 1,000 ft

Figure 14.14. Example IHNC Basin I-Wall Locations with Existing Structures in Close Proximity

14.5. IHNC Basin Operational Modification

As noted in Section 9.4, stakeholders have identified two key IHNC Basin operational elements which affect the risk of surge inundation in the adjacent Metro, NO East, and St. Bernard Polders and which could potentially be improvemed as a compartmentalization project. They are:

1. Requirements for barge and large vessel mooring and securing large, potentially buoyant structures to their foundations—such as fuel storage tanks, floating docks, trailers, and portable buildings.
2. Use of the Bayou Bienvenue Sector Gate to divert IHNC Basin surge into the Central Wetlands.

Current Condition
The current IHNC Basin operations are described in the *Master Water Control Manual for the IHNC Basin* (USACE October 2013). The *Manual* identifies the lead operating agency for the IHNC Basin as the Louisiana CPRA. CPRA and SLFPA-E have a cooperative agreement that delegates responsibility for IHNC Basin operations to SLFPA-E.

Mooring Barges and Large Vessels and Securing Structures
As noted in Section 14.4 above, the USACE has specified that there is ***no*** IHNC Basin Levee/Floodwall SWL Safe Limit for major impacts from unsecured barges, large vessels, and large buoyant structures. These impacts have the potential to damage both floodwalls and levees, and the hazard increases as the SWL, waves, and wind rise. In the case of floodwalls, the impact does not have to break an opening in the wall to create a breach—if the impact deforms (tilts) the wall the action of hydrostatic and wave forces can change, precipitating a collapse. In the case of levees, objects can contribute to scour and lead to a rapid erosion breach.

Regarding the mooring of barges and large vessels, Section 7-9, *Navigation*, of the *Manual* states:

> As per 33 CFR 165.838 "Regulated Navigation Area; New Orleans Area of Responsibility, New Orleans, LA," the IHNC is a regulated navigation area (RNA) from Mile Marker 22 East of Harvey Locks, west on the GIWW, including the Michoud Canal and the Inner Harbor Navigation Canal (IHNC), extending North 1/2 mile from the Seabrook Flood Gate Complex out into Lake Pontchartrain and South to the IHNC Lock in New Orleans, LA. The provisions of the RNA will be enforced during a tropical event beginning 24 hours in advance of the predicted closure of the Lake Borgne Surge Barrier Structure. If the Coast Guard receives notice of closure less than 24 hours before closure, the RNA will be enforced upon the Captain of the Port (COTP) receiving notice of the predicted closing. The COTP may require all floating vessels to evacuate the RNA beginning as early as 72 hours before predicted closure of any navigational structure or upon notice that particularly dangerous storm conditions are approaching. During enforcement, all floating vessels are prohibited from entering or remaining in the RNA, unless they meet the minimum mooring requirements listed in the RNA. Transient vessels will not be permitted to seek safe haven in the RNA. The COTP will announce enforcement periods through Marine Safety Information Bulletins and Safety Broadcast Notices to Mariners.

The Sector Commander of the US Coast Guard serves as the New Orleans COTP. In April 2014, subsequent to the stakeholder meetings discussed in Section 9, the Coast Guard updated requirements for mooring barges and vessels in the IHNC Basin RNA. These regulations are included in Appendix J. No entity regulates the proper securing of large, potentially buoyant structures from the standpoint of protecting the Levee/Floodwall.[9]

[9] Fuel and hazardous material tanks are regulated under the Clean Water and Oil Pollution Acts to reduce the risk of spills.

Use of Bayou Bienvenue Sector Gate to Divert IHNC Basin Surge into the Central Wetlands

The location of the Bayou Bienvenue Sector Gate inside the IHNC Basin—see Figure 14.15—presents an option of reopening the Gate after closing the four IHNB Basin gates for a pending surge (Barge, Bayou Bienvenue Lift, IHNC Surge Barrier Sector, and Seabrook Surge Barrier Sector). Reopening the Bayou Bienvenue Sector Gate would allow rising water in the IHNC Basin to be diverted into the much larger Central Wetlands,[10] including surge from overtopping at the IHNC Surge Barrier (and the Seabrook Surge Barrier and IHNC Lock) and pump station discharges. As previously noted the 9,400-ft IHNC Surge Barrier was designed to allow significant overtopping for extreme surges—with overtopping at a rate of 1 cfs/ft equating to more than 1.2 inches of rise in the IHNC Basin rise every 30 minutes. Appendix I shows that the partially revised 2057 100-and 500-yr Q50/Q90 for the IHNC Surge Barrier are 1.8/16.0 and 7.5/85.3 cfs/ft.

The *Master Water Control Manual for the IHNC Basin* identifies the Bayou Bienvenue Sector Gate only as a "related facility," and does not address its operation for IHNC Basin surge management. The *2015 Orleans Levee District Emergency Operation Plan (OLD EOP) Manual, Attachment 5, Complex Structure, Part VI Bayou Bienvenue Sector Gate* prepared by USACE specifies that the gate will be closed when a hurricane warning is issued for the coast and will remain closed. The closure procedure means that the Bayou Bienvenue Sector Gate will be closed prior to the IHNC Basin Sector Gate. The procedure stipulates that the Bayou Bienvenue Sector Gate will not be re-opened until the IHNC Basin SWL is less than 0.5 ft above the Central Wetlands SWL.

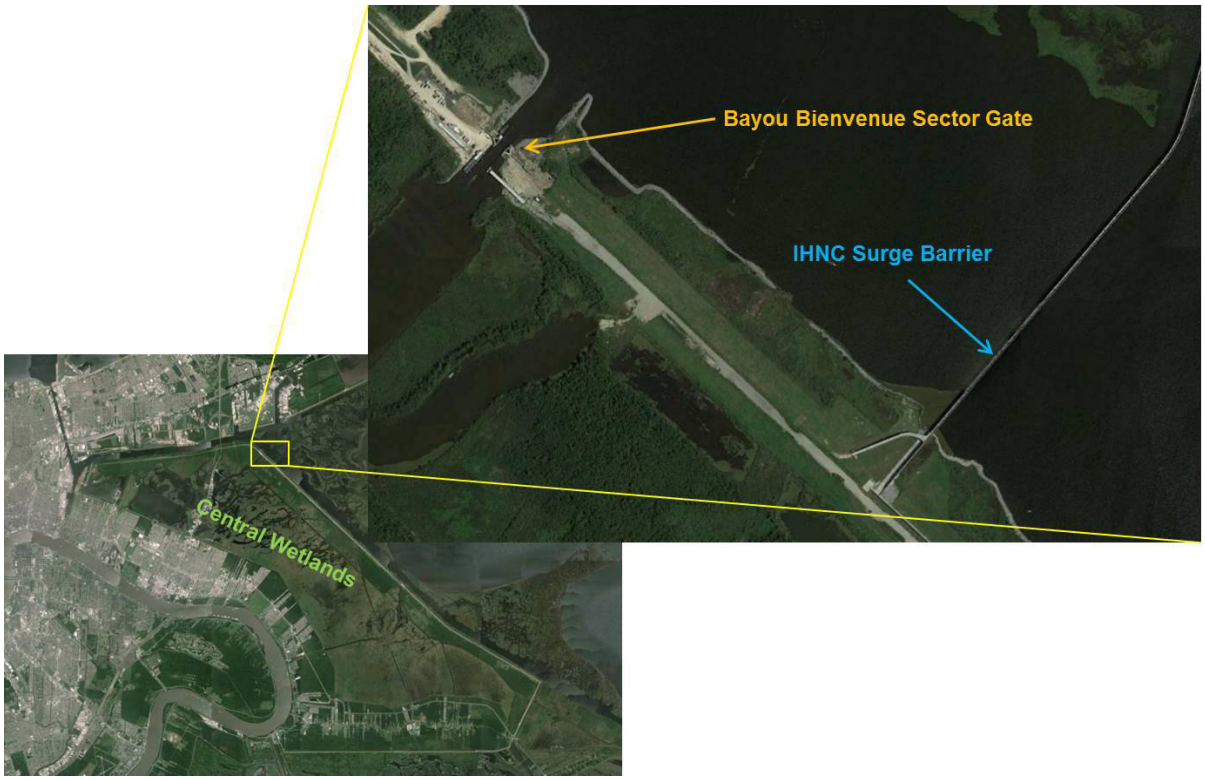


Figure 14.15. Bayou Bienvenue Sector Gate

[10] The Central Wetlands has about eight times the storage area as the IHNC Basin—roughly 29,400 versus 3,700 acres measured within their respective Levee/Floodwall perimeters. At normal tide the IHNC Basin water surface is less than 2,500 acres.

The OLD currently closes the Bayou Bienvenue Sector Gate according to forecasts of local wind-driven tides—coupled with rainfall—to maintain Central Wetlands SWL below 1.2 ft NAVD88, which is about 0.7 ft above mean level. This target prevents flooding of facilities and minor access roads along Bayou Bienvenue near Paris Rd (within the Central Wetlands) and requires frequent closure of the Gate.[11]

Due to the risks associated with IHNC Basin surge, in 2012 SLFPA-E raised the issue of using the Bayou Bienvenue Sector Gate to divert IHNC Basin surge into the Central Wetlands.[12] This interest precipitated an initial USACE hydraulic analysis: *Central Wetlands Flow/Velocity Analysis By Evacuation of Water Through the Old Bayou Bienvenue Structure* (2014). This initial analysis considered the IHNC Basin and the Central Wetlands each as basic level-pool storage reservoirs and then evaluated the simple question of equalization time between the two after reopening the Bayou Bienvenue Sector Gate. The analysis was performed with HEC-RAS and used:

- Only the Central Wetlands area west of Bayou Dupre.
- Stage-storage curves for both areas.
- A range of initial SWLs in the IHNC between 2.0 and 6.0 ft NAVD88.
- An initial Central Wetlands SWL of 1.0 ft NAVD88.

This analysis showed that the IHNC Basin took between 9 and 33 hours to completely drain to the Central Wetlands for these initial SWLs, equalizing at between 1.4 and 2.4 ft NAVD88. Peak velocities at the Gate over this range of scenarios were 6.8 to 17.5 ft/s, generally greater than the 7.0 ft/s maximum velocities considered in the Gate design. On the basis of these initial results the USACE noted that reopening the Bayou Bienvenue Sector Gate might not be able to divert water from the IHNC Basin quickly enough to reduce risks in the Basin, and could potentially face serious operational and perhaps structural challenges. The USACE has not conducted any further examination of the diversion option and has not modified the relevant Bayou Bienvenue Sector Gate operating manuals.

Upgrade to Reduce Surge Inundation Risk
As discussed in Section 13.4 upgrading the IHNC Basin Operations is a priority compartmentalization alternative for reducing Class D inundation risk to all three polders. One upgrade option, the baseline Option 0, has been defined. Residual surge risk management purposes dictate that reasonable improvements of IHNC Basin operations be addressed in the baseline upgrade.

Option 0 Finalize the plan for using the Bayou Bienvenue Sector Gate to divert IHNC Basin surge into the Central Wetlands and modify the *Master Water Control Manual for the IHNC Basin* and *OLD EOP Manual*. [Also, support a CPRA-led detailed review of the current and best practices for mooring barges and large vessels and securing potentially buoyant structures, and expedited implementation of recommendations.]

<u>Option 0, Use of Bayou Bienvenue Sector Gate to Divert IHNC Basin Surge into the Central Wetlands</u>
The initial (first-pass) reservoir routing approach used by the USACE in their 2014 hydraulic analysis of the diversion option was not able to evaluate the reduction of IHNC Basin peak SWL with early Gate reopening. Reopening the Gate shortly after closure of the four other Basin gates allows diversion to

[11] Central Wetland SWLs are controlled by operating the Bayou Bienvenue Sector Gate in conjunction with the Bayou Dupre Sector Gate—located about 6.4 miles to the southeast.

[12] See minutes of SLFPA-E Board, September 13, 2012.

begin well before levels in the IHNC Basin peak, thus lowering IHNC Basin peak SWLs. Early reopening would also reduce Gate velocities compared with opening near the peak IHNC Basin SWL.

To provide a more realistic evaluation of the diversion and early reopening of the Gate Bob Jacobsen PE employed a dynamic routing analysis (performed with one-dimensional HEC-RAS, see Appendix I). The HEC-RAS geometry features are illustrated in Figure 14.16 and provide a "next step" in capturing greater physical detail for the IHNC Basin and Central Wetlands channel cross-sectional capacity, head-loss, and flow conditions. In turn, these allow modeling of transient conditions during surge scenarios—i.e., time-varying flow inputs, gate opening/closure, and IHNC Basin and Central Wetlands SWLs.

Three primary surge inflow scenarios were used to produce peak IHNC Basin SWLs of 6.2, 9.3, and 12.5 ft NAVD88 Without-Diversion. Simulations were then run Without-Diversion and With-Diversion, the latter by reopening the Bayou Bienvenue Sector Gate at approximately 20 hours prior to peak inflows. Peak conditions for the three scenarios Without- and With-Diversion are shown in Table 14.4. The analysis shows that early reopening of the Gate provides a major reduction of IHNC Basin peak SWL—by 2.6, 4.4, and 5.9 ft in these three scenarios—which indicates significant surge risk reduction for the IHNC Basin. The analysis also shows that diversions with early reopening could have much lower peak velocities at the Bayou Bienvenue Sector Gate than indicated by the USACE's 2014 initial analysis, implying that associated operational and structural concerns may be moderated.

With the Gate closed, the highest Central Wetlands peak SWLs typically occur at the channel heads concurrent with peak inflows. The dynamic analysis shows that these peaks are unaffected by diversion. Under all three scenarios, SWLs peaked near 7.5 ft NAVD88 at the head of both Bayou Bienvenue and Bayou Dupre both Without- and With-Diversion. The exception is at the head of the Pipeline Canal at the far eastern end of the Central Wetlands where peak SWL rises by 0.3 ft With Diversion.

The dynamic routing analysis shows that diversion is a potentially effective approach to reducing the residual surge risks presented by the IHNC Basin to all three polders. However, while sufficient for the purposes of this Report, this analysis is not sufficient for making final operational plans. Therefore, Option 0 includes conducting an Advanced Hydraulic Analysis of the diversion, with:

- A more detailed, rigorous 2D model to better capture topographic/bathymetric and landscape (frictional) conditions in the Central Wetlands and routing and head loss for diversion flows.
- Calibration of the model with IHNC Basin and Central Wetlands SWL and velocity data. Data were not available to calibrate either the USACE or the Bob Jacobsen PE model.
- More simulations, with a wider range of rainfall and surge inflow scenarios, including shorter, more intense IHNC Surge Barrier overtopping.
- Possibly converting IHNC Basin Levee segments east and west of the Gate to spillways. Spillways would reduce diversion time and potential velocity impacts at the Gate and in the Bayou.
- More detailed hydraulic modeling of velocities and scour conditions at the Bayou Bienvenue Sector Gate, Paris Rd bridge, and other sensitive locations.

This more rigorous Option 0 analysis will define appropriate surge circumstances for reopening the Bayou Bienvenue Sector Gate and provide recommended changes to the IHNC Basin Manual and the OLD EOP Manual. The Option 0 analysis will also define if conversion of portions of the IHNC Basin Levee/Floodwall to spillways is warranted. Upon receiving the results of this analysis, SLFPA-E will work with CPRA and the USACE to expedite implementation of recommendations.

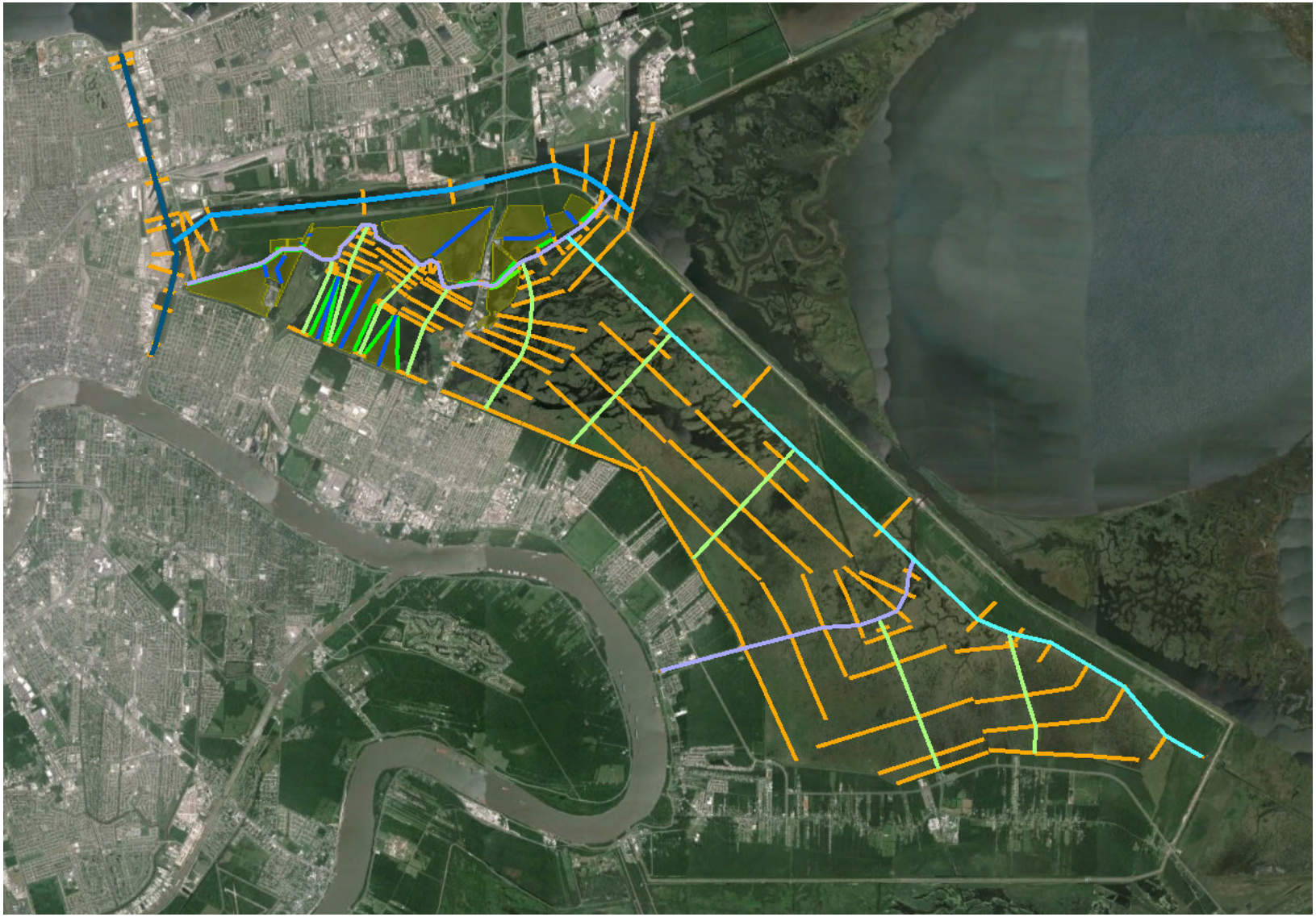


Figure 14.16. Channels and Cross Sections for Dynamic Routing Model of Diversion to Central Wetlands

Table 14.4. Surge Scenarios Evaluating Diversion Option with Dynamic Routing Analysis

Scenario	Peak SWL ft NAVD88			
	IHNC Basin	Head of Bayou Bienvenue	Head of Bayou Dupre	Head of Pipeline Canal
1. IHNC Surge Barrier Peak Overtopping Rate 0.7 cfs/ft				
Without-Diversion	6.2	7.35	7.55	3.98
With-Diversion	3.6	7.43	7.49	3.98
Difference	-2.6	+0.08	-0.06	0.0
Bayou Bienvenue Sector Gate Reopened Velocity, 3.1ft/s				
2. IHNC Surge Barrier Peak Overtopping Rate 1.8 cfs/ft				
Without-Diversion	9.3	7.36	7.55	3.98
With-Diversion	4.9	7.43	7.49	3.99
Difference	-4.4	+0.07	-0.06	+0.01
Bayou Bienvenue Sector Gate Reopened Velocity, 7.1 ft/s				
3. IHNC Surge Barrier Peak Overtopping Rate 3.1 cfs/ft				
Without-Diversion	12.5	7.35	7.55	3.98
With-Diversion	6.6	7.42	7.49	4.30
Difference	-5.9	+0.07	-0.06	+0.32
Bayou Bienvenue Sector Gate Reopened Velocity, 9.8 ft/s				

Importantly, previous environmental impact investigations, findings, and approvals obtained for the HSDRRS (including the *IHNC Basin Manual*) did not include diversion to the Central Wetlands. These are required under the National Environmental Policy Act, NEPA. Thus, besides the diversion hydraulics, Option 0 will examine potential environmental impacts of diversion on the Central Wetlands and define any efforts required under NEPA, including possible mitigation requirements.

In addition, the Option 0 diversion plan must address remote monitoring of IHNC Basin and Central Wetlands SWLs during surge events and the possible circumstances under which remote re-closure of the Bayou Bienvenue Sector Gate could be required. Option 0 would thus require implementation of necessary monitoring equipment and remote controls.

Under Option 0, SLFPA-E will also support CPRA's undertaking of a detailed review of the April 2014 mooring requirements—as well as an investigation of the current mooring practices and practices for securing potentially buoyant structures in the IHNC Basin. This review should be undertaken by professionals experienced in this field, and should address engineering design, construction, maintenance, and operational considerations in light of best practices *for comprehensive surge risk management*. These reviews should be conducted by the CPRA—as they are likely to apply at the HSDRRS West-Bank Closure Complex and other locations across the Louisiana coast. The reviews must also address expanding the responsibilities of CPRA—including expanding statutory authority—for oversight, inspection, permitting, enforcement, corrective action, and emergency actions to ensure that best practices are followed. In addition, the review should define any additional resources (staff, contractors, etc.) required by CPRA to implement recommendations.

15. Risk Assessment of Priority Compartmentalization Alternatives

As discussed in Section 5 (see Table 5.1), the East-Bank polders face significant inundation threats from hurricane surge. Factoring in partial correction to the 2008 FIS, a reasonably conservative assessment of uncertainty, and changing conditions, the return period for the FIS *Nominal* 500-yr surge occurring somewhere around the East-Bank HSDRRS perimeter could well approach 100 years,. The East-Bank return period for a Class D surge inundation event—with over 10,000 acre-ft of inflow—could well approach 200 years (with a 10 percent probability during any 20-yr time-frame), or worse if HSDRRS O&M is not effectively maintained and operated.

Table 15.1 summarizes the qualitative assessment of inundation risk changes resulting from the various upgrade options for each of the five priority compartmentalization alternatives. Risk changes are defined by ranking (Major+, Major, Moderate, Minor, and Negligible) both a) the relative HSDRRS reach vulnerability (see Table 10.1) and b) the inundation impact of the upgrade. Impacts are ranked for areas which experienced reductions as well as increases in inundation consequences. Inundation impact ranks were based on the results of the Class D 30,000-acre ft breach inundation modeling discussed in Section 12, together with sub-basin (see Figures 7.1 a – h) demographic, economic, and other information presented in Section 7 (Tables 7.1, 7.2, and 7.3). Table 15.2 reproduces some selected socio-economic statistics for sub-basins affected by the compartmentalization alternatives.

The EJ/SC Levee Floodwall and IHNC Basin alternatives address Major HSDRRS vulnerabilities while the Maxent Levee and 40 Arpent/Violet Canal Levee/Floodwall alternatives address Minor HSDRRS vulnerabilities. All options provide net impact reduction. All the alternative options have Negligible increased impacts except for the three EJ/SC Levee Floodwall options—which have Minor, Moderate, and Major increased impacts in St. Charles Parish. The IHNC Basin projects are the only ones to address a Major HSDRRS vulnerability and provide Major impact reductions with Negligible impact increases.

As discussed in Section 6.1, for purposes of this Report residual hurricane surge risks do ***not*** include the polder population and assume that comprehensive evacuation is implemented whenever there is a threat of inundation.[13] Hurricane evacuation is the responsibility of the parish emergency management departments, working in conjunction with the GOHSEP, state and local transportation departments, and state and local law enforcement. These evacuation responsibilities extend to those residents with health, financial, and/or logistical challenges to self-evacuation. Evacuation effectiveness will continue to improve with advances in the accuracy and timeliness of surge forecasts. Surge forecasts rely on an ensemble of HPC/High-Resolution model simulations considering probable variations in hurricane landfall locations and conditions. The surge forecast ensemble is re-run every few hours as the NOOA Hurricane Center updates its hurricane forecast range.

[13] . A more rigorous risk assessment—which could consider less than comprehensive evacuation—could be included during a detailed “feasibility-level “analysis, part of any subsequent phase for moving forward with alternatives.

Table 15.1. Risk Assessment for Five Priority Compartmentalization Alternatives*

Alternative Upgrade Option	**Impacts**	**Sub-Basin**	**Description**
EJ/SC Parish-Line Levee/Floodwall—Relative HSDRRS vulnerability: **Major**			
Option 0 (Baseline)	Reductions: *Moderate*	JE1, JE3	Barrier at 6 ft NAVD88—with extension south to Mississippi River Levee—enhances inflow restriction from St. Rose breach into SW East Jefferson Parish (western JE1, south of Airline Hwy and western JE3 north of Airline Hwy); reduces damages from a range of breach sizes. But doesn't fully contain 30,000 acre-ft St. Rose inflow; could fully contain smaller breach, or more St. Charles breaches further to the west.
	Increases: *Minor*	SC1, SC2	Increases inundation in eastern St. Charles Parish from a St. Rose breach. Greatest impact in undeveloped SC1. Some increased inundation footprint and depth in eastern SC2/St. Rose.
Option 1	Reductions: *Major*	JE1, JE3	Barrier at 8 ft NAVD88 further restricts inflow from St. Rose breach into SW East Jefferson Parish (western JE1, south of Airline Hwy and western JE3 north of Airline Hwy); Still doesn't fully contain 30,000 acre-ft St. Rose inflow.
	Increases: *Moderate*	SC1, SC2	Greatest impact in undeveloped SC1, but would increases impact in eastern SC2, south of Airline Hwy.
Option 2	Reductions: *Major+*	JE1, JE3, JE2	New T-Wall at 14 ft NAVD88 fully contains Class D inflow and protects northern East Jefferson, including portions of JE2 as far east as Bonnabel.
	Increases: *Major*	SC1, SC2	New T-Wall increases inundation throughout St. Charles Parish for a Class D breach (see Figures 14.5 and 14.6).
Maxent Levee—Relative HSDRRS vulnerability: **Minor**			
Option 0 (Baseline)	Reductions: *Minor*	NOE5	Improved resiliency of Maxent Levee segment north of I-10 reduces chance of breaching and inflow into NOE5protects developed portion of NO East.
	Increases: *Negligible*	NOE1, NOE2	
Option 1	Reductions: *Moderate*	NOE5	Further reduces chance of breaching and inflow into NO East.
	Increases: *Negligible*	NOE1, NOE2	Higher inundation east of segment—but in undeveloped BSNWR north of I-10, which would already have been inundated.
40 Arpent/Violet Canal Levee/Floodwall—Relative HSDRRS vulnerability: **Minor**			
Option 0 (Baseline)	Reductions: *Minor*	SB1, SB3, SB4	Improved temporary barriers to 7.0 ft NAVD88 at eastern Bayou Rd, LA Hwy 46 at Violet, and cross over openings in I-Wall, protects developed portion of St. Bernard Polder, reduces breaching and inflow into SB1, SB3, and SB4, respectively.
	Increases: *Negligible*	SB2, SB5	
Option 1	Reductions: *Moderate*	SB1, SB3, SB4	Improved Safe SWL Limit of 8 ft NAVD88 further reduces chance of breaching and inflow into developed portion of St. Bernard Polder.
	Increases: *Negligible*	SB2, SB5	Higher inundation in undeveloped Central Wetlands, which would already have been inundated.

Table 15.1. Risk Assessment for Five Priority Compartmentalization Alternatives*

Alternative Upgrade Option	**Impacts**	**Sub-Basin**	**Description**
IHNC Basin Levee/Floodwall—Relative HSDRRS vulnerability: **Major**			
Option 0 (Baseline)	Reductions: *Major*	OM1, OM3, OM5, NOE4, NOE5, SB1	I-Wall resiliency improvements reduce chance of breaching and inflow to all three polders.
	Increases: *Negligible*		
Option 1	Reductions: *Major*	OM1, OM3, OM5, NOE4, NOE5, SB1	Upgrade 8.2-mi of I-Wall to L-Wall for major impact loading at 8 ft NAVD88; would further reduce chance of breaching and inflow to all three polders.
	Increases: *Negligible*		
Option 2	Reductions: *Major*	OM1, OM3, OM5, NOE4, NOE5, SB1	Upgrade 13.1-mi I-Wall to T-Wall for major impact loading at 11.0 ft; would further reduce chance of breaching and inflow to all three polders
	Increases: *Negligible*		
IHNC Basin Operational Modifications—Relative HSDRRS vulnerability: **Major**			
Option 0 (Baseline)	Reductions: *Major*	OM1, OM3, OM5, NOE4, NOE5, SB1	Diversion to Central Wetlands by re-opening Bayou Bienvenue Sector Gate reduces IHNC Basin surge levels and chances of breaching and inflow to all three polders.
	Increases: *Negligible*	SB2, SB5	Slightly raises SWL in Central Wetlands.

*See Figure 7.1 a – h for sub-basins.

Table 15.2. Selected Socioeconomic Statistics for Sub-Basins Affected by Compartmentalization Alternatives (from Tables 7.1, 7.2, and 7.3)

Sub-Basin	**Total Population**	**Total Housing Units**	**Total Personal Income**	**Schools**	**Hospitals**
SC1	8,438	3,137	$206,500,466	0	0
SC2	17,585	6,634	$311,309,069	11	0
JE1	41,427	20,658	$1,043,494,111	15	5
JE2	58,444	30,260	$1,780,147,807	17	1
JE3	133,613	57,383	$3,380,059,820	38	6
NOE5	54,814	25,769	$694,783,409	20	3
SB1	17,399	9,530	$269,192,641	17	1
SB3	17,310	7,749	$276,279,060	8	0
SB4	8,232	3,988	$87,874,048	5	0
OM1	28,978	15,749	$584,157,233	14	0
OM3	38,916	25,114	$610,828,646	28	0
OM5	135,171	80,605	$3,737,326,716	99	10
NOE4	433	239	$983,551	0	0

Given that the HSDRRS has been designed essentially for the NFIP—and with NFIP treatments of uncertainty and FOSs—reasonable precaution dictates that polder evacuation plans encompass any hurricane with a reasonable chance for the surge to approach the HSDRRS ***design*** 100-yr SWL50 (per the December 2014 *DER*). As noted in Section 5.1, an NFIP 100-yr overtopping event (a Class A inundation) has an expected return period of about 20 years for the East-Bank as a whole (perhaps 10 years for the combined East- and West-Banks). Importantly, a large stalled Category 1 hurricane is capable of producing a Class A inundation event.

The following qualitative assessment of non-life/health surge inundation risk impacts is consistent with a reconnaissance-level feasibility analysis, and supports the compartmentalization recommendations presented in the *Executive Summary.*

15.1. East Jefferson/St. Charles Parish-Line Levee/Floodwall

Hurricane surge entering eastern St. Charles Parish naturally flows toward the much lower lying portions of Jefferson Parish (see Section 7.1). The current EJ/SC Parish-Line Levee/Floodwall already provides some risk reduction to East Jefferson and increases risk in St. Charles. The three EJ/SC Parish-Line Levee/Floodwall upgrade options further reduce surge inundation risk for East Jefferson sub-basins JE1, JE2, and JE3, ***but increase risk*** for St. Charles Parish sub-basins SC1 and SC2.

The polder inundation impacts for the EJ/SC Parish-Line Levee/Floodwall compartmentalization upgrade alternative are illustrated by the Class D inundation scenario MSC-3, with a breach located along the HSDRRS in St. Charles Parish near St. Rose. The MSC-3 30,000-acre-ft breach scenario (St. Rose) is depicted in Figures 14.5. A significant portion of the breach inflow in St. Charles is routed through the largely undeveloped sub-basin SC1. However, flow towards the lower lying East Jefferson results in substantial flooding for the western portions of sub-basins JE1 and JE3. An even larger 60,000 acre-ft breach inundates JE2 as far east as Bonnabel Blvd.

Table 15.1 shows that the East Jefferson—which is entirely heavily developed—has a vastly greater population, personal income, and collection of public facilities than St. Charles. JE3 is the second most populated sub-basin in the three-polder area. In contrast, 40 percent of St. Charles sub-basins (mostly SC1) is undeveloped. With its lower ground elevation and much greater development, surge inundation consequences are much greater for East Jefferson than for St. Charles.

The EJ/SC Parish-Line Levee/Floodwall upgrade options provide increased compartmentalization against a significant vulnerability in the East-Bank HSDRRS discussed in Section 5.2—the very low 100- and 500-yr freeboard of the HSDRRS levees in St. Charles Parish. The partially revised F50 for reach SC-02A is only 3.4 ft for 100-yr, and is a negative -0.1 ft for 500-yr. The F90s are both negative: -0.47 and -6.1 ft. The St. Charles HSDRRS levee has the highest probability—the lowest return period—of any East-Bank location for experiencing overtopping leading to a Class D breach inflow event.

As an alternative to upgrading the EJ/SC Parish-Line Levee/Floodwall, this significant vulnerability can be addressed by improving the St. Charles Parish HSDRRS levee as discussed in Section 6.4. The latter could very well represent a more cost-effective risk reduction approach than upgrading compartmentalization. Further analysis of flood risk reductions and increases in East Jefferson and St. Charles, any mitigation requirements for upgrading the EJ/SC Parish-Line Levee/Floodwall, as well as the relative merits of upgrading the St. Charles HSDRRS levee is required during any subsequent preliminary engineering.

The risk impacts for the three EJ/SC Parish-Line Levee/Floodwall compartmentalization upgrade options are as follows:

Option 0 (Baseline)
Option 0 does not change the height of the current Levee/Floodwall segments. This option simply improves temporary barriers and installs new closures for openings consistent with the working assumption for the SWL Safe Limit of the current Levee/Floodwall—6.0 ft NAVD88. The openings are at the CN Railroad (North), Airline Hwy, KCS & CN Railroads, E-W Ditch, and the Private Property. Option 0 slightly extends the current risk impacts to East Jefferson and St. Charles. Option 0 moderately reduces JE1 and JE3 inundation risks by lowering inflow from a Class D 30,000 acre-ft breach at St. Rose and eliminating inflow from much smaller St. Rose breaches, as well as larger breaches further to the west along the St. Charles HSDRRS. Option 0 results in minor increases for flood risks in St. Charles from a St. Rose HSDRRS breach—particularly in the more developed eastern parts of SC2 and the community of St. Rose.

Option 1
Option 1 lifts some levee segments,[14] improves floodwall foundations, and upgrades barriers to achieve a SWL Safe Limit of 8.0 ft NAVD88. This option yields major risk reduction for JE1 and JE3—though again not fully eliminating inundation from a St. Rose breach with Class D inflow—and moderate risk increases in eastern SC2.

Option 2
Option 2 totally replaces the current Levee/Floodwall with a new structure to 14.0 ft NAVD88, to provide containment of a 30,000 acre-ft St. Rose breach. This option will provide the greatest risk reduction for JE1 and JE3—plus additional risk reduction for JE2. However, this option will also result in major risk increases throughout St. Charles—raising the inundation footprint and depth westward toward Norco.

15.2. Maxent Levee

The current Maxent Levee contains inflow from an exterior HSDRRS breach introducing surge into sub-basins NOE1 and potentially NOE2—the BSNWRR and the largely undeveloped Maxent Lagoon area.[15] The Maxent Levee reduces the risk of hurricane surge then entering the developed portion of NO East—sub-basins NOE3, NOE4, and NOE5. The two Maxent Levee upgrade options further increase surge containment in NOE1 and NOE2 but further reduce surge inundation risk in the developed portion of NO East, primarily for NOE5. NOE5 is the fourth most populated sub-basin in the three-polder area.

The polder inundation risk impacts for the Maxent Levee compartmentalization upgrade alternative are illustrated by the Class D inundation scenario NOE-3, with a breach located along the northern half of Levee. This 30,000-acre-ft inflow scenario is depicted in Figures 12.4.c. The risk impacts for the two Maxent Levee upgrade options are as follows:

[14] The lift likely compensates for decades of subsidence, settlement, and consolidation. The Option 1 is generally consistent with the original intent of the EJ/SC Parish-Line Levee/Floodwall.

[15] As discussed in Section 7.3, the BSNWR and the Maxent drainage area are separated by the low BSNWR Levee.

Option 0 (Baseline)
For similar HSDRRS breach scenarios outside the Maxent Levee, the Interstate 10 embankment would cause inflow from a breach along the Lakefront to produce the greatest SWLs against the Maxent Levee, with these occurring along the segment north of Interstate 10. Option 0 improves the resiliency of the segment of the Maxent Levee north of Interstate 10, which yields a minor reduction in NOE5 surge inundation risks.

Option 0 does not change the height of the Maxent Levee and thus does not increase the NOE 1/NOE2 inundation level. Option 0 only increases the inundation level probability to the degree that breach probabilities for the Maxent Levee itself are reduced. For practical purposes, improving the Maxent Levee resiliency is therefore considered to have a negligible adverse impact on the BSNWRR and Maxent Lagoon area.

Option 1
Option 1 lifts the Maxent Levee segment north of Interstate 10 to provide a SWL Safe Limit of 5.0 ft NAVD88. This option provides a further, moderate reduction in surge inundation risk for NOE5. The lift only negligibly increases surge risk for NOE1 and NOE2 given that:

- The low level of development in NOE1 and NOE2.
- The surge scenario involves extensive inundation of NOE1 and NOE2 without the lift.
- The segment lift only slightly increases surge containment in the overall NOE1 and NOE2 area.

15.3. 40 Arpent/Violet Canal Levee/Floodwall

The current 40 Arpent/Violet Canal Levee/Floodwall contains inflow from an exterior HSDRRS breach introducing surge into sub-basins SB2 and SB5, the largely undeveloped Central Wetlands sub-basins. This reduces surge inundation risks to sub-basins SB1, SB3, and SB4 the developed portion of the St. Bernard Polder. The two 40 Arpent/Violet Canal Levee/Floodwall upgrade options further increase surge containment in SB2 and SB5 while further reducing surge inundation risk for SB1, SB3, and SB4. The 40 Arpent/Violet Canal Levee function in the St. Bernard Polder is similar to that of the Maxent Levee in NO East. However, while largely developed, SB1, SB3, and SB4 are not as populated as sub-basins in the Metro and NO East Polders. The population of NOE5 exceeds the combined population of SB1, SB3, and SB4 by more than 10,000 residents.[16]

The polder inundation risk impacts for the 40 Arpent/Violet Canal Levee/Floodwall upgrade alternative are illustrated by eight Class D inundation scenarios USB-2, 3, 4, 5, and 6 and LSB-1, 2, and 3, with breaches located along the Levee/Floodwall. These 30,000 acre-ft scenarios are depicted in Figures 12.5.b – f and 12.6.a - c. The risk impacts for the two 40 Arpent/Violet Canal Levee/Floodwall upgrade options are as follows:

Option 0 (Baseline)
Improve temporary barriers at openings to 7.0 ft NAVD88. Option 0 improves the temporary barriers for openings in the 40 Arpent/Violet Canal Levee/Floodwall, consistent with SWL Safe Limit of 7.0 ft

[16] At more than 2.5 times longer than the Maxent Levee—and protecting less development—the 40 Arpent/Violet Canal Levee/Floodwall is arguably a less efficient risk reduction measure. However, unlike the Maxent Levee, the 40 Arpent/Violet Canal Levee/Floodwall constitutes a nearly totally redundant surge protection barrier.

NAVD88. The openings include eastern Bayou Rd, LA Hwy 46 at Violet, and cross over openings in the I-Wall. These improvements reduce breaching and inflow risks for SB1, SB3, and SB4, respectively.

Option 0 does not change the height of the 40 Arpent/Violet Canal Levee/Floodwall and thus does not increase the SB2/SB5Central Wetlands inundation level. Option 0 only increases the Central Wetlands inundation level probability to the degree that breach probabilities for the Levee/Floodwall itself are reduced. For practical purposes, improving the 40 Arpent/Violet Canal Levee/Floodwall temporary barriers is therefore considered to have a negligible adverse impact on the Central Wetlands.

Option 1
Option 1 lifts 350 ft of levee and improves sheet pile foundations to provide a SWL Safe Limit of 8.0 ft NAVD88. Option 1 provides a further, moderate reduction in surge inundation risk for SB1, SB3, and SB4. This option only negligibly increase surge risk for SB2 and SB5—the Central Wetlands—given that:

- The low level of development in SB2 and SB5.
- The surge scenario involves extensive inundation of SB2 and SB5 without Option 1.
- Option 1 only slightly increases surge containment in the overall SB2 and SB5 area.

15.4. IHNC Basin Levee/Floodwall

During hurricanes, the current IHNC Basin Levee/Floodwall contains rainfall, drainage discharge, and surge overtopping—from the IHNC and Seabrook Surge Barriers and the IHNC Lock—within the Basin, and prevents surge inundation in all three adjacent polders. Protected sub-basins include OM1, OM3, OM5, NOE4, NOE5, and SB1. The three IHNC Basin Levee/Floodwall upgrade options further increase the reliability of IHNC Basin surge containment and thus further reduce surge inundation risk for these sub-basins.

Nearly half of the total three-polder regional population resides within these six sub-basins, with the three Metro Orleans sub-basins constituting over 43 percent. In addition the three Metro Orleans sub-basins include 37, 49, 73, and 52 percent of the East-Bank hospitals, schools, colleges, and state-governmental facilities—as well as the core of the region's economy and cultural assets. Of the four priority compartmentalization structures, the IHNC Basin Levee/Floodwall is the most critical in reducing inundation consequences,

The polder inundation risk impacts for the IHNC Basin Levee/Floodwall compartmentalization alternative are illustrated by four Class D inundation scenarios MO-4, MO-5, NOE8, and SB-1, with breaches located along the IHNC Basin perimeter. These 30,000 acre-ft scenarios are depicted in Figures 12.3.d. – g, 12.4.h, and 12.5.a.

There are some residences (trailers/mobile homes) and important commercial/industrial port facilities within the IHNC Basin. The three upgrade options do not change the height of the current IHNC Basin Levee/Floodwall and thus do not increase the inundation level inside the IHNC Basin. The three upgrade options only increase the probability of Basin inundation levels to the degree that breach probabilities for the Levee/Floodwall itself are reduced. For practical purposes, improving the IHNC Basin Levee/Floodwall is therefore considered to have a negligible adverse impact on the IHNC Basin inundation risk.

The risk reductions for the three IHNC Basin Levee/Floodwall upgrade options are as follows:

Option 0 (Baseline)

Option 0 I-Wall resiliency improvements reduce surge inundation risks in all three adjacent polders, including six sub-basins OM1, OM3, OM5, NOE4, NOE5, and SB1. Excluding the Michoud Slip and Canal, of the 8.3 miles of IHNC Basin I-Walls, 61 percent are along the Metro Polder. Furthermore, 89 percent of IHNC Basin barrier along the Metro Polder is comprised of I-Wall. Given the significant consequences for inundating the Metro Orleans sub-basins, upgrading I-Wall resiliency—particularly foundation improvements—to provide FOSs more consistent with residual risk management provides a major degree of risk reduction.

Option 1
During both the Hurricanes Katrina and Gustav barges and other large buoyant structures broke free from moorings/anchorings in the IHNC Basin. Thus, the probability for a major impact on the IHNC Basin Levee/Floodwall during a surge event is not trivial. The 2014 changes to RNA regulations for barges and vessels have reduced but not eliminated the probability, and importantly, the RNA regulations do not address buoyant structures. The review of IHNC Basin mooring/anchoring practices and ensuing implementation of its recommendations—which is part of Option 0 for the final compartmentalization alternative (see Section 14.5 above)—will define the residual probability of a major impact loading on the IHNC Basin Levee/Floodwall. If this residual probability remains significant, Option 1—a further upgrade of the IHNC Basin Levee/Floodwall for major impact loading with a surge SWL at 8.0 ft NAVD88—would provide a major degree of risk reduction.

Option 2
Option 2 further upgrades the IHNC Basin Levee/Floodwall for major impact loading with a surge SWL at 11.0 ft NAVD88. Depending on the residual probability of major impact loading, Option 2 would also provide a further, major reduction in inundation risk.

15.5. IHNC Basin Operational Modification

Option 0 (Baseline)

IHNC Basin Operational Modifications Option 0, with two elements:

A. Requirements affecting the mooring of barges and large vessels and securing of buoyant structures, and
B. Use of the Bayou Bienvenue Sector Gage to divert IHNC Basin surge to the Central Wetlands)

can also provide major surge inundation risk reduction from IHNC Basin Levee/Floodwall breach scenarios for the same six sub-basins in the three East-Bank polders—OM1, OM3, OM5, NOE4, NOE5, and SB1. These include the risks illustrated in the same four Class D inundation scenarios MO-4, MO-5, NOE8, and SB-1n noted above.

Option 0 diversion of surge into the Central Wetlands increases inundation risk for sub-basins SB2 and SB5,. The limited dynamic routing analysis of diversion indicates that the Central Wetlands SWL rise—above what is produced by direct rainfall and drainage discharge—would be slight, and not greater than what is associated with extreme non-hurricane flood events in the Central Wetlands. The increase inundation risk to the limited commercial and residential development in the Central Wetlands (along Paris Rd) and the NOS&WB treatment plant is considered negligible.

In addition to a negligible impact on the limited development activity, the diversion option may have some environmental impact on Central Wetlands. The environmental impact largely depends on the salinity of the diverted water and the duration of retention in the Central Wetlands. Given that the Central Wetlands is already subject to tidal exchange with Lake Borgne the environmental impact of the diversion option is also considered negligible. This environmental risk impact of a rare diversion of IHNC Basin surge to the Central Wetlands would be evaluated further as part of pursuing this option.

16. Cost Estimates for Priority Compartmentalization Alternatives

This section provides "order of magnitude" cost estimates for the five priority compartmentalization alternatives described in Section 14:

1. EJ/SC Parish-Line Levee/Floodwall
2. Maxent Levee
3. 40 Arpent/Violet Canal Levee/Floodwall
4. IHNC Basin Levee/Floodwall
5. IHNC Basin Operational Modification

These order-of-magnitude cost estimates, which address the various upgrade options, are consistent with a reconnaissance-level feasibility evaluation of the alternatives and support the compartmentalization recommendations presented in the *Executive Summary*.

Cost estimates for each option include:

- Preliminary engineering
- Geotechnical or advanced hydraulic investigations
- Final engineering
- Right of Way (ROW) acquisition
- Construction (including relocations and flood risk mitigation for adversely impacted areas)
- Construction oversight
- A contingency of 25 percent

Preliminary engineering will refine the design approaches for the compartmentalization alternative upgrade options—employing the results of the investigations—including the development of new options, more detailed construction scopes and risk assessment/mitigation, and better cost estimates.

The order of magnitude unit cost of an Option 0 (Baseline) geotechnical investigation for residual surge risk management purposes is $300,000 plus $75,000 per mile—based on adjusting the recent NFIP accreditation evaluations for the Maxent Levee and 40 Arpent/Violet Canal Levee/Floodwall. The cost of geotechnical investigations for Options 1 and 2 are increased to address additional design elements.

Construction costs are based on order of magnitude unit costs—such as per linear foot (LF) of floodwall. Table 16.1 present some typical unit costs and sources. Additional SLFPA-E O & M costs are not considered a significant factor and are not included in the cost estimates.

Table 16.2 summarizes the total estimated cost for alternatives and all the respective options. The costs presented for Options 1 and 2 are separate and all inclusive—i.e., Option 1 or 2 costs do not need to be added to the Option 0 (Baseline) costs. The five Baseline Option 0 projects range between $1.1 and $2.2 million and total about $8.4 million—assuming design/construction for the IHNC Basin Levee/ Floodwall upgrade is undertaken by the USACE HSDRRS Resiliency Program. Costs for Options 1 and 2 are many times higher than for the Baseline Options and appear prohibitive without outside funding. Table 16.3 summarizes the cost breakdown for the five project Baseline Options.

Table 16.1. Order of Magnitude Unit Costs for Construction

Item	Cost $	Units
Erectable Temporary Barrier		
4 ft High Barrier; add $500/LF for each additional 1 ft in height; includes reinforced concrete pad with footings for vertical posts.[17]	2,000	LF
I-Wall Deep Soil Mixing		
I-Wall deep soil mixing and concrete protected-side scour pad. [18]	3,000	LF
I-Wall Protected-Side Berm Improvements		
I-Wall protected-side berm improvement, including slope paving[19]	800	LF
Levee Lift		
Compacted clay, plus re-sodding, for levee lift[20]	40 - 60	CY
Conversion of I-Wall to L-Wall		
I-Wall conversion to L-Wall[21]	5,000 - 7,500	LF
Concrete Buttresses		
Concrete base slab, including base preparation (if not already included)	500	LF
Buttress, based on one 5 ft x 2 ft x 5 ft (L x W x H) concrete buttress every 10 linear feet	200	LF
I-Wall		
Sheet pile with no concrete cap or base[21]	1,500 – 3,000	LF
T-Wall		
T-Wall, grade prep, sheet pile, batter piles, and concrete base and cap.[22]	8,000 - 10,000	LF
Highway or railroad gate at gap in T-Wall[23]	30,000	LF
Levee Protected-Side Armoring with HPTRM		
HPTRM installation, includes prep and re-sod. [24]	60 - 90	SY

[17] Based on general pricing from Presray Corporation and Flood Control International.
[18] Based on actual cost for HPO LPV-120.01 Rch III - IHNC W Levee (Cycle Construction, 2009).
[19] Based on actual cost for TFG I8 IHNC W/S Benefit –Almonaster (Boh Brothers, 2006).
[20] Based on 2015 engineering estimates for EJLD levee lift projects.
[21] Based on Engineering Alternative Report, WBV-39b.2: Cousins Pump Station Outfall Canal, Jefferson Parish, LA (for smaller quantity higher end of unit cost).
[22] Based on actual cost for LPV-145 (for larger quantity lower end of unit cost) and Engineering Alternative Report, WBV-39b.2: Cousins Pump Station Outfall Canal, Jefferson Parish, LA (for smaller quantity higher end of unit cost).
[23] Based on actual construction cost for new gate at CSX Railroad in NO East.
[24] Based on project bids for HPTRM installation for USACE resiliency program.

Table 16.2. Cost Estimates for Five Priority Compartmentalization Alternatives/Options

Alternative	Option 0 (Baseline)	Option 1	Option 2
EJ/SC Parish-Line Levee/ Floodwall			
	Improve two temporary barriers to provide continuous containment at current SWL Safe Limit & close the E-W Ditch, assume 6 ft NAVD88.	Improve segments to raise SWL Safe Limit to 8 ft NAVD88; install resiliency measures. Additional and higher temporary barriers and closures for continuous containment.	Upgrade the EJ/SC Parish-Line Levee/Floodwall to contain a Class D 30,000-acre-ft breach at St. Rose with a T-Wall and gates to 14 ft NAVD88.
Cost:	**$1,928,125**	**$21,050,000**	**$144,375,000**
Maxent Levee			
	Install resiliency measures along lower elevation points north of Interstate 10.	Improve Levee north of Interstate 10 and install additional resiliency measures.	
Cost:	**$1,100,000**	**$4,550,000**	
40 Arpent/Violet Canal Levee/ Floodwall			
	Improve temporary barriers at openings to 7.0 ft NAVD88.	Improve a few segments to raise SWL Safe Limit to 8.0 ft NAVD88, and install additional resiliency measures.	
Cost:	**$1,375,000**	**$11,125,000**	
IHNC Basin Levee/ Floodwall			
	Implement resiliency measures to improve I-Wall SWL Safe Limits and FOSs (e.g., deep soil mixing, buttresses, etc.).	Upgrade the IHNC Basin Levee/Floodwall for major impact loading at 8.0 ft NAVD88. 8.2 mi of I-Wall upgraded to L-Wall.	Upgrade the IHNC Basin Levee/Floodwall for major impact loading at 11.0 ft NAVD88. 13.1 mi of I-Wall upgraded to T-Wall.
Cost:	**$2,187,500****	**$302,937,500**	**$925,000,000**
IHNC Basin Operational Modifications***			
	Finalize the plan for using the Bayou Bienvenue Sector Gate to divert IHNC Basin surge into the Central Wetlands and modify the *Master Water Control Manual for the IHNC Basin* and *OLD EOP Manual*. Install remote monitoring & controls.		
Cost:	**$1,775,000**		

*All upgrade designs will be defined for *residual surge risk management purposes*—including SWL Safe Limit and FOS.

**For preliminary engineering and geotechnical investigation only—$64,125,000 design/construction under USACE HSDRRS Resiliency Program.

***In addition, CPRA to also undertake detailed review of the current and best practices for mooring barges and large vessels and securing potentially buoyant structures, and expedited implementation of recommendations to ensure best practices are followed. Estimated cost of this review is $250,000,

Table 16.3. Cost Estimates for Baseline Options for the Five Priority Compartmentalization Alternatives ($)

Preliminary Engineering	Investigations	Final Engineering	ROW Acquisition	Construction	Construction Oversight	Subtotal	Contingency 25 percent	Total Estimate
EJ/SC Parish-Line Levee/ Floodwall								
50,000	442,500	150,000	100,000	740,000**	60,000	1,542,500	385,625	1,928,125
Maxent Levee								
40,000	160,000	60,000	0	570,000	50,000	880,000	220,000	1,100,000
40 Arpent/Violet Canal Levee/ Floodwall								
60,000	1,040,000	0	0	0	0	1,100,000	275,000	1,375,000
IHNC Basin Levee/ Floodwall								
Preliminary engineering and investigations only—design/construction under USACE HSDRRS Resiliency Program.								
250,000	1,500,000	0	0	0	0	1,750,000	437,500	2,187,500
IHNC Basin Operational Modifications								
150,000	650,000	50,000	0	530,000	40,000	1,420,000	355,000	1,775,000
Total								
550,000	**3,792,500**	**260,000**	**100,000**	**1,840,000**	**150,000**	**6,692,500**	**1,673,125**	**8,365,625**
Final Engineering and Construction of IHNC Basin Levee/Floodwall by USACE HSDRRS Resiliency Program								
		400,000	500,000	50,100,000	300,000	51,300,000	12,825,000	64,125,000

*All upgrade designs will be defined for *residual surge risk management purposes*—including SWL Safe Limit and FOS.
**Includes an allowance for mitigation of flood risk increases for St. Charles Parish.

16.1. East Jefferson/St. Charles Parish-Line Levee/Floodwall

Upgrading the 1.9-mi EJ/SC Parish-Line Levee/Floodwall described in Section 14.1 reduces the risk of East Jefferson inundation in the event of an HSDRRS breach in St. Rose, but increases risk in St. Charles Parish. Preliminary engineering includes additional analysis of flood risk reductions and increases in East Jefferson and St. Charles, mitigation requirements for upgrading the EJ/SC Parish-Line Levee/Floodwall, and the relative merits of instead upgrading the St. Charles HSDRRS levee. The following are order of magnitude cost estimates for the three upgrade options.

Option 0 (Baseline)

The working assumption for purposes of this Report is that the current SWL Safe Limit for the existing levees and floodwalls is 6 ft NAVD88. The actual current SWL Safe Limit will be determined in a geotechnical investigation. Option 0 has several minor upgrades for temporary barriers and unfinished reaches and includes:

- Geotechnical investigation to determine the SWL Safe Limit and FOSs for residual risk management purposes along the entire EJ/SC Parish-Line Levee/Floodwall.
- Improved CN Railroad (North) and Airline Hwy temporary erectable barriers (50 and 220 LF). For costing purposes the two temporary barriers are upgraded to 4 ft high barriers (see Figure 14.4). During preliminary engineering continuing with the current practice of using HESCO and sand bags can be considered.
- Closing the E-W Ditch and property to the south to provide continuous containment, 1,000 cy.
- ROW expenses and flood risk mitigation allowances both of $100,000.

The estimated cost for Option 0 is:

Item	Quantity	Cost $
Preliminary Engineering	1	50,000
Geotechnical Investigation	1	442,500
Final Engineering, Detailed Plans, and Specifications	1	150,000
ROW Acquisition	1	100,000
Construction		
Relocations	1	0
Mobilization	1	50,000
Flood Risk Mitigation for St. Charles	1	100,000
Erectable Barrier CN Railroad (North)	50 LF	100,000
Erectable Barrier Airline Highway and South to Floodwall 3	220 LF	440,000
E-W Ditch closure and fill on Private Property, 200 LF	1,000 CY	50,000
Construction Subtotal		740,000
Construction Oversight	1	60,000
Subtotal		1,542,500
Contingency (25 percent)		385,625
Total Estimate		**1,928,125**

Option 1

Option 1 raises the SWL Safe Limit to 8 ft NAVD88. The working assumption—to be re-evaluated during preliminary engineering—is that this can be achieved with some modest levee lifting, I-Wall foundation improvements, higher temporary barriers and closures, and resiliency measures. For the purposes of this Report, Option 1 includes:

- Geotechnical investigation with an additional $157,500 beyond Option 0.
- 3,400 LF levee lift to provide a crown elevation of 9.0 ft NAVD88, 6 cy of clay per linear LF or 20,400 cy of clay.
- HPTRM installed on the protected-side of 5,200 LF of levee, 40,000 sy.
- 2,000 LF of deep soil mixing for sheet pile wall.
- 3,200 LF of protected-side berm improvement along sheet pile walls.
- 6 ft high erectable barriers at CN Railroad (North) and Airline Hwy, 50 and 220 LF.
- 4 ft high erectable barriers at KCS and CN Railroad (South) and River Rd, 40, 20, and 40 LF.
- New I-Wall extending from Floodwall 3 to south of CN Railroad (South), 160 LF.
- ROW, relocation, and flood risk mitigation costs of $200,000, $500,000, and $500,000.

Item	Quantity	Cost $
Preliminary Engineering	1	150,000
Geotechnical Investigation	1	600,000
Final Engineering, Detailed Plans, and Specifications	1	200,000
ROW Acquisition	1	200,000
Construction		
Relocations	1	500,000
Mobilization	1	500,000
Flood Risk Mitigation for St. Charles	1	500,000
Erectable Barrier CN Railroad (North)	50 LF	150,000
Erectable Barrier Airline Highway and South to Floodwall 3	220 LF	660,000
Erectable Barrier KCS and CN Railroads (South)	40 and 20 LF	180,000
New I-Wall from Floodwall 3 to south of CN Railroad (South)	160 LF	400,000
E-W Ditch closure and fill on Private Property, 350 LF	2,000 CY	100,000
Erectable Barrier River Rd	40 LF	120,000
I-Wall Deep Soil Mixing	2,000 LF	6,000,000
I-Wall Protected-Side Berm Improvements	3,200 LF	2,560,000
Levee Lift,	20,400 CY	1,020,000
Levee Protected-Side Armoring with HPTRM	40,000 SY	2,800,000
Construction Subtotal		15,490,000
Construction Oversight	1	200,000
Subtotal		16,840,000
Contingency (25 percent)		4,210,000
Total Estimate		**21,050,000**

Option 2

Option 2 upgrades the Levee/Floodwall to contain a Class D 30,000-acre-ft breach at St. Rose with a new T-Wall to 14 ft NAVD88 along the length of the alignment. For the purposes of this Report, Option 2 includes:

- Geotechnical investigation with an additional $357,700 beyond Option 0.
- 9,800 LF T-Wall.
- Five gates: at CN (North), KCS, CN (South), Airline Hwy, and River Rd.
- New I-Wall extending from Floodwall 3 to south of CN Railroad (South), 160 LF.
- ROW, relocation, and flood risk mitigation costs of $200,000, $500,000, and $5,000,000.

Item	Quantity	Cost $
Preliminary Engineering		500,000
Geotechnical Investigation		800,000
Final Engineering, Detailed Plans, and Specifications		500,000
ROW Acquisition		200,000
Construction		
Relocations		500,000
Mobilization	1	500,000
Flood Risk Mitigation Allowance for St. Charles	1	5,000,000
New T-Wall to 14 ft NAVD88	9,800 LF	98,000,000
Gate CN Railroad (North)	50 LF	1,500,000
Gate Airline Highway	150 LF	4,500,000
Gate KCS Railroads	40 LF	1,200,000
Gate CN Railroads (South)	20 LF	600,000
Gate River Rd	40 LF	1,200,000
Construction Subtotal		113,000,000
Construction Oversight		500,000
Subtotal		115,500,000
Contingency (25 percent)		28,875,000
Total Estimate		**144,375,000**

16.2. Maxent Levee

The following are order of magnitude cost estimates for the two upgrade options for the 4.8-mi long Maxent Levee/Floodwall described in Section 14.2. Both options focus on improving the 6,500-ft portion of the Maxent Levee north of Interstate 10, which reduces the risk of overtopping and breaching should surge enter the BSNWRR east of the Maxent Levee.

Option 0 (Baseline)

For the purposes of this Report, Option 0 includes:

- Geotechnical investigation to determine the SWL Safe Limit and FOSs for residual risk management purposes along the full 4.8 mile levee, $660,0000, less $500,000 for the recently completed NFIP accreditation investigation.
- HPTRM on the protected-side of 1,000 LF of Levee where the crown is below 5.0 ft NAVD88, 6,000 sy.

The estimated cost for Option 0 is:

Item	Quantity	Cost $
Preliminary Engineering	1	40,000
Geotechnical Investigation	1	160,000
Final Engineering, Detailed Plans, and Specifications	1	60,000
ROW Acquisition	1	0
Construction		
Relocations	1	0
Mobilization	1	30,000
Levee Protected-Side Armoring with HPTRM	6,000 SY	540,000
Construction Subtotal		570,000
Construction Oversight	1	50,000
Subtotal		880,000
Contingency (25 percent)		220,000
Total Estimate		**1,100,000**

Option 1

Option 1 upgrades the Maxent Levee north of Interstate 10 to provide a SWL Safe Limit of 5.0 ft NAVD88. For the purposes of this Report, Option 1 includes:

- Geotechnical investigation with an additional $40,000 beyond Option 0.
- 2,500 LF levee lift of 2 ft, 15,000 cy.
- HPTRM on the protected-side of 6,500 LF of Levee, 36,000 sy.

The estimated cost for Option 1 is:

Item	Quantity	Cost $
Preliminary Engineering	1	80,000
Geotechnical Investigation	1	40,000
Final Engineering, Detailed Plans, and Specifications	1	100,000
ROW Acquisition	1	0
Construction		
Relocations	1	0
Mobilization	1	100,000
Levee Lift,	15,000 CY	750,000
Levee Protected-Side Armoring with HPTRM	36,000 SY	2,520,000
Construction Subtotal		3,370,000
Construction Oversight	1	50,000
Subtotal		3,640,000
Contingency (25 percent)		910,000
Total Estimate		**4,550,000**

16.3. 40 Arpent/Violet Canal Levee/Floodwall

The following are order of magnitude cost estimates for the two upgrade options for the 23.2-mi long 40 Arpent/Violet Canal Levee/Floodwall described in Section 14.3. Both options focus on minor improvements to the SWL Safe Limit, which reduce inundation risk for the developed portion of the St. Bernard Polder in the event surge enters the Central Wetlands.

Option 0 (Baseline)

Option 0 incorporates an operational upgrade to HESCO Bags for the full Bayou Rd closure, as well as for a new closure at LA Hwy 46 in Violet, to provide a SWL Safe Limit of 7.0 ft NAVD88. As an alternative to HESCO bags, erectable flood barriers—as discussed in Sections 14.1 and 15.1, Option 0 (and shown in Figure 14.4)—can be considered during Preliminary Engineering. For the purposes of this Report, Option 0 includes:

- Geotechnical investigation to determine the SWL Safe Limit and FOSs for residual risk management purposes along the full 23.2 mile levee, $2,040,0000, less $1,000,000 for the recently completed NFIP accreditation investigation.

The estimated cost for Option 0 is:

Item	Quantity	Cost $
Preliminary Engineering	1	60,000
Geotechnical Investigation	1	1,040,000
Subtotal		1,100,000
Contingency (25 percent)		275,000
Total Estimate		**1,375,000**

Option 1

Option 1 improves sections of the 40 Arpent/Violet Canal Levee/Floodwall to provide a higher SWL Safe Limit of 8.0 ft and adds some resiliency measures. For the purposes of this Report, Option 1 includes:

- Geotechnical investigation with an additional $60,000 beyond Option 0.
- 150 LF levee lift of 2 ft, 2,000 cy.
- 3,500 LF of protected-side berm improvement along sheet pile walls and construction of buttresses.
- HPTRM on the protected-side of 5,200 feet of levee.
- Relocation expense allowances of $500,000.

The estimated cost for Option 1 is:

Item	Quantity	Cost $
Preliminary Engineering	1	100,000
Geotechnical Investigation	1	1,100,000
Final Engineering, Detailed Plans, and Specifications	1	200,000
ROW Acquisition	1	0
Construction		
Relocations	1	500,000
Mobilization	1	500,000
I-Wall Protected-Side Berm Improvements	3,500 LF	2,800,000
I-Wall Buttresses	3,500 LF	700,000
Levee Lift,	2,000 CY	100,000
Levee Protected-Side Armoring with HPTRM	40,000 SY	2,800,000
Construction Subtotal		7,400,000
Construction Oversight	1	100,000
Subtotal		8,900,000
Contingency (25 percent)		2,225,000
Total Estimate		**11,125,000**

16.4. IHNC Basin Levee/Floodwall

The following are order of magnitude cost estimates for the three upgrade options for the 28.7-mi long interior IHNC Basin Levee/Floodwall described in Section 14.4. These upgrades reduce inundation risks for all three polders from possible breaching of the IHNC Basin Levee/Floodwall, especially remaining I-Walls.

Option 0 (Baseline)

Option 0 upgrades the strength and stability of existing IHNC Basin I-Walls to raise SWL Safe Limits with appropriate FOSs. For the purposes of this Report, working assumptions for Option 1 include:

- A geotechnical investigation to determine SWL Safe Limits and FOSs over the entire Levee/Floodwall consistent with residual surge risk management, as well as improvements with upgrade options. At the base rate this would be $2,452,500. Available USACE post-Katrina geotechnical engineering investigations and reports for I-/ L-/T-Walls, levees, and other improvements are assumed to reduce the cost to $1,500,000.
- 10,000 LF of deep soil mixing, about 23 percent of the I-Wall west of Paris Rd).
- 22,000 LF (about 48 percent of the I-Wall west of Paris Rd) of protected-side berm improvement or I-Wall buttresses.
- ROW and relocation expense allowances of $500,000 and $2,000,000.

The estimated cost for Option 0 is shown below. As previously noted in Section14.4, I-Wall strength and stability are an essential part of HSDRRS resiliency. *The working assumption of this Report is that SLFPA-E would fund the preliminary engineering and additional geotechnical investigation only—$2,187,500 with contingency, and that the authorized USACE Resiliency Program would fund the remaining $64,125,000 for design/construction*. The Option 0 scope and costs could be greatly reduced if Operational Modifications are implemented.

Item	Quantity	Cost $
Preliminary Engineering	1	250,000
Additional Geotechnical Investigation	1	1,500,000
Final Engineering, Detailed Plans, and Specifications	1	400,000
ROW Acquisition	1	500,000
Construction		
Relocations	1	2,000,000
Mobilization	1	500,000
I-Wall Deep Soil Mixing	10,000 LF	30,000,000
I-Wall Protected-Side Berm Improvements or Buttresses	22,000 LF	17,600,000
Construction Subtotal		50,100,000
Construction Oversight	1	300,000
Subtotal		53,050,000
Contingency (25 percent)		13,262,500
Total Estimate		**66,312,500**

Option 1

Option 1 upgrades the IHNC Basin Levee/Floodwall for major impact loading at 8.0 ft NAVD88. For the purposes of this Report, Option 1 includes:

- Geotechnical investigation with an additional $500,000 beyond Option 0.
- 8.2 mi (43,300 LF) I-Wall converted to L-Wall. (Detailed investigations may show that some reaches require no or minimal upgrade, only an upgrade of foreshore barriers, or some additional foundation improvements such as grout injection and/or deep soil mixing. Other reaches may require total replacement with T-Walls. Construction access and other issues for some segments could dictate the use of impact barriers in place of I-Wall upgrade.) Due to the very large quantity, the unit cost is reduced from $7,500/LF (Table 16.2) to $5,000/LF.
- 3,800 LF flood-side temporary impact barriers for nine railroad and 29 road gates. Detailed investigations may show that some gates do not require flood-side impact barriers, or that complete replacement of the existing gate and adjacent floodwall is more appropriate for some gates. A unit cost of $2,000/LF is used for this item.
- ROW and relocation expense allowances of $2,000,000 and $10,000,000.

The estimated cost for Option 1 is:

Item	Quantity	Cost $
Preliminary Engineering	1	500,000
Geotechnical Investigation	1	2,500,000
Final Engineering, Detailed Plans, and Specifications	1	650,000
ROW Acquisition	1	2,000,000
Construction		
Relocations	1	10,000,000
Mobilization	1	2,000,000
Conversion of I-Wall to L-Wall	43,300 LF	216,500,000
Outfitting gates for temporary flood-side impact barriers	3,800 LF	7,600,000
Construction Subtotal		236,100,000
Construction Oversight	1	600,000
Subtotal		242,350,000
Contingency (25 percent)		60,587,500
Total Estimate		**302,937,500**

Option 2

Option 2 upgrades the IHNC Basin Levee/Floodwall for major impact loading at 11.0 ft NAVD88. For the purposes of this Report, Option 2 includes:

- Geotechnical investigation with an additional $500,000 beyond Option 0.
- 15,900 LF flood-side temporary impact barriers for levee and L-/T-Wall. Most of the 12 levee (13.48 mi) and six L-/T-Wall (2.06 mi) reaches are assumed to have an acceptable FOS with no need for further upgrade. A unit cost of $1,000/LF is used for this item.
- 13.12 mi (69,300 LF) upgrade from I-Wall to T-Wall. (Detailed investigations may show that some reaches can be cost-effectively addressed with other approaches, such as upgrade to L-Wall with buttresses; foundation improvements—e.g., grout injection and/or deep soil mixing; use of impact barriers; etc.) Due to the very large quantity, the unit cost is reduced from $10,000/LF (Table 16.2) to $8,000/LF.
- 3,800 LF flood-side temporary impact barriers for nine railroad and 29 road gates. Detailed investigations may show that some gates do not require flood-side impact barriers, or that complete replacement of the existing gate and adjacent floodwall is more appropriate for some gates. A unit cost of $2,000/LF is used for this item.
- ROW and relocation expense allowances of $2,000,000 and $10,000,000.

The estimated cost for Option 2 is:

Item	Quantity	Cost $
Preliminary Engineering	1	600,000
Geotechnical Investigation	1	3,000,000
Final Engineering, Detailed Plans, and Specifications	1	1,000,000
ROW Acquisition	1	2,000,000
Construction		
Relocations	1	10,000,000
Mobilization	1	2,000,000
T-Wall	69,300 LF	554,400,000
Flood-side impact barriers	15,900 LF	159,000,000
Outfitting gates for temporary flood-side impact barriers	3,800 LF	7,600,000
Construction Subtotal		733,000,000
Construction Oversight	1	1,000,000
Subtotal		740,000,000
Contingency (25 percent)		185,000,000
Total Estimate		**925,000,000**[25]

[25] The cost of upgrading the entire IHNC Basin Levee/Floodwall to even higher levels could easily run into several billion dollars, which is why the USACE opted to build the IHNC and Seabrook Surge Barriers. By greatly reducing the NFIP 100-yr SWL50 many feet throughout the whole IHNC Basin, the IHNC Surge Barrier at a cost of approximately $1.35 billion—and together with the much small Seabrook Surge Barrier—offered a substantially cheaper approach to meeting NFIP requirements than a massive upgrade of the complete IHNC Basin Levee/Floodwall.

16.5. IHNC Basin Operational Modification

The following is the order of magnitude cost estimates for the IHNC Basin Operational Modification described in Section 14.5. IHNC Basin Operational Modification reduces inundation risks for all three polders from possible breaching of the IHNC Basin Levee/Floodwall, especially remaining I-Walls.

Option 0 (Baseline)
Option 0 finalizes the plan for using the Bayou Bienvenue Sector Gate to divert IHNC Basin surge into the Central Wetlands and modifies the *Master Water Control Manual for the IHNC Basin* and the OLD *EOP Manual*. Option 0 includes:

- An Advanced Hydraulic Analysis, incorporating a) a rigorous 2D routing model for the IHNC and Central Wetlands and simulation of a wide range of potential diversion scenarios; b) hydraulic impacts on operation of the Bayou Bienvenue Sector Gate; and c) hydraulic impacts on the Paris Rd Bridge and other sensitive locations in the Central Wetlands.
- An environmental assessment of potential diversion impacts on the Central Wetland biota, including ongoing restoration plans.
- Installation of remote SWL monitoring (both sides of gate) and gate controls.

Option 0 also supports a CPRA-led detailed review of the current and best practices for mooring barges and large vessels and securing potentially buoyant structures, and expedited implementation of recommendations to ensure best practices are followed.

The estimated cost for Option 0 is:

Item	Quantity	Cost $
Preliminary Engineering, including environmental impact and modifications to Master Water Control Manual and OLD EOP Manual	1	150,000
Advanced Hydraulic Analysis, including IHNC Basin & Central Wetlands 2D routing; velocities/scour Bayou Bienvenue Sector Gate &, Paris Rd bridge	1	650,000
ROW Acquisition	1	0
Final Engineering, Detailed Plans, and Specifications		50,000
Construction		
Relocations	1	0
Mobilization	1	30,000
Remote Monitoring and Controls	1	500,000
Construction Subtotal		530,000
Construction Oversight	1	40,000
Subtotal		1,420,000
Contingency (25 percent)		355,000
Total Estimate		**1,775,000**
For CPRA: Review of current and best practices for mooring barges and large vessels and securing potentially buoyant structures, and development of recommendations.		**250,000**

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