LACPR Summary Report

By many measures, the 2005 hurricane season was the worst in the nation's history. Across the United States and around the world people were shocked by the images of destruction along the Gulf Coast. The hurricanes took over 1,800 lives, destroyed billions of dollars of residential, commercial, and public property, and changed the landscape of the coast. In response to the destruction caused by Hurricanes Katrina and Rita, the U.S. Congress directed the Secretary of the Army to develop plans for hurricane risk reduction and coastal restoration in both Louisiana and Mississippi.

In Louisiana, Congress directed the Secretary of the Army (Public Laws 109-103 and 109-148), acting through the Chief of Engineers, to:

- Conduct a comprehensive hurricane protection analysis and design in close coordination with the State of Louisiana and its appropriate agencies;
- Develop and present a full range of flood control, coastal restoration, and hurricane protection measures exclusive of normal policy considerations for South Louisiana;
- Consider providing protection for a storm surge equivalent to a Category 5 hurricane; and
- Submit preliminary and final technical reports.

The Louisiana Coastal Protection and Restoration (LACPR) Final Technical Report was prepared by the United States Army Corps of Engineers (Corps) New Orleans District in response to the Congressional direction for Louisiana. The Mobile District has prepared a separate report for the Mississippi Coastal Improvements Program (MsCIP) to meet the Congressional direction for Mississippi. The identification, selection, and implementation of comprehensive, long range plans for the reduction and management of hurricane storm damage risk is a highly complex and collaborative effort. Decisions on these plans will require a high level of engagement and cooperation at the Federal, State, local, and even individual level. The technical information to inform some of these long-term decisions is now available through the LACPR report.

Congress directed a technical report rather than a reconnaissance or feasibility report as described by normal Corps policy. The LACPR technical report contains many of the same components as a reconnaissance or feasibility report. For purposes of this technical report, the term "final array" is the identification of high performing alternatives. This final array of alternatives may be changed with future action. This report does not contain construction recommendations or the National Environmental Policy Act (NEPA) alternatives evaluation, feasibility-level designs, real estate plan, and detailed cost estimates that are required for the Corps to make such recommendations. Rather, this technical report presents an array of alternatives for further consideration and informs decision makers, stakeholders, and the public of the tradeoffs among these alternatives that should be considered in future decisions in order to maintain existing risk levels and/or reduce risk along the Louisiana coast. The hard work of collaborative decision making must continue.

Professional and Technical Expertise

As the nation's water resource planning and development experts, the Corps was charged with conducting the LACPR planning and technical effort. The LACPR effort is the result of collaboration by more than 60 organizations including the Corps and Louisiana's Coastal Protection and Restoration Authority, as well as other State agencies, Federal agencies, non-Corps scientists and academics, non-governmental organizations, the Dutch Rijkswaterstaat, Dutch Water Partnership, private engineering firms (U.S. and Netherlands), and stakeholders.

The LACPR report has undergone several technical reviews by independent scientists and engineers. In June 2007, the National Research Council of the National Academies established a committee to review LACPR. The Committee reviewed the LACPR's February 2008 and March 2009 drafts with the purpose of providing the Corps with an external independent technical assessment, including an assessment of the economic, engineering, and environmental methods, models, data, and analyses used in the report. The Committee's concerns were related to:

- The lack of a single recommended plan and priority projects;
- The feasibility of sustaining the coast, given uncertainties about the availability of sufficient sediment;
- Quantifying scientific uncertainties associated with wetlands restoration and river diversions;
- Quantifying risk of failure for structural systems;
- Preventing induced development and limiting development in the floodplain;
- Multi-criteria decision making and plan rankings; and
- Adaptive management of a comprehensive systems approach.

The Chief of Engineers will issue a formal response to the National Academies.

Public and Agency Review

A significant purpose of this report is to communicate risk to the public and enable a risk-informed consideration of the alternative approaches for reducing and managing storm-related risk. On June 9, 2009, the Corps' New Orleans District released the LACPR report for a 45-day review by other Federal agencies, the State of Louisiana, local government, non-governmental organizations (NGOs), and the public. A Comment Addendum summarizing all comments received during the public comment period and the Corps' responses to those comments has been appended to this report. This review represents an important step in the risk-informed decision process.

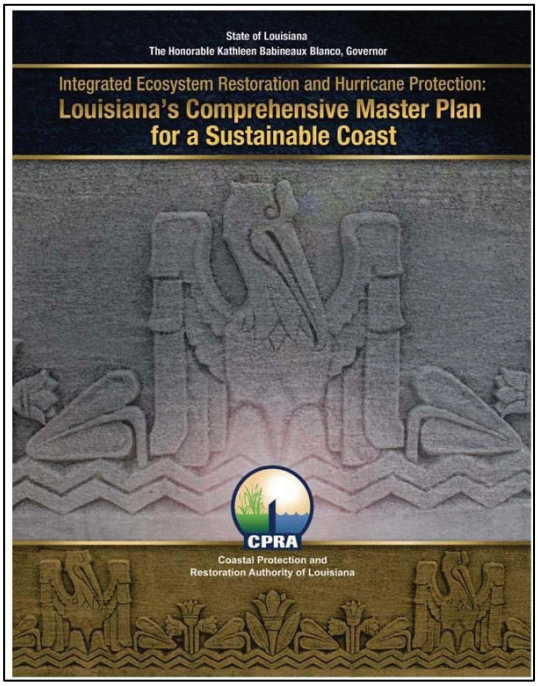
This summary report has been revised to emphasize and more clearly articulate the LACPR Final Technical Report's main points in response to comments from the public, agencies, NGOs, and the National Academies. As a result, some portions of the summary report, such as the Path Forward, have been expanded beyond what is contained in the technical report.

Louisiana's Comprehensive Master Plan for a Sustainable Coast

At the same time that Congress directed the LACPR technical report, the Louisiana Legislature restructured the State's Coastal Wetlands Conservation and Restoration Authority to form the Coastal Protection and Restoration Authority (CPRA). The CPRA is the single State entity with the authority to focus development and implementation efforts for comprehensive coastal protection and restoration and to interface with the Corps on LACPR coordination.

The State's plan entitled *Integrated Ecosystem Restoration and Hurricane Protection: Louisiana's Comprehensive Master Plan for a Sustainable Coast* was unanimously approved by the Louisiana Legislature with final approval being provided on May 30, 2007. This State Master Plan, which is available at www.lacpra.org, presents the State's conceptual framework of a sustainable coast and is the overarching vision for LACPR.

Although the State Master Plan recommends certain actions, it contains many unanswered questions about specific hurricane risk reduction and coastal restoration measures. The LACPR technical report complements the State Master Plan by presenting detailed technical evaluation and comparison of outputs for those components within the Corps' mission.



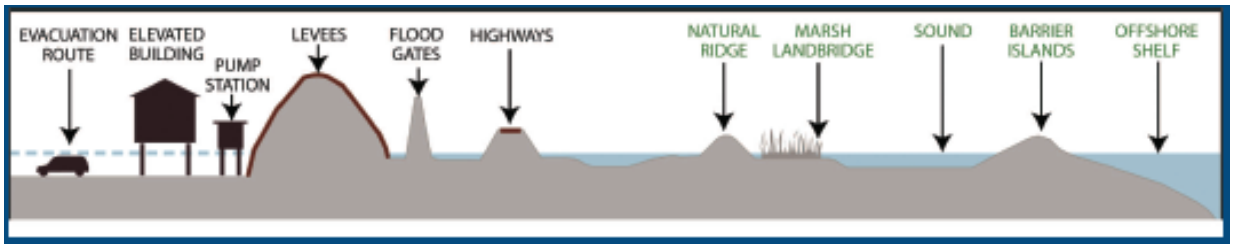
Cover of Louisiana's State Master Plan

The State and Federal government must balance the need for urgent action with a full understanding of the tradeoffs and impacts of decisions. A number of large uncertainties surround these decisions. The complex social, environmental, and economic impacts of potential plans require further evaluation by local and state partners, as well as prioritizing and sequencing measures for implementation over time. These decisions are a shared responsibility of the Federal Government and State of Louisiana.

Multiple Lines of Defense Strategy

The public has sent a clear message that a levees alone approach is not enough. No single measure or approach for achieving risk reduction will be sufficient for achieving the multiple risk reduction objectives established for coastal Louisiana. No alternatives can be formulated that will provide total protection to the entire planning area against all potential storms. The reason that total protection is not possible is a matter of practicality, technical inability and construction challenges, and extremely high costs. Therefore, the best strategy is to rely on multiple lines of defense. As shown in the following illustration, the lines of defense include natural features such as barrier

islands, marshes, and ridges and engineered structures such as highways, levees, and raised homes



Multiple lines of defense strategy as depicted by the Lake Pontchartrain Basin Foundation.

What this two-dimensional representation fails to capture is the complexity and diversity of the coastal landscape of Louisiana and the challenges specific to each area. From basin to basin, landscape features contribute differently to risk reduction.

Within the context of a multiple lines of defense, or comprehensive system, numerous risk reduction measures can be combined to form alternative plans. Each type of measure provides unique opportunities to reduce risk of hurricane-induced flooding. For the LACPR effort, three categories of alternatives were formulated and evaluated:

- **Coastal restoration alternatives** consist of hundreds of coastal restoration measures, which may include land/marsh-building river diversions, freshwater redistribution, mechanical marsh creation, barrier island/shoreline restoration, bank/shoreline stabilization, and/or ridge restoration.
- **Structural measures and alternatives** reduce flood risk using features that are designed to withstand the forces of storm events, such as surge reduction weirs, floodgates, continuous earthen levees, floodwalls, and ring levees.
- **Nonstructural measures and alternatives** reduce the exposure to risk by removing vulnerable populations and assets from the threat through measures such as buyout of properties or raising structures in place.

Comprehensive alternatives contain combinations of at least two types of risk reduction measures—nonstructural, structural, and/or coastal restoration—in a multiple lines of defense strategy, providing comparable levels of risk reduction to all economic assets in the surge impacted areas.

The Lake Pontchartrain Basin Foundation, Coalition to Restore Coastal Louisiana, and Gulf Restoration Network have applied the lines of defense strategy and developed a plan depicting specific habitat goals, coastal restoration projects, levee alignments, changes to navigation routes, etc. The State Master Plan contains a similar but different set of measures. The LACPR report has similarities and differences to both the NGO and State plans. Everyone agrees that plans should be based on a multiple lines of defense strategy; however, no clear decision has been made on the appropriate features or scale of restoration. The LACPR report therefore presents implementation options along with the technical information needed to begin to evaluate those options and tradeoffs.

Preventing Induced Development

The Corps recognizes that certain proposed levee alignments have the potential to induce development. In the context of a levee project, the term "induced development" refers to the potential to facilitate or inadvertently encourage residential, recreational, and/or commercial development in high risk areas enclosed within the levee alignment. Coastal wetlands are by definition high risk areas prone to flooding. When enclosed within a levee system, however, these areas are theoretically less prone to flooding from storm surges and thus more susceptible to development. Many examples of the potential for levees to induce development can be seen in coastal Louisiana.

The potential for a levee project to induce development is a concern for many reasons. Most obviously, encouraging development in wetlands would be directly counter to the wetland restoration goals of LACPR and the other Federal and State efforts to restore coastal Louisiana. The destruction of wetlands within levee systems can result in the loss of natural flood attenuation functions, while at the same time putting people and properties at greater risk of flooding during heavy rains and/or in the event of levee overtopping or failure.

"The most state of the art hurricane protection system can actually increase the assets at risk if it encourages development in wetlands or areas near the levee footprint. Such action would not only be risky from a safety and economic standpoint, but it would also degrade wetlands and eliminate interior flood storage capacity."

(State Master Plan, page 68)

The LACPR report addresses induced development in three ways:

(1) Levee alternatives that minimize the potential for induced development in wetlands were developed.

(2) Levee alternatives were evaluated and compared to assess the potential to induce development in wetlands.

(3) The coordination and communication approach acknowledges that additional actions by other Federal, State, parish, and municipalities are necessary to ensure consistency between coastal restoration efforts, regulatory decisions, and other civil works projects.

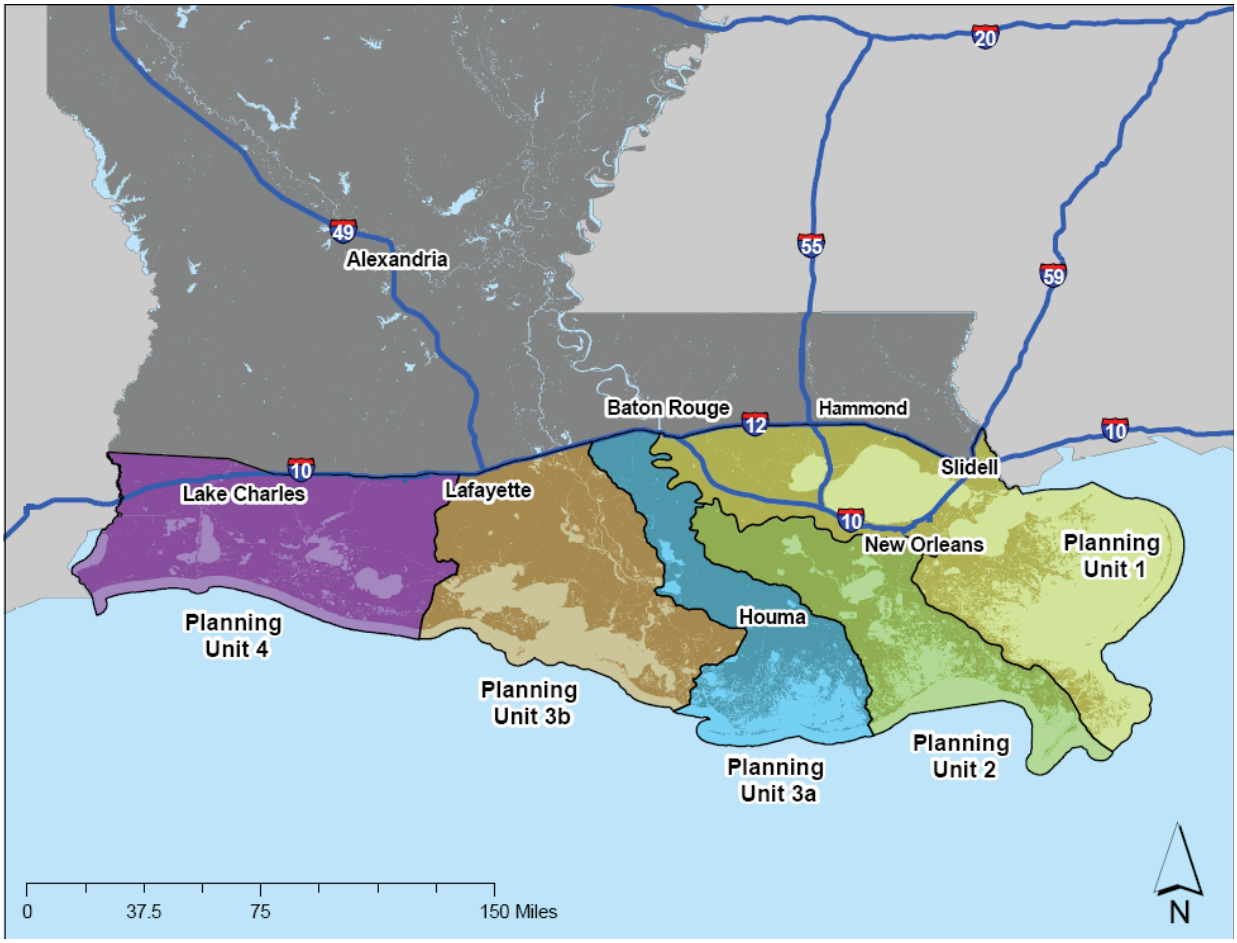
Federal, State, and local entities have a shared responsibility to prevent induced development. Future increases in vulnerability can only be limited by an integrated set of measures, including land use planning, floodplain management, conservation easements, and strictly enforced zoning regulations. Levee systems should be built in a way that contributes to the long-term sustainability of the region rather than destroying wetlands and encouraging unwise development in flood-prone areas.

LACPR Planning Area and Planning Units

The LACPR planning area (see map below) stretches across Louisiana's coast, including offshore islands, from the Pearl River on the Mississippi border to the Sabine River on the Texas border. Based on 2000 U.S. Census Bureau data, the planning area contains approximately 2.4 million people. The planning area was divided into five planning units based on hydrologic basins as previously established in other coastal planning efforts such as the Louisiana Coastal Area (LCA) study:

- Planning Unit 1 – Lake Pontchartrain Basin
- Planning Unit 2 – Barataria Basin
- Planning Unit 3a – Eastern Terrebonne Basin
- Planning Unit 3b – Atchafalaya Influence Area
- Planning Unit 4 – Chenier Plain

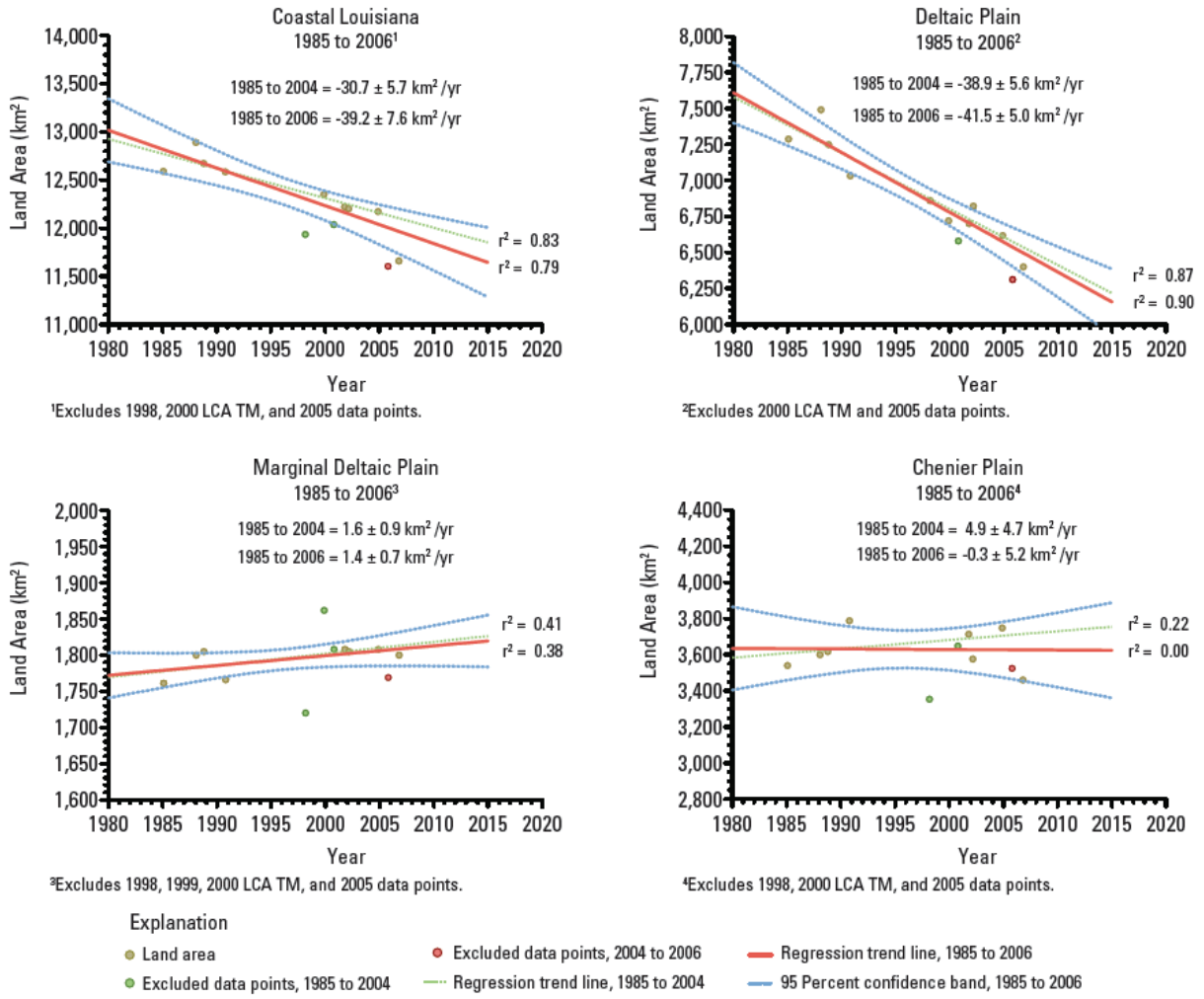
For detailed economic analyses, the planning units were further divided into approximately 900 planning subunits based on consistent hydrological characteristics.



Map showing LACPR planning area and planning units

Coastal Erosion Trends and Implications for Restoration Priorities

Rather than focusing energy and resources on trying to maintain the entire coastline, the National Research Council encouraged the Corps to focus its protection and restoration plans on high-priority projects. As shown in the figure below, not all areas of the coast are experiencing land loss at the same rate. The Deltaic Plain (roughly Planning Units 1, 2, and 3a) has the highest land loss rates. At the same time, the Marginal Deltaic Plain (roughly Planning Unit 3b) has experienced land gain, primarily the result of growth in the Atchafalaya River and Wax Lake delta complexes. The Chenier Plain (roughly Planning Unit 4) is relatively stabile.



Land area change trends and projections in coastal Louisiana (USGS Barras et. al. 2008)

As emphasized by the National Academies, readily and immediately available sediment is a limited resource in the Louisiana coastal environment and prioritization is needed. Sea level rise and subsidence further present uncertainties for the long-term sustainability of coastal Louisiana. Acquiring adequate sediment resources to sustain

the coast involves potential tradeoffs, opportunity costs, and long-term fiscal investment. The Corps is developing a Regional Sediment Budget for coastal Louisiana to determine the feasibility and impact of sustaining the coast. The Corps is also closely coordinating with the Gulf of Mexico Alliance as they develop the Gulf Regional Sediment Management Master Plan. The objective of the Sediment Management Master Plan is to provide a regional blueprint for the beneficial use of dredged material for habitat restoration.

Diversion of Mississippi River freshwater, nutrients, and sediment is essential for the restoration of natural deltaic processes to sustain coastal wetlands in the areas of greatest land loss across coastal Louisiana. Projects to divert freshwater and sediments from the Mississippi River into adjacent estuaries are integral components of coastal protection and restoration plans. Currently, more than 20 diversions are either being studied or constructed along the Mississippi River. These projects and studies, all developed through various authorizations, require strategic coordination with other Mississippi River management efforts to ensure success in construction and operation. The LACPR report includes diversions that could be classified as large diversions with high flow design capacities greater than 15,000 cfs with the largest diversion being over 175,000 cfs.

As pointed out by the National Academies, the high level of uncertainty of the effects of proposed river diversions suggests the need for careful monitoring and evaluation of existing diversions. They also stressed the importance of an adaptive strategy that can adjust to and build upon the new information learned from the responses of these coastal wetlands systems to human interventions. Under the Louisiana Coastal Area authority in WRDA 2007, the Corps and State of Louisiana are pursuing a comprehensive hydrodynamic model and analysis of the Mississippi River to assess cumulative impacts and allocation of sediment under a regional sediment management plan.

Land change projections have implications for both ecosystem restoration and hurricane risk reduction. The Louisiana Coastal Area authority addresses the ecosystem restoration aspects of coastal restoration while the LACPR analysis attempted to quantify the benefits of maintaining the coast for risk reduction. The LACPR analysis revealed that areas immediately east and west of the Mississippi River have the highest potential for increasing hurricane surges associated with predicted land loss. In the remainder of the coast, predicted land loss does not translate to future increases in storm surge. Additional research and modeling of specific features has been identified as a necessary component of comprehensive restoration plan development (also called for under WRDA 2007) to determine the most strategic or high priority projects.

Proactive Risk Management and Communication

In addition to the threat imposed by natural forces, human decisions and policies contribute to the risk equation. In the absence of proactive communication of risk to residents, many adopt a false sense of safety, which becomes inherently more dangerous in the face of potential increases in storm intensity. One of the lessons learned from Hurricane Katrina is that no system is completely effective at eliminating risk and residual risk will always remain. Residual risk is the risk that remains after all possible risk reduction measures have been implemented as shown below. The Corps has adopted the phrase “hurricane and storm damage risk reduction system” in place of what has previously been referred to a “hurricane protection system.” Although wind damage is often associated with hurricanes, this report primarily addresses damages from surge, not wind damage.

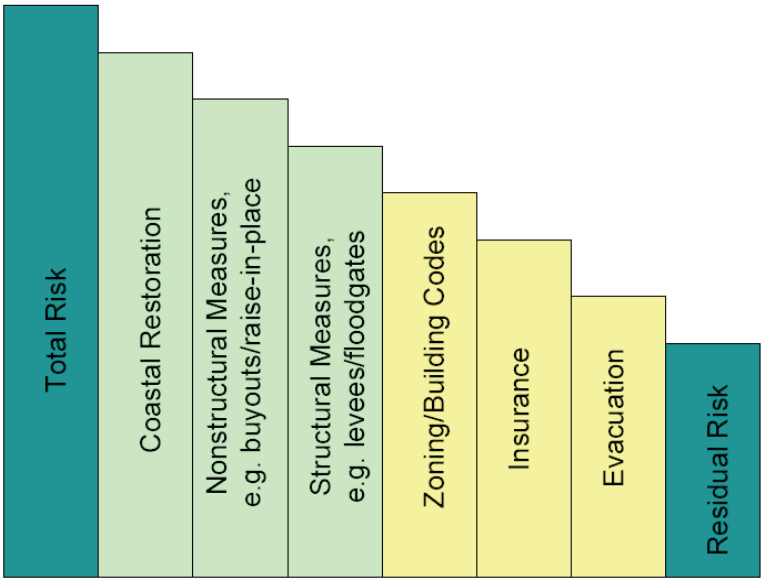
The LACPR effort attempts to assess residual flood risk and to effectively communicate that risk to policy makers and to the general public so that informed decisions can be made. The Corps fully supports open risk communication and has held over 100 public meetings to discuss flooding risk in the New Orleans area. Risk is difficult to communicate because it means different things to different people and involves statistical probabilities that may not be easily understood.

A risk assessment must answer the following questions: What can go wrong? How can it happen? What is the likelihood? What are the consequences?

The LACPR report only begins to answer to these questions in terms of hurricane-related flood risk. Much work is left to be done in terms of quantifying risk of failure; communicating risks to the public and their role in reducing risk; and determining acceptable levels of residual risk.

Determining acceptable risk involves balancing the fundamental competing principles of equity, the right of individuals and society to be protected, and efficiency, the need that society has to distribute and use its available resources in such as way as to gain maximum benefit.

Risk can be reduced through various types of measures; however, residual risk will always remain. The Corps may implement coastal restoration, nonstructural, and structural measures as described in the LACPR report; at the same time, others must implement measures such as zoning, insuring property, and having an evacuation plan.



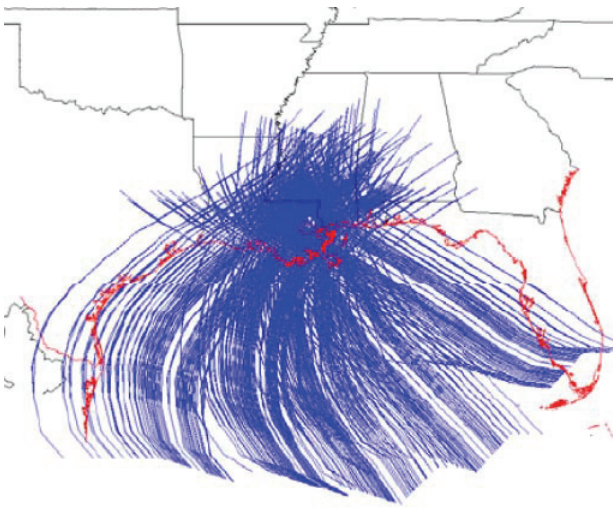
Methods for reducing risk (in no particular order)

Advances in Risk-based Hurricane Surge Frequency Simulation

Congress directed the LACPR effort to address “Category 5” surges. In order to meet this Congressional mandate, the Federal government had a lot more to learn about hurricanes, in particular their potential storm surge elevations along the coast. For decades, the Corps, the National Oceanic and Atmospheric Administration (NOAA), and the National Weather Service have used the Saffir-Simpson Hurricane Scale for categorizing hurricane strength; however, the Saffir-Simpson scale is not an adequate tool for the design of hurricane surge risk reduction systems. Coastal Louisiana has been hit by hurricanes with higher Saffir-Simpson ratings than Hurricane Katrina, a Category 3 storm at landfall, but none left anywhere near the destruction of Hurricane Katrina.

The use of advanced technology has vastly improved the ability of the Corps to evaluate hurricane threats along the northern Gulf Coast. One of the most significant accomplishments since 2005 is the development and application of advanced computer storm simulation models to replicate hurricanes and to determine statistically the potential frequency of surge events at individual locations across the coasts of Louisiana and Mississippi. The models are capable of fluctuating storm strength as a storm approaches the coast in order to estimate the surge at the coast. This capability is important because storms often decay as they make landfall.

The Federal government has adopted these models for the rebuilding of the New Orleans levee system; for determining flood insurance maps; and for evaluation of hurricane risk to the Louisiana and Mississippi coasts. The LACPR technical evaluation also applied these state-of-the-art storm surge models to quantify the risk reduction benefits provided by the coastal landscape.



Advanced Computer Modeling

ADCIRC (ADvanced CIRCulation) is a physics-based computer model that can simulate powerful tropical storms, from their formation in the Atlantic to landfall, and the resulting storm surges.

For the LACPR modeling effort, the ADCIRC program was run on two supercomputers; it would take 4,000 desktop computers linked together to equal the computing power available in each supercomputer.

For the LACPR technical evaluation, a sufficient number of different computer simulated storms had to be run on different tracks to develop a statistically significant database. A total of 304 storms (152 in the east side of the State and 152 in the west side) were run for the entire Louisiana coast.

Risk-Informed Decision Framework

Since December 2005, the LACPR team has faced a unique challenge in conducting a comprehensive hurricane risk reduction analysis for a 26-parish area in South Louisiana covering 23,273 square miles, an area almost the size of West Virginia. The magnitude of data, and the tools required to analyze the data, far exceed any prior Corps hurricane risk reduction efforts. The LACPR team considered a full range of risks to people, cultural heritage, the environment, property and the economy as well as infrastructure, construction, operations, and maintenance costs in a Risk-Informed Decision Framework. The primary activities, inputs, and outputs of the Risk-Informed Decision Framework, as well as its relationship to the Corps' 6-step planning process are shown in the graphic presented on the following page. Some of the highlights of the Risk-Informed Decision Framework are as follows:

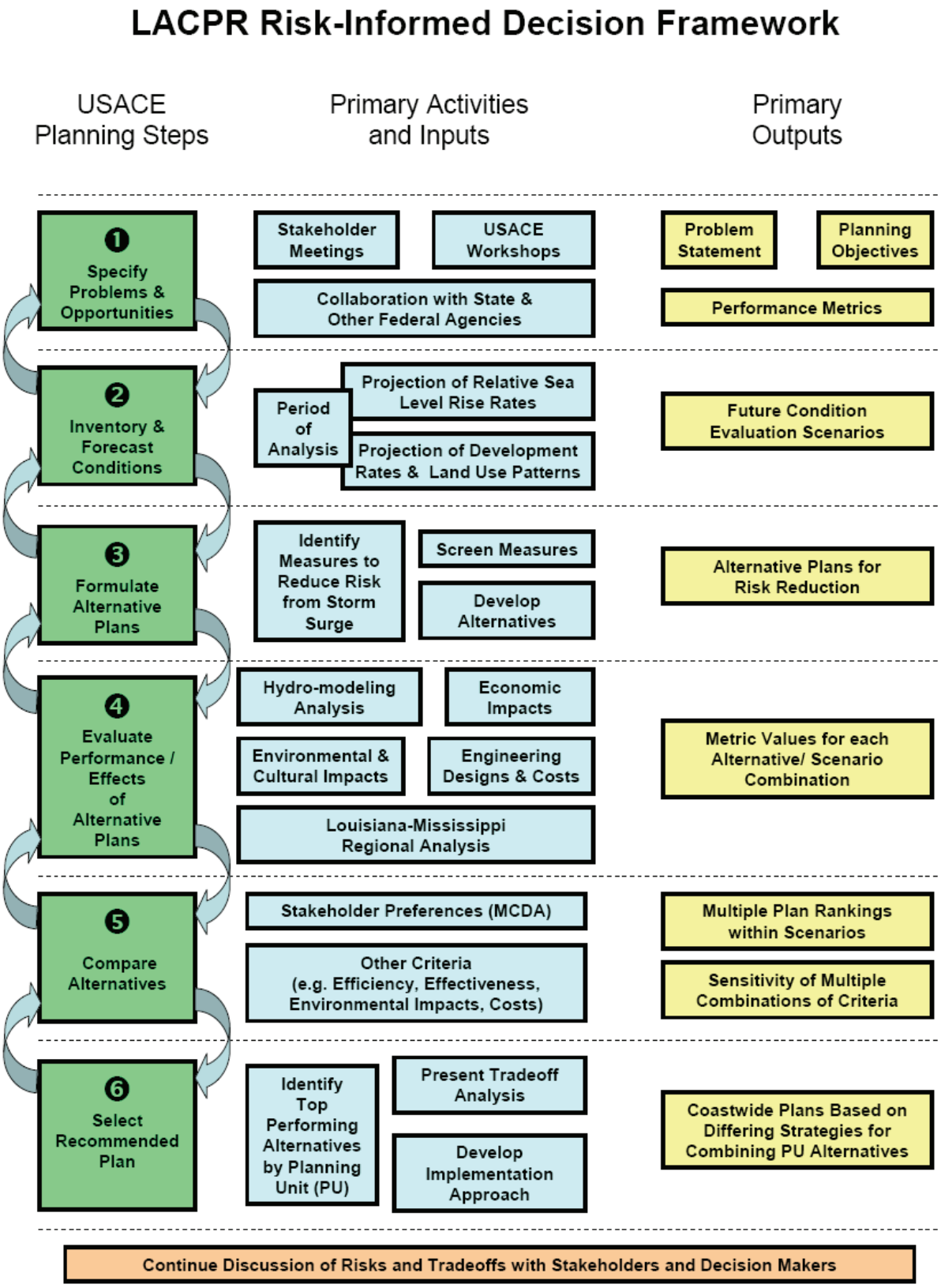
- **Stakeholder Involvement** - In developing the State Master Plan and the LACPR Technical Report, the Corps and State of Louisiana sought input from individuals, private entities, local governments, academia, and other State and Federal agencies, in addition to other stakeholders such as environmental, navigation, commercial fishing, recreation, agricultural, and oil and gas interests. The LACPR team actively engaged stakeholders using a multi-criteria decision analysis (MCDA) tool to elicit their preferences and values.

- **Scenario Planning** - Scenario planning is an approach for dealing with key uncertainties. Four future scenarios were developed based on possible relative sea level rise (subsidence and sea level rise) and development rates/patterns.

- **Alternatives Development** - The technical report identifies hundreds of measures that could be combined into over 200 million alternatives across the coast. Alternatives were developed for three hurricane surge risk reduction design levels (100-year, 400-year, and 1000-year) and then screened down to a set of 111 alternatives for evaluation and comparison and then further narrowed down to five or six alternatives in each of the five planning units.

- **Socio-Economic Evaluation** - As a means to process data for approximately 72,000 census blocks under multiple future scenarios, the LACPR team developed a customized geographic information system (GIS) to assess population impacts, economic impacts, and impacts to cultural resources associated with various frequency flood events. These inventories allow the LACPR team to evaluate alternatives and interact with stakeholders using a flexible and meaningful level of outputs.

- **Louisiana–Mississippi Regional Analysis** - The Corps has taken a systematic approach to the Louisiana-Mississippi Gulf Coast region. A systems analysis was conducted to assess potential regional impacts primarily associated with storm surge as it relates to economic damages, environmental/cultural impacts, and other social effects upon plans formulated separately for MsCIP and LACPR.



The Risk-Informed Decision Framework closely follows the Corps' 6-step planning process.

Selection of the Final Array of Alternatives[*]

In order to identify the final array of alternatives, the team performed a multi-criteria evaluation and comparison of alternatives. Part of this process involved seeking input from a small but diverse set of stakeholders on which criteria were most important to each of them. This Multi-Criteria Decision Analysis (MCDA) is just one tool for communicating risk or informing decisions on risk reduction systems. The LACPR report explicitly describes the purpose and limitations of the MCDA approach as applied to the LACPR effort. The MCDA exercise highlighted the need for the Corps to incorporate other factors in the decision besides damages and dollars.

In order to get input from stakeholders for the MCDA process, the LACPR team held a series of workshops in four locations across coastal Louisiana in July 2008 to gather data on how stakeholders allocate importance across performance objectives. The results give a good indication of stakeholder preference toward plan selection criteria. The top five most valued criteria (based on the number of times each metric was ranked as a workshop participant's top metric) were (1) population impacted, (2) direct wetland impacts, (3) indirect environmental impacts, (4) residual damages, and (5) construction time. These results indicate that stakeholders are most concerned with reduction of risk to people followed by concern for the environment, property damage, and obtaining risk reduction as quickly as possible.

Although stakeholders clearly stated their values, the LACPR team is not confident that the ultimate MCDA rankings based on the metric weights reflect the stakeholders' true preference for risk reduction plans. For example, the outputs of the stakeholder MCDA indicate that the MCDA process, as conducted to date, could potentially eliminate plans that may best meet stakeholder preferences for reducing risk to people. The MCDA ranking of plans seemed to place less emphasis on alternatives that provide high levels of risk reduction and cost efficiency and more emphasis on alternatives that avoid environmental impacts at the expense of higher levels of risk reduction. Therefore, some comparison of MCDA to traditional criteria related to effectiveness and cost efficiency is fundamental to supporting the needs of stakeholders and decision makers.

To ensure that such plans were not prematurely or inappropriately eliminated from further consideration, a comparison was made incorporating additional evaluation criteria that included (1) the stakeholder input on preferences; (2) direct and indirect environmental impacts; (3) cost efficiency; (4) effectiveness in reducing risk; as well as (5) project costs and the realities of future funding requirements for both Federal and non-Federal interests. By comparing these criteria, a more fully risk-informed assessment can be made among alternatives, considering specific tradeoffs and similarities across these evaluation criteria. Ranking results based on these criteria also provided an indication of alternatives that may be valued by stakeholders and decision makers absent the necessary additional iterations and refinement of the MCDA process and results. Additional or hybrid alternatives will likely be evaluated in more detail prior to implementation.

[*] See Glossary for definition of final array.

Final Array of Alternatives[*]

A broad range of viable options is available for the reduction of risk from large or "Category 5" surge events. The identified final array of alternatives consists of five or six plans in each of the five planning units, including plans at the 100-year, 400-year, or 1000-year design levels, which are based on flood elevations that statistically have a 1%, 0.25%, or 0.1% chance of being equaled or exceeded in any given year, respectively. Over half of the plans achieve a degree of "Category 5" risk reduction by providing significant surge reduction for a 400-year frequency storm event or greater in some areas. Hurricane Katrina was approximately a 400-year flood event.

The 100-year flood is a statistical event that has a one percent chance of occurring each year in a given area. A common misperception is that the 100-year flood will only occur once every 100 years. On average, there is a 63 percent chance of the 100-year flood occurring over a 100-year timeframe.

All plans that are described as providing 400-year or 1000-year risk reduction could be considered "Category 5" plans. In addition, some of the alternatives with a structural component (e.g. barrier-weir plans and other levees that are removed from developed areas) that were designed at the 100-year level actually achieve "Category 5" risk reduction in some areas of the planning unit by providing significant risk reduction (based on residual damages) for a 400-year frequency storm event or greater. For example, the Lake Pontchartrain barrier-weir is designated as a 100-year design because the design elevation of the weir was based on the 100-year storm surge at that location; however, the level of risk reduction it would provide to New Orleans would be much greater.

All of the alternatives evaluated for LACPR initially included coastal restoration; however, in Planning Units 3a, 3b, and 4, structural, nonstructural and comprehensive plans have been carried forward into the final array independent of this coastal restoration component. The reason for removing the coastal component from alternatives in Planning Units 3a, 3b, and 4 is that the current planning unit-scale technical evaluation failed to detect any measureable risk reduction that could be attributed to maintenance of the coastal landscape in its existing state. This exclusion does not mean that coastal restoration would not be needed in these planning units, but that the focus should be on ecosystem restoration and strategic restoration for risk reduction. More detailed modeling is needed to identify significant coastal restoration features capable of producing discrete risk reduction benefits in these areas.

In all planning units, key tradeoffs exist between risk reduction effectiveness, environmental impacts, social impacts, and cost efficiency. For example, in order to implement nonstructural measures, tradeoffs must be made between risk reduction effectiveness and social impacts associated with buyouts of structures. Also, actual participation in the implementation of any nonstructural measures is a critical factor in being able to achieve the level of risk reduction projected for nonstructural components or alternatives. At this point in time, acceptability of plans has only been measured through the stakeholder MCDA process, and references to high or low acceptability in the following paragraphs equates to high or low MCDA rankings.

[*] See Glossary for definition of final array.

Planning Unit 1 Tradeoffs

In Planning Unit 1, the final array includes alternatives that span the full range of possible categories for achieving risk reduction and key tradeoffs can be demonstrated between the alternatives. In addition to sustaining the coastal landscape through shoreline protection, marsh creation, and diversions, the most viable options are **either**

- Nonstructural measures at the 100-year, 400-year, or 1000-year design level **or**
- Lake Pontchartrain surge reduction barrier-weir across the mouth of Lake Pontchartrain and 100-year upper Plaquemines levees **either**:
    - With 100-year nonstructural measures added to areas outside of the levee system **or**
    - Without any nonstructural measures.

Alternatives (in no particular order)	**Strengths**	**Weaknesses**
Stand alone coastal restoration	Relatively moderate cost of implementation combined with measurable, although not high, effectiveness.	Less effective at risk reduction than the other alternatives.
100-year nonstructural	Effective, efficient, and acceptable.	Risk reduction effectiveness is very sensitive to levels of participation.
400-year nonstructural	Effective, efficient, and acceptable; can provide risk reduction equivalent to the barrier-weir plans; less sensitive to the level of participation than the 100-year nonstructural plan and maintains its relative position in terms of risk reduction at 60 percent participation and above.	Requires greater first cost investment than barrier-weir and purchase or modification of more than 200,000 structures.
1000-year nonstructural	Effective, efficient, and acceptable; less sensitive to the level of participation than the 100-year nonstructural plan and maintains its relative position in terms of risk reduction at 60 percent participation and above.	Provides the best overall risk reduction of the final array for Planning Unit 1 but with greater cost and purchase or modification of nearly 300,000 structures.
Lake Pontchartrain barrier-weir (structural) or Lake Pontchartrain barrier-weir with nonstructural (comprehensive)	Similar in cost to 100-year nonstructural plan but significantly more effective particularly for the surge events greater than 100-year, even providing significant risk reduction up to the 1000-year event in some areas.	Relatively low acceptability related to potential indirect environmental impacts and potential for regional impacts to the Mississippi coast.

Planning Unit 2 Tradeoffs

Of all the planning units, tradeoffs in the Planning Unit 2 final array are the most pronounced with major differences between the structural plans. In addition to sustaining the coastal landscape through shoreline protection, marsh creation, and diversions, the most viable options are **either**

- Nonstructural measures at the 400-year level **or**
- A new sector gate on Bayou Barataria either:
    - Without other measures **or**
    - With 100-year nonstructural measures added to areas outside of the levee system **and**
        - With additional 100-year ring levees around Boutte and Lafitte **or**
        - With a barrier-weir and levees along the Gulf Intracoastal Waterway (GIWW) to reduce risk to areas within the Barataria Basin.

Alternatives (in no particular order)	**Strengths**	**Weaknesses**
400-year nonstructural	Can provide risk reduction similar to the GIWW barrier-weir plan, although it is less effective at the 2000-year surge level; maintains its relative positions in terms of risk reduction at 40 percent participation and above.	The nonstructural plan requires greater first cost investment and purchase or modification of more than 150,000 structures.
Ring levees around Boutte and Lafitte with nonstructural (comprehensive)	More acceptable, environmentally preferred alternative than the GIWW barrier-weir.	Risk reduction limited to the 100-year frequency.
GIWW barrier-weir with nonstructural (comprehensive)	High efficiency and effectiveness; provides exceptional risk reduction with significant benefits for the West Bank extending up to the 2000-year surge event.	Potential negative indirect environmental impacts.
Sector gate (structural) or Sector gate with nonstructural (comprehensive)	More acceptable, environmentally preferred alternative than the GIWW barrier-weir; High acceptability combined with low cost and relative efficiency.	Risk reduction limited to the 100-year frequency.

Planning Unit 3a Tradeoffs

The most viable options in Planning Unit 3a include,

- Nonstructural measures at the 100-year, 400-year, or 1000-year level **or**
- The 100-year Morganza to the Gulf levee with 100-year nonstructural measures added to areas outside of the levee system with **either**
  - An extension tying into high ground west of Morgan City (Variation 1) **or**
  - A tieback to high ground south of Thibodaux and ring levee around Morgan City (Variation 2).

Alternatives (in no particular order)	**Strengths**	**Weaknesses**
100-year nonstructural	Acceptability; less costly than the structural plans.	Purchase or modification of some 30,000 structures; very sensitive to levels of participation.
400-year nonstructural	Acceptability; less costly than the structural plans; similar to the Morganza variation 2 in terms of average percent risk reduction.	Falls below the structural plans in terms of risk reduction effectiveness at levels of participation less than 90 percent; purchase or modification of approximately 60,000 structures.
1000-year nonstructural	Acceptability; less costly than the structural plans; could provide the best overall reduction of risk particularly for the 1000-year and 2000-year surge events; similar to the Morganza variation 1 with extension to Morgan City in terms of average percent risk reduction.	Falls below the structural plans in terms of risk reduction effectiveness at levels of participation less than 80 percent; purchase or modification of approximately 70,000 structures.
Morganza levee variation 1 with nonstructural (comprehensive)	High effectiveness; more effective than the 100-year nonstructural alternative across all surge events, particularly for the 100-year and 400-year events.	Potential for direct and indirect environmental impacts, such as wetlands impacts from levee footprints, disruption of sheetflow, and the potential for induced development.
Morganza levee variation 2 with nonstructural (comprehensive)	Achieves a balance of acceptability, efficiency, and effectiveness; more effective than the 100-year nonstructural alternative across all surge events, particularly for the 100-year and 400-year events.	Potential for direct and indirect environmental impacts, such as wetlands impacts from levee footprints, disruption of sheetflow, and the potential for induced development.

Planning Unit 3b Tradeoffs

The most viable options in Planning Unit 3b include,

- Nonstructural measures at the 400-year or 1000-year level, **or**
- Ring levees at the 100-year level around Patterson/Berwick, Franklin/Baldwin, New Iberia, Erath, Delcambre, and Abbeville, Louisiana with 100-year nonstructural measures added to areas outside of the levee system **or**
- Continuous 100-year levees across the planning unit with 100-year nonstructural measures added to areas outside of the levee system with **either**
    - The levees following the GIWW west to the boundary of Planning Unit 4 **or**
    - The levees following the edge of development north of the GIWW to high ground west of Abbeville, Louisiana.

Each of the structural-based alternatives includes the improvement of the existing Patterson/Berwick levee at the lower extent of the Atchafalaya Basin.

Alternatives (in no particular order)	**Strengths**	**Weaknesses**
400-year nonstructural	Efficient and effective; less costly than the comprehensive plans.	Purchase or modification of roughly 24,000 structures, requires greater than 90 percent participation to maintain effectiveness.
1000-year nonstructural	Less costly than the plans with structural components; not as effective as GIWW levee.	Purchase or modification of roughly 33,000 structures; requires greater than 90 percent participation to maintain effectiveness.
Ring levees with nonstructural (comprehensive)	Balances efficiency, effectiveness, and acceptability; slightly less costly than GIWW alignment; significant risk reduction benefits extending just up to the 400-year surge event.	Large direct wetland impacts.
Continuous levees along the GIWW with nonstructural (comprehensive)	Highly effective; exceptional overall risk reduction with benefits into the 2000-year surge event; performs better than the 400-year and 1000-year nonstructural plans.	Potential for large direct and indirect environmental impacts; relatively high cost; requires continuation of levees in Planning Unit 4 that were not identified as part of the final array.
Continuous levees along the edge of development with nonstructural (comprehensive)	Balances efficiency, effectiveness, and acceptability; slightly less costly than GIWW alignment; significant risk reduction benefits extending just up to the 400-year surge event.	Large direct wetland impacts.

Planning Unit 4 Tradeoffs

In Planning Unit 4, the final array consists of two types of plans:

- Nonstructural measures at the 100-year, 400-year, or 1000-year level **or**
- Comprehensive ring levee plans with nonstructural measures at the same three design levels. Ring levees are included to the east and west of Lake Charles, Louisiana; within Lake Charles to separate the river from the land; and around Kaplan and Gueydan, Louisiana.

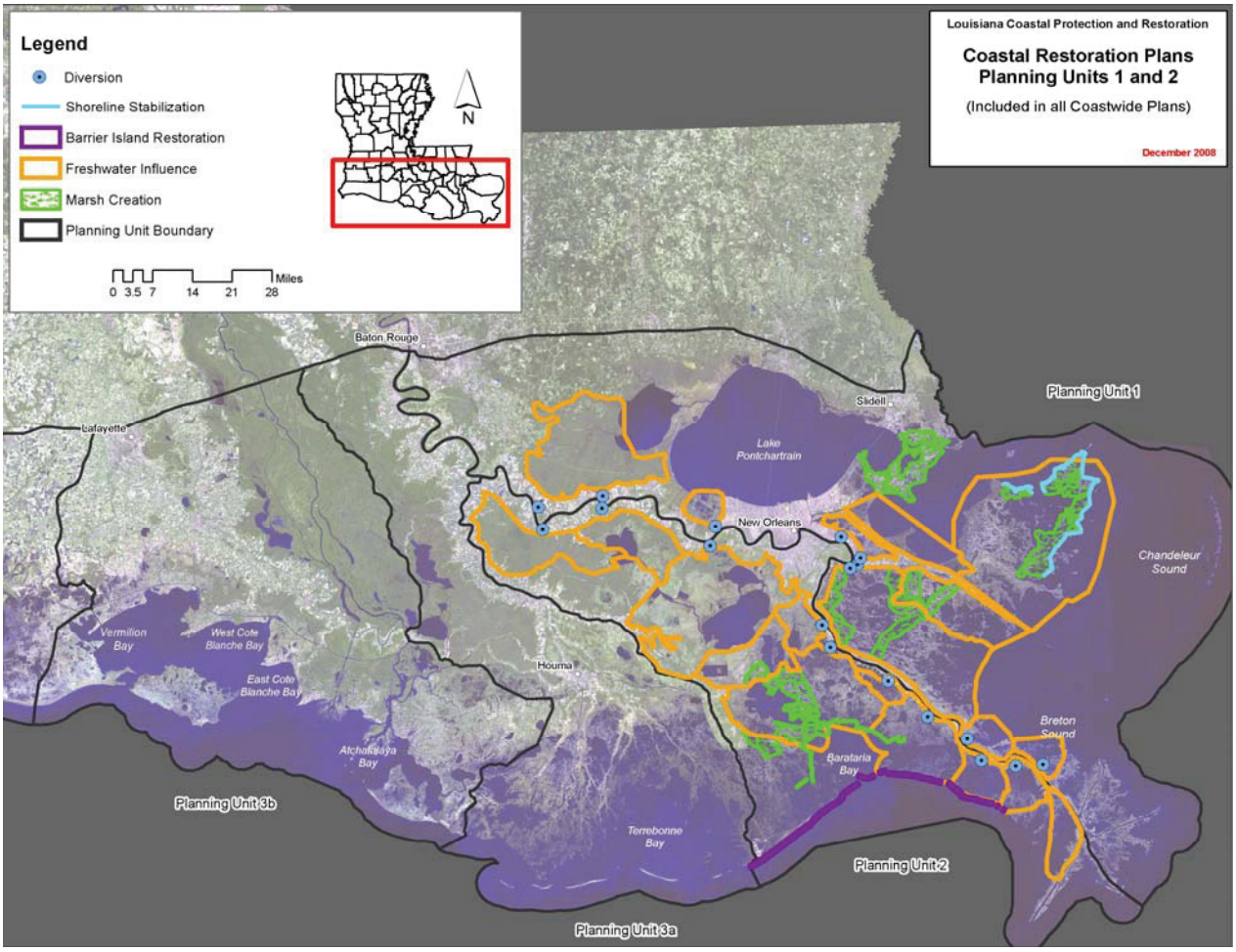
The level of risk reduction is roughly equivalent between the two sets of alternatives at each design level; however, the risk reduction effectiveness for the nonstructural plans is dependent on levels of participation.

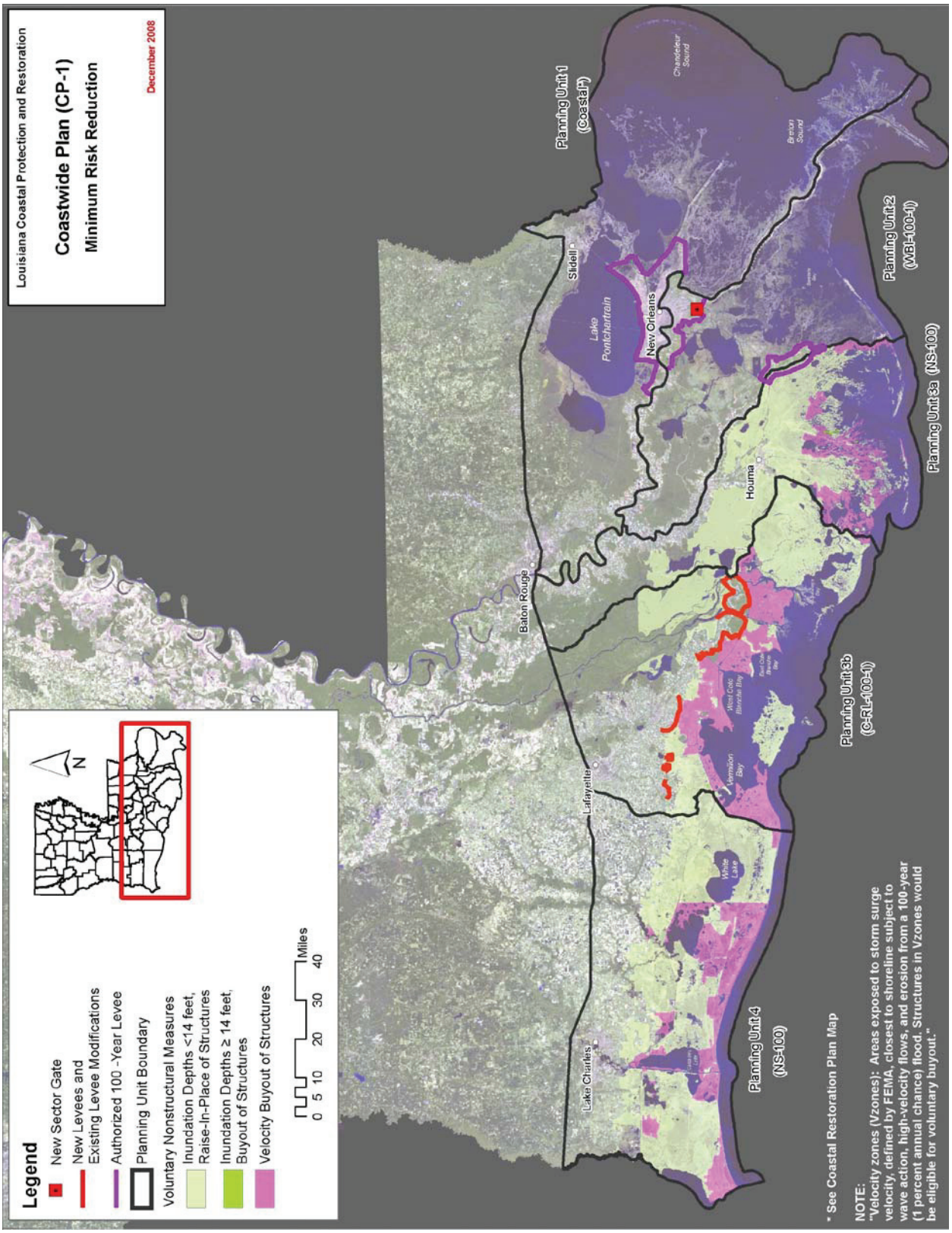
Alternatives (in no particular order)	**Strengths**	**Weaknesses**
100-year nonstructural	Slightly less costly than the ring levee plans at each corresponding design level.	Purchase or modification of roughly 8,500 structures. Relative position in terms of residual risk falls if participation less than 40 percent.
400-year nonstructural	Slightly less costly than the ring levee plans at each corresponding design level.	Purchase or modification of roughly 19,000 structures. Requires between 60 and 90 percent participation to maintain effectiveness.
1000-year nonstructural	Slightly less costly than the ring levee plans at each corresponding design level.	Purchase or modification of roughly 30,000 structures. Requires between 70 and 90 percent participation to maintain effectiveness.
100-year ring levees and nonstructural (comprehensive)	Balances efficiency, effectiveness, and acceptability; focuses structural measures in the most densely developed communities.	Purchase or modification of roughly 7,500 structures; direct wetland impacts.
400-year ring levees and nonstructural (comprehensive)	Balances efficiency, effectiveness, and acceptability; focuses structural measures in the most densely developed communities.	Purchase or modification of roughly 14,000 structures; direct wetland impacts.
1000-year ring levees and nonstructural (comprehensive)	Balances efficiency, effectiveness, and acceptability; focuses structural measures in the most densely developed communities.	Purchase or modification of roughly 21,000 structures; direct wetland impacts.

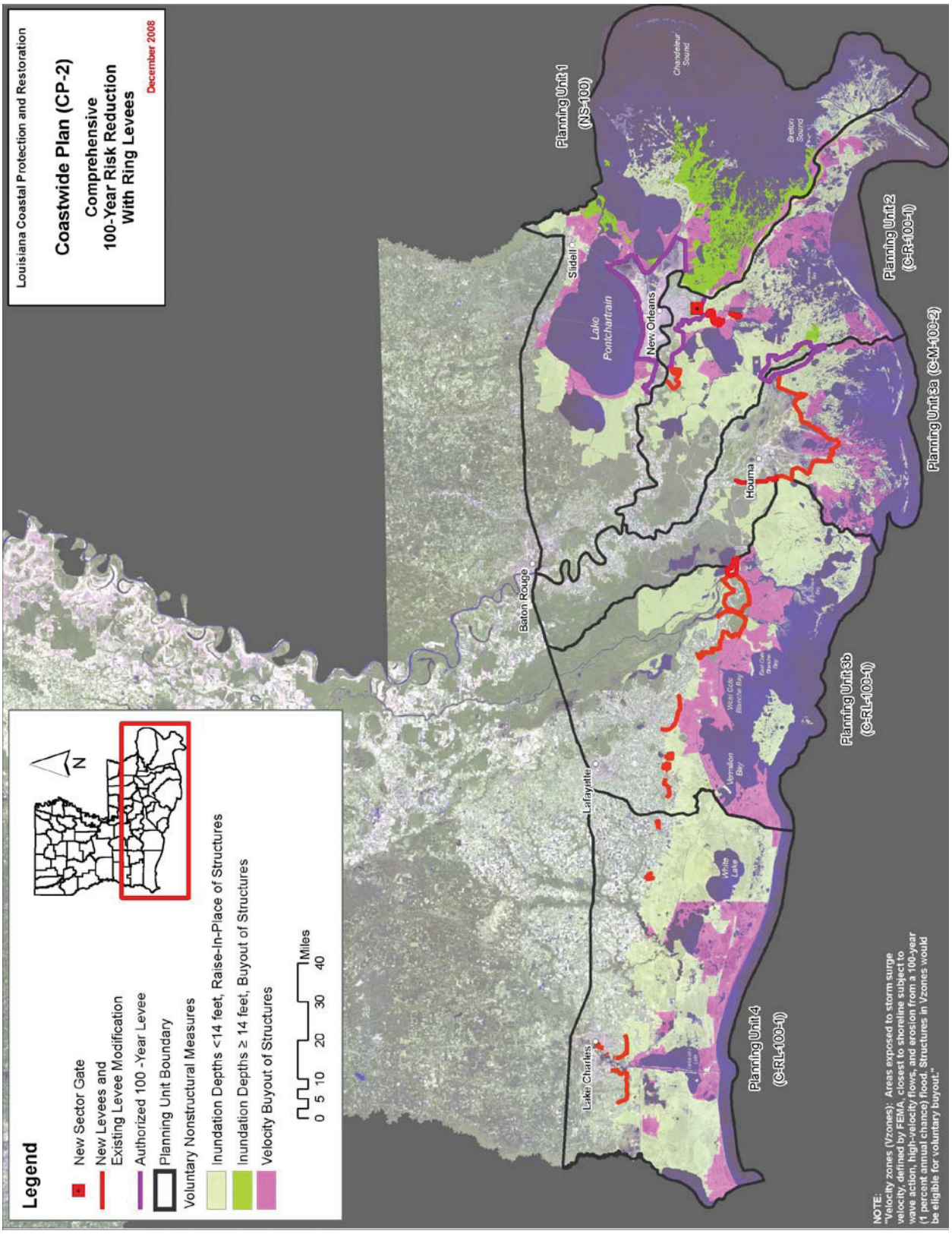
Conceptual Coastwide Plans

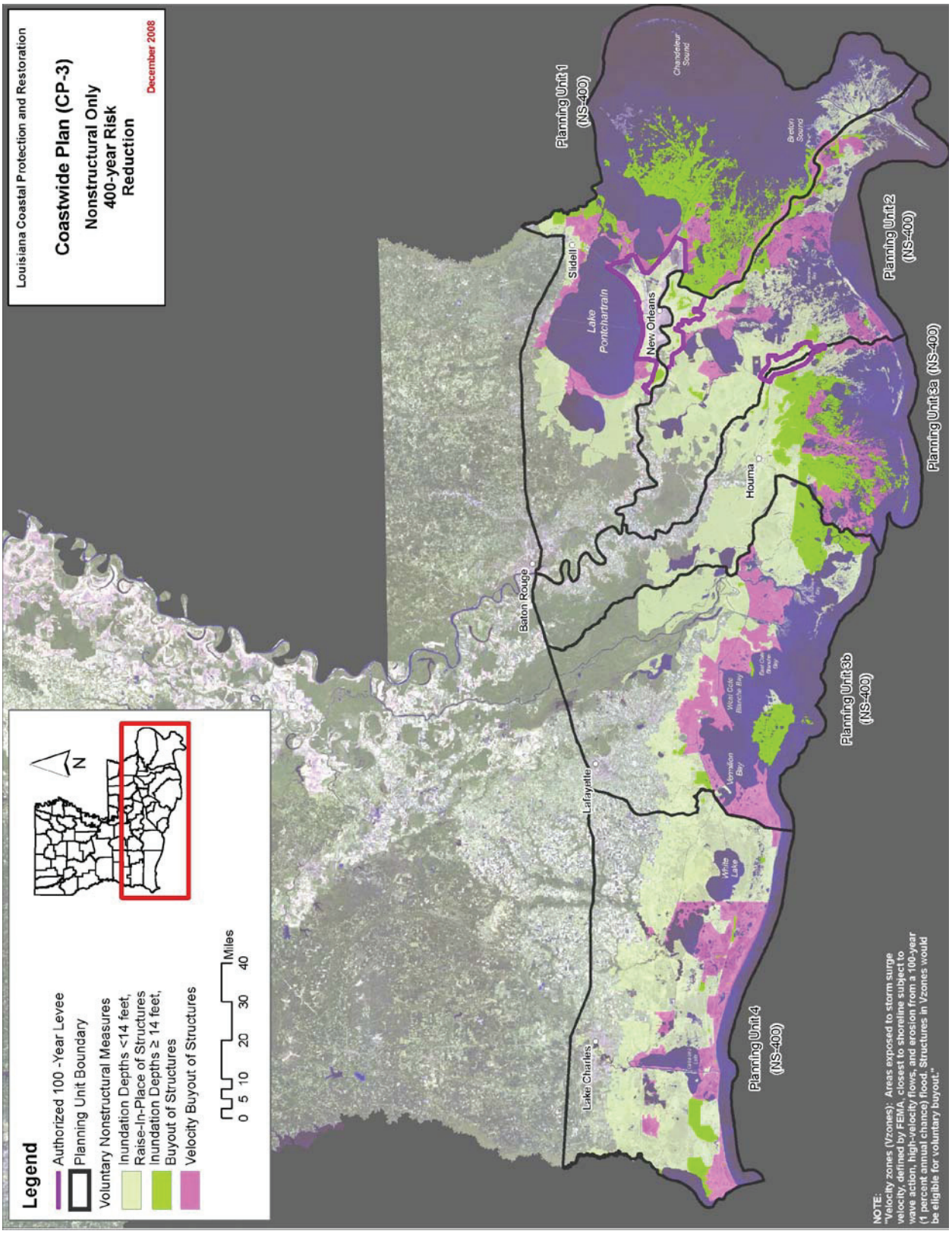
Even after narrowing down the final array of alternatives to five or six alternatives in each planning unit, there are still several thousand possible combinations of those alternatives that could create a coastwide plan. Rather than create thousands of maps, the LACPR team chose seven different combinations as examples to help decision makers visualize the possible coastwide plans. The coastwide combinations may not seem entirely logical; however, the goal was not to present definite strategies but to present each of the alternatives at least once in a coastwide map that could be used for visualization and discussion among stakeholders and decision makers.

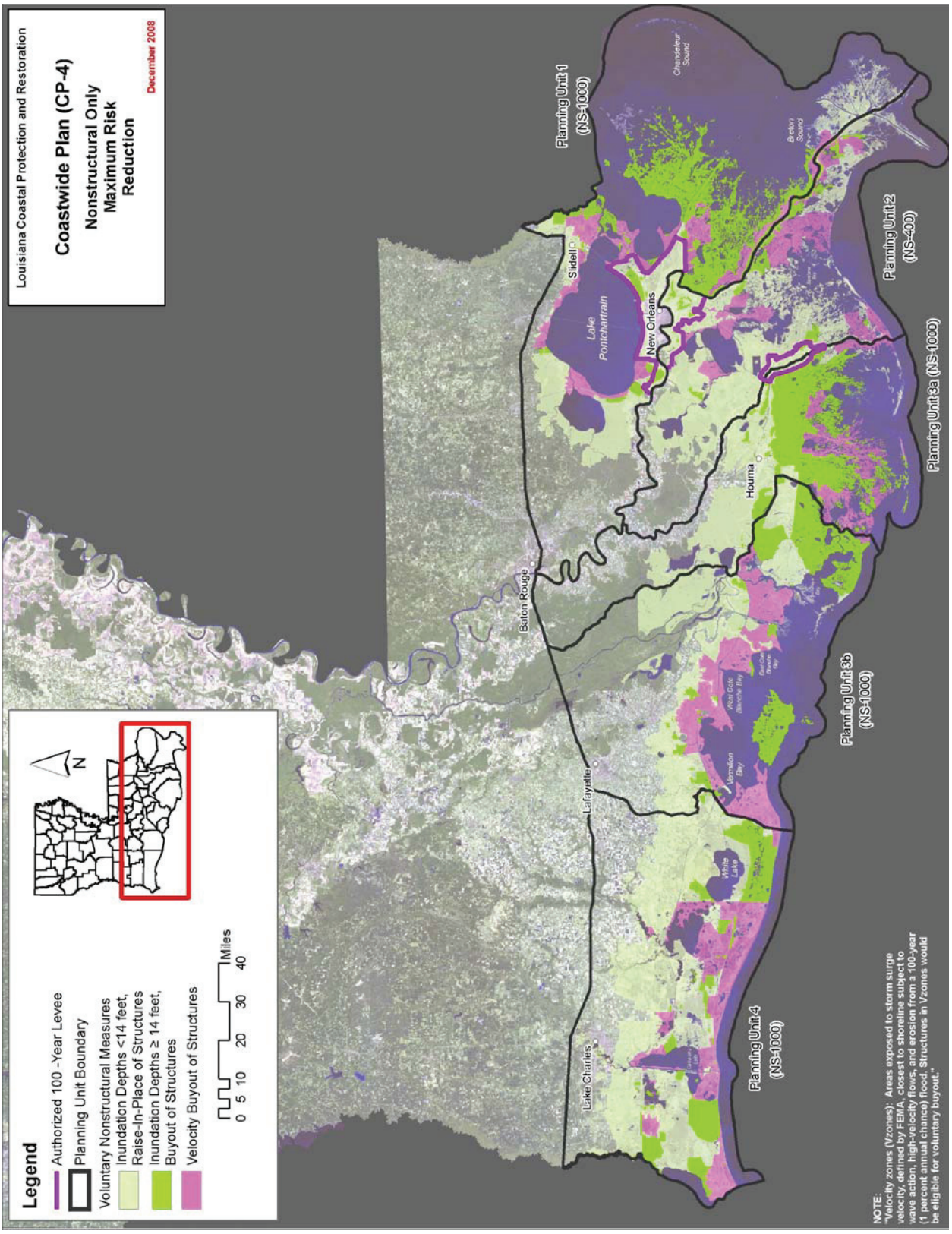
Maps are included for each of the coastwide plans on the following pages (coastal features shown on a separate map below). These coastal restoration plans are only included in Planning Units 1 and 2 because maintaining the coastal landscape in the rest of the State was not shown to have significant risk management benefits, partially because the critical landscape features (landscape components that tend to have significant effects on surge) are not predicted to be lost due to degradation. The absence of coastal restoration features in these planning units, however, does not mean that coastal restoration for ecological reasons or strategically placed features for risk reduction are not warranted.

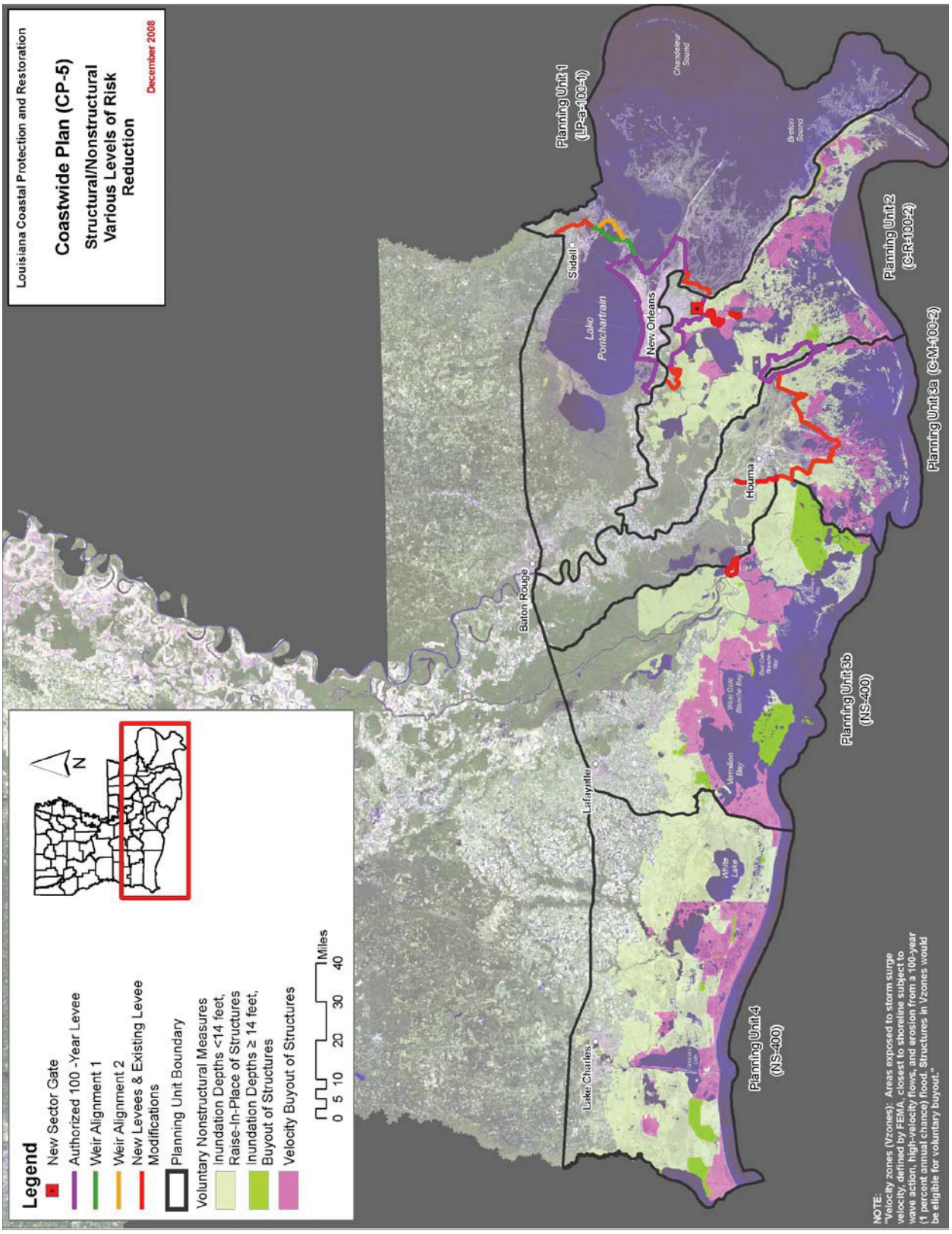


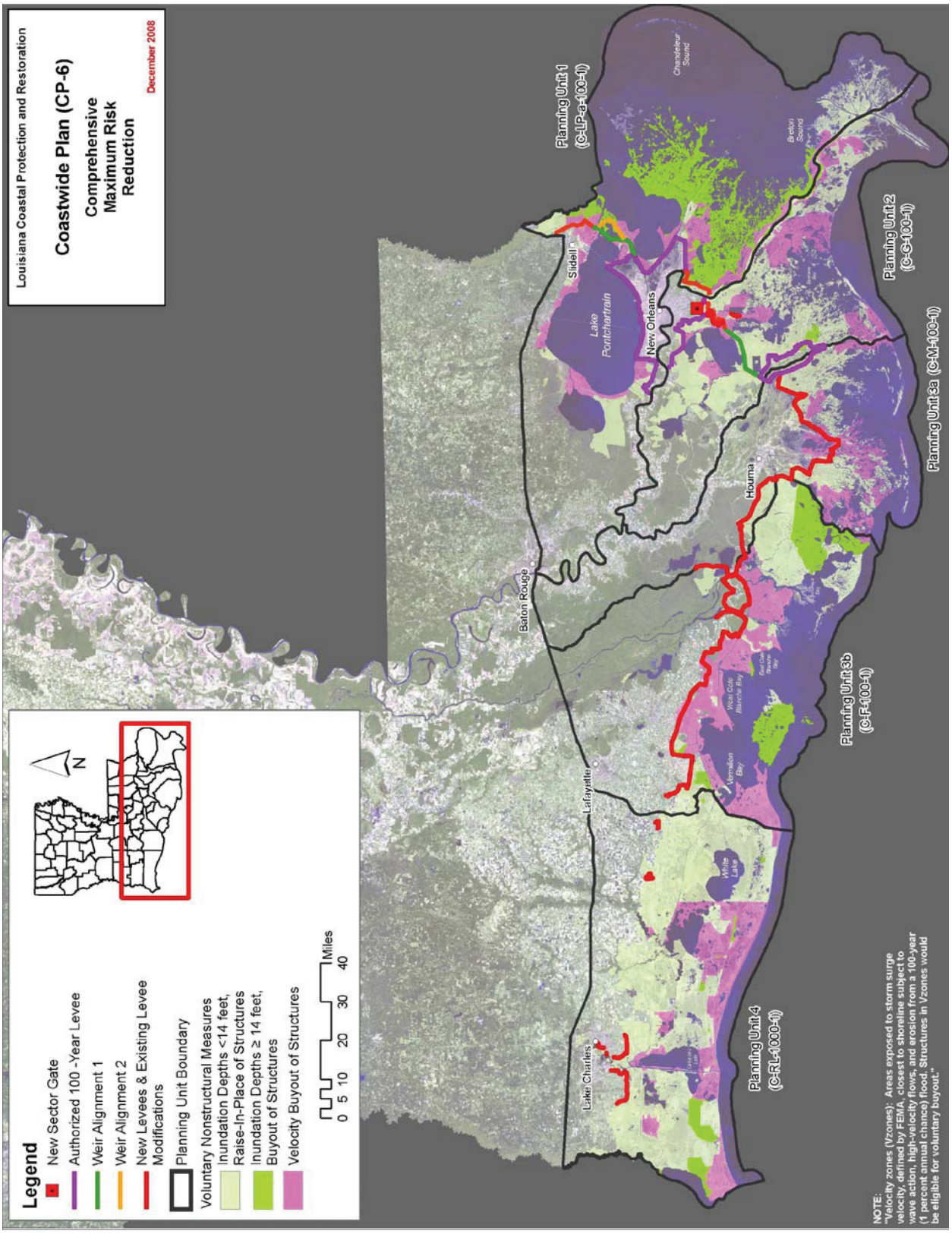

Louisiana Coastal Protection and Restoration
Coastwide Plan (CP-1)
Minimum Risk Reduction
December 2008
Legend
New Sector Gate
New Levees and Existing Levee Modifications
Authorized 100 -Year Levee
Planning Unit Boundary
Voluntary Nonstructural Measures
Inundation Depths <14 feet, Raise-In-Place of Structures
Inundation Depths ≥ 14 feet, Buyout of Structures
Velocity Buyout of Structures
N
0 5 10 20 30 40 Miles
Planning Unit 1 (Coastal*)
Planning Unit 2 (WBI-100-1)
Planning Unit 3a (NS-100)
Planning Unit 3b (C-RL-100-1)
Planning Unit 4 (NS-100)
Slidell
New Orleans
Lake Pontchartrain
Houma
Baton Rouge
Lafayette
Lake Charles
Chandeleur Sound
Breton Sound
Vermilion Bay
West Cote Blanche Bay
White Lake
* See Coastal Restoration Plan Map
NOTE:
"Velocity zones (Vzones): Areas exposed to storm surge velocity, defined by FEMA, closest to shoreline subject to wave action, high-velocity flows, and erosion from a 100-year (1 percent annual chance) flood. Structures in Vzones would be eligible for voluntary buyout."

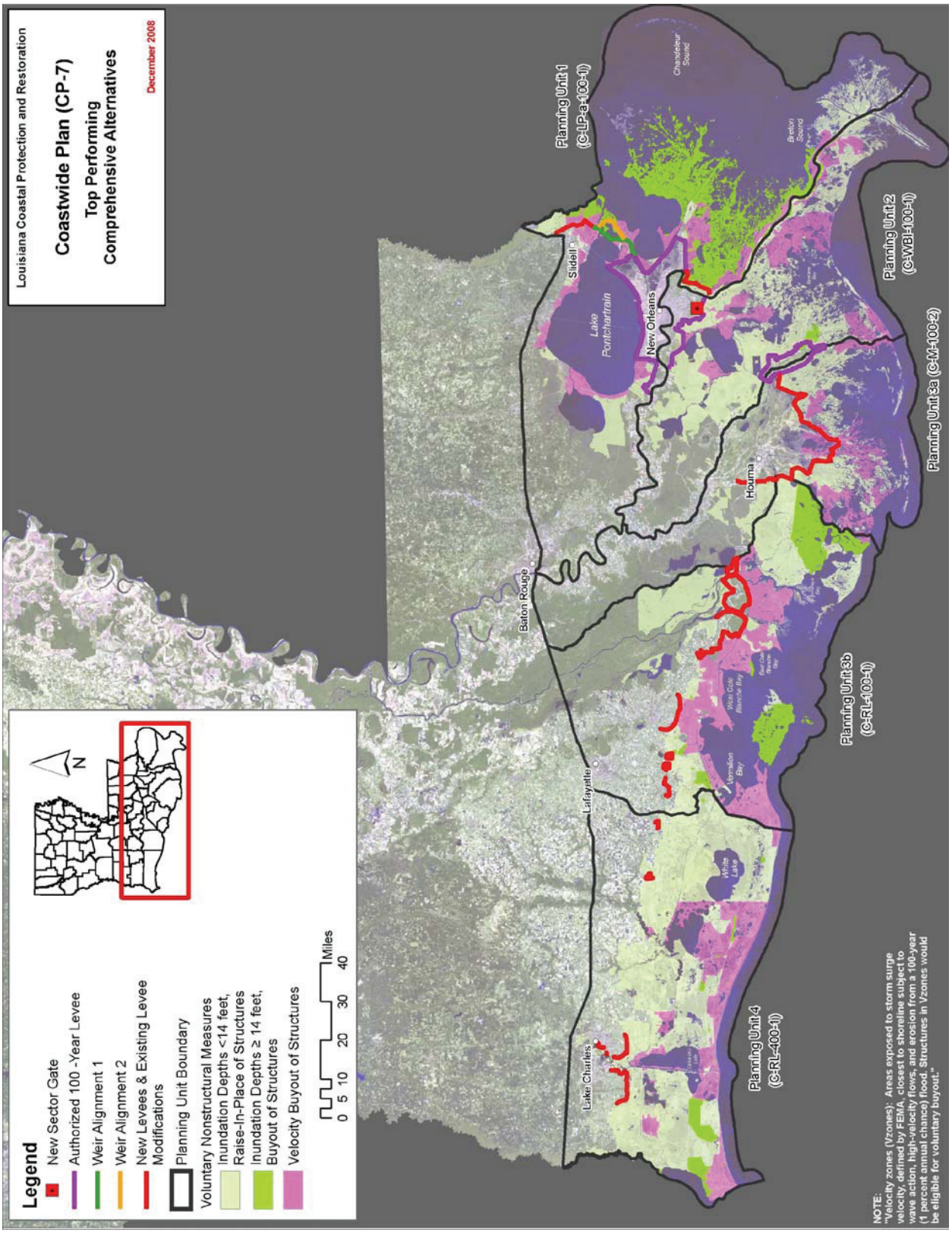

Louisiana Coastal Protection and Restoration
Coastwide Plan (CP-2)
Comprehensive
100-Year Risk Reduction
With Ring Levees
December 2008
Legend
New Sector Gate
New Levees and
Existing Levee Modification
Authorized 100 -Year Levee
Planning Unit Boundary
Voluntary Nonstructural Measures
Inundation Depths <14 feet, Raise-In-Place of Structures
Inundation Depths ≥ 14 feet, Buyout of Structures
Velocity Buyout of Structures
0 5 10 20 30 40 Miles
N
Planning Unit 1
(NS-100)
Planning Unit 2
(C-RL-100-1)
Planning Unit 3a (C-M-100-2)
Planning Unit 3b
(C-RL-100-1)
Planning Unit 4
(C-RL-100-1)
Lake Pontchartrain
Lake Charles
Lafayette
Baton Rouge
New Orleans
Houma
Sidell
Chandeleur Sound
Breton Sound
White Lake
Atchafalaya Bay
West Cote Blanche Bay
Terrebonne Bay
NOTE:
"Velocity zones (Vzones): Areas exposed to storm surge velocity, defined by FEMA, closest to shoreline subject to wave action, high-velocity flows, and erosion from a 100-year (1 percent annual chance) flood. Structures in Vzones would be eligible for voluntary buyout."


Louisiana Coastal Protection and Restoration
Coastwide Plan (CP-3)
Nonstructural Only
400-year Risk
Reduction
December 2008
Legend
Authorized 100 -Year Levee
Planning Unit Boundary
Voluntary Nonstructural Measures
Inundation Depths <14 feet, Raise-In-Place of Structures
Inundation Depths ≥ 14 feet, Buyout of Structures
Velocity Buyout of Structures
0 5 10 20 30 40 Miles
N
Planning Unit 1 (NS-400)
Planning Unit 2 (NS-400)
Planning Unit 3a (NS-400)
Planning Unit 3b (NS-400)
Planning Unit 4 (NS-400)
Chandeleur Sound
Breton Sound
Lake Pontchartrain
Slidell
New Orleans
Baton Rouge
Houma
Lafayette
Lake Charles
White Lake
Vermilion Bay
West Cote Blanche Bay
East Cote Blanche Bay
NOTE:
"Velocity zones (Vzones): Areas exposed to storm surge velocity, defined by FEMA, closest to shoreline subject to wave action, high-velocity flows, and erosion from a 100-year (1 percent annual chance) flood. Structures in Vzones would be eligible for voluntary buyout."


Louisiana Coastal Protection and Restoration
Coastwide Plan (CP-4)
Nonstructural Only
Maximum Risk
Reduction
December 2008
Legend
Authorized 100 -Year Levee
Planning Unit Boundary
Voluntary Nonstructural Measures
Inundation Depths <14 feet, Raise-In-Place of Structures
Inundation Depths ≥ 14 feet, Buyout of Structures
Velocity Buyout of Structures
0 5 10 20 30 40 Miles
N
Planning Unit 1 (NS-1000)
Planning Unit 2 (NS-400)
Planning Unit 3a (NS-1000)
Planning Unit 3b (NS-1000)
Planning Unit 4 (NS-1000)
Lake Pontchartrain
Lake Maurepas
Chandeleur Sound
Breton Sound
Sidell
New Orleans
Houma
Baton Rouge
Lafayette
Lake Charles
White Lake
Vermilion Bay
West Cote Blanche Bay
Barataria Bay
NOTE:
"Velocity zones (Vzones): Areas exposed to storm surge velocity, defined by FEMA, closest to shoreline subject to wave action, high-velocity flows, and erosion from a 100-year (1 percent annual chance) flood. Structures in Vzones would be eligible for voluntary buyout."


Louisiana Coastal Protection and Restoration
Coastwide Plan (CP-5)
Structural/Nonstructural
Various Levels of Risk
Reduction
December 2008
Legend
New Sector Gate
Authorized 100 -Year Levee
Weir Alignment 1
Weir Alignment 2
New Levees & Existing Levee
Modifications
Planning Unit Boundary
Voluntary Nonstructural Measures
Inundation Depths <14 feet,
Raise-In-Place of Structures
Inundation Depths ≥ 14 feet,
Buyout of Structures
Velocity Buyout of Structures
0 5 10 20 30 40
Miles
N
Planning Unit 1
(LP-a-100-1)
Planning Unit 2
(I-R-100-2)
Planning Unit 3a (C-M-100-2)
Planning Unit 3b
(NS-400)
Planning Unit 4
(NS-400)
Lake Pontchartrain
Lake Borgne
Chandeleur Sound
Breton Sound
Sidell
New Orleans
Houma
Baton Rouge
Lafayette
Lake Charles
White Lake
Vermilion Bay
West Cote Blanche Bay
Atchafalaya Bay
Terrebonne Bay
NOTE:
"Velocity zones (Vzones): Areas exposed to storm surge velocity, defined by FEMA, closest to shoreline subject to wave action, high-velocity flows, and erosion from a 100-year (1 percent annual chance) flood. Structures in Vzones would be eligible for voluntary buyout."


Louisiana Coastal Protection and Restoration
Coastwide Plan (CP-6)
Comprehensive
Maximum Risk
Reduction
December 2008
Legend
New Sector Gate
Authorized 100 -Year Levee
Weir Alignment 1
Weir Alignment 2
New Levees & Existing Levee Modifications
Planning Unit Boundary
Voluntary Nonstructural Measures
Inundation Depths <14 feet, Raise-In-Place of Structures
Inundation Depths ≥ 14 feet, Buyout of Structures
Velocity Buyout of Structures
0 5 10 20 30 40 Miles
N
Planning Unit 1 (C-LP-a-100-1)
Planning Unit 2 (C-G-100-1)
Planning Unit 3a (C-M-100-1)
Planning Unit 3b (C-F-100-1)
Planning Unit 4 (C-RL-1000-1)
Lake Pontchartrain
Chandeleur Sound
Breton Sound
Sidell
New Orleans
Baton Rouge
Houma
Lafayette
Lake Charles
White Lake
Atchafalaya Bay
West Cote Blanche Bay
Terrebonne Bay
NOTE:
"Velocity zones (Vzones): Areas exposed to storm surge velocity, defined by FEMA, closest to shoreline subject to wave action, high-velocity flows, and erosion from a 100-year (1 percent annual chance) flood. Structures in Vzones would be eligible for voluntary buyout."


Louisiana Coastal Protection and Restoration
Coastwide Plan (CP-7)
Top Performing
Comprehensive Alternatives
December 2008
Legend
New Sector Gate
Authorized 100 -Year Levee
Weir Alignment 1
Weir Alignment 2
New Levees & Existing Levee Modifications
Planning Unit Boundary
Voluntary Nonstructural Measures
Inundation Depths <14 feet, Raise-In-Place of Structures
Inundation Depths ≥ 14 feet, Buyout of Structures
Velocity Buyout of Structures
0 5 10 20 30 40 Miles
N
Planning Unit 1 (C-LP-a-100-1)
Planning Unit 2 (C-WBI-100-1)
Planning Unit 3a (C-M-100-2)
Planning Unit 3b (C-RL-100-1)
Planning Unit 4 (C-RL-400-1)
Slidell
Lake Pontchartrain
New Orleans
Chandeleur Sound
Breton Sound
Baton Rouge
Houma
Lafayette
Lake Charles
Vermilion Bay
West Cote Blanche Bay
White Lake
NOTE:
"Velocity zones (Vzones): Areas exposed to storm surge velocity, defined by FEMA, closest to shoreline subject to wave action, high-velocity flows, and erosion from a 100-year (1 percent annual chance) flood. Structures in Vzones would be eligible for voluntary buyout."

Implementation of Coastal Protection and Restoration Plans

As previously described, the State of Louisiana established the Coastal Protection and Restoration Authority (CPRA) to develop, implement, and enforce a comprehensive coastal protection and restoration master plan. For the first time in Louisiana's history, a single State authority will integrate coastal restoration and hurricane protection to speak with one clear voice for the future of Louisiana's coast. Incorporating input from a diverse set of stakeholders, Louisiana's Comprehensive Master Plan for a Sustainable Coast (State Master Plan) and subsequent annual plans portray the State's desires and needs relative to hurricane risk reduction and coastal restoration.

Some components of coastal protection and restoration described in the State Master Plan and annual plans lie within the Corps mission; additional elements require actions that are outside of the Corps mission. Therefore, many other entities must be involved in the implementation of the State Master Plan to achieve comprehensive hurricane risk reduction and coastal restoration. Federal agencies that may have a role in implementing the State Master Plan along with the Corps include:

- Department of Homeland Security (FEMA, U.S. Coast Guard)
- Department of the Interior (Minerals Management Service, U.S. Geological Survey, U.S. Fish and Wildlife Service)
- Department of Commerce (National Oceanic and Atmospheric Administration)
- Department of Energy
- Department of Transportation
- Department of Agriculture (National Resource Conservation Service)
- Environmental Protection Agency

In addition to the Corps and other Federal agencies, the CPRA will implement the State Master Plan working in conjunction with other State and local agencies, levee districts, parishes, private interests, non-governmental organizations, and the public.

Key Findings on the Multiple Lines of Defense Strategy

No single measure or approach for achieving risk reduction will be sufficient for achieving the multiple risk reduction objectives established for coastal Louisiana. Each individual measure has weaknesses and tradeoffs. Therefore, an integrated comprehensive system comprising coastal restoration features, nonstructural measures, and structural components is the most promising approach for reducing storm surge risk in South Louisiana.

- **The only way to provide adequate personal safety from hurricanes is through evacuation before the storm.** Hurricane risks can never be eliminated or entirely prevented. Therefore, individuals have a personal responsibility to evacuate as directed by local officials or sooner.

- **Individual and community decisions have a primary role in determining future risks to both life and property.** Recognizing hurricane threats and risks

inherent to life in South Louisiana, individuals and communities must decide where and how to build or rebuild; how to adequately insure that property; and when to evacuate. State and local governments have a critical role to play in implementing certain nonstructural measures such as evacuation planning, land use planning, zoning, and permitting. As emphasized in the State Master Plan, all residents of coastal Louisiana should buy flood insurance; homeowners can elevate or retrofit their homes using available hazard mitigation funds; and citizens must comply with the provisions of the 2007 Louisiana State Uniform Construction Code, which is designed to ensure that new construction can better withstand hurricane force winds.

- **Some features in the coastal landscape are critical contributors to the long-term sustainability of a comprehensive risk reduction system for coastal communities.** While the effect of the coastal landscape on surge is not a substitute for structural and nonstructural risk reduction measures, coastal features can significantly increase the reliability and sustainability of comprehensive risk reduction systems. Critical features within the coastal landscape (e.g. wetlands, land bridges, highways, etc.) that have a measureable influence on surges have been identified across the entire Louisiana coast.

- **Rule of thumb approaches for estimating the contribution of wetlands to risk reduction are unreliable.** Prior to the storm surge modeling performed for LACPR, a common rule of thumb (“x miles of wetlands reduce surge heights by y feet”) was used to predict the storm surge reduction potential of wetlands; however, the results of the LACPR model have shown that a general rule of thumb is not appropriate for making risk-informed decisions. Protecting and restoring coastal wetlands in some areas of the coast provides greater risk reduction potential and in others greater ecologic benefit.

- **Structural measures provide the greatest level of risk reduction when removed from the immediate proximity of development**. Levee alignments that allow some distance between the levee and the development footprint produce greater, and often significant residual protection above the indicated design level. Structural alignments which are adjacent to developed areas (e.g. ring levees) are susceptible to higher consequences once the design level surge is exceeded. This effect is correlated to the relative capacity for storing flood water once surge exceeds the design associated with each plan.

- **Structural measures are not always the best solution.** Building and maintaining structural features is a large, long-term investment, and structural features have significant drawbacks such as environmental impacts, intensive resource requirements, the potential for being exceeded or possible failure, inducing development, or other unintended consequences.

- **Nonstructural measures are a key component for risk reduction.** Hurricane risks can never be eliminated or entirely prevented; however, the relocation or

- **Relocation of all residents out of the coastal floodplain is not a viable option.** Coastal Louisiana will continue to be a population and employment center because many industries, such as port facilities, oil and gas reserves, navigation fabrication facilities, and commercial fisheries, are directly linked to the Gulf of Mexico, the Mississippi River, and other geographic features of coastal Louisiana.

- **The effectiveness of buyout and raise-in-place nonstructural plans depends on the level of participation.** Successful implementation of nonstructural measures requires a high degree of direct participation by individuals and other government agencies besides the Corps. Incentives may be needed to improve participation in buyouts and raise-in-place measures in order to make these types of plans successful.

Key Findings on Risk-Informed Decision Making

- **Tradeoffs are critical to risk informed decision making.** In order to make risk-informed decisions, tradeoffs between efficiency, effectiveness, cost, and environmental and social impacts must be considered.

- **Consideration of risk reduction for extreme events or a range of events requires use of non-traditional evaluations of efficiency and effectiveness.** The traditional presentation of annualized costs and benefits understates the potential impact of large storm surge events by expressing probabilities over a short, one year, timeframe. Considering the probability of these larger events occurring over a longer period more effectively communicates risk.

- **The determination of acceptable levels of risk is part of the ultimate goal of a risk-informed decision framework.** The determination of acceptable risk is contingent on the stakeholders' understanding of the range of risk and available options for addressing that risk. Future efforts should pay attention to the concept of acceptable risk as an aid to risk management decisions through increased and improved communication of the relative potential risk either with or absent any alternative actions.

Key Findings on Long-Term Sustainability of the Coast

- **Diversion of Mississippi River freshwater, nutrients, and sediment is essential for the restoration of natural deltaic processes that sustain coastal wetlands.** The Corps is working to implement a near-term plan for diversions as well as a comprehensive plan that will include significant scientific developments to better understand the hydrodynamics of the system and the potential long-term configuration of the river delta system.

- **Adequate sediment resources are available to implement proposed coastal restoration plans but acquiring those resources involves tradeoffs.** In addition to riverine sediments from proposed diversions along the Mississippi River and tributaries, construction of the coastal landscape features included in the extensive restoration plans considered for the final array would require significant sediment from either offshore sources or from interior bay and lake bottoms. Tradeoffs include cost and potential impacts to the ecosystem.

Other Key Findings

- **The size and magnitude of storm threats are generally greater in the area of the central Gulf Coast near the Mississippi River.** Statistical analysis of historic storm data indicates the potential for occurrence of larger, more intense storms (Category 2 or greater) increases toward the center of the Gulf Coast near the Mississippi River.

- **Regional tradeoffs across state boundaries must be considered.** A regional analysis conducted for Louisiana and Mississippi identified potential impacts and tradeoffs for each state. The significance of those relative impacts should be weighed against the benefits achieved on a regional scale.

- **Uncertainties are amplified in planning large-scale coastal restoration and hurricane risk reduction systems.** Some of the large uncertainties associated with relative sea level rise and land use/population growth have been accounted for through the use of scenarios. To a large extent uncertainty with water levels has been addressed as part of the development of the storm surge and hydrodynamic data and extrapolated to the performance metrics; however, there are always additional uncertainties that cannot be quantified. Adaptive management can be used to resolve ecosystem, engineering, policy, socio-economic issues and interactions, and other processes by reducing some of the uncertainties over time.

- **Changes in social, political, economic, engineering, and environmental conditions over the next decades will require an adaptive management framework to guide program and project management.** Adaptive management incorporates new information and technology into new and existing projects as it becomes available and assimilates lessons learned as new projects are developed. Since adaptive management requires continuing evaluation and introduction of the latest science, investment in science and technology is needed.

Conclusions

As revealed by the hurricanes of 2005, South Louisiana is highly vulnerable to catastrophic flooding from large hurricanes. In response to those devastating events, Congress directed the Corps to conduct a comprehensive “Category 5” hurricane risk reduction analysis and design in close coordination with the State of Louisiana. In collaboration with the State and many others, the Corps developed and analyzed a full range of alternatives, which are based on a number of structural, nonstructural, and coastal restoration measures, to reduce storm surge risk in South Louisiana.

The technical analysis in this report has provided a clearer picture of the probability of large, storm related surge events that will significantly impact the population, property, and national and regional economy. The LACPR effort quantified that probability by using supercomputers to simulate a spectrum of hurricanes that could strike the Louisiana coast. Scientists have concluded that the two primary parameters for estimation of maximum storm surges along the coast are storm intensity (related to the Saffir-Simpson scale) and storm size (not related to the Saffir-Simpson). As a representation of “Category 5” risk reduction, this technical report presents alternatives at the 100-year, 400-year, and 1000-year design levels. The 400-year flood event is an approximation of Hurricane Katrina.

The manner of attaining risk reduction, as well as the level attainable, is influenced by the range of considerations and tradeoffs presented in this technical report. Historically, the most significant consideration has been the relative potential return on investment, or benefit versus cost, provided by any alternative action taken to reduce risk. Hurricanes Katrina and Rita clearly highlighted that this type of investment decision does not necessarily result in a full understanding of the level of risk exposure. The information presented in this technical report has been developed and presented to enable consideration of decisions without the emphasis on economic outputs but with regard to the cost and tolerance for potential residual or remaining risks. Although property damages can be reduced through various risk reduction measures, evacuation is the only effective means to substantially reduce loss of life related to hurricane events.

A stakeholder-engaged, risk-informed approach is highly desirable in considering options for the reduction of storm damage risks. The broad and inclusive consideration of potential risks, costs, and tradeoffs in other performance attributes is significant to the ultimate decision. Therefore, a Risk-Informed Decision Framework serves as the overarching approach for evaluating, comparing, and identifying the final array of alternative plans. This framework serves two functions: first, to inform affected stakeholders and decision makers of the magnitude of risks related to hurricane storm surge in South Louisiana, and second, to enable stakeholders and decision makers to clearly understand the tradeoffs that would be required to reduce those risks.

An important input into the LACPR Risk-Informed Decision Framework was the use of a Multi Criteria Decision Analysis (MCDA) tool, which facilitated the incorporation of stakeholder values into the decision-making process. The process of developing the

stakeholder-based MCDA tool will continue to provide valuable understanding of broader stakeholder interests and values for plan performance; however, it will require additional feedback to and engagement with stakeholders to fully develop reliable plan preference information and be effective in communicating risks.

A broad range of viable options is available for the reduction of risk from large or "Category 5" surge events. The comparison of alternatives through the Risk-Informed Decision Framework resulted in a final array consisting of five or six plans in each of the five planning units. Over half of those plans would achieve some degree of "Category 5" risk reduction by providing significant surge impact reduction for a 400-year frequency storm event or greater; however, in some cases, the level of risk reduction varies throughout the planning unit. The final array consists primarily of nonstructural and comprehensive (structural and nonstructural) alternatives. The balance of the final array consists of two structural alternatives and a single stand alone coastal restoration alternative.

The restoration and maintenance of the coastal landscape are important considerations in a comprehensive system for risk reduction. The extensive effort represented by simply maintaining the Louisiana coast in its current state raises questions regarding long-term sustainability of this landscape. Robust hydromodeling enabled the analysis of the performance and contribution of the coastal landscape in limiting storm surges. Critical features within the coastal landscape (e.g. wetlands, land bridges, highways, etc.) that have a measureable influence on surges have been identified across the entire Louisiana coast. This indicates that restoration and maintenance of specific coastal landscape features, as opposed to the coastal landscape as a whole, could significantly increase the reliability and sustainability of comprehensive risk reduction systems as well as existing development. Additional detailed modeling and evaluation is needed to further define the most efficient and sustainable actions to enhance risk reduction.

Nonstructural measures, such as raising structures in place, appear to be viable, efficient, and effective. Cost effectiveness and potential to reduce risk make the implementation of nonstructural measures, along with structural and costal restoration measures, a logical next step toward creating sustainable and resilient communities across the extent of South Louisiana. However, since a simplifying assumption of 100 percent participation was used for the LACPR analysis, further evaluation and collaboration with stakeholders will be needed to develop realistic, implementable plans.

Plans in the final array have the potential to reduce damages by approximately 15 to 85 percent on average across the range of storm events. The theoretical coastwide property damages (based on no further action to reduce risk) range from $77 billion for a 100-year event to $219 billion for a 1000-year event. The total first costs of the final array plans range from approximately $2 billion for a 100-year nonstructural plan in Planning Unit 4 to $69 billion for a 1000-year nonstructural plan in Planning Unit 1. Total first costs for potential coastwide plans (consisting of an alternative from each planning unit) range from approximately $59 billion for the combination of least costly alternatives

in each planning unit to approximately $139 billion for the combination of most costly alternatives in each planning unit.

Even for the best performing plans presented in the final array, substantial residual risk remains for the most extreme surge events. In evaluating the performance of alternatives across a wide range of surge events an assumption of continuous resilience has been employed. In other words features designed based on a more frequent event are exceeded but would not fail for less frequent, larger events. This assumption was used to evaluate initial alternatives and would need to be further evaluated in future analyses. All structural measures are capable of providing significant risk reduction, particularly with increasing design levels. However, evaluation results have indicated that some 100-year level structural alignments could potentially provide significant risk reduction for the 400-year to 1000-year surge events if those features remains intact for these higher level events.

The technical evaluation has indicated that levee alignments that allow some distance between the levee and the development footprint produce greater, and often significant residual protection above the indicated design level. However, the assumption of continuous resilience, the design requirements to support such an assumption, and the specific potential for system failure, should be investigated in detail at the planning unit scale. A quantitative risk assessment similar to the IPET analysis is critical. That type of analysis, however, requires a more detailed design than was developed for LACPR. The LACPR report includes an assessment of failure potential for the components of the alternatives. Structural components were gauged relative to levee length and numbers and sizes of structures, with increasing length and numbers of structures implying greater susceptibility to failure. Nonstructural plan performance was tested against the relative level of participation, with diminishing public participation correlating to potential failure of an overall plan. Further development of quantitative risk assessments will be performed as priorities are established and projects are developed to a higher (feasibility) level of detail.

Large uncertainties surround any large-scale, long-term plans for coastal protection and restoration in South Louisiana. Although this technical report considers some of these uncertainties by varying relative sea level rise rates, economic growth, and population trends across future scenarios, critical issues surrounded by large uncertainties, such as climate change, future hurricane patterns, land loss, sediment sources, and funding remain. The documentation of risk and uncertainty allows stakeholders and decision makers to appreciate the tradeoffs inherent in decisions for action. The extensive technical evaluation and diverse comparison of plan performance presented in this technical report provides a basis for making risk-informed decisions.

Implementation Options

The final array* of alternative plans and implementation options presented in this technical report provide a basis for continued development of an approach for addressing the comprehensive reduction of risks associated with large storm surge events. The range of performance and tradeoffs represented in these alternatives also present initial choices that both stakeholders and decision makers will need to make. Resolving tradeoffs begins at the stakeholder and local sponsor level.

While the LACPR technical report strives to be consistent with the Louisiana master plan for comprehensive protection and restoration, the State's plan was completed without the benefit of complete performance evaluation of the plans and their tradeoffs. Since the tradeoffs have not been vetted through the stakeholders and our State partners, it is premature to definitively determine which plans or components are more desirable for either continued development or implementation.

Each major type of measure, such as nonstructural, or any combination of measures can provide some level of risk reduction. Implementation time and resultant effect are also tradeoff considerations. The State of Louisiana working with the public, stakeholders, and agencies should consider options for implementation as well as the final array of alternatives. The following implementation options should be considered in each planning unit:

1. Execute through a comprehensive basin plan
2. Focus on structural features
3. Focus on coastal features
4. Focus on nonstructural actions
5. Develop hazard mitigation efforts

These options reflect the tradeoffs regarding an implementation approach. Option 1 is a comprehensive effort that would investigate alternatives that leverage all possible combinations of measures (nonstructural, structural, coastal, and hazard mitigation) for the entire basin. Other options could focus on individual measures or combinations of measures. Each option would require utilization of different authorities.

The Corps in partnership with the State of Louisiana is prepared to continue refinement of the plans and decision process. Steps have been taken during this technical effort to provide the foundation for refining both evaluations and the continued dialog between the Federal and State partners and stakeholders.

Authorities for Implementation

Numerous project and study authorities exist throughout the coastal area. In instances where risk reduction features and existing authorities coincide, further analyses through the process of Post Authorization Change reports may be possible. The decision of whether a new legislative authorization is needed, however, depends on a case-by-case

* See Glossary for definition of final array.

examination of the original authority and the proposed change, as well as approval by the appropriate decision maker. In some areas of coastal Louisiana, continued development of a comprehensive risk reduction system by the Corps, if desired, will require new authority. In addition, policy waivers may be needed in cases where current policy procedures requiring a traditional economic analysis would make it difficult to economically justify the levels of risk reduction presented in this report. Ultimately, the scale and duration associated with effective implementation and maintenance of a comprehensive system for risk reduction will require an adaptive management approach.

The Louisiana Coastal Area (LCA) ecosystem restoration authority contained in the Water Resource Development Act (WRDA) of 2007 provides for the initiation of coastal restoration efforts. WRDA 2007 also provides study authority for a Comprehensive Plan to be consistent with both the LACPR effort and the protection and restoration master plan mandated by State statute. These authorities provide opportunities for the continuing development of coastal restoration measures, as well as refining the analysis and improving the understanding of strategic coastal landscape contributions to risk reduction.

Nonstructural measures are also clearly important based on the analysis in the technical report. A programmatic framework for the potential implementation of nonstructural measures, however, overlaps the missions of several Federal and state agencies and would benefit from further development of coordinated guidelines.

Planning Unit 1

Coastal features are an important consideration for risk reduction in Planning Unit 1. The key coastal restoration authorities are the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA program) and Title VII of WRDA 2007 (Louisiana Coastal Area). If the decision is made to pursue a structural and/or nonstructural approach, the following project and study authorities may be available to investigate and potentially implement elements of the final array:

- Lake Pontchartrain and Vicinity (project)
- New Orleans to Venice (project)
- Pearl River Basin, St. Tammany Parish (project)
- Southeast Louisiana Urban Flood Control (projects and studies)
- West Shore Lake Pontchartrain (study)

Planning Unit 2

Similar to Planning Unit 1, coastal features are an important consideration for risk reduction in Planning Unit 2. The same coastal restoration authorities apply, i.e. the CWPPRA program and Title VII of WRDA 2007 (Louisiana Coastal Area). The ongoing Donaldsonville to the Gulf Feasibility Study is investigating structural, nonstructural, and environmental mitigation measures as part of a comprehensive basin-wide study. In addition to the Donaldsonville to the Gulf study, the following project authorities could

potentially be expanded to incorporate additional or modified structural or nonstructural measures:

- West Bank and Vicinity
- New Orleans to Venice
- Larose to Golden Meadow
- Grand Isle and Vicinity

Planning Unit 3a

In Planning Unit 3a the contribution of coastal features to risk reduction and reliability needs additional refinement to investigate the merits of strategic placement of coastal measures. This refinement can be accomplished through the Section 7002 Comprehensive Plan authority in WRDA 2007.

In this planning unit, decisions must be made regarding stand alone nonstructural versus structural/nonstructural approaches. Both of the comprehensive plans in the final array are variations of the Morganza to the Gulf of Mexico project authorized in WRDA 2007. The Corps is currently pursuing a Post Authorization Change under the Morganza to the Gulf authority. This study will evaluate both structural and nonstructural measures for the Morganza project area.

In addition to the Morganza to the Gulf authority, the following project and study authorities may be available to investigate and potentially implement structural and nonstructural elements of the final array:

- Larose to Golden Meadow (project)
- Morgan City and Vicinity (project)
- Atchafalaya Basin (project)
- Lower Atchafalaya Basin (study)

Planning Unit 3b

In Planning Unit 3b the contribution of coastal features to risk reduction and reliability needs additional refinement to investigate the merits of strategic placement of coastal measures. This refinement can be accomplished through the Section 7002 Comprehensive Plan authority in WRDA 2007.

In this planning unit, decisions must be made regarding stand alone nonstructural versus structural/nonstructural approaches. In Planning Unit 3b the final array contains a suite of three comprehensive plans that have no common structural features; therefore, decisions must also be made regarding the extent of the structural alignment, e.g. continuous levees versus ring levees.

A portion of Planning Unit 3b, from approximately Abbeville westward, is included in the Southwest Coastal Louisiana Feasibility Study authority; however, there is a lack of authority for study or implementation in most of this planning unit. Therefore, new

authority would be needed to complete additional investigation or implementation of the LACPR structural and/or nonstructural risk reduction plans in Planning Unit 3b.

Planning Unit 4

In Planning Unit 4 the contribution of coastal features to risk reduction and reliability needs additional refinement to investigate the merits of strategic placement of coastal measures. This refinement can be accomplished through the Section 7002 Comprehensive Plan authority in WRDA 2007 and/or the Southwest Coastal Louisiana Feasibility Study.

Nonstructural measures play a dominant role in all of the plans including the comprehensive ring levee plans. The limited extent of the ring levees results in the nonstructural component of the comprehensive plans being comparable to the corresponding stand alone nonstructural plan. The Southwest Coastal Louisiana Feasibility Study authority provides the ability to further study these alternatives in addition to others, such as a 12-foot barrier along the GIWW.

Path Forward

The LACPR technical report contains many of the same components as a reconnaissance or feasibility report. For purposes of this technical report, the term “final array” is the identification of high performing alternatives. This final array of alternatives may be changed with future action. This report does not contain construction recommendations or the National Environmental Policy Act (NEPA) alternatives evaluation, feasibility-level designs, real estate plan, and detailed cost estimates that are required for the Corps to make such recommendations. Future actions must contain those elements.

Using the information in this technical report, the Corps recommends immediate coordination with the State of Louisiana to further develop options and priorities in each planning unit. Rapid resolution of tradeoffs and priorities is critical for completing detailed investigations and identifying any recommended actions for construction. The comments received on the LACPR report and its findings resulting from the formal public review comment period, and the Corps’ responses, represent the start of this broad discussion to set priorities. The Corps and the State will share the responsibility of coordinating those options and priorities with other Federal agencies, local entities, non-governmental organizations, and the public. Completing this process will help focus the Corps’ and State’s efforts to develop final recommendations for consideration by Congress for implementation authority. Development and documentation of these recommendations will be formulated in accordance with the requirements of applicable statutes, policies and specific project guidance. In order to proceed in the most expeditious manner, the Corps recommends maximizing the use of available construction and study authorities (i.e., modifications of on-going projects/studies, post-authorization change reports, or new authorizations), subject to the direction of Congress.

Prior to initiation of more detailed assessment, comparison, and selection of alternatives as part of follow-on actions and studies, it is proposed that tradeoff analysis with the State, stakeholders, public, etc. should be completed subject to additional funding by Congress. The tradeoff analysis could be done as a separate comprehensive action for the entire coast or as the first step in separate study efforts for each planning unit, etc. This effort is viewed as necessary to assist and better inform decision makers, etc. in the tough choices to be made in recommending a comprehensive plan or plan components thereof for implementation. This effort would validate or possibly amend the final array of alternatives currently identified in the LACPR report. The resulting final array of alternatives identified could possibly include plans previously screened from further consideration, as well as hybrid plans developed from plan components of the existing array. The findings, conclusions and recommendations of this effort would be documented in a letter report, white paper, or interim report to set the stage/foundation for subsequent study efforts.

The LACPR report would be the foundation of any continuation of evaluation and reporting for the individual features or alternatives in the report and the prioritization discussed above. The LACPR effort and report support and provide much of the necessary data required for the development and completion of the necessary environmental assessments for any component part, feature, or alternative recommended for implementation in subsequent efforts.

The process for development of the final report(s) with construction recommendations may optimize the final array of LACPR alternatives or use LACPR information to improve on-going efforts by supplementing applicable policy and project guidance, with revised decision considerations and processes. The accompanying environmental impact statements (under the leveraged authority) would be done by complementing the on-going work being implemented under other authorities or continuing to build on the work accomplished in the current LACPR effort.

Upon completion of an expanded tradeoff analysis, the next proposed action(s) would be to use existing authorities to continue development of feasibility (or post authorization change) level decision reports (actionable reports) to present recommendations for construction to Congress. These follow-on detailed designs and plan selection could be done seamlessly.

The conclusion of this effort(s) would be a full feasibility or post authorization change report(s) with complete NEPA documentation that can support a Chief of Engineer’s Report.

Potential paths forward for proceeding with full feasibility reports or post authorization change reports in each planning unit would depend on the choices made from the implementation options and authorities previously discussed.

Acronyms

ADCIRC	ADvanced CIRCulation (wind and wave modeling system)
CPRA	Coastal Protection and Restoration Authority (State of Louisiana)
CWPPRA	Coastal Wetlands Planning, Protection, and Restoration Act
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
GIWW	Gulf Intracoastal Waterway
IPET	Interagency Performance Evaluation Task force
LACPR	Louisiana Coastal Protection and Restoration
LCA	Louisiana Coastal Area (*Ecosystem Restoration Study*, 2004)
MCDA	Multi-Criteria Decision Analysis
MsCIP	Mississippi Coastal Improvements Program
NEPA	National Environmental Policy Act
WRDA	Water Resources Development Act

Glossary

100-year Design: A hurricane risk reduction design (e.g. a levee design) based on a flood elevation that statistically has a 1% chance of being equaled or exceeded in any given year. Similarly, a 400-year design has a 0.25% chance of being equaled or exceeded in any given year, and a 1000-year design has a 0.1% chance of being equaled or exceed in any given year.

Adaptive Management: A “learning by doing” management approach which promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood (National Academy of Sciences 2004).

ADCIRC: The ADvanced CIRCulation hydrodynamic model simulates water levels and is used to calculate the design still water level in storm events.

Alternative or Alternative Plan: A collection of one or more risk reduction measures.

Barrier Islands: A linear landform created by the interaction between water and sediments within or extending into a body of water. The barrier islands along the Louisiana coast are a result of sediments deposited by the Mississippi River during its wandering over the past several thousand years. Examples of this phenomenon are the Isles Dernieres chain west of Terrebonne Bay and the Breton Island chain east of St. Bernard Parish.

Barrier-Weir: A structural measure similar to a continuous levee that can withstand overtopping. In LACPR alternatives, barrier-weirs serve as an outer line of defense in a multiple lines of defense strategy. Barrier-weirs are designed to reduce storm surge, blocking the surge for lower surge heights but eventually allowing reduced overtopping at higher surge heights.

Category 5 Hurricane: A storm on the Saffir-Simpson Hurricane Scale having winds greater than 155 mph (135 kt or 249 km/hr). Storm surges are generally greater than 18 feet above normal. Only three verified Category 5 Hurricanes have made landfall in the United States since recordkeeping began: The Labor Day Hurricane of 1935 (Florida Keys), Hurricane Camille in

1969 (Mississippi and Louisiana), and Hurricane Andrew in August 1992 (Florida and Louisiana).

Comprehensive: In general, comprehensive means “large in scope or content.” The term comprehensive has been used for LACPR in the following three ways:

> **(1) Comprehensive Alternatives** are plans that contain at least two of the three types of **risk reduction measures**—nonstructural, structural, and coastal restoration—presenting a **multiple lines of defense strategy** and providing comparable levels of risk reduction to all economic assets in the surge impacted areas.
>
> **(2) “*Comprehensive Category 5 Protection”* -** This terminology was used in the Congressional authority.
>
> **(3) “*Comprehensive Hurricane Protection Analysis and Design”* -** This terminology was used in the Congressional authority. The LACPR effort addresses this requirement by presenting a full range of structural, nonstructural, and coastal restoration hurricane risk reduction measures across South Louisiana.

Construction Costs: Construction costs include the cost of materials and construction of physical structures as well as construction management costs. Construction costs also include costs associated with maintaining the risk reduction levels of structural measures into the future associated with relative sea level rise and/or degradation of the coast, i.e. future levee lifts. See also **First Costs** and **Life Cycle Costs**.

Critical Landscape Features: Features of the coastal landscape that tend to have significant effects on surge. The features identified through modeling range from critical wetland segments to natural ridges to manmade embankments.

Diversion: A turning aside or alteration of the course or flow of water. In coastal restoration, this action usually consists of channeling water through a canal, pipe, or conduit to introduce water and water-borne resources into a receiving area.

Final Array: The identification of high performing alternatives for purposes of this technical report. The final array of alternatives may be changed with future action. This report does not contain construction recommendations or the National Environmental Policy Act (NEPA) alternatives evaluation, feasibility-level designs, real estate plan, and detailed cost estimates that are required for the Corps to make such recommendations.

First Costs: First costs include engineering and design, facility relocations, real estate, mitigation, and construction costs. See also **Construction Costs** and **Life Cycle Costs**.

Levee: An earth embankment, floodwall, or structure whose purpose is flood damage reduction or water conveyance. A continuous levee is generally long and linear; in contrast, a ring levee partially or completely encircles or "rings" a small area.

Life Cycle Costs: Life cycle costs are the total cost of implementing an alternative plan, which includes first costs plus operation and maintenance, repair, replacement and rehabilitation costs. See also **Construction Costs** and **First Costs.**

Measure: A component of alternative plans for risk reduction. Categories of risk reduction measures include structural, nonstructural and coastal restoration.

Metric: A parameter for measuring the performance of objectives.

Multi-Criteria Decision Analysis: Multi-criteria decision analysis is a discipline aimed at supporting decision-makers who are faced with making numerous and conflicting evaluations, highlighting these conflicts and deriving a way to come to a compromise in a transparent process.

Multiple Lines of Defense: The Multiple Lines of Defense concept (Lopez 2006) integrates the following natural and engineered risk reduction elements in coastal Louisiana: (1) the Gulf of Mexico shelf, (2) barrier islands, (3) bays or sounds, (4) marsh landbridges, (5) ridges, (6) highways, (7) flood gates, (8) levees, (9) pump stations, (10) elevated buildings, and (11) evacuation routes.

Period of Analysis: The time horizon for which project benefits, deferred construction costs, and operation, maintenance, repair, rehabilitation, and replacement costs are analyzed. For LACPR, the period of analysis is from the base year 2025 to 2075. See also **Base Year**.

Relative Sea Level Rise: In coastal Louisiana, relative sea level rise is often segmented into a global increase in water mass (global **sea level rise**), a rise in local water level due to density changes in the water, and a drop in local land elevation (**subsidence**).

Residual Risk: The flood risk that remains after a hurricane surge risk reduction project has been implemented.

Ridges: Geographical features along the Louisiana coast where wind and wave action has built linear barriers of sand and soil parallel to the coastline.

Risk: The probability for an adverse outcome. Risk = (Frequency of an event) x (Probability of occurrence) x (Consequences).

Risk-Informed Decision Framework: A new decision framework that augments the six-step Corps planning process by incorporating specific techniques and methods from risk analysis and multi-criteria decision analysis. The approaches incorporated within the risk informed decision framework enhance communication and collaboration among decision-makers and stakeholders by providing structure and mechanisms for capturing information about attitudes and values of decision-makers and stakeholders that are essential to defining objectives, metrics, and weights for metrics that reflect priorities.

Saffir-Simpson Hurricane Scale: The Saffir-Simpson Hurricane Scale is a 1-5 rating based on a hurricane's intensity at a given point in time. This scale is used to give an estimate of the potential property damage and flooding expected along the coast from a hurricane landfall. Wind speed is the determining factor in the scale, as storm surge values are highly dependent on the slope of the continental shelf and the shape of the coastline in the landfall region.

Sea Level Rise: Sea level rise is an increase in sea level.

Still Water Level: The elevation of the water surface without waves. See **Water Level**.

Storm Surge: A rise above normal water level on the open coast due only to the action of wind stress on the water surface; includes the rise in level due to atmospheric pressure reduction as well as that due to wind stress. Also known as storm wave; surge *(McGraw-Hill Dictionary of Scientific and Technical Terms, 6th edition).*

Subsidence: Subsidence is the motion of a surface (usually, the Earth's surface) as it shifts downward relative to a datum such as sea level.

Sustain: To support and provide with nourishment to keep in existence; maintain.

Sustainability: The ability of a coastal landscape feature to maintain its general location, spatial configuration, and habitat functions over time.

Systematic: Of or pertaining to a system, e.g. a hurricane risk reduction system; methodical in procedure or plan, e.g. systematic approach; formed with regular connection and adaptation or subordination of parts to each other, and to the design of the whole (based on Merriam-Webster and Webster's Revised Unabridged Dictionary).

Uncertainty: Lack of confidence in a risk prediction.

Water Level: The height of the water surface measured above a datum.