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Protecting New Orleans: From Hurricane Barriers to Floodwalls

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Protecting New Orleans:
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Summary

Breaches of the floodwalls protecting New Orleans during Hurricane Katrina caused significant flooding in many areas of downtown. Although most of the levee breaches in coastal Louisiana were the result of the storm's surge flowing over levees, preliminary evidence suggests that three major breaches in downtown New Orleans occurred prior to the floodwalls being overtopped; that is, the floodwalls failed before their design was exceeded. The failure of these floodwalls has many stakeholders' speculating about the causes of the failures, the reliability of the system of levees and floodwalls, and future options for protecting the city.

One cause of failure being discussed is a poor or inadequate design for protecting the city from a Category 3 hurricane. The original design for the city's hurricane protection infrastructure was to control storm surge flowing into water bodies near downtown by building inlet barriers and canal floodgates. The U.S. Army Corps of Engineers was responsible for designing and building much of the infrastructure as part of its *Lake Pontchartrain and Vicinity Hurricane Protection Project* to protect New Orleans and the surrounding parishes from a Category 3 hurricane; the local levee districts shared 30% of the construction costs and maintained the infrastructure. During the project's construction which began with authorization in 1965 and was ongoing when Hurricane Katrina made landfall, numerous factors contributed to changing the design of how to protect the city (e.g., including local environmental concerns, changing cost estimates, local flood protection preferences, and litigation); the final design attempted to reduce hurricane-related flooding in the city by increasing the height of levees and floodwalls, in lieu of the barriers and floodgates. The findings of ongoing investigations about the causes of the floodwall failures are likely to shape not only the future design of the city's hurricane protection system but also plans for rebuilding sections of the city and perspectives on the federal role and responsibility in the city's rebuilding efforts.

This report documents the evolution in the design of the *Lake Pontchartrain* project, with specific reference to how and by whom design decisions were made. The focus is on two major design developments relevant to the current investigations into floodwall failures in downtown New Orleans: (1) the shift from barriers at Lake Pontchartrain's inlets to higher levees along the lakeshore; and (2) the shift from floodgates at the mouth of the city's stormwater outfall canals that drain into Lake Pontchartrain to higher floodwalls along the length of the canals.

The Corps' decision in the mid-1980s to recommend higher levees instead of the inlet barriers it had recommended in 1965 was shaped by multiple factors, including environmental litigation, project economics, and local preferences. The Corps preferred floodgates to floodwalls along the Orleans Avenue and London Avenue canals. The decision to not build floodgates, and instead build floodwalls along the canals, was made by local project sponsors. The original design and the final design were intended to provide the same level of protection, i.e., protection from the rough equivalent of a Category 3 storm surge. This report will be updated as events warrant.

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Introduction

New Orleans' location on the Gulf Coast with water on three sides and below-sea-level terrain makes this densely populated section of Louisiana highly susceptible to flooding from hurricane storm surges. New Orleans' flooding threats are not only from the coast but also from the Mississippi River and rainfall that gets trapped in the city, known as *stormwater*. The system of levees and floodwalls around the city is designed to provide a specified level of protection from riverine and coastal flooding; where as, massive pumps and drainage canals that flow into Lake Pontchartrain manage the city's stormwater.[1] Local levee districts maintain the hurricane levees and floodwalls that were built largely by the U.S. Army Corps of Engineers as part of its *Lake Pontchartrain and Vicinity Hurricane Protection Project* to protect New Orleans and the surrounding parishes from a Category 3 hurricane. The Sewerage and Water Board of New Orleans is responsible for the city's stormwater management infrastructure.

Breaches of the floodwalls protecting New Orleans during Hurricane Katrina were the major contributor to significant flooding in many areas of downtown. Although most of the levee breaches in coastal Louisiana were the result of the storm's surge flowing over levees, preliminary evidence suggests that three major breaches in downtown New Orleans occurred prior to the floodwalls being overtopped; that is, the floodwalls failed before their design was exceeded. The failure of these floodwalls to reliably perform has many stakeholders' speculating about the causes of the failures.

A question central to many of the investigations into Katrina-related damage and of concern in rebuilding efforts is: were the levees and floodwalls breached because their design was exceeded, or did they fail due to faulty design, construction, or maintenance? To answer these questions, evidence has and continues to be collected on numerous fronts, including evidence of the height of the storm surge in various locations, and how the levees and floodwalls performed. Technical experts from universities, professional engineering organizations, and the Corps are using this evidence to model and explain the performance of New Orleans' hurricane protection system. The findings are likely to shape not only the future design of the hurricane protection system but also plans for rebuilding sections of the city and perspectives on the federal role and responsibility in the city's rebuilding efforts. Moreover, the

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[1] Levees are broad, earthen structures, while floodwalls are concrete and steel walls, built atop a levee or in lieu of a levee. Floodwalls are often used in urban areas because they require less land than levees.

findings may improve understanding and change perceptions of the level of flood protection and risk in other U.S. cities.

Understanding why New Orleans' hurricane protection system failed is essential for moving beyond simply making repairs to damaged levees and floodwalls. Knowing why the floodwalls failed is central to assessing the city's vulnerability to storm surge flooding and deciding on how to most effectively combine approaches for managing flood risk during rebuilding efforts (e.g., investing in coastal wetlands loss and hurricane protection infrastructure, requiring flood-proofing in certain areas, and mapping areas for the federal flood insurance program). Nonetheless in order to be prepared for the 2006 hurricane season, the Corps is having to proceed with immediate repairs of damaged levees and floodwalls using available information and integrating new information as it is available.

One of the causes of failure being discussed is a poor or inadequate design for protecting the city from a Category 3 hurricane. The original project design was to control storm surge flowing into water bodies near downtown by building inlet barriers and canal floodgates. During the project's construction which began with authorization in 1965 and was ongoing when Hurricane Katrina made landfall, numerous factors contributed to changing the design of how to protect the city (e.g., including local environmental concerns, changing cost estimates, local flood protection preferences, and litigation); the final design attempted to reduce hurricane-related flooding in the city by increasing the height of levees and floodwalls, in lieu of the barriers and floodgates.

The Corps' decision in the mid-1980s to recommend higher levees instead of the inlet barriers it had recommended in 1965 was shaped by multiple factors, including environmental litigation, project economics, and local preferences. The Corps preferred floodgates to floodwalls along the Orleans Avenue and London Avenue canals. The decision to not build floodgates, and instead build floodwalls along the canals, was made by the local project sponsors. The original design and the final design were intended to provide the same level of protection, i.e., protection from the rough equivalent of a Category 3 storm surge.

This report discusses the evolution in the project's design, with specific reference to how and by whom design decisions were made. The focus is on two major design developments relevant to the current investigations into the floodwall failures in downtown New Orleans' during Hurricane Katrina: (1) the shift from the barriers at the inlets to Lake Pontchartrain to higher levees along the lake; and (2) the shift from floodgates at the mouth of the city's stormwater outfall canals that drain into Lake Pontchartrain to higher floodwalls along the length of the canals. The report includes an appendix summarizing the federal funding history for the *Lake Pontchartrain* project. The analysis contained herein is based on currently available information and is limited in scope.[2]

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[2] Many of the documents referenced in this memo are available online at a site maintained by the Corps:[https://ipet.wes.army.mil]. Because this site has many documents that cannot be hyperlinked, please contact CRS for assistance in locating specific documents. Factors (continued...)

New Orleans Hurricane Protection

Hurricane Katrina's Floodwall Breaches: A Primer. Although there were more than a dozen breaches and many other segments of damaged levees and floodwalls in the greater New Orleans area and numerous in other coastal Louisiana parishes, the four breaches (see **Figure 1**) of the *Lake Pontchartrain* project that have received the greatest attention due to their impact on downtown New Orleans were the following:

- a breach of the 17th Street Canal floodwall;
- two breaches of the London Avenue Canal floodwall; and
- a breach of the western flank of the Inner Harbor Navigation Canal (IHNC, also known as the Industrial Canal) floodwall.

Flooding due to overtopping of city's levees and floodwalls was predicted for storm surges from a storm stronger than a Category 3 hurricane passing close to the New Orleans region.[3] Extensive overtopping may cause a levee or floodwall breach. Breaching in urban areas often produces catastrophic damage. Hurricane Katrina had weakened from a Category 5 storm to a Category 4 storm by the time passed east of New Orleans. Overtopping was the cause of much of the flooding and most of the breaches and damage to the hurricane protection infrastructure in coastal Louisiana. However, overtopping does not appear to have caused much of the flooding and some of the breaches in downtown New Orleans.

A November 2005 preliminary analysis of the performance of New Orleans' hurricane protection system by technical expert teams from the University of California at Berkeley and the American Society of Civil Engineers indicate the method of failures at the breaches in downtown New Orleans.[4] The teams' preliminary evidence suggests that breaches along the 17th Street and London Avenue canals occurred before the floodwalls were overtopped; that is, these floodwalls failed before their design was exceeded. The immediate and underlying causes of these breaches (i.e., what led to the failures) are the subject of conjecture; hypotheses

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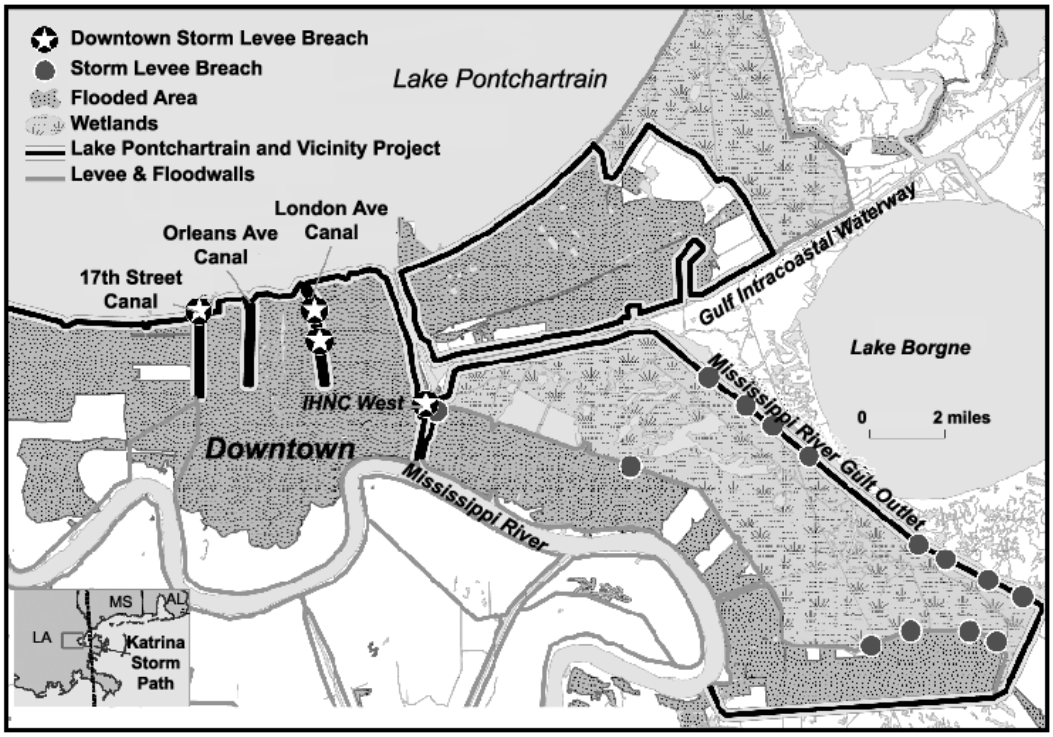
[2] (...continued)
that are often debated in the discussions of the performance during Hurricane Katrina of the *Lake Pontchartrain* project and other levees in coastal Louisiana (e.g., levee maintenance, operation of the Mississippi River Gulf Outlet (MRGO) deep-draft navigation channel, loss of coastal wetlands, and increasing sea surface temperature) are not discussed in this report. The many other breaches of the *Lake Pontchartrain* project (such as the breaches on the eastern flank of the IHNC that contributed to the flooding of the Lower Ninth Ward) and levees constructed as elements of other U.S. Army Corps of Engineers (Corps) and local projects also are not discussed.

[3] Hurricane Categories are based on the Saffir-Simpson Hurricane Scale of 1-5, with Category 4 storms having 131-155 mile per hour (mph) winds and a 13- to 18-foot storm surge, and Category 5 storms having winds exceeding 155 mph and surges above 18 feet.

[4] R.B. Seed, et al., *Preliminary Report on the Performance of the New Orleans Levee Systems in Hurricane Katrina on August 29, 2005* (Berkeley, CA: University of California Berkeley and American Society of Civil Engineers, November 2, 2005), available at [http://hsgac.senate.gov/_files/Katrina/Preliminary_Report.pdf], visited Dec. 13, 2005.

range from exceeded design, poor design, faulty construction, maintenance issues, incomplete construction due to the level of construction appropriations (see the **Appendix** for information on the project's federal funding), and modifications to the project's original design. The Corps has initiated a forensic investigation of the floodwall breaches; the results are expected in June 2006. According to the teams' preliminary analysis, the combined storm surges from several direction along the IHNC and the Mississippi River Gulf Outlet (MRGO) overtopped the IHNC and MRGO.

Figure 1. New Orleans Hurricane Protection with Hurricane Katrina Breaches and Flooding



Source: National Oceanic and Atmospheric Administration; Federal Emergency Management Agency; U.S. Army Corps of Engineers

Prepared by the Congressional Cartography Program, Geography and Map Division, Library of Congress, 2005

***Lake Pontchartrain* Project.** Congress authorized the Corps to protect New Orleans from the rough equivalent of a Category 3 storm when it authorized the *Lake Pontchartrain and Vicinity Hurricane Protection Project* in October1965.[5] The project consists of levees and floodwalls, most of which were constructed by the

[5] The *Lake Pontchartrain* project included structures in St. Charles (located west of Jefferson Parish, not shown in **Figure 1**), Jefferson, Orleans, and St. Bernard Parishes. In 1999, the House Committee on Transportation and Infrastructure authorized, via a Committee Resolution, a *Hurricane Protection Louisiana* study to investigate providing hurricane protection from a Category 4 or 5 storm.

Corps and cost-shared by the federal government and local levee districts.[6] The Orleans Parish segments of the *Lake Pontchartrain* project, which encompass downtown New Orleans, were 90% complete as of May 2005. The total cost for the Lake Pontchartrain and Vicinity project is $738 million, with the federal responsibility $528 million.[7] Federal allocations totaled $457 million through FY2005, leaving around $70 million to complete federal funding.

The original design of the *Lake Pontchartrain* project was sent to Congress in July 1965. The project was designed to protect the city from a *standard* hurricane for the region, which was roughly equivalent to a Category 3 hurricane on the Saffir-Simpson Scale. The standard hurricane was defined as high sustained wind speeds reasonably characteristic for a specified coastal location. Reasonably characteristic was defined as only a few hurricanes on record over the general region had been recorded to have more extreme wind and other meteorological characteristics. The standard hurricane was determined by the U.S. Weather Service.

Two months later in September 1965, Hurricane Betsy, a Category 3 hurricane, struck Louisiana's coast, causing damage in New Orleans. Congress authorized construction of the *Lake Pontchartrain* project in the Flood Control Act of 1965, enacted in October 1965. Modifications to the authorization have been made in subsequent legislation. Since that original design, there have been two major developments in the project relevant to current investigations into the floodwall failures: (1) the shift from the barriers at the inlets to Lake Pontchartrain to higher levees along the lake; and (2) the shift from floodgates at the mouth of the city's stormwater outfall canals that drain into Lake Pontchartrain to higher floodwalls along the length of the canals. These two decisions are discussed below.

Choosing Higher Levees over Inlet Barriers. The original July 1965 *Lake Pontchartrain* project design consisted of the Barrier Plan for constructing inlet barriers at Lake Pontchartrain's three main tidal entrances as well as levees and floodwalls for surge protection. The barriers generally would remain open and allow for navigation, and would close during coastal storms to reduce storm surges from entering the lake.[8] Based on updated weather data and experience learned during the city's flooding in September 1965 by Hurricane Betsy, changes in the project were sought before construction began. For almost two decades, technical issues,

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[6] The Corps was responsible for most, but not all, of the construction of the *Lake Pontchartrain* project; the *Lake Pontchartrain* project often was built atop existing levees constructed by locals or as part of earlier federal projects.

[7] Most Corps storm damage reduction construction projects are cost-shared 65% federal and 35% non-federal. Operation and maintenance of these projects generally is a 100% non-federal responsibility.

[8] U.S. House of Representatives, *Lake Pontchartrain and Vicinity, Louisiana*, H. Doc. No. 231 (GPO: July 6, 1965). The three barriers in the Barrier Plan were the Seabrook Lock for navigation and flood protection, Menteur Pass gates for navigation and flood protection, and Rigolets floodgates and navigation lock. The Barrier Plan also would have included higher levees along the northwestern edge of Lake Borgne as part of the inlet controls to Lake Pontchartrain.

environmental concerns, legal challenges, and local opposition to various components slowed construction.

The design that the Corps eventually chose was the High-Level Plan which consists of higher levees and floodwalls, instead of the originally planned inlet barriers and lower levees and floodwalls. (**Figure 2** shows the existing hurricane protection infrastructure as well as the elements of the Barrier Plan that were rejected in favor of higher levees and floodwalls.) The change from the Barrier Plan to the High-Level Plan was approved by the Corps' Chief of Engineers in February 1985; both the barrier and the high-level plans were designed to protect from the rough equivalent of a fast-moving Category 3 hurricane.[9] The Chief's decision to adopt the High-Level Plan was based on a 1984 project reevaluation study conducted by the agency in response to a 1977 court injunction on the construction of inlet barriers until an adequate Environmental Impact Statement (pursuant to the National Environmental Policy Act of 1969 P.L. 91-190) was completed.[10] The re-evaluation study recommended the change because "the High Level Plan has greater net benefits, is less damaging to the environment, and is more acceptable to the public" than the Barrier Plan.[11]

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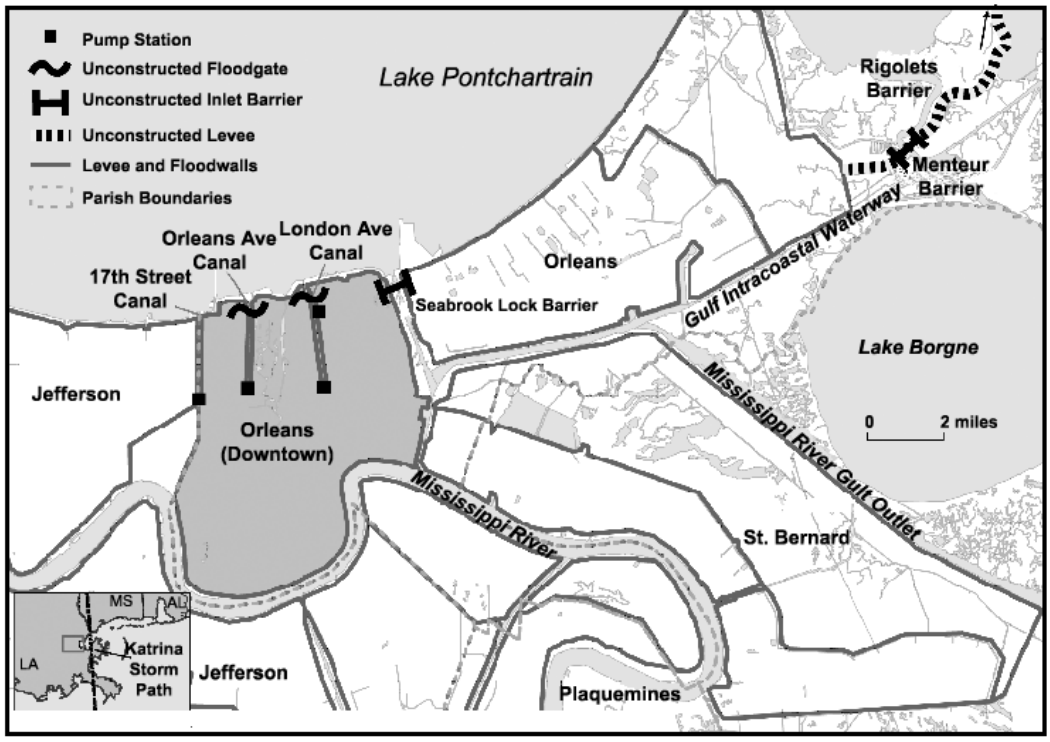
[9] Corps, *Lake Pontchartrain, Louisiana, and Vicinity Hurricane Protection Project: Reevlauation Study* (New Orleans: July 1984). According to the 1984 re-evaluation study, the design storm for protection bordering Lake Pontchartrain had a return frequency of approximately 300 years. The return frequency of the design critical to other project areas, such as Inner Harbor and New Orleans East Bank Levees, was approximately 200 years.

[10] For more information on the injunction, see CRS Report RL33104, *NEPA and Hurricane Response, Recovery, and Rebuilding Efforts*, by Linda Luther.

[11] Corps, *Lake Pontchartrain, Louisiana, and Vicinity Hurricane Protection Project: Reevlauation Study*.

Figure 2. Rejected Inlet Barriers and Canal Floodgates



Source: National Oceanic and Atmospheric Administration; Federal Emergency Management Agency; U.S. Army Corps of Engineers

Prepared by the Congressional Cartography Program, Geography and Map Division, Library of Congress, 2005

Choosing Improved Canal Levees and Floodwalls over Floodgates. To drain the city of stormwater (i.e., accumulated rainfall), the city pumps water into three outfall canals — the 17th Street canal, the Orleans Avenue canal, and the London Avenue canal — that flow into Lake Pontchartrain. The pumps are located at the southern ends of the canals, away from the lake. To protect the city from rising water in Lake Pontchartrain during hurricanes, levees were built along the length of the canals. The levees along the outfall canals were considered adequate when the Corps developed the original design for the *Lake Pontchartrain* project that was sent to Congress in July 1965.

Subsequent to the U.S. Weather Bureau's adoption of a more severe standard hurricane for the region, the Corps determined that the levees along the outfall canals were inadequate in their height and stability to protect the city from the standard hurricane. The Corps eventually integrated hurricane storm protection for the canals into its *Lake Pontchartrain* project. The Corps considered Improved canal protection necessary regardless of the selection of the Barrier or High-Level Plan. The two basic canal options evaluated were:

- "butterfly" floodgates at the mouths of the outfall canals that would close when water levels in Lake Pontchartrain exceeded levels in the canals (known as fronting protection); and
- higher and stronger levees and floodwalls along the canals (known as parallel protection).

The Orleans Levee District and the Sewerage and Water Board of New Orleans favored parallel protection over floodgates; they were concerned that the operation of the butterfly floodgates would reduce the ability to pump stormwater out of the city during storms. The Corps analyzed the options and recommended parallel protection for the 17th Street Canal;[12] in contrast, the Corps recommended butterfly floodgates for the Orleans and London Avenue canals. The Corps concluded that the butterfly floodgate plan for the London Avenue canal

> fully satisfies the project's mandate to provide protection against the hurricane generated tidal surges and yet provides the maximum latitude for operation of local interest interior drainage [i.e., stormwater removal]. The butterfly control valve plan has been shown to be the least costly fully responsive plan. When compared to the parallel protection plan it is approximately three times less costly.[13]

The conclusion for the Orleans Avenue canal was similar; the Corps found the butterfly gates to fully satisfy the project purpose of hurricane storm surge protection and to be one-fifth the cost of parallel protection.[14]

Rather than having the Corps proceed with construction of the butterfly floodgates, the Orleans Levee District decided to construct on its own most elements of the parallel protection on the Orleans and London Avenue canals. This local construction was designed in accordance with Corps criteria, so that the parallel protection would be incorporated into the larger *Lake Pontchartrain* project. (**Figure 2** shows the existing hurricane protection infrastructure as well as the canal floodgates that were rejected in favor of higher canal levees and floodwalls.) The Corps recommended that the federal cost-share contribution for the parallel protection of the two canals be capped at 70% of the less-costly butterfly floodgates design. (The *Lake Pontchartrain* project was authorized in 1965 based on a construction cost share of 70% federal - 30% nonfederal. See the **Appendix** for a 40-year history of the federal construction funding.) In H.Rept. 101-966, the Conference Report for the Water Resources Development Act (WRDA) of 1990 (P.L. 101-640), Congress directed the Corps to consider favorably parallel protection for the two canals and for the federal government to bear part of the costs, but did not specify

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[12] Corps, *Lake Pontchartrain High Level Plan, Design Memorandum No. 20, 17th St. Outfall Canal* (New Orleans: March 1990).

[13] Corps, *Lake Pontchartrain High Level Plan, Design Memorandum No. 19A: London Avenue Outfall Canal* (New Orleans: January 1989).

[14] Corps, *Lake Pontchartrain High Level Plan, Design Memorandum No. 19: Orleans Avenue Outfall Canal* (New Orleans: August 1988).

what percentage of the cost.[15] This report was followed by the Energy and Water Development Appropriations Act of 1992 (P.L. 102-104) in which Congress stated:

> The Secretary of the Army is authorized and directed to provide parallel hurricane protection along the entire lengths of the outfall canals and other pertinent work necessary to complete an entire parallel protection system, to be cost shared as an authorized project feature, the Federal cost participation in which shall be 70 percent of the total cost of the entire parallel protection system, and the local cost participation in which shall be 30 percent of the total cost of such entire parallel protection system.

Current Issues and Conclusion

In summary, the original project design aimed to control storm surge flowing into water bodies around downtown New Orleans using inlet barriers and canal floodgates (in combination with levees). The constructed project, however, attempted to reduce the city's flooding from water bodies affected by hurricane storm surge and wind through higher levees and floodwalls. The Corps' decision to recommend higher levees instead of inlet barriers was shaped by multiple factors, including environmental litigation, project economics, and local preferences. The Corps preferred floodgates to floodwalls along the Orleans Avenue and London Avenue canals. The decision to not build floodgates, and instead build floodwalls along the canals, was made by the local project sponsors. The original design and the final design were intended to provide the same level of protection, i.e., protection from the rough equivalent of a Category 3 storm surge.

Hurricane Katrina's storm surge overtopped and breached New Orleans' hurricane protection system. In addition to causing extensive flood in downtown New Orleans, the floodwall failures decreased confidence in the reliability of the existing hurricane infrastructure to protect the city from Category 3 and less-severe hurricanes.

Confidence in both the reliability of hurricane infrastructure and the level of protection provided by natural and constructed hurricane protection is a factor shaping near-term and long-term investment decisions, as residents and businesses decide whether and how to rebuild. (For an analysis of wetlands restoration opportunities, see CRS Report RS22276, *Hurricanes Katrina and Rita and the Coastal Louisiana Ecosystem Restoration*, by Jeffrey Zinn.) In the near-term, many are concerned with the level of protection that will be available at the start of the 2006 hurricane season. By June 2006, the Corps expects to have completed its repairs of the existing infrastructure. However, the findings from the Corps' investigation into the causes of the floodwall failures are not anticipated until June 2006, raising the question of whether the agency will be able to respond to the findings and

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[15] The report directed "the Corps to treat the outfall canals as part of the overall hurricane protection project, and to favorably consider a plan that raises the levees along the entire lengths of the London Avenue and Orleans Avenue Canals to grades sufficient to confine a standard project hurricane with costs borne by both Federal and local assuring authorities."

improve the floodwalls' reliability when repairing the damaged levees and floodwalls for the 2006 hurricane season in June 2006.[16]

Concerns about levee and floodwall reliability are compounded by concerns about the level of protection provided by the existing infrastructure given New Orleans' increasing vulnerability to hurricane storm surge. Land in the city has subsided; barrier islands and wetlands have been disappearing;[17] and sea levels have risen. These factors have raised concerns about the ability of the city's infrastructure to provide Category 3 protection. According to the project justification sheet included in the Administration's Corps FY2006 budget request, "the project was initially designed in the 1960s, and a reanalysis was performed for part of the project in the mid-1980s. Continuing coastal land loss and settlement of land in the project may have impacted the ability of the project to withstand the design storm."[18] The challenge of protecting New Orleans could become even greater. According to some scientists, higher sea surface temperatures may result in increased hurricane intensity.[19] Climate change concerns and other factors have raised questions about whether both estimates of the likelihood of hurricanes of various strengths and past infrastructure investment decisions based on these estimates need to be re-evaluated.

Hurricane Katrina has resulted in some questioning why a Category 4 or 5 hurricane protection system was not in place for New Orleans, and whether it should be part of the rebuilding effort. The Corps currently only has congressional authorization for a Category 3 system; additional congressional authorization would be necessary to build a more protective system. Discussions of Category 4 or 5 protection for the city often include the extent to which coastal wetlands restoration may play a role in reducing the city's vulnerability to storm surge and whether some of the regional navigation improvements may increase storm surge vulnerability. These discussions raise broader policy issues related to the appropriate level of investment to protect against low probability-high consequences events; to protect against loss of life and economic disruption; and whether structural storm and flood control measures provide a false sense of security in vulnerable areas like New Orleans. The Corps' cost estimates are $1.6 billion to return coastal Louisiana's federal levees and floodwalls to pre-Katrina conditions by June 2006, and an

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[16] The Corps has indicated that the agency's team working on the investigation will be communicating interim results to the repair team.

[17] For information on coastal wetlands loss, see CRS Report RL32673, *Coastal Louisiana: Attempting to Restore an Ecosystem*, by Jeffrey Zinn.

[18] U.S. Army Corps of Engineers, *Fiscal Year 2006, Mississippi Valley Division*, visited Dec. 12, 2005, available at [http://www.usace.army.mil/inet/functions/cw/cecwb/just_states06/mvd.pdf].

[19] For example, see Intergovernmental Panel on Climate Change, *Climate Change 2001: Working Group II: Impacts, Adaptation and Vulnerability*, visited on Dec. 12, 2005, available at [http://www.grida.no/climate/ipcc_tar/wg2/029.htm], or T.R. Knutson and R.E. Tuleya, "Impact of CO_2-Induced Warming on Simulated Hurricane Intensity and Precipitation: Sensitivity to the Choice of Climate Model and Convective Parameterization," *Journal of Climate*, c. 17, no. 18 (15 Sept. 2004), available at [http://www.gfdl.noaa.gov /reference/bibliography/2004/tk0401.pdf].

additional $3.5 billion to increase protection for New Orleans from Category 3 to Category 5. State officials have estimated the cost of Category 5 protection and wetlands restoration for all of coastal Louisiana as high as $32 billion. Most local stakeholders argue for the inclusion of coastal wetlands restoration in any plan to improve hurricane protection.

Neither a consensus nor proposed plans on how to improve hurricane protection for New Orleans or costal Louisiana in the aftermath of Hurricane Katrina have emerged. Discussions continue about the advantages and disadvantages of additional infrastructure compared to other policy options, such as protection and restoration of wetlands that attenuate storm surges, buyouts of structures on the most flood-prone lands, flood-proofing structures, and improvements to the flood insurance program. For a discussion of managing flood risks, see CRS Report RL33129, *Flood Risk Management: Federal Role in Infrastructure*, by Nicole T. Carter.

Understanding why the hurricane protection system failed in New Orleans is essential to moving beyond simply making repairs, to identifying and reducing vulnerabilities in the system, addressing coastal wetlands loss, and rebuilding the city. Nonetheless, the Corps is having to proceed with available information in order to perform repairs to the failed floodwalls and other breaches to meet the June 2006 deadline, which marks the start of the hurricane season. Consequently, congressional oversight of New Orleans' hurricane protection is likely to continue as the nation grapples with decisions on what type and level of hurricane protection to provide New Orleans and other coastal areas around the nation, and who should bear responsibility and costs for protection in coastal, floodplain, and other hazard-prone areas.

Appendix: Lake Pontchartrain Project Federal Funding — 1965-2006

Table 1 provides the federal funding history for the constructions of the *Lake Pontchartrain* project. This information was provided to CRS by the Army Corps of Engineers. **Table 1** does not include project funding by non-federal project sponsors which are responsible for 30% of construction expenses and 100% of maintenance costs.

The *Initial Work Allowance* column represents the final enacted amount; this amount differs from the amount shown for the *Lake Pontchartrain* line item in appropriations conference reports due to rescissions and other reductions made by Congress. The Corps has some authority to reprogram funds across construction projects during the fiscal year; the *Year End Work Allowance* represents the *Initial Work Allowance* and any reprogrammings that occurred, which are shown in the *Transferred Funds* column. A negative in the *Transferred Funds* column indicates funds were reprogrammed away from the *Lake Pontchartrain* project during the fiscal year.

Beginning with the Fiscal Year 1994 Budget Justification, the Corps stopped scheduling the Orleans Avenue and London Avenue components of the *Lake Pontchartrain* project as part of its annual budget request. As shown in **Table 1**, Congress provided more than requested for the *Lake Pontchartrain* project by the Administration. Some of these funds may have been used to construct parallel protection for Orleans Avenue and London Avenue canals; however, CRS was not able to determine the federal funding level for the Orleans Avenue and London Avenue parallel protection based on currently available information. When Hurricane Katrina hit, the floodwalls along all three canals were complete; the canal work that remained to be built was the floodproofing of bridges (that is, the extension of a floodwall across a bridge to connect with a floodwall on the other side) and the extension of floodwalls across the front of pumping stations.

Table 1. Lake Pontchartrain and Vicinity Project: Federal Construction Funding History

(in thousands, nominal dollars)

Fiscal Year	President's Budget Request	Initial Work Allowance	Year End Work Allowance	Transferred Funds
2006	2,977	na	na	na
2005	3,937	5,081	4,945	-136
2004	3,000	4,694	7,206	2,512
2003	4,900	5,708	10,082	4,374
2002	7,500	11,972	9,484	-2,488
2001	3,100	8,380	14,295	5,915
2000	11,887	14,482	26,204	11,722
1999	5,676	16,000	16,000	0
1998	6,448	22,920	22,920	0
1997	4,025	17,025	17,025	0
1996	7,848	13,348	13,348	0
1995	10,000	13,300	13,300	0
1994	9,619	24,319	28,619	4,300
1993	11,607	18,194	19,160	966
1992	21,491	18,295	9,852	-8,443
1991	11,655	10,524	-4,989	-15,513
1990	39,898	35,639	32,882	-2,757
1989	40,400	36,384	9,214	-27,170
1988	17,000	14,784	13,140	-1,644
1987	16,000	15,375	13,375	-2,000
1986	25,000	20,288	20,358	70
1985	17,500	15,100	11,158	-3,942
1984	16,800	15,800	8,800	-7,000
1983	na	14,800	13,716	-1,084
1982	15,000	15,000	13,000	-2,000
1981	10,800	9,600	8,800	-800
1980	11,000	10,000	13,320	3,320
1979	0	0	230	230
1978	12,400	10,000	7,500	-2,500
1977	12,000	10,700	10,575	-125
1976 & 3rd Qtr	29,350	19,985	15,980	-4,005
1975	3,300	2,100	-2,080	-4,180
1974	6,400	0	2,660	2,660
1973	20,000	17,500	14,840	-2,660
1972	4,555	10,946	13,946	3,000
1971	8,250	11,250	11,040	-210
1970	6,000	8,050	5,260	-2,790
1969	7,800	6,274	6,269	-5
1968	2,300	4,000	4,086	86
1967	450	1,600	1,600	0
1966	0	450	0	-450
1965	0	na	na	na
TOTAL	**447,873**	**509,867**	**457,120**	**-52,747**

Source: Data provided by Army Corps of Engineers, 2005.
na = not available