DECISION-MAKING CHRONOLOGY FOR THE LAKE PONTCHARTRAIN & VICINITY HURRICANE PROTECTION PROJECT

FINAL REPORT FOR THE HEADQUARTERS,
U.S. ARMY CORPS OF ENGINEERS

SUBMITTED TO THE INSTITUTE FOR WATER RESOURCES OF THE U.S. ARMY CORPS OF ENGINEERS

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Forward

The one-two punch of Hurricanes Katrina and Rita in August and September of 2005 proved calamitous to a vast swath of the U.S. Gulf Coast across the States of Louisiana, Mississippi, Alabama, Florida, and Texas. While still offshore in the Gulf of Mexico, Hurricane Katrina's 175 mph winds created the highest storm surge yet recorded at landfall in North America.

Katrina's storm surge overwhelmed many of the levees and floodwalls for greater New Orleans designed and constructed by the U.S. Army Corps of Engineers, collectively known as the *Lake Pontchartrain & Vicinity Hurricane Protection Project* (LP&VHPP). The result was a human tragedy—more than 1,600 people killed or missing and presumed dead, with over 1,250 confirmed deaths in Louisiana alone. In economic terms, the flooding from Katrina represents the costliest natural disaster in U.S. history. Direct flood damages to residential, non-residential, and public properties and infrastructure in greater New Orleans approached $28 billion, with further indirect economic effects and long-lasting socio-economic disruption to the region.

In the immediate aftermath of the tragedy, the Secretary of Defense directed that that Army enlist the National Academy of Sciences to conduct a thorough review of the engineering aspects of the performance of the levees and floodwalls in place in New Orleans on August 29, 2005. In aid of this effort, the Corps of Engineers (Corps) initiated the *Interagency Performance Evaluation Task Force* (IPET) to analyze the engineering performance of the LP&VHPP and subject that analysis to independent peer review by the American Society of Civil Engineers.

This commitment to document the facts also led the Corps to concurrently commission the enclosed *Hurricane Protection Decision Chronology* (HPDC). The HPDC is the result of an unprecedented effort to document and interpret the chronological record of decision-making for the LP&VHPP, including the legislative, policy, economic, financial, and organizational factors that influenced decisions made over the 50-year project history. The HPDC focus on project decision-making complements the technical focus of the IPET investigation, and the resulting report and database of project-related documents provides invaluable insights into "how" and "why" the decisions were made that led to the LP&VHPP network of levees and floodwalls that existed when Katrina made landfall.

Although many layers of government—from Federal through state to local—were involved in the decision process, the Corps is, in the end, responsible for leading the planning, design, and construction of LP&VHPP levees and floodwalls. As an agency of professional engineers and public servants entrusted with mitigating flood risks to public safety and welfare, the Corps holds itself to the highest professional standards. Consistent with being stewards of the public trust is the obligation to document the facts surrounding both "what happened" from an engineering performance perspective, and "why it happened," with full consideration and disclosure of the chronology of decisions that led to the New Orleans network of levees and floodwalls that was in place on August 29, 2005.

It is with that commitment to the American people that we, the civilian and military leaders of the Corps, are pleased that the HPDC report has been completed by the independent study team and is being published by the Corps' Institute for Water Resources. We are confident in the completeness and soundness of the report, particularly after a rigorous peer review by an external panel of experts convened by the National Association of Flood and Storm Water Management Agencies (NAFSMA), and the subsequent public review of the draft final report this past summer, which yielded a few additional project documents that were incorporated into the final report and source database. All of the project-related documents that were used to prepare the HPDC report have been made available for public review along with the publication of the final HPDC report.

We have thoroughly read the report, examined its findings and, in particular, studied the author's reflections. While the report is critically important because of what the historical record tells us about past hurricane project decision-making in the Gulf Coast region, it is of even greater value as a national resource and database for informing planners, decision-makers, and stakeholders on how to make better future decisions on the nation's critical public works infrastructure and the communities it serves. Accordingly, the disclosure of the facts is being accompanied by an agency commitment to apply the lessons learned from the HPDC to inform future flood mitigation efforts and flood preparedness and response processes across the nation.

Those lessons are already being incorporated into a wide range of Corps initiatives aimed at avoiding future loss of life, human suffering, and economic losses within flood-prone areas across the nation. Lessons from the HPDC, IPET and other ex-post investigations are now being activated through the Corps' *Actions for Change* initiative, which represents a new direction for the Corps in terms of how it plans, decides upon, and then implements water resources management programs and projects. The *Actions for Change* incorporate not only technical considerations, but organizational, human, and social factors as well, and how they in turn impact engineering system decision processes. They emphasize the need for dynamic, risk-based decision-making within a comprehensive systems focus for the planning, design, construction, and operation and maintenance of flood and storm damage reduction projects. The *Actions for Change* call for enhanced risk assessment and communication, including periodic assessment of the potential consequences of flooding as populations at risk and potential flood hazards change over time, and openly sharing information on residual risks with project sponsors and the public. Finally, the *Actions for Change* also focus on strengthening Corps professional standards and agency commitments to technical competency and professional conduct throughout its entire workforce across the nation.

The Corps is now incorporating these actions into the improvement and augmentation of the LP&VHPP network of levees and floodwalls for New Orleans, and for the planning of broader flood and storm damage reduction and wetlands restoration efforts for the Gulf region as part of the *Louisiana Coastal Protection and Restoration* (LACPR) project. They are also being implemented nationwide through the *National Flood Risk*

Management Program, including a more rigorous and effective *Inspection of Completed Works Program* for assessing and reporting on the conditions of levees and floodwalls nationwide.

In closing, we would like to express our sincere appreciation to the many people who contributed to the HPDC. First and foremost is the independent study team of Drs. Douglas Woolley and Leonard Shabman who conducted the HPDC inquiry and prepared the study report. Drs. Woolley and Shabman applied to this effort their extensive breadth and depth of expertise in water resources management policy and practice, and provided their candid reflections on lessons learned.

We would also like to thank the many former and current Corps employees and other individuals with knowledge of the planning and implementation of the LP&VHPP who agreed to be interviewed as part of the study, and who helped the study team to obtain project-related documents. Finally, we thank the members of the External Review Panel convened by the NASMA to review and provide comments on the HPDC draft report, and the people who provided additional project documents through the public review process. These individuals, through their contributions to the HPDC, have greatly contributed to the Corps and the nation learning from the past to inform the future.

The Honorable John Paul Woodley, Jr., *Assistant Secretary of the Army (Civil Works)*

Major General Don T. Riley, *Director of Civil Works, U.S. Army Corps of Engineers*

Lieutenant General Robert L. Van Antwerp, Jr., *Chief of Engineers and Commander, U.S. Army Corps of Engineers*

Preface and Acknowledgements

The Hurricane Protection Decision Chronology (HPDC) study was chartered by the Institute for Water Resources (IWR) of the U.S. Army Corps of Engineers (Corps). The Corps Directorate of Civil Works, acting on behalf of Lieutenant General Carl A. Strock, Commanding General and Chief of Engineers, and the Honorable John Paul Woodley Jr., Assistant Secretary of the Army for Civil Works, requested this work. The Directorate provided executive contact to the HPDC study through Major General Don T. Riley, Director of Civil Works; Mr. Steven Stockton, Deputy Director of Civil Works; Mr. Thomas Waters, Chief, CECW-MVD RIT/Planning Community of Practice; and Mr. Zoltan Montvai, Civil Deputy, CECW-MVD. These leaders supported the work throughout, were briefed on progress, and made constructive suggestions, but always respected the independence of the study authors.

The HPDC study charter was to document and examine decision-making for the Lake Pontchartrain & Vicinity Hurricane Protection Project (LP&VHPP). The HPDC study team was asked to assemble all available documents relevant to project planning, design, and implementation decisions made over the more than 50-year project history. The report was expected to relate those documents to each other in order to provide an understanding of project decisions and the factors that influenced them. That IWR was asked to secure this report is evidence of the genuine interest within the leadership of the Corps in understanding the decision-making processes that resulted in the LP&VHPP that was in place when Hurricane Katrina made landfall on August 29, 2005.

We, Dr. Douglas Woolley and Dr. Leonard Shabman, prepared the report as contractors to IWR and the content of this report is our sole responsibility. However, we would be remiss if we did not acknowledge the support of the many people who contributed in different ways to report development. Of special note is the work of Mr. Paul Scodari of IWR. He was a full partner throughout the effort, securing and compiling documents, summarizing materials, arranging for and participating in interviews, reviewing and editing drafts, and providing administrative management for the project.

We benefited from a separate report to IWR prepared by independent contractors, Mr. Scott Tucker (former Executive Director of the Urban Drainage and Flood Control District, Denver, Colorado), and Mr. Doug Harrison (former General Manager-Secretary, Fresno Metropolitan Flood Control District). Their report focused on local sponsor project roles and responsibilities, and was developed based on the information they had available to them and on interviews with local sponsor representatives that they were able to conduct. That report is included in the database of source documents that accompanies the HPDC final report.

We also must thank all those people who contributed to the report by agreeing to interviews, by providing documents, and by reviewing sections of earlier drafts. Appendix C lists study interviewees. The report has benefited from their many hours of effort. However, none of the content of this report is attributed to any of these individuals. The report includes no comments from any persons interviewed, nor are comments reported that were made on early and partial report drafts. Also, an earlier draft of this report was reviewed by an independent External Review Panel (ERP) convened by the National Association of Flood and Stormwater Management Agencies.

Finally, we offer special thanks to IWR Director Robert Pietrowsky and Dr. David Moser of IWR who is the Corps Chief Economist. They were steadfast in supporting this study and served as valued sounding boards throughout report development.

The content of this report is the responsibility of the authors alone and does not represent the views of the report's sponsor, the Corps. It is our hope that this report will give the administration, the Congress, the Corps, and non-federal entities an enriched understanding of the basis for past decisions associated with the LP&VHPP. In turn, that understanding can inform future planning, policy, budgeting, and legislative changes aimed at avoiding future loss of life and human suffering in the project area as well as in other storm-prone areas across the nation.

Douglas Woolley

Leonard Shabman

Executive Summary

Hurricane Protection Decision Chronology Origin and Purpose

The Assistant Secretary of the Army for Civil Works [ASA(CW)], John Paul Woodley, Jr., and the U.S. Army Corps of Engineers (Corps) Director of Civil Works, Major General Don Riley, commissioned the Hurricane Protection Decision Chronology (HPDC) shortly after Hurricane Katrina struck the Gulf Coast of the United States on August 29, 2005.

The requested report was to provide an explanation, as opposed to an evaluation, of how Corps policies and organization, legislation, and financial and other factors influenced the decisions that led to the Lake Pontchartrain and Vicinity Hurricane Protection Project (LP&VHPP) protective structures in place when Hurricane Katrina struck the Gulf Coast.

The study focus on project decision-making is intended to complement the engineering forensics investigations on the performance of the LP&VHPP during Katrina conducted by the Interagency Performance Evaluation Task Force and other institutions.

The HPDC represents an exhaustive examination of a highly complex 50-year record of project decision-making and project implementation involving the Corps, local sponsors, government at all levels, and the courts. It can serve as a national resource for planners and decision-makers to make better future decisions about the nation's critical public works infrastructure by learning from the past.

The HPDC authors are solely responsible for the content of this report, and the report does not necessarily represent the views of the Office of the ASA(CW) or the Corps.

Background

Hurricane Katrina had a disastrous impact along the Gulf Coast, and the Greater New Orleans metropolitan area in particular, when it made landfall on August 29, 2005. Soon thereafter, Corps leadership recognized the need for two comprehensive studies to address many of the nation's questions about the New Orleans-area hurricane protection network.

Lieutenant General Carl A. Strock, former Corps Commander, first commissioned the Interagency Performance Evaluation Task Force (IPET) to answer five key questions:

- what was the hurricane protection network in place on Aug. 29, 2005,
- what forces did Hurricane Katrina put on the protection network,
- how did the protection network perform (what worked, what failed and why),
- what were the consequences of this event, and
- what would be the risk and reliability of the protection network on June 1, 2006?

It became apparent during the course of the IPET study that while that investigation would provide engineering and scientific insight into how the New Orleans-area hurricane protection system performed during Katrina, it would not address critical questions about how the protection network that existed on August 29, 2005 came to be.

The Honorable Mr. Woodley and Major General Riley then commissioned the Corps' Institute for Water Resources (IWR) to convene an external group to collect, record, and analyze project memoranda, reports, and related documentation in order to describe and explain decision-making for the LP&VHPP.

The IWR established the independent study team of Drs. Douglas Woolley and Leonard Shabman, both water resources planning and policy experts, to conduct the inquiry and prepare the HPDC. (Brief biographies for the report authors are included at the end of this summary.) Mr. Paul Scodari of the IWR supported the study team throughout its inquiry.

Focus

The 50-year history of the LP&VHPP contains many more decisions and actions than could be fully addressed in the HPDC. Accordingly, this report focuses on the chronology of project decisions identified as important by the report authors from their reviews of engineering forensic investigation reports, and other post-Katrina reporting. These include, but are not limited to, the IPET report, media accounts, and congressional testimony in the aftermath of Hurricane Katrina. Specifically, the HPDC report focuses on project decision-making in three areas:

- the selection of the overall protection approach for the project area (Barrier Plan versus High Level Plan), and for the outfall canals in metro New Orleans (Frontage Protection versus Parallel Protection),

- the selection of the design hurricane, and the treatment of new information as it became available during the project history on hurricane science, surge modeling, and land subsidence that determined the design and constructed heights of protective structures across the project network, and

- the design of I-wall parallel protection structures for the outfall canals.

Map ES-1 displays the project area and the names of the various political jurisdictions, waterways, and different locations within the overall project area that are referred to throughout this report. Map ES-1 also shows the perimeter of LP&VHPP protective structures that were in place, as well as the locations where breaches occurred in the project protection network, when Katrina made landfall. Most breaches occurred where storm-driven water overtopped project structures. However, one breach occurred along the 17th Street Outfall Canal and two occurred along the London Avenue Outfall Canal before water reached the tops of the floodwalls that parallel each canal. Also, one of the breaches along the Inner Harbor Navigation Canal (IHNC) occurred before water reached the tops of the canal floodwalls. (The source of the information presented on project breaches is the IPET report.)

Approach

The study team followed a structured process to obtain all relevant and available project documents, and to ensure that logical descriptions and explanations of project decisions were made from those documents. Report preparation began after reviewing an initial compilation of project documents. Those documents were used to record project decisions and to formulate preliminary explanations for those decisions and the forces affecting them. The sequencing, description, and explanation of project events were then tested against the recollections of former and present Corps employees and officials from local assuring agencies in a series of interviews. The effort to secure project documentation continued throughout the report development process, and the report text was modified as new documents were obtained (see Chapter 1).

While it is impossible to know what records may have been lost over the 50-year project history, the HPDC report authors are confident that most, if not all, of the key reports prepared for the LP&VHPP were reviewed, as were many internal Corps memoranda, and letters related to the development of those reports. These documents are referenced in the report and are cited in an annotated master chronology of project events presented in Appendix A. Copies of all original project documents used in preparing the report are available electronically on a compact disc accompanying this report.

The master chronology of project events includes project planning reports, design memoranda, administrative correspondence, letters, budget justification statements, hearing records, and much more. Each chapter of the report includes a shorter chronology relevant to the subject of that chapter.

The reliance on project chronologies disciplined the development of the report in two ways. First, the chronologies made it impossible to attribute causes to decisions and events that were not consistent with the order of their occurrence. Second, the chronologies helped to ensure that project decisions were explained in the context of their own time by reducing the opportunity for contemporary scientific understandings, technical capabilities, and current civil works policies to affect the description and explanation of historical project decisions. This placed a premium on understanding the legal, regulatory, budgetary, and organizational setting at the time that the project decisions were made.

Map ES-1: The LP&VHPP Area, Protective Structures, and Breach Areas

This summary includes three timelines that trace the broad history of key project decisions and the significant historical events that provided the context for those decisions. The timelines are brief summaries of the more-detailed chapter chronologies. They are provided in this summary to illustrate the 50 years that elapsed during project planning, design, and construction, as well as the complexity of the decisions made and the multiplicity of decision-makers.

A first, rough draft of the full report was prepared in July 2006 and reviewed by Corps internal technical review teams who were asked to identify any errors of fact and errors of omission that could be demonstrated through the provision of documents that had not been available to the HPDC team at the time the draft was prepared. In this way, new documents were identified and a second draft was prepared in December 2006. That draft went through another round of Corps internal review that helped the study team to identify and secure additional project documents. This second draft was also reviewed by an independent External Review Panel (ERP) convened by the National Association of Flood and Stormwater Management Agencies. The ERP was asked to evaluate the clarity of the report's description and explanation of project decisions, and to identify any errors of logic. The ERP report was delivered to the HPDC team through IWR, and Drs. Woolley and Shabman addressed the ERP comments and suggestions in a draft final HPDC report completed in June 2007.

In July 2007, the draft final HPDC report, as well an electronic database of project documents that were used for its preparation, were placed on the IWR website for public review. The announcement that accompanied the public release provided an overview of the study origin and purpose, solicited public comments on the report contents that could help to clarify the record of project decision-making that could be supported with the provision of corroborating project-related documentation. Through this public review process, which lasted for several months, a few additional project-related documents were secured. Those additional project documents have been folded into the database of source documents are reflected in the final report presented here.

Report Organization

This final report is organized into six chapters and several appendices. Chapter 1 provides a detailed description of the study origin, purpose, focus, and approach. Because of the long history and complexity of project decision-making, Chapter 2 offers a high-level overview of the decades-spanning sequence of project decisions that resulted in the project structures in place in August 2005.

With this broad overview as a background, Chapter 3 provides a detailed examination of particular project performance decisions, including a description of how the choice of storm parameters, surge modeling approaches, and the treatment of subsidence and datum issues were initially analyzed and then further evaluated in light of new information.

Chapter 4 details design decisions for the outfall canals, including the selection of the parallel protection approach over the frontage protection approach, and the designs for the I-walls that were eventually constructed along the canals. Reference is made throughout Chapters 2–4 to the concerns of local sponsors and the Corps New Orleans District office about project cost increases, budget limitations, and continuing delays in project completion. Chapter 5 provides a detailed and data-driven description of the basis for these concerns, and how they focused the Corps New Orleans District on finishing the project as it was then designed and budgeted.

Chapter 6 summarizes report findings and concludes with the authors' own reflections on project decision-making and lessons learned for flood and storm damage reduction efforts. Appendix A presents the master chronology of project events. Appendix B provides a glossary of key terms used throughout the report. Appendix C lists those individuals who were interviewed for this report, and Appendix D provides brief biographies for the report authors.

Overview of Selected Key Events in the Project History

The Original Barrier Plan: The Corps' New Orleans District (the District) completed an "Interim Survey Report" for the LP&VHPP in 1962, after seven years of planning, that outlined a comprehensive plan for preventing flooding in the greater New Orleans area resulting from the "Standard Project Hurricane" (SPH). The original project plan, termed the "Barrier Plan," included floodgates (surge barriers) in the passes to Lake Pontchartrain to prevent SPH-driven surges from entering the lake. The planned barriers were meant to reduce the "stillwater" surge heights along the lakefront. Barrier-dampened hurricane surges would then be contained by the existing local levees along the three outfall canals that penetrated into metro New Orleans from Lake Pontchartrain. The barrier complexes were to be accompanied by levees and floodwalls in other locations designed to withstand SPH surges (see Chapter 2).

The Design Storm: The SPH performance standard was chosen for the design of the Barrier Plan in order to prevent loss of life and catastrophic damage. Although a benefit-cost analysis was completed for the plan, considerations of cost or of optimizing net economic benefits were not factors in the District selecting the SPH standard as the recommended degree of project protection. Moreover, according to data reported in the 1962 planning report, the design elevations of project structures, including freeboard or extra height to account for wave action, were estimated to protect against the stillwater surge heights resulting from the SPH as well as from the "Probable Maximum Hurricane" (PMH). The PMH represented the most severe storm thought possible in the project area at that time (see Chapters 2 and 3).

Congressional Authorization: Congress authorized the Barrier Plan in 1965 to provide protection from a storm with the SPH wind speed and central pressure parameters established in the report of the Chief of Engineers. The Congress also required the federal government to assume 70 percent of the construction cost, and local sponsors to pay the remaining 30 percent either in the form of cash or as in-kind contributions of lands, easements, rights-of-way, or project work. After authorization, the District set out to develop the detailed engineering designs for plan features, secure the required funding, acquire land rights needed for project implementation, and construct project features. At the time of authorization, the District estimated that the project would be completed by the mid-to-late-1970s (see Chapter 2).

Hurricane Betsy Challenged the Original Design: Doubts about the adequacy of the original project designs were soon raised by the experience of Hurricane Betsy in 1965. While Hurricane Betsy had wind speed and central pressure parameters very similar to those chosen to define the design hurricane (SPH), Betsy's wind fields and associated wave action called into question the adequacy of the original design heights for project levees and floodwalls. Accordingly, the District requested and received permission from the Corps' Lower Mississippi Division (the Division) and Corps Headquarters to increase structure heights by 1-2 feet across the project network (see Chapters 2 and 3).

Opposition to the Barrier Plan: Soon after authorization, the planned surge barriers at the passes to Lake Pontchartrain met with opposition from certain state government elected officials, congressional representatives, and various local citizen and interest groups. Some opponents feared the barriers would adversely affect navigation access to the lake, while others cited the possible flooding of the north shore of the lake when the barriers were closed. The operation and maintenance costs of the barrier complexes were also issues of concern. However, potential adverse environmental effects were the most widely-cited concern of organized opponents to the Barrier Plan (see Chapter 2).

Federal Court Injunction: In 1975, a local environmental advocacy group challenged the adequacy of the project environmental impact statement (EIS) in the U.S. District Court for the Eastern District of Louisiana. That EIS had been prepared by the District in order to comply with the National Environmental Policy Act (NEPA). After protracted deliberations, the court found that the project EIS did not meet NEPA requirements, and in December 1977 the court issued an injunction on further construction of the Barrier Plan until the analytical deficiencies were resolved. In March 1978, the court lifted the injunction for all non-barrier elements of the project, noting that those levees and floodwalls had no adverse effect on the lake and therefore could proceed. However, the injunction effectively placed on hold project work on certain lakefront levees and the outfall canals, since the design and construction of those features would be affected by the final resolution of the proposed barriers (see Chapter 2).

Switch to the High Level Plan: In response to the court injunction against the barriers, the District in consultation with the Division initiated an engineering and environmental reevaluation of both the Barrier Plan and the alternative "High Level Plan," which involved higher lakefront levees in lieu of barrier complexes. In 1985, well after the original date projected for project completion, the Director of Civil Works approved replacing the barriers with increased levee heights along the lakefront, under the discretionary authority vested in the Chief of Engineers. No other elements of the original LP&VHPP plan were reevaluated or modified; construction of those elements proceeded in accordance with the original designs as modified after Hurricane Betsy (see Chapters 2 and 3).

Treatment of the Outfall Canals: The original Barrier Plan did not include any project works for the three main outfall canals in metro New Orleans, since the 1962 planning report had concluded that the existing local levees along the canals would be sufficient to withstand barrier-dampened hurricane surges from Lake Pontchartrain. However, the District subsequently determined, based on the experience of Hurricane Betsy in 1965, that the existing canal levees did not meet the design height or stability required for the LP&VHPP under the recommended Barrier Plan or the alternative High Level Plan, and thus would need to be addressed by the project.

The District and the relevant local sponsor, the Orleans Levee District (OLD), engaged in a protracted debate over how best to address surges into the outfall canals. The District favored placing gates at the canal mouths to the lakefront that would close automatically when there was a threatening storm surge. The District determined that this "frontage protection" alternative was the most cost-effective plan for providing hurricane protection for the outfall canals. However, the OLD adamantly preferred higher walls along the canals, termed "parallel protection," as the best means to protect against hurricane surges from Lake Pontchartrain while still allowing the canals to be used to pump storm water from the city into the lake during storm conditions. Congressional action in the early 1990s resolved the debate in favor of the local sponsor by directing the Corps to implement parallel protection for the outfall canals and requiring the federal government to assume 70% of the total cost (see Chapters 2 and 4).

Revisions to I-wall Design Guidance: The Division in 1989 issued revised design guidance governing sheet pile penetration depths for I-type floodwalls (I-walls) used for hurricane protection. The revised guidance followed a field experiment, the results of which the Division interpreted as indicating that reduced sheet pile penetration depths would reduce the costs of hurricane protection I-walls without compromising engineering reliability. The revised design guidance was applied for design of the I-walls used to implement parallel protection along the outfall canals (see Chapters 2 and 4).

Reported Project Completion Progress as of August 2005: The District annually prepares a project Budget Justification Sheet (BJS) for the administration and the Congress. The BJS include, among other things, estimates of the current completion status for different project "units." The project BJS for fiscal year 2006 reported that the Chalmette Unit, which includes project works in St. Bernard Parish and some parts of Orleans Parish, was 98 percent complete in 2005. The New Orleans East Unit, which includes project work in most of Orleans Parish except for the floodwalls along the outfall canals, was reported to be 92 percent complete in 2005. The reported completion percentages for these project units has remained virtually unchanged since 1994, when the Chalmette Unit was first reported to be 98 percent complete and the New Orleans East Unit was reported to be 90 percent complete. Project work along the outfall canals was reported to be nearing completion in 2005. Project work in the New Orleans West

Unit, which includes project elements in Jefferson Parish and St. Charles Parish, was reported to be only 65 percent complete in 2005 (see Chapters 2 and 5).

It is important to recognize that the reported completion percentages for project units are in reference to the original project design heights as modified after Hurricane Betsy, and in accord with design changes introduced by the 1985 switch to the High Level Plan. Further, the reported project completion progress does not reflect the fact that many completed reaches of the project were below design grades due to datum errors when they were implemented and regional land subsidence over time since construction.

Figure ES-1 presents a chronology of project events relating to significant congressional, judicial, and Corps Headquarters decision-making for the project. Chapter 2 provides more detail on these project decisions.

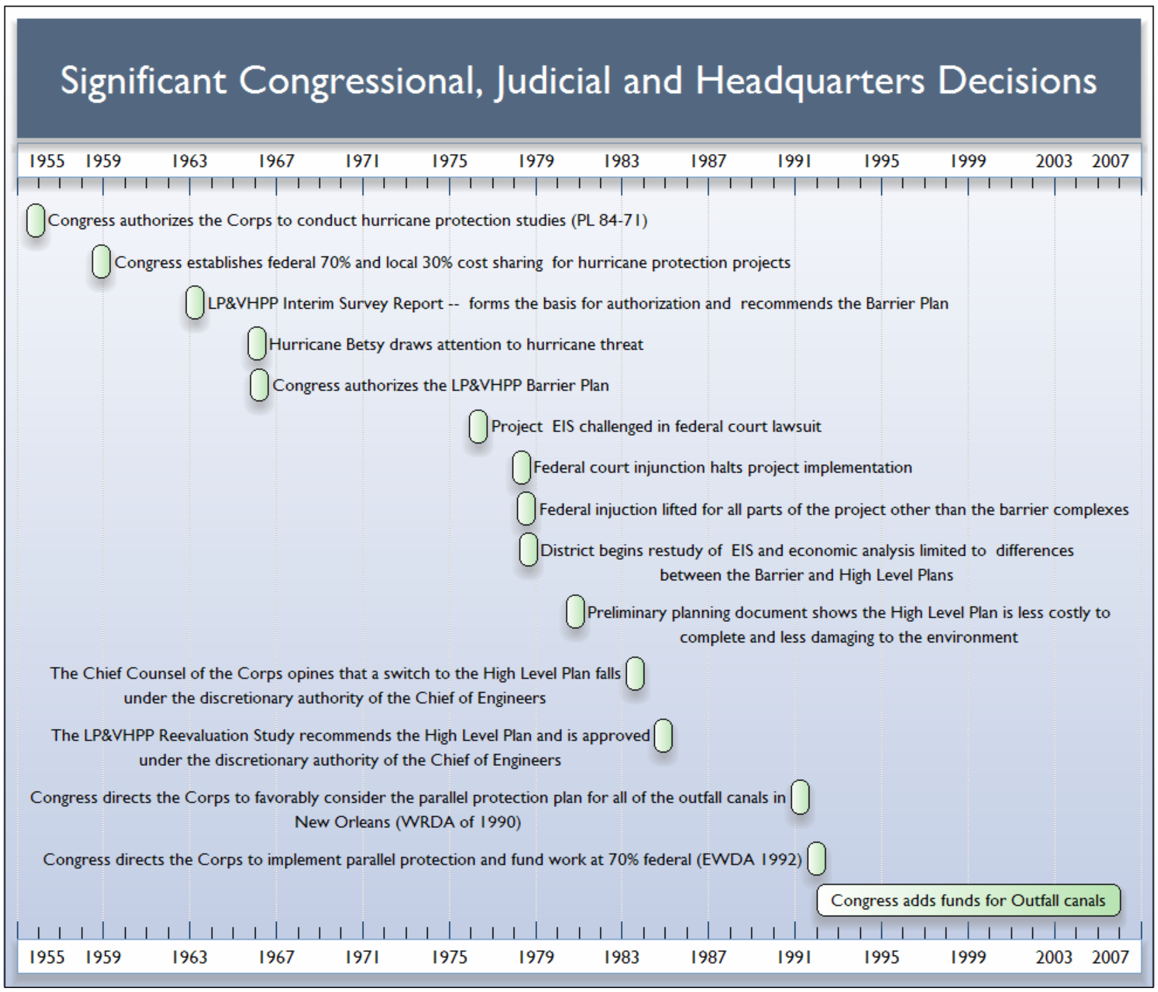

Figure ES-1: Significant Congressional, Judicial, and Corps Headquarters Decisions

The Context for Project Decision-Making

The planning, design, and construction of the LP&VHPP took place over a time period roughly equivalent to one-quarter of the history of the United States. Project implementation has been complicated by numerous factors, including the large scope and complexity of the project, the many federal budget cycles in which project construction was funded, the varied partnership relationships between the District and multiple local sponsors, and the difficulties for project construction caused by variable and often poor foundation conditions. Throughout this long implementation period, new conceptual understanding was gained about the potential intensity of storms in the Gulf of Mexico, and about the changing landscape of coastal Louisiana and its implications for hurricane protection. This new knowledge was accompanied by increased and higher-quality data, new modeling capabilities, and advances in computing power.

The District and Division offices were aware of the relevant new information as it became available and had to make a series of often difficult decisions about how to accommodate that knowledge into ongoing project design and construction. Concerns about further delaying project completion and for escalating project costs in a budget-constrained environment were significant considerations that played a role in how the District responded to new information.

Project Cost Growth: The total estimated cost of the LP&VHPP when it was authorized in 1965 was $80 million. By 2005, the total estimated cost of the project was over $700 million, or nearly nine times the originally estimated price. Project cost growth was driven by significant price inflation over the period 1973-1983 and project design changes made over time (see Chapters 2 and 5)

Constrained Federal and Local Budgets: The amount of federal funds available for water development projects nationwide did not increase after 1980, even as demands for civil works funding increased across the nation. In Louisiana, a significant share of federal funding was allocated to projects other than the LP&VHPP. At the same time, the local sponsors for the project who were required to provide 30 percent of the costs of construction had difficulty raising the funds to meet this cost-sharing obligation. Various local sponsors for the project expressed concern for their ability to pay their required cost-shares as project costs grew over time, and Congress acted at different times to relieve part of that cost burden. Local funding for the project, apart from project work in St. Bernard Parish, was eventually secured. However, it is questionable whether the local sponsors for project works in Orleans, Jefferson, and St. Bernard Parishes would have been able to pay for any additional project changes that significantly increased project costs beyond what was budgeted (see Chapters 2 and 5).

Delays in Project Completion: One effect of project cost growth within a constrained budget environment was to extend the time to project completion. Growing project costs had to be funded from a static federal budget spread among competing civil works priorities nationally and in Louisiana.

A variety of other factors slowed project completion over time, including 1) the challenge of unifying local support and assigning cost-sharing responsibility among the various local sponsors of the project, 2) local sponsors' difficulty in securing needed rights-of-way, 3) the unanticipated extra length of time required between lifts for certain levees in order to allow for settlement, 4) addressing the requirements of the Barrier Plan litigation, and, 5) reconciling disagreements between the District and the OLD over the choice of surge protection alternatives for the outfall canals.

Frustration with delays in project implementation and escalating project costs in the face of constrained federal and local budgets was apparent within the District and among local sponsors. This focused the District and local sponsors on completing the project as then designed and budgeted. At the same time, project sponsors were reluctant to seek approval for project changes that would increase project costs, and thus required funding, and that would extend the time for project completion further into the future. Another effect of project cost growth within a constrained budget environment was to motivate the District to seek out cost efficiencies for the project that were consistent with engineering reliability (see Chapters 2 and 5).

Hurricane Protection Performance Decisions

Treatment of New Information on Storm Risks: The District, following Corps policy for the provision of flood protection in urban areas, intended to build project levees and floodwalls that could withstand and not be significantly overtopped by the most severe storm event reasonably characteristic of the project area (the SPH). The project record shows that over time new information became available on storm parameters, potential surge levels, and datum issues that indicated significant overtopping of project structures as designed and constructed was increasingly likely to happen during the life of the project. However, the District did not request authority or funds to incorporate this new information into project design and construction once project construction was underway.

As one example, District staff reported that Hurricane Camille, which sideswiped New Orleans in 1969, had higher wind speeds and lower central pressure than what was thought to be the meteorological worst case scenario—the PMH as estimated in the 1962 Interim Survey Report. Camille and other more recent storm experiences were reflected in downward revisions to central pressure parameters (more severe) for the project area SPH and PMH made by the National Weather Service in 1979. In the years following, new storm data further affirmed the increased likelihood that storms more severe than the design storm could occur over the project's life.

However, the design heights across the LP&VHPP were not updated after 1968 to reflect the new meteorological information. Reasons for the adherence to the original design storm parameters were variously related to the District's interpretation of the 1965 project authorization language, concerns among the District and local sponsors about increases in project costs in relation to limited federal and local budgets, and the District's concern about maintaining, to the extent possible, consistency in the degree of protection being provided across the protective network as different parts of the project were completed over time (see Chapters 2 and 3).

Treatment of New Information on Vertical Datum and Benchmarks: The District's 1985 decision on the use of datum benchmarks for project construction provides another example of the difficulties inherent in the incorporation of new information into project implementation. Project construction to that point had relied largely on 1964-era benchmark elevations for the National Geodetic Vertical Datum (NGVD) to ensure that structures were built to intended design grades. When the National Geodetic Survey adjusted benchmark elevations in the area in the early 1980s to reflect subsidence over the previous 20 years, the District adopted a policy to not switch to the new benchmarks. The stated rationale for this decision was that to do otherwise would result in varying levels of protection across the project area, since it would be impractical and too costly to modify already constructed project features.

The 1985 benchmark decision exacerbated a more fundamental error with respect to the District's use of the NGVD as the reference point for project construction. The NGVD was originally established in 1929 using mean sea level (MSL) measured at 21 stations in the U.S. and five stations in Canada. Project structures were constructed relative to NGVD under the erroneous assumption that this datum corresponds with local MSL—the reference point used for the engineering design of project structures. However, the NGVD was actually lower than local MSL; the result was that many LP&VHPP structures were constructed to grades that were below intended design heights. Project records indicate that the District was generally aware of this disparity by the early 1990s; nevertheless, project construction continued forward using NGVD (see Chapters 2 and 3).

Treatment of New Surge Modeling: By the early 1990s, the District recognized in general terms that accumulated new knowledge indicated that the authorized degree of project protection was not being provided by the project as designed and constructed. About that time, District-sponsored work began on the adaptation of a sophisticated long-wave surge model, the Advanced Circulation (ADCIRC) model, for use in the technical evaluation of storm surges.

A 1993 District-sponsored pilot study conducted by the Corps Coastal Engineering Research Center used an early version of the ADCIRC model to estimate the effects of the 1979 downward revision of the SPH central pressure parameter on surges elevations in the project area. That study found that the revised central pressure parameter produced an increase in SPH surge heights of 1-2 feet for certain storm tracks under one set of assumptions, while under another set of assumptions the change had little effect on originally estimated storm surge elevations. The pilot study also concluded that local MSL had increased with respect to NGVD by approximately one foot since 1929.

In 1994, the District requested authority from the Division to conduct a numerical model study using the ADCIRC model and modern data to more-precisely determine the existing degree of project protection. However, noting limitations with the available ADCIRC model, the District decided to pursue further model refinement and testing before using the model for a project reevaluation that might form the basis for recommending project changes. The District undertook an effort to improve the model from 1995 to 2004, and in 2004 an independent technical review team gave the model development work a positive review (see Chapters 2 and 3).

Figure ES-2 presents a chronology of project events related to project performance decisions and the District's response to new information on storm risks, surge modeling, and datum issues in the project area that emerged over time. These decisions are reviewed in detail in Chapter 3.

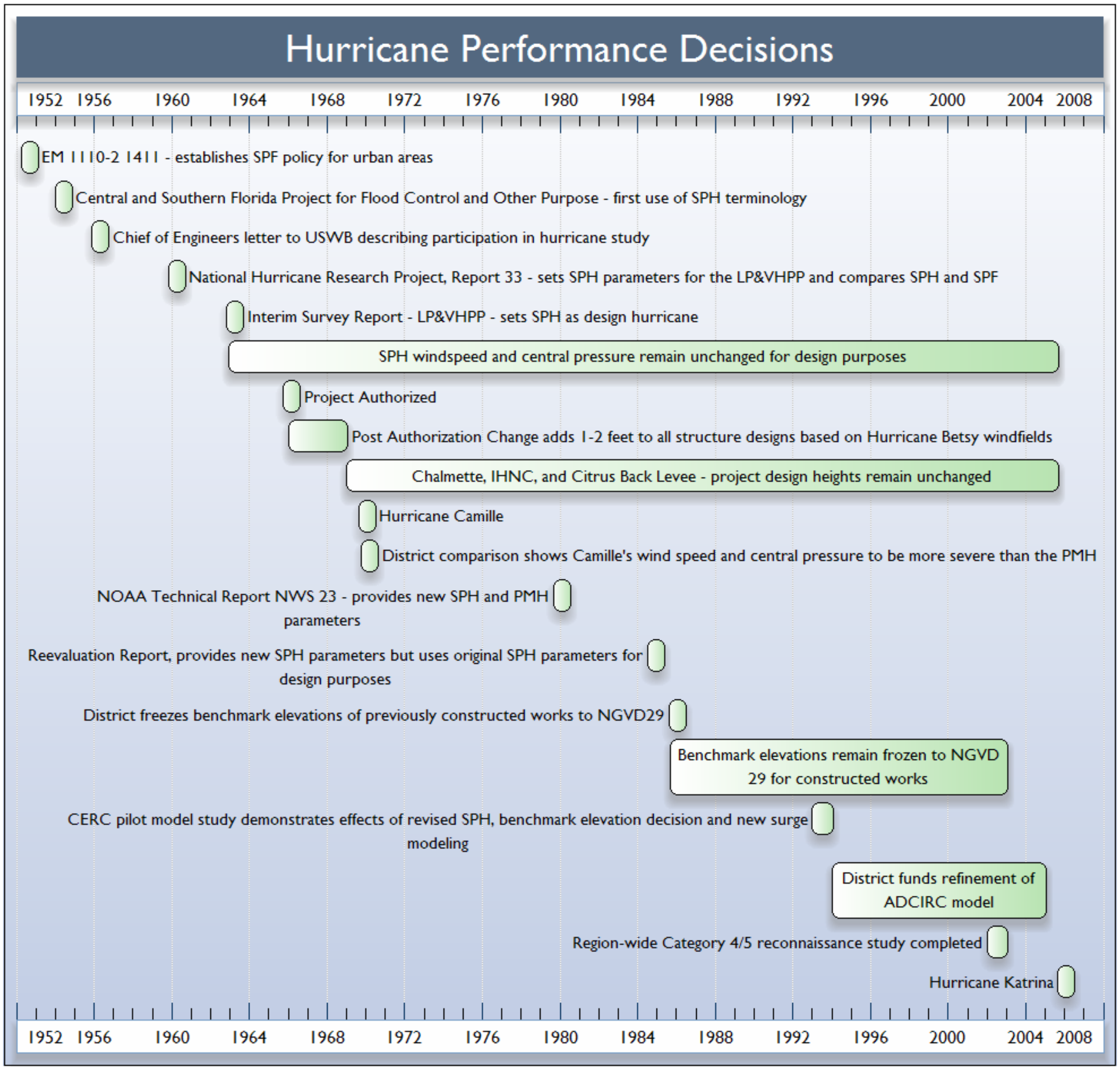

Figure ES-2: Project Performance Decisions

Design Decisions for the Outfall Canals

The selection of protection approach for the outfall canals was complicated by the different objectives and constraints of the relevant local sponsor, the OLD, and the federal government, as represented by the District. The District's sole objective was to identify and recommend the most inexpensive (least-cost), reliable means of providing SPH surge protection for the outfall canals, in accordance with the District's interpretation of federal policy and the project authorizing language regarding local responsibility for internal drainage. The District recommended a frontage protection alternative (butterfly gates) for two of the three outfall canals as the least-cost plan for providing SPH surge protection.

The OLD had two objectives for the choice of protection alternative for the outfall canals—enhancement of hurricane protection, and the capacity to drain rainfall from the city via the canals during storm conditions. The OLD's opposition to the District-recommended frontage protection plan was based on these dual objectives and the distribution of costs to local agencies and the federal government under the different alternatives. The OLD, together with the New Orleans Sewerage & Water Board (SWB), the city agency responsible for interior drainage, viewed the frontage protection plan as incompatible with the need to drain rainfall from the city during storm events. Also, costs were a major concern to these local agencies.

The SWB and OLD were already planning to drive sheet pile walls along the existing levees of at least one canal in order to increase interior drainage capacity. Thus, if the frontage protection gates were implemented as part of the LP&VHPP, then the OLD as the local sponsor would be required to pay 30 percent of its cost, and the SWB and the OLD would bear the full costs of improving the canal levees for interior drainage purposes (as well the costs of any local decision to install auxiliary pumps at the canal mouths to allow for continuous pumping of rainwater out of the city to Lake Pontchartrain via the canals when the gates were closed during storm events). From the local perspective, the parallel protection plan was the best way to address both hurricane protection and interior drainage objectives and secure 70 percent federal funding toward those ends.

However, the District maintained that if the local sponsor insisted on pursuing parallel protection within the LP&VHPP, then any incremental costs of this plan above the cost of the least-cost, reliable alternative plan (the frontage protection gates) would be considered a project "betterment." Corps policy and the original project authorization defined such betterments as the full responsibility of the local sponsor. Thus, the District informed the local sponsor that if the parallel protection plans were pursued, the federal government would restrict its financial contribution for the plan to 70 percent of the total cost of the least-cost, frontage protection plan.

At the request of OLD, Congress acted through conference report language accompanying the 1990 Water Resources Development Act to resolve the disagreement between the District and the OLD. In that conference report, the Congress directed the Corps to incorporate hurricane protection for the outfall canals into the project, and to favorably consider implementing the parallel protection alternative. However, this conference report did not address how the costs of parallel protection would be shared among federal and local project sponsors.

The Congress, in the Energy and Water Development Appropriations Act of 1992, finally resolved the choice of the parallel protection alternative and its cost-share apportionment in favor of the local sponsor. In that act, Congress directed the Corps to implement parallel protection along the outfall canals and stipulated that the federal government pay 70 percent of the total cost. The effect of this congressional action was to redistribute much of the costs for drainage and storm protection from the OLD to the federal government.

In subsequent years, the Executive Branch, through successive administrations, did not budget for parallel protection work at the outfall canals. This was based on an interpretation that the congressional directive to implement parallel protection at 70 percent federal cost violated administration budget rules that require the Corps to implement the least-cost alternative for providing the authorized project purpose, and that define interior drainage as a local responsibility. Nevertheless, Congress added federal funding each year for parallel protection that the District used to implement the work (see Chapters 2 and 4).

I-type floodwalls (I-walls) were the dominant structural approach chosen to implement parallel protection along the canals, largely because they could be constructed within the very limited existing rights-of-way. During the mid-to-late-1980s, the District and Division offices were concerned that existing Corps criteria for I-wall sheet pile design were too conservative, and thus more costly than necessary, for the type of short-term loading conditions believed to characterize hurricane events.

Accordingly, the District in consultation with the Division conducted the so-called E-99 Sheet Pile Wall Field Load Test in the East Atchafalaya Basin to investigate I-wall performance under poor foundation and short-term loading conditions. The interpretation of the test results led to the Division issuing revised design criteria that reduced required sheet pile penetration depths for hurricane protection I-walls. Use of the guidance to develop final plans and specifications for I-walls resulted in substantial cost reductions for constructing parallel protection along the outfall canals (see Chapters 2 and 4).

The two project decisions described above on the design of project protection for the outfall canals were driven largely by cost considerations. However, none of the design memoranda and other project documentation reviewed for this study indicate that the District or local sponsor viewed the parallel protection approach as involving potentially greater risk of failure than the frontage protection approach. Similarly, the project record indicates that the revisions to I-wall design criteria that were used to implement parallel protection works were made with the expectation that cost savings could be realized without compromising engineering reliability.

Figure ES-3 summarizes key project decisions relating to the design of project protection for the outfall canals. These decisions are reviewed in detail in Chapter 4.

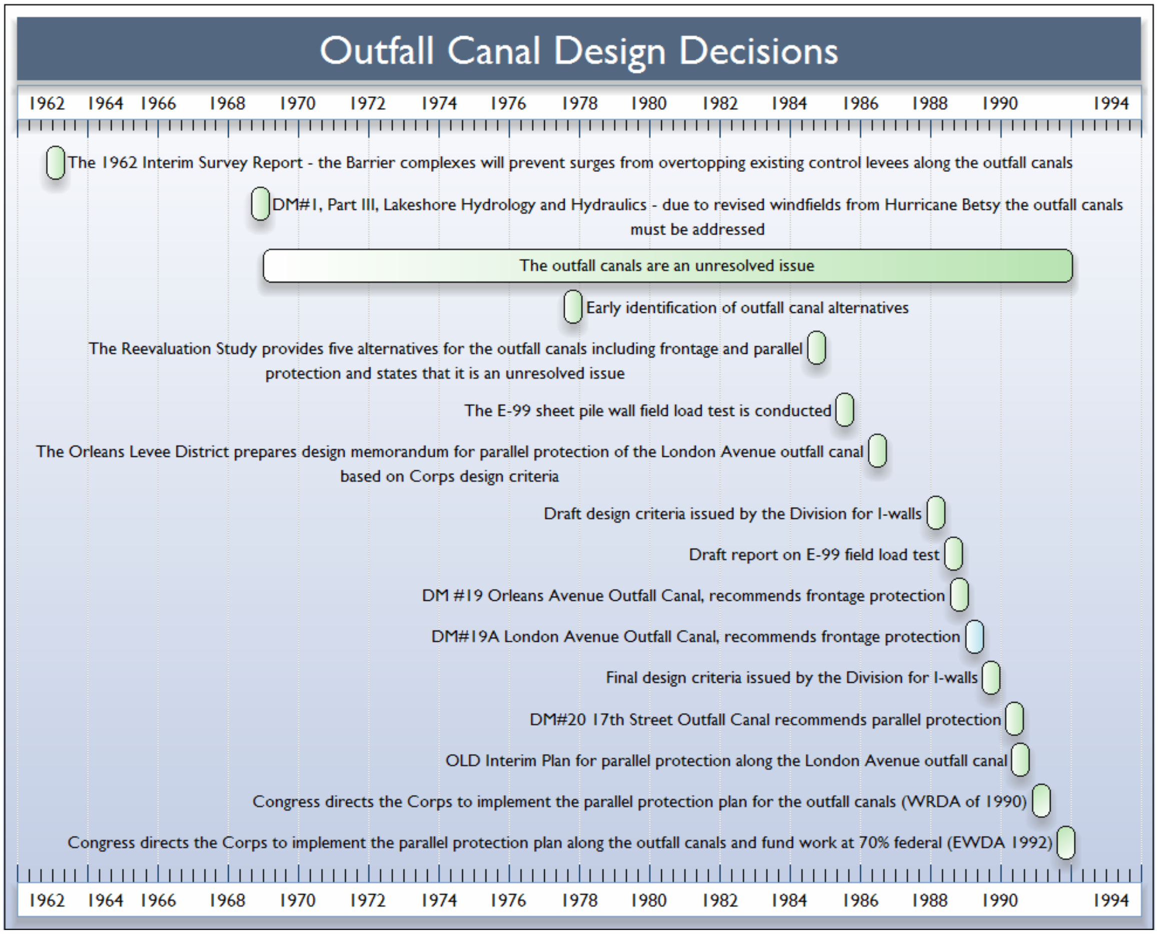

Figure ES-3: Design Decisions for the Outfall Canals

Authors' Reflections on Project Decision-Making

1. **Concerns about project cost growth, constrained federal and local budgets, delays in project completion, and the possible need for reauthorization if major changes were proposed, help to explain District decisions to construct the project according to original designs and datum benchmarks**

Project construction was not yet underway when significant project design changes were requested and approved following Hurricane Betsy. At that time, the increase in project costs associated with the design change might have appeared readily affordable to project sponsors, and the change involved virtually no delay in project implementation.

In later years, however, the accommodation of new information in project design and construction would have required adjustments to ongoing construction activities as well as retrofitting project features that had already been constructed. Such changes would have significantly increased project costs and implementation delays at a time when local concerns about project costs and urgency for project protection were paramount, and a stagnant Corps construction general budget had to be spread among competing priorities. It was in the context of a history of local sponsors' frustrations over project delays and costs, federal and local budget limits, and increasing scrutiny of water project investment proposals at the Washington, DC level, that new information suggesting the need for project reevaluation and redesign that might take years to analyze and get approved was either put aside for later consideration (e.g., the 1985 datum benchmark decision), or subjected to further study (e.g., the decision to refine the ADCIRC surge model before applying it for project reevaluation) (see Chapter 6).

2. There was no Corps organizational process that required and provided funding for a continuing assessment of project performance capability during the post-authorization implementation period

The District was not expected to routinely track and as needed revisit—using whatever tools were available at the time—the ability of the project to provide the authorized degree of protection as new information became available. The absence of a standing, agency-wide process for continuing assessment and reporting of project performance capability left the District to make its own determination as to whether the analytical foundation was adequate for requesting changes to project designs, and for satisfying higher federal authorities and local sponsors that additional project funding was warranted (see Chapter 6).

3. There is no evidence in the project record indicating that project engineers believed that the decisions made would threaten engineering reliability

The adoption of parallel protection for the outfall canals significantly increased the number of miles of floodwalls and other structures exposed to storm surges, and increased the probability that a storm surge could find a weak spot in the project network. Conservative designs for I-walls, the primary means of providing parallel protection, would minimize the likelihood that weak spots might develop.

Meanwhile, in a separate effort, the E-99 Sheet Pile Wall Field Load Test was initiated to determine whether sheet pile penetration beyond a certain depth was unnecessarily costly for I-walls exposed to only short-term loading conditions. That sequence of events started by limiting the design and purpose of the test, and extended through analysis of a relatively limited amount of data. The interpretation of the test data resulted in revised design criteria that reduced sheet pile penetration depths for the I-walls used to implement parallel protection at the outfall canals. The available project record does not indicate recognition of possible limitations of the test procedures, possible uncertainties in the test results data or the Division's interpretation of that data, or the potential significance of the resulting revised design criteria once parallel protection plans were chosen for surge protection at the outfall canals.

These two design decisions for the outfall have been criticized in some post-Katrina engineering reports as reducing the reliability of project protection. Ultimately, engineering experts will need to resolve whether the selection of parallel protection and the use of reduced sheet pile penetration depths, or the combination of the two, actually did reduce the reliability of the protection along the outfall canals when compared to the alternative frontage protection approach. The sequence of project events outlined in this report can not answer these questions.

However, the available project record does clearly show that cost considerations and policy interpretations, at both local and federal levels, played a significant role in these design decisions for the outfall canals. That same record also includes no evidence that anyone within the Corps had fully evaluated the possible joint effects of the two design decisions on the reliability of the protection network.

At that time, formal engineering reliability evaluation methods were not highly developed by the engineering community outside of a few areas such as nuclear power plant safety. Nonetheless, the concept of engineering reliability would not have been unfamiliar to project engineers and designers, and the nascent state of formal evaluation methods at the time that the project decisions were made can not fully explain the absence in the project record of engineering reliability questions and considerations (see Chapter 6).

4. The only recurring organizational provision for systematically reporting the expected performance capability of the project was the annual Budget Justification Sheet (BJS)

The limited purpose of the BJS is to justify requested federal appropriations for ongoing project work in the next fiscal year. Thus, the BJS are not recognized by District and Division offices as an appropriate vehicle for reporting accumulating information indicating that significant hurricane surge overtopping of at least some project reaches was increasingly likely to happen over the life of the project. Nevertheless, the BJS represents the only routine means for reporting on the status of the project to the administration and the Congress, and the HPDC team found no records of other formal communications before 2005 suggesting that these matters were conveyed by the District or Division to Corps Headquarters, Congress, or local sponsors (see Chapter 6).

Author's Reflections on the Future

1. The importance of sharing knowledge

By the early-to-mid-1990s, the District was aware in the most general terms that a project completed with the funds being requested would provide less than the authorized degree of protection (DOP). However, at that time the leaders in the District were not sufficiently confident in the best available surge model for specifying the detailed design changes that might be needed to provide the authorized DOP, and for justifying the cost increases they would entail, in a post-authorization change report. This decision was made in the context of long-standing concerns of the District and local sponsors about project affordability, completion delays, and ensuring consistency in protection levels across the project network. In that context, the District made the judgment that further refinement and testing of the best available surge model was needed before applying the model to identify project changes that might be required to meet the SPH surge protection standard, and for securing those changes under the Chief's discretionary authority or through a new congressional authorization.

These District decisions, although understandable, point to the need for changes in the way the Corps shares information and communicates risk, particularly as related to possible changes in expected project performance over time. To argue for this change is not to suggest that modified or additional project structures would have been funded and built if the general understanding of the diminished capability of the project had been shared. In fact, it is unlikely given the history told here that the necessary detailed studies, approvals, authorities, funding, and construction sequences all would have rolled out in time to provide a project built to the original design intent by the year 2005. Moreover, it is questionable whether the project, if it had been built and maintained to original design intent, would have prevented to a significant extent the flooding of New Orleans that occurred as a result of Katrina.

Nevertheless, other decisions might have been made differently if the District's general knowledge about project performance deficiencies had been disseminated outside the District and Division offices. Perhaps the sharing of this information would have had effects on land development and use decisions, or decisions on new or enhanced drainage pumping capability, evacuation planning and emergency response programs, and specialized protection of critical infrastructure. Even if no changes in project structures or any other responses were made, the organization would have made available to higher federal authorities and local sponsors the knowledge and understanding, however limited, that it possessed.

Moving forward, Corps project evaluation and reporting protocols must be attentive to ensuring that all project sponsors and relevant government officials at all levels are as fully informed about project capabilities and limitations as are the technical specialists within the Corps. Further, Corps policies and procedures should seek ways to ensure that the affected public and its political leadership share with the Corps the project decisions that do get made in consideration of new information (see Chapter 6).

2. Need for flexibility and adaptation in planning, design, and implementation

As future protection of the Gulf Coast is planned, it must be recognized that the vision set forth in any plan will necessarily change during implementation in response to new information, changing costs, stakeholder values, and agency missions, policies, and budget priorities. Indeed, past decision influences that led to cost increases and completion delays for the LP&VHPP remain endemic in the way the nation manages and directs the Corps program today. Decision-making that is the result of competing values, diverse interests, and disagreement between experts gives the appearance of being chaotic. But it is that reality that must be recognized and then orchestrated for providing protection for the Gulf Coast region. Future decisions, whether made within or outside the Corps, will be a continuing process requiring planning and decision-making mechanisms that recognize, accommodate, and then adapt plans to changing values and new information (see Chapter 6).

.

TABLE OF CONTENTS

Bibliography

Appendices

Figures

Tables

Maps

Chapter 1. Introduction

Two broad questions were being asked about the Lake Pontchartrain and Vicinity Hurricane Protection Project (LP&VHPP) in the aftermath of Hurricane Katrina:

1) Why were many project levees and floodwalls significantly overtopped?
2) Why were some project levees and floodwalls compromised even where no overtopping occurred?

These two questions focused attention on the engineering performance of the LP&VHPP protective structures in place when Hurricane Katrina made landfall on August 29, 2005. Several engineering forensic investigations of the LP&VHPP were initiated to answer these and related questions. The "Independent Levee Investigation Team" (ILIT), a volunteer group of engineers and other scientists, secured support from the National Science Foundation and offered their own answers to these questions in a report released on May 22, 2006.[1] Another engineering forensics report by "Team Louisiana" was commissioned by the Louisiana Department of Transportation and Development and released on March 21, 2007.[2] There were, and continue to be, a stream of newspaper articles addressed to these questions, and several books have been brought to press on an accelerated pace when compared with the normal book production and publishing cycle.

The federal government effort to answer these questions was led by the U.S. Army Corps of Engineers (Corps), which established the Interagency Performance Evaluation Task Force (IPET) with the charge to study and report on the engineering performance of the LP&VHPP protection network and other projects in place at the time of Hurricane Katrina.[3] The IPET study process and results were reviewed by an external review panel (ERP) administered through the American Society of Civil Engineers. In addition, the results of both the IPET study and the ERP report were the focus of a second independent review panel led by the National Research Council (NRC), as requested by the Assistant Secretary of the Army for Civil Works.

The focus of the IPET study was limited to describing LP&VHPP and other project features and designs in place and to evaluating why some of those protective structures were compromised during Hurricane Katrina. While the IPET study did not specifically address questions about why LP&VHHP planning and design decisions were made, such questions continued to be asked. For example, an August 11, 2006 draft of the ERP comments on the draft final IPET report includes the following:

> "The one general comment that we would offer is that while there is a wealth of information and significant findings, there is too little to address the 'why' behind the facts. For instance, there is probably a rationale, not told in the IPET report, behind

[1] This report is available at: http://www.ce.berkeley.edu/~new_orleans
[2] This report is available at: http://www.dodt.louisiana.gov/administration/teamlouisiana
[3] This report is available at: https://ipet.wes.army.mil

why the levees were not armored. The report should not try to criticize or judge these types of decisions, but where information exists to explain the rationale behind key decisions, that information would provide a very valuable context to assist in understanding the finding."

1.1 Study Purpose

Recognizing the limited scope of the IPET study, the Corps leadership in late 2005 commissioned the Hurricane Protection Decision Chronology (HPDC) study to assemble, document, and interpret the chronological record of planning and decision-making for the LP&VHPP, including the economic, policy, legislative, organizational, and financial factors that influenced the designs, configuration, and condition of the project protection network that was in place prior to Hurricane Katrina.[4] The study focused on project decisions made by the Corps as influenced by relevant decisions made by various administrations, congresses, and the courts during the many years of project planning and implementation. The development of the record of project decisions and related events was intended to complement the technical focus of the IPET and other engineering investigations. As an illustration of such complementarity, an engineering forensics study might ask why a floodwall breached as a matter of engineering performance, while the HPDC study would consider past planning, policy, and legislative decisions that influenced why a floodwall of a particular design had been chosen.

Many books, reports, and articles have speculated on why certain LP&VHPP decisions were made. These speculations typically were made as extensions of engineering reviews. For example, the ILIT devotes several sections of its report to project decision-making, drawing upon the investigators own professional experiences, news articles, and testimony from congressional hearings. News articles that addressed the decision-making process often were based on interviews and access to documents that had been made part of the public record at the time the particular article was written.

The study reported here sought to compile, assemble, and analyze a comprehensive set of original project documents before developing its report. For this reason, the results of this inquiry challenge some of the observations on decision-making that have been reported in other places. As one example, many reports and articles have claimed that benefit-cost calculations drove decisions to not armor the backside of project structures that were overtopped during Hurricane Katrina. A July 18, 2006 article in the *Baton Rouge Advocate* stated:

> "The [IPET] interagency task force, as well as independent studies done by other organizations, pointed out that the Corps' way of deciding which projects can be justified does not take into account the risk associated with not building the project. Earlier this year, [the] interagency task force Project Director ... said

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[4] A separate report on the history of hurricane protection projects across the Louisiana coast was commissioned by the Corps Office of History soon after Hurricane Katrina. That report provides a broad historical overview of hurricane protection efforts in New Orleans and the lower delta region and does not delve into LP&VHPP decision-making at the same level of detail as this report.

> levees that protect people — such as those in New Orleans — need to be designed with more back-up protections that will allow some room for error. However, those redundancies are hard to justify under the cost-benefit ratio method the Corps uses, he said."

But this study, after an examination of the documented record of project decision-making, found no evidence that benefit-cost analysis of back-up protection was ever undertaken and used as part of the project decision process.

A related assertion, implied in the preceding quotation and explicitly made in some reports, is that the narrowness of project benefit-cost calculations led the Corps to ignore the need to prevent loss of human life in its project design decisions. However, this study found that LP&VHPP initial structure design heights were set to minimize the possibility of loss of life, and were not dictated by benefit-cost analysis, although the study did identify a series of other project decisions that led to the intended and actual elevations of many LP&VHPP structures being well below Hurricane Katrina surge heights.

To ensure that the influences on project decisions were described as accurately as possible, the central task of this study was to collect, chronologically record, and then describe documents related to key LP&VHPP decisions. Only then could an examination of why certain decisions were made be placed in the correct historical sequence and understood in the context of other project decisions and events. This report includes a master chronology of project events (in Appendix A) as well as derivative chronologies included in the report chapters that describe event sequences for specific topics. The chronologies also include matters that had a bearing on project decisions made over time, such as the evolution of local sponsor cost-sharing agreements and federal budget allocations made for the LP&VHPP over time. We are not aware of any other document that has placed the breadth and depth of LP&VHPP documentation into its broad historic time sequence.

1.2 The Challenge

The planning, design, and budgeting decisions that resulted in the complex network of project levees and floodwalls in place in August 2005 were made over multiple decades. These decisions had to accommodate interior drainage and other storm protection infrastructure built and operated over the years by non-federal interests. Project planning and construction covered a period roughly equal to one-fourth the history of the United States. During that time there were eight changes in presidential administrations, numerous changes in congressional delegations, and concomitant changes in political philosophy that affected national polices and public attitudes towards water development projects and the budgets for them. This time span included a period of price inflation that was one of the country's worst, and it was during this same period that federal support for water development programs plummeted, as evidenced by the static level of federal water project funding after 1980.

Over the many years of project planning and implementation, there have been many different military commanders and chiefs of planning, engineering, and other relevant branches at the Corps New Orleans District (hereafter referred to as "the District"), and at the Mississippi Valley Division (hereafter referred to as "the Division").[5] There have also been many different Parish and local levee district leaders and staff, and Governors of the State of Louisiana. And the Washington, DC-based leadership of the Corps of Engineers also changed through time. Some of these past leaders were interviewed for this report and were able to contribute to understanding project decision-making, although at times recollections of the same events differed among people and from the evidence in the written record.

Building the project chronology was also complicated by the fact that there is no way to know with confidence whether the full record of key project documents had been acquired. The Corps reports required for compliance with law and regulation were all available. However, over the decades many individuals in many places prepared and sent letters and memoranda relating to many different aspects of project decision-making. The study team had access to the extensive database of project documents collected for the IPET study, and current District and Division staff gave the study team access to file cabinets and storage areas where other available project records were kept. The study team also acquired relevant project documents from record repositories in College Park, MD, and Fort Worth, TX, and secured and reviewed the minutes of board meetings at the Orleans Levee District, a prominent local sponsor of the project. While a substantial number of project documents were secured for this study, there is no way to know how large a sample this is of the total record. As people retired and offices moved and reorganized, relevant project records might have been lost or destroyed. Of particular note is that a series of office moves over the years and consolidation of space resulted in many individuals at Corps Headquarters discarding files. Furthermore, Corps Headquarters apparently had no central repository for correspondence and file notes for the project. The study team did, however, locate copies of some Headquarters correspondence relating to the project at District and Division offices.

In the end, the secured project documentation that informed this report is extensive in numbers and scope. The documentation includes 42 pre- and post-authorization planning and design documents, design memoranda, and supplements. It includes many documents on correspondence between different Corps offices, between the District and architecture and engineering firms under contract to either the District or one of the local sponsors, and between local sponsors and the District. The record also includes many separate signed acts of assurances with several different local sponsors; documents relating to reporting and approval of several significant post-authorization changes; two Government Accounting Office reports critical of project cost increases and delays; and the records surrounding the federal court injunction that halted work on the initially-preferred and congressionally-authorized Barrier Plan. Each year, successive administrations and congresses made budget allocations for the project based on information provided in budget justification statements that were secured for this study.

[5] When the LP&VHPP was authorized in 1965, the Division was known as the Lower Mississippi Valley Division.

Another complicating factor for this study, in addition to the many different people involved with project planning and implementation and the large volume of project documents, relates to the wide geographical scope and significant complexity of the LP&VHPP. The project includes more than 120 miles of levees and floodwalls. These structures pass through wetlands, along waterways and canals, under and around bridges, and behind docks, loading facilities, schools, parks, and backyards. Many different issues necessarily accompanied the design and then construction of this project network, including acquiring the necessary lands, easements, and rights-of-way, and complying with federal, state, and local laws, policies, and regulations. Project construction has been complicated because levees must be constructed with multiple lifts, years apart, due to uneven settlement in areas of variable soil conditions. And the design and implementation of lifts across the various reaches must be coordinated so as not to leave any particular reach deficient in its relative degree of protection.

In consideration of the scope and complexity of the LP&VHPP and the project record, the study focused on certain project decisions that may have most affected project performance during Hurricane Katrina. Specifically, the study focused on decision-making that led to:

- the selection of the overall protective approach for the project area (Barrier Plan versus High Level Plan), and for the outfall canals in metro New Orleans (Frontage Protection versus Parallel Protection),
- the selection of the design hurricane, and the treatment of new information as it became available during the project history on hurricane science, surge modeling, and land subsidence that determined the design and constructed heights of protective structures across the project network, and
- the design of the I-wall parallel protection structures for the outfall canals.

This choice of topics is consistent with questions and issues raised in congressional inquiries, newspaper reports, the IPET report, the ILIT report, the Team Louisiana report, post-Katrina congressional reports, and other sources. Also, while the study did not focus specifically on decisions relating to project construction and maintenance, this report makes some limited observations on those issues as supported by the available project documentation.

1.3 Report Development Process

A structured approach was employed to obtain all relevant and available project documents and to ensure that logical interpretations of project decisions were made from the content and significance of those documents. The resulting products are chapters that describe the complex decision-making processes for certain project decisions and that relate key project events to each other.

Construction of the narratives in each chapter began by formulating preliminary conceptual models of project decisions of interest, how those decisions may relate to each other, and the forces affecting the decisions. This placed a premium on understanding and reflecting the details of the legal, regulatory, budgetary, and organizational setting for the LP&VHPP. Narratives were initially developed and then modified as new documentation was acquired from diverse sources, including published project reports and administrative records.

As noted earlier, the master chronology of project events provided the structure for organizing project materials used to prepare the chapter narratives. That chronology includes planning reports, design memoranda, administrative correspondence, letters, budget justification statements, hearing records, and much more. The development of the event chronology provided a powerful discipline on the development of the report in two important ways. First, development of the chronology made it impossible to attribute causes to decisions and events that are not consistent with the chronological order of their occurrence. Second, the chronology disciplined the report authors to ensure that project decisions were explained in the context of their own time; documenting the event chronology reduces the opportunity for contemporary scientific understandings, technical capabilities, and current civil works policies to affect the description and interpretation of historical project decisions.

The descriptions and explanations of project decisions are based on reviews of key project documents and extensive interviews with persons familiar with the project and area who also understand the federal water resources development planning and decision-making processes. Interviews with people who were involved in project decisions had a central, but constrained, role in the development of the report. Interviews were conducted since Katrina, but the events of interest may have occurred decades ago. The interviews revealed that memory fades and different people sometimes have different recollections of the same events. For these reasons, the interviews were used not as primary sources per se, but rather to more fully understand the key project events and decisions revealed in the project documentation. In some limited instances, information gathered from interviewees was used to help describe and explain project decisions, but only when that information was in accord with the available project documentation. The report does not, however, quote any interviewee or in any other way attribute statements to individuals.

The credibility of a narrative is enhanced if different kinds of evidence fall logically into place as perceived by an outside reader, and if decision participants can affirm that the narrative fits with their recollections and understanding of the decisions they were involved in or familiar with. For this reason, the general arguments, as well as some aspects of the text, were reviewed by current and former Corps staff who were present at the time that project decisions were being made and who have knowledge of historical Corps polices and procedures.

1.4 Guide to the Report

This report was prepared for Corps leadership and the Office of the Assistant Secretary of the Army for Civil Works. With that audience in mind, the report was written under the assumption that readers have a good understanding of the Corps civil works organization as well as its planning and budgeting requirements and procedures. In addition, readers are assumed to have a comprehensive understanding of the history of federal water policies affecting the execution of the Corps program.

However, it is expected that the Corps will make this report available to others who have an interest in or responsibility for agency oversight and policy development as well as to the general public. As an aid to this wider report audience, the report briefly describes some elements of the federal water development process. In addition, Appendix B includes a report glossary that defines key concepts and terms used throughout the report. That glossary is meant to avoid confusion with respect to key project concepts (such as the “standard project hurricane”) and items relating to the Corps organization (such as the different forms of internal agency guidance). The glossary definitions are used consistently throughout the report.

As noted, thousands of pages of project documents were reviewed and used as the basis for preparing this report. Those documents include letters, official reports, budget justification sheets, and other materials relating to LP&VHPP decision-making. The referencing system used in this report relates specifically to those project documents that the study team collected and that would not otherwise be readily available to readers. Those project documents are included in an electronic database of source documents to accompany this report. Citations to those documents are made at appropriate locations in the report text using a coding system developed for this report. For example, a project document dated January 31, 1962 would be cited as 19620131. By using the coding for each citation as it appears in the text, the reader can quickly locate the relevant coded source file in the accompanying source database and then read the original text of the cited document.

Given the mass of the original project documents collected for this report and the intended readership for the report, citations are not provided for major trends or events in national water policy that provide context for project decision-making. As a specific example, the National Environmental Policy Act of 1969 is noted in several places within the report; however, no citation is provided for that act. It is assumed in the report that trends and events of this nature will be recognized and understood by the primary report audience.

The report is organized as follows. Chapter 2 provides an overview of the 50-year period of LP&VHPP decision-making that ends with a brief commentary on the project protective structures in place in August 2005, and what is currently reported about the pre-Katrina conditions of those structures. Key project decisions are described at an initial level of detail. Chapters 3-5 provide more-detailed explorations of some of the topics covered in Chapter 2. Chapter 3 describes project performance decisions that led to the design heights of LP&VHPP protective structures. This is a topic of great interest because many project structures were overwhelmed by Hurricane Katrina’s storm surge in key locations. Chapter 4 focuses on protection design decisions for the three outfall canals in metro New Orleans. This is a topic of great interest because the I-walls along the outfall canals have been a focus of much of the engineering forensics work. Chapter 5 returns to considering the larger project context by discussing and relating project costs, budgeting, and implementation delays to project decisions addressed in Chapters 2-4. These chapters also include short event chronologies relating to specific topics that have been derived from the master chronology of project events, and include notes that describe the content of the listed event and its relation to other events. Chapter 6 summarizes report findings, and offers the authors' own reflections on the factors and forces that affected project decision-making, as well as lessons learned for flood and storm damage reduction efforts.

The chapters are followed by a report bibliography and several appendices. The bibliography includes project documents that are referenced in the report chapters as well as other project documents reviewed as part of report preparation. The master chronology of project events appears in Appendix A. Readers are encouraged to peruse the master chronology if for no other reason than to gain an appreciation of the breadth and depth of materials that were used to construct the report. Appendix B provides a glossary of key terms used throughout the report. Appendix C lists those individuals who were interviewed for this report; these include current and former Corps employees who were involved with project decision-making, as well as representatives of some project local sponsor agencies. Finally, Appendix D provides brief biographies for the report authors.

Chapter 2. LP&VHPP Decision-Making: A 50-Year Overview

2.1 Introduction

This chapter provides a broad overview of key project decisions and events over the 50-year history of LP&VHPP planning and implementation, and the various factors and forces that influenced those decisions. More detail on the project decisions and events reviewed here can be found in Chapters 3-5.

The next section of this chapter is a chronology of selected project decisions and events that the study team believes are central to understanding LP&VHPP decision-making. Simply reading through the chronology is a first step toward understanding the history of project decision-making; however, it is only a first step. Following the chronology is a narrative that explains project decisions and events in more detail, and relates the events to each other and to their relevant historical context. The narrative also includes information and events that are not fully described in the chronology.

Map 2-1 shows the project area and the names of the many political jurisdictions, waterways, and different parts of the project area that are referred to throughout this report. The map also shows the perimeter of LP&VHPP protective structures and the locations where breaches occurred at those structures during Hurricane Katrina. There were 50 breach locations throughout the project area, primarily as a result of overtopping. However, one breach occurred along the 17th Street Canal and two along the London Avenue Canal before water reached the tops of the floodwalls that parallel each canal. And the evidence available at this time suggests that one of the breaches along the Inner Harbor Navigation Canal (also known as the Industrial Canal) occurred before water reached the tops of the floodwalls.

Map 2-1: The LP&VHPP Area, Protective Structures, and Breach Areas

2.2 Chronology of Key Project Decisions and Events

The chronology of project events presented below represents a subset of those included in the master chronology found in Appendix A to this report. These key events were derived from the master chronology and then annotated in the notes section.

Event Name	**Start Date**	**End Date**	**Notes**
Sea Level Datum of 1929, Later Renamed the National Geodetic Vertical Datum (NGVD)	1929		The U.S. Department of Commerce Coast & Geodetic Survey establishes the first official national vertical datum using mean sea level (MSL) measured at 21 tide stations around the U.S. (including one in the Gulf Coast) and 5 stations in Canada. This becomes the datum to adjust all vertical control in North America. LP&VHPP structures were constructed relative to this datum under the erroneous assumption that it corresponds with local MSL, the reference point used for the design of project structures. In 1973, the National Geodetic Survey changes the name of this datum to NGVD to avoid confusion, since it represents a land-based reference system that does not truly reflect local MSL at any location.
Engineering Manual 1110-2 1411	Mar 26, 1952		The Corps establishes a policy to provide no less than Standard Project Flood (SPF) protection for river areas where catastrophic storms may result in social disruption and loss of life. This policy logic was transferred to hurricane protection projects as requiring Standard Project Hurricane (SPH) protection. The policy was reaffirmed in 1965 and 1980.
Public Law 84-71	Jun 15, 1955		Following a series of severe hurricanes, Congress authorizes the Corps to conduct hurricane protection studies for multiple locations along the eastern and southern U.S. coasts. One of the studies is for the LP&VHPP. This study authorization followed an earlier federal hurricane protection project for the more limited area of Jefferson Parish lakefront and the parish side of the 17th Street Canal that was authorized by Congress on July 24, 1946.

Event Name	Start Date	End Date	Notes
Public Law 85-500	Jul 3, 1958		In Section 203 of this act, Congress requires local beneficiaries of hurricane protection projects to be responsible for 30% of project construction costs. This substantive local cost responsibility, predating the cost-sharing reforms of 1986 by almost 30 years, makes the Congress and the Corps New Orleans District (the District) sensitive to local sponsor preferences and budget limits.
National Hurricane Research Project Report #33	Nov 1959		The Chief of Engineers secures the assistance of the U.S. Weather Bureau to select hurricane parameters of wind speed and central pressure for defining the SPH for the project area. A second conceptual storm is also defined, the Probable Maximum Hurricane (PMH), that is larger but less likely to occur that the SPH.
Interim Survey Report	Nov 1962		This is the District planning document that is used for project authorization in 1965. The Secretary of the Army, after review of the District's analysis by the Corps hierarchy, relevant state and federal agencies, and prospective local beneficiaries, transmits a report to the Congress with interim findings and a recommendation of the District Engineer for what will come to be called the "Barrier Plan" to provide a degree of protection (DOP) equivalent to the stillwater surge and wave action predicted to result from the SPH parameters. The District plans protective structures for the LP&VHPP project to 1) withstand the predicted stillwater storm surge and wave regime associated with SPH storm parameters, 2) have technical feasibility, and 3) address local preferences for low levees along the lakefront. The plan, which relies on a complex of barriers to prevent surges into Lake Pontchartrain accompanied by levees and floodwalls along the perimeter of the project area, is recommended over an alternative High Level Plan that would protect the lakefront with higher levees instead of barriers for Lake Pontchartrain. Of note is that the estimated storm surges from the SPH and PMH parameters are relatively close in size, so the design heights of structures, once freeboard is included, would contain both SPH and PMH surges with only minor wave overtopping. Also of note is that natural resource agency comments express concern that adverse fish and wildlife effects may result from construction and operation of the proposed barrier structures.

Event Name	Start Date	End Date	Notes
Hurricane Betsy	Sep 9, 1965		This storm has parameters that are similar to those chosen for the SPH. Extensive flooding occurs through the region, seriously damaging six thousand homes near the Port of New Orleans. Flooding inundates the Lower Ninth Ward with twelve feet of water, and blocks the lower Mississippi River with a hundred destroyed or grounded barges and other sunken objects.
Public Law 89-298	Oct 27, 1965		Congress authorizes LP&VHPP "…substantially in accordance with the recommendations of the Chief…" At authorization the expected project cost is $65 million for the barrier complex and related areas and $15 million for the Chalmette area, of which 30% of the cost is a non-federal responsibility. The state of Louisiana assures the federal government that locally required financial requirements will be met, although local cost-sharing and the required legal assurances are still to be signed. The project is authorized to provide protection against the stillwater surge and associated wave action predicted to result from the chosen SPH wind speed and central pressure parameters.
Final Design Elevations are Established 1-2 Feet Higher than Original Designs	Aug 1966	Sep 1968	Based on new wind field parameters associated with Hurricane Betsy, the design elevations of all project structures are raised by 1-2 feet during the detailed design phase in comparison with those recommended in the 1962 Interim Survey Report.
Design Memorandum #3, Chalmette	Jan 1967		The District in this design memorandum reports (as is reported in the 1962 report before the rise of 1-2 feet in structure heights) that the SPH degree of protection (DOP) has a return frequency 1/200 years. Termed the level of protection (LOP), this is one way that the District communicates risk; surges from storms less frequent than the 200-year event would exceed structure design heights. The DOP and LOP, and hence the potential for overtopping of project structures, would depend on wave action and the height of the storm surge, the stage of project completion, and subsidence of the surrounding land. The project annual budget justification sheets report right up to Hurricane Katrina that, once the project is completed, it will provide SPH or 200-year surge protection.

Event Name	Start Date	End Date	Notes
Construction	1968	2005	Construction begins in the Chalmette area. By 1990, the District reports construction in the Citrus and Chalmette areas are near completion. In 2005, the District will report that the “New Orleans East Unit” (Citrus and metro New Orleans except for the outfall canals) is 92% complete, the “New Orleans West Unit” (lakefront areas in Jefferson and St. Charles Parishes) is 65% complete, and the Chalmette Unit is 98% complete.
Hurricane Camille	1969		The District Chief of Hydraulics reports that Camille’s central pressure and wind speed parameters are more severe than those of the project PMH reported in the 1962 Interim Survey Report. A minimum pressure of 26.84 inches is reported in Bay St. Louis, Mississippi, which makes Camille the second most intense hurricane of record to hit the United States. The actual maximum sustained winds will never be known, as the hurricane destroys all the wind-recording instruments in the landfall area. The estimates at the coast are 200 mph. Columbia, Mississippi, located 75 miles inland, reports 120 mph sustained winds.
Design of Barrier Structures	1970	1975	The District continues to design barrier structures for The Rigolets, Chef Menteur Pass, and the Seabrook lock, even as there is increasing opposition to those elements of the Barrier Plan from many local sources. New environmental analyses required for compliance with the 1969 National Environmental Policy Act (NEPA) are incorporated, with ongoing analysis of fish and wildlife concerns expressed in the 1962 Interim Survey Report and in subsequent comments by natural resource agencies.

Event Name	Start Date	End Date	Notes
1971 Budget Justification Sheet (BJS)	Jan 1, 1970		Estimated total project costs are now $182 million, more than two times the cost at authorization five years earlier, and the only project unit where there has been construction, Chalmette, is reported as 13% compete. In language included in the original 1962 project planning report before Betsy, and that will be repeated in all subsequent BJS through 2005, the District asserts that the completed project will provide protection against storms such as Betsy and the 1915 hurricane that was the basis for the SPH parameters. The BJS states, "Hurricanes more severe than any of record are possible. In the event of the occurrence of such a severe hurricane, catastrophic property damage and loss of human life would be experienced. Local interests have requested protection against these threats to life and property."
Focus on the Outfall Canals	Circa 1970	1992	In the original 1962 Barrier Plan, the existing local levees along the outfall canals were predicted to be of sufficient height to contain barrier-dampened SPH surges coming into the canals from the lake. However, District analyses after Hurricane Betsy concluded that those existing levees could be overtopped even with the planned barriers in place. What follows is a 20-plus year period during which the District, the Orleans Levee District (OLD), and the New Orleans Sewerage and Water Board (SWB) debate different project alternatives for the outfall canals to accommodate the twin local objectives of hurricane protection and effective interior drainage of rainfall from New Orleans. During these years, the District recommends "frontage protection" involving butterfly gates at the canal mouths that would close automatically during hurricane-driven high lake water events. A requirement to recommend the least-cost, reliable solution as the federally preferred alternative for surge protection, combined with the federal policy defining interior drainage as a non-federal responsibility, is the basis for the District position. The OLD and SWB prefer higher canal walls ("parallel protection") to contain surge that might enter the canals, since the higher walls would not interfere with (and would even enhance) interior drainage capacity during hurricanes and heavy rainfall events.

Event Name	**Start Date**	**End Date**	**Notes**
Water Resources Development Act of 1974	1974		Soon after project authorization, local sponsors and the District are concerned about the local sponsors' ability to make cost-share payments in a timely fashion. The Congress in WRDA 1974 authorizes future balloon payments for local sponsors' cost-sharing obligations in order to ensure that local sponsor cash payment requirements do not delay project implementation.
Public Hearing on Draft Environmental Impact Statement for Barrier Plan	Feb 22, 1975		The EIS for the Barrier Plan is filed with the Council on Environmental Quality in compliance with NEPA. At the subsequent public hearing on the EIS, the breadth of local opposition to the surge barriers is expressed on more than environmental grounds, although (with one exception) local sponsors for the project remain supportive. The District in testimony and in other venues argues for the need to move forward with the barrier complex, and that the EIS shows that the barriers would have no significant adverse environmental impact.
Save Our Wetlands, Inc. Contests the Project In Federal Court	Dec 8, 1975		Save Our Wetlands, Inc. (SOWL) files suit in the U.S. District Court for the Eastern District of Louisiana against the District Engineer, the Secretary of the Army, the Administrator of the EPA, and the President of the Orleans Levee District (OLD). The Cilo Sportsman's League joins the suit on June 21, 1976. The suit alleges that a regional cumulative EIS should be accomplished prior to proceeding with the project; that the Corps had not complied with conditions of final approval by the EPA; and that the Corps EIS for the project had not completely eliminated the St. Charles lakefront levee as required by the EPA. The suit is modified by SOWL on March 8, 1976 to include allegations about the inadequacy of the project economic analyses, and questioning the capability of the OLD to provide local assurances. St. Tammany Parish files a similar suit on March 30, 1977.
General Accounting Office Report	Aug 31, 1976		After noting the escalating project cost, the GAO in a report on project financing reports that local sponsors may be unable to make the balloon payments required under WRDA 1974. This report is an early indication of what will become an ongoing concern in the District and in the region about the ability of local sponsors to afford local cost-shares.

Event Name	Start Date	End Date	Notes
Federal Court Injunction Against the Barrier Plan	Dec 1977	Mar 1978	The court orders a halt to project implementation citing inadequacies in the District EIS analysis of the surge barrier effects on lake salinity regimes and habitat. The injunction also includes findings that the project economic analyses are inadequate and that local assurances provided by OLD are inadequate under Section 221 of PL 91-61. Four months later, after arguments by local sponsors and the District, the injunction is lifted for project levees and floodwalls apart from the barrier complexes, since they would have no adverse affect on the Lake environment; however, the injunction remains in force for the barrier structures at Chef Menteur Pass, the Rigolets, and the Seabrook Lock. In addition, the injunction against the barriers effectively places on hold certain project work on the lakefront levees, since the design of those levees and treatment of the outfall canals would be affected by the final resolution of the barriers.
The Orleans Levee District Expresses Concerns About Project Cost Increases	Jan 4, 1978		The OLD Board President writes to the LA Department of Public Works to express concerns about local sponsors' ability to meet rising project costs. After listing the financing problems faced by other local sponsors, the Board President notes, "The Orleans Levee Board's share of the project approximates 67% of local participation. As of this date, if there are no further delays in the project, we estimate that we will have just enough money to pay our share…Any delay which will inflate the cost of the project in excess of the $400 million now estimated will place the cost beyond our ability to pay."
The District Submits and the Division Approves Project Restudy Plan and Schedule	Apr 14, 1978	Apr 24, 1978	The District Engineer submits a schedule to address deficiencies cited by the court injunction, including: 1) the EIS does not describe what the Corps proposed to build; 2) the alternatives to the barrier are not adequately described and evaluated; and, 3) the impact on the surrounding wetlands and on movement of aquatic organisms through the passes is not adequately addressed. The memorandum notes that economic reanalysis is necessary for compliance with the court, and engineering, model, and environmental studies must be conducted. The Division Engineer approves the District plan and states that it is imperative to correct the legal inadequacies of the EIS in the shortest time possible. A 36-month timeline is mandated and a February 1980 deadline for alternatives analysis and economic documentation is established. All subsequent

Event Name	Start Date	End Date	Notes
			economic and environmental analysis for the project restudy and revised EIS in response to the court injunction is limited to redesign of the barriers and the higher lakefront levees that could replace the barriers. This narrow scope will ensure that the plan revisions are sufficiently limited that it can be approved by the Chief of Engineers without requiring new congressional authorization.
National Weather Service Report #23	Sep 1979		Major new analysis of storm events. Continues enveloping methodology and leaves out worst-case storm events from calculation of the project area SPH. (Events such as Camille are not included within the SPH envelope.) The SPH central pressure index (cpi) for the project area is lowered (more severe) to 27.35 from 27.6 as in 1962 report, and there are no changes to the SPH wind speed estimates. However the project area PMH cpi is changed more dramatically, to 26.2 from 26.9, since the PMH calculation is affected by the inclusion of Camille data. The new calculations show that from 1959 to 1979 the difference between the project SPH and PMH has increased.
The District Completes Alternative Plans Study	Feb 1980		The study describes a variety of engineering alternatives for the LP&VHPP. Numerous levee alignments and approaches are presented. The Barrier Plan and a High Level Plan providing SPH protection, and another High Level Plan providing 100-year protection, are given priority study. Altogether, ten alternative plans are considered. The cost analysis assumes that the existing condition includes all constructed project features as of October 1979.
The District Completes Draft Preliminary Analysis of Alternative Plans	Jun 1980		This is the consolidated alternatives analysis for the LP&VHPP. It incorporates the February 1980 engineering alternatives and subjects each to economic and environmental assessment. It notes, "[The] study used a ‘zero-based budgeting approach,’ that is, sunk costs or costs of common features were not of interest, nor were the impacts associated with these features; only differences between the plans were analyzed and displayed." The assessment concludes that the High Level Plan providing SPH protection is less costly, less damaging to the environment, and more acceptable to local interests than the Barrier Plan.

Event Name	Start Date	End Date	Notes
The District Briefs OLD and Other Local Sponsors on Preliminary Alternatives Analysis	Sep 24, 1980		The District briefs local sponsors on the results of the June 1980 draft Preliminary Alternatives Analysis, which shows that the High Level Plan for providing SPH protection compares favorably with the original Barrier Plan. The OLD President expresses urgency to the District to move forward as soon as possible to implement a plan to provide hurricane protection.
General Accounting Office Report	Aug 17, 1982		It is now four years since the injunction was lifted on the non-barrier project features and project costs are rapidly escalating, in large part due to general price inflation. Construction in the New Orleans East Unit and the Chalmette Unit is underway as the District continues to consider redesigns for the barriers and alternatives to the barriers. The GAO reports local sponsors' frustration that the District is moving too slowly to provide authorized protection for the lakefront in ways that address the environmental concerns of the court injunction. The GAO also reports local sponsors' concerns over their ability to afford their share of the increasing project cost, observing that one local sponsor "believed that the Corps' standards may be too high to attain adequate, affordable and speedy protection."
The ASA(CW) Expresses Reservations About Chief's Discretionary Authority to Switch to the High Level Plan	Nov 17 1982		In a memorandum to the Chief of Engineers, the Assistant Secretary of the Army for Civil Works expresses concerns about possible use of the Chief's discretionary authority to switch to the High Level Plan. The ASA(CW) requests a copy of the draft revised EIS, and directs that all District documents pertaining to the possibility of abandoning the Barrier Plan be retained in the District pending review and issuance of further guidance for the project by the ASA(CW).
The Corps Chief Counsel Renders Opinion on Chief's Discretionary Authority to Switch to the High Level Plan	Mar 2, 1983		The Corps Chief Counsel presents a memo to the Chief of Engineers providing a legal opinion that change from the Barrier Plan to the High Level Plan falls under the Chief's discretionary authority. The memo provides background information and rationale. The Counsel opinion rests on three determinations that the change would not involve: "a) a material alteration of the function of the project; b) a material change in the scope of the authorized plan of improvement; and c) a change in legal relationships." Counsel states that this is a departure from earlier Corps views on the need for reauthorization and that the rationale should be communicated to Congress.

Event Name	Start Date	End Date	Notes
The Chief Provides ASA(CW) with Position Paper on Chief’s Discretionary Authority to Switch to the High Level Plan	Mar 31, 1983		Drawing heavily on the legal opinion of the Corps Chief Counsel and an earlier position paper prepared by the Division, the Chief recommends that the High Level Plan be undertaken under his discretionary authority. He states that use of discretionary authority to make the change is appropriate because the new plan involves no change in project purpose, scope, or legal relationships.
1984 Budget Justification Sheet	Jan 1, 1983		The New Orleans East and Chalmette Units are reported to be over 50% complete. The BJS reports that the District is still working on plans to redesign the barriers to accommodate the court injunction. Total project cost is now estimated to be $645 million, approaching a nine-fold cost increase since authorization.
Reevaluation Report and Post Authorization Change Approval	Jul 1984	Feb 7, 1985	In a significant departure from the authorized project features, the District Engineer recommends the High Level Plan for the lakefront and formally recommends against the barrier structures. The engineering and economic analyses in the reevaluation report focus only on the replacement of the barriers elements with higher lakefront levees designed to secure protection from the surge and wave effects corresponding to the originally authorized SPH parameters. The report also notes that surge protection for the outfall canals remains unresolved, but the canals are identified as a matter that will be addressed, consistent with the original authorization that defines interior drainage as a local responsibility. The new plan for the lakefront is less costly than modifying the barriers to address environmental objections. By 1987, the costs for the new plan are estimated as $510 million. Cost estimates for providing protection for the outfall canals assume frontage protection. In 1985, the Director of Civil Works, acting on behalf of the Chief, approves a post authorization change, and the reevaluation report is sent to Congress. The revised project EIS is submitted to the EPA in December 1984.

Event Name	**Start Date**	**End Date**	**Notes**
E-99 Sheet Pile Wall Field Load Test Report	May 1985	Sep 1985	The Division initiates a test to determine whether new design criteria for I-wall sheet pile penetration depths are warranted for cases where loading is short-term, as would be the case during a hurricane. The test is motivated by the anticipated extensive use of I-type floodwalls (I-walls) for hurricane protection projects throughout the region, as well as a general sense that existing design criteria may be overly conservative. The interpretation of the results of the test ultimately leads to new Division guidance that includes criteria calling for reduced sheet pile penetration depths for hurricane protection I-walls, as a cost-saving measure that will not compromise I-wall reliability. Draft guidance including revised criteria is forwarded to the District in 1987, and final guidance with the same criteria is issued by Division in 1989. For the LP&VHPP, the use of I-walls along the outfall canals is preferred by local sponsors as a means to limit real estate acquisition requirements and overall costs.
District Memorandum on Datum (NGVD) Benchmarks	Aug 7, 1985		New data on NGVD benchmark elevations provided by the National Coast and Geodetic Survey indicate that the area is subsiding. The District establishes a policy to not employ the new benchmarks for construction of works in hurricane protection projects that have been partially completed. The logic offered is that practicality and cost considerations prevent modifying already constructed project features according to the new benchmarks, and to apply the new benchmarks to parts of a partially completed project would lead to higher protective structures in some places, rendering opposite side areas that had been previously constructed at lower heights as “fuse plugs.”
Design for Outfall Canals	1986	1992	Design memoranda for parallel protection plans are developed independently by the OLD and the District. The District continues to recommend the frontage protection butterfly gates plan for the London Avenue and Orleans Avenue canals as the least-cost means to provide SPH surge protection, but does not argue that the frontage plan is a more reliable approach to surge protection. The local sponsors defend the parallel protection plan as being more compatible with their need to maintain drainage capability in large storm events, while also providing SPH surge protection equivalent to the frontage alternative.

Event Name	Start Date	End Date	Notes
Orleans Levee District-Sponsored Design Memorandum for London Avenue Outfall Canal	Aug 1986		I-walls for parallel protection are designed under contract issued by the OLD. The designs conform to current Division design criteria, and are estimated to cost up to $44 million. The OLD deems this cost to be too high and cancels further work on the design.
1990 Budget Justification Sheet	Jan 1, 1989		The New Orleans East Unit and Chalmette Unit are reported by the District to be nearly completed. Despite the use of frozen datum benchmarks and concerns raised by new surge analyses, the BJS continues to report that, once completed, “the project will provide protection from flooding from the standard project hurricane (SPH).”
Design Memorandum #19A - London Avenue Outfall Canal	Jan 1989		This design memorandum, prepared by the District and reviewed by the Division, recommends frontage protection (butterfly gates) for the canal as the least cost alternative. However, in Volume 2 the District describes an alternative parallel protection plan. That plan includes I-wall designs based on draft revisions to Division sheet pile guidance criteria as modified following the E-99 test that call for lesser required sheet pile penetration depths.
Design Memorandum #20 - 17th St. Outfall Canal	Mar 1990		The District recommends a parallel protection plan for the 17th Street Canal, since with the new sheet pile guidance and other factors, the cost difference between parallel protection and butterfly gates is minimal for this canal, and the local sponsor (OLD) prefers parallel protection. Designs for the west side of the canal include I-wall specifications similar to those in the London Avenue Canal DM #19A.
Water Resources Development Act of 1990	Oct 1990		Conference report language accompanying Public Law 101-640 seeks to resolve the choice of protection approach for the outfall canals by, at the request of the OLD, directing the Secretary of the Army to instruct the Corps to incorporate protection for outfall canals into the LP&VHPP, and to favorably consider implementing the locally-preferred parallel protection approach.

Event Name	Start Date	End Date	Notes
Energy and Water Development Act of 1992	Aug 17, 1991		The Congress directs the Corps to implement parallel protection for the outfall canals and requires federal payment for 70% of its total cost (instead of 70% of the lower-cost, federally-preferred frontage plan) in order to ease the cost burden on local sponsors. The act also asks for a study of the benefits from the Chalmette Unit derived by local sponsors in St. Bernard Parish, and whether such benefits are in accord with local cost-sharing requirements.
1994 Budget Justification Sheet	Jan 1, 1993		This and all subsequent BJS show that the administration budget does not request funding for the Orleans and London Avenue outfall canals (calling these unscheduled items), forcing Congress to add funds for parallel protection at the canals, which the District uses to implement the work. Eleven years later, the BJS for 2005 will report that work at the Orleans Avenue Canal will be finished in FY 2006 and that work at the London Avenue Canal is nearing completion.
The Corps Coastal Engineering Research Center Conducts Lake Pontchartrain Storm Surge Pilot Study	1993		The District contracts with CERC to perform a model pilot study to assess the impacts of changes in SPH parameters on design stages, and the effects of changes in the relationship between local MSL and NGVD with respect to the required elevations of structures designed to prevent overtopping from a SPH surge derived in the MSL frame of reference. The CERC study uses an early version of the Advanced Circulation (ADCIRC) surge model to validate the original storm surge estimates for the project under the original SPH parameters. That application of the ADCIRC model reinforces the 1980s-era modeling findings that the 1962-era surge estimates may have overestimated the surge associated with the SPH along the lakeshore, and underestimated the SPH surge along the GIWW and IHNC corridors and the eastern boundary of Chalmette. With respect to the new 1979 SPH parameter for central pressure index, CERC uses the ADCIRC model to conclude that the change produces an increase in surge heights of 1-2 feet for certain storm tracks under one set of assumptions, while under another set of assumptions the new SPH parameter has little effect on SPH surge elevations. The CERC study also concludes that local MSL, the reference point used for project design, is about one foot higher than NGVD, the reference point used for project construction. Based on these findings, CERC

Event Name	**Start Date**	**End Date**	**Notes**
			recommends a thorough hydrodynamic modeling of the basin and reevaluation of the project using ADCIRC and a statistical procedure making use of the full database on historical storms within a joint probability approach or empirical simulation technique.
The District Requests Authority to Conduct Model Study of Existing Degree of Project Protection	Sep 1994		The District, citing the CERC pilot surge study results and recommendations as well as earlier 1980s-era surge modeling results, requests from the Division authority to conduct a numerical model study of project protection using modern models (ADCIRC) and data. The District notes that the restudy would be conducted with a view toward ensuring that the authorized degree of protection is uniformly designed and constructed throughout the protection network.
London Avenue Canal Plans and Specifications	1994		These parallel protection plans are completed under the auspices of the District. The designs, prepared using the new Division design guidance criteria for I-wall sheet pile design results in significantly reduced sheet pile penetration depths and lower costs than for the 1986 designs that were contracted for by the OLD and ultimately rejected by the OLD as too costly.
ADCIRC Model Refinement, Testing, and Independent Technical Review	1995	2004	The District notes problems with the ADCIRC model due to its inability to mimic known events, and decides to pursue further model development and testing before applying the model to reevaluate project protection. An effort to improve the model is funded between 1995 and 2004, and Independent Technical Review of the model is completed in 2004.
Water Resources Development Act of 1996	1996		Congress relieves St. Bernard Parish of its past obligations for project costs, after the administration had denied the request.
Hurricane Georges	Sep 18, 1998		This hurricane passes over the Florida Keys and eventually veers away from New Orleans into southern Mississippi. Hurricane damage estimates in the United States exceed $5 billion.

Event Name	**Start Date**	**End Date**	**Notes**
Reconnaissance Report on Upgraded Hurricane Protection for Southeastern Louisiana	1999	2005	Motivated by Hurricane Georges, the District receives congressional instruction for a reconnaissance-level study to evaluate the need and justification for a region-wide feasibility study of protection against “category 4/5 storms” for Southeast Louisiana. The reconnaissance study, completed in June 2002, provides justification for a more in-depth feasibility study, and the State of Louisiana pledges to find local cost-sharing sponsors for that study (as required by WRDA 1986). Later that year, the District briefs local officials on the proposed feasibility study and seeks local sponsors for the study. In that meeting local officials express the view that the District and state and local governments should concentrate on completing already authorized hurricane protection projects in the region before embarking on a new study for upgraded protection. The Corps Headquarters continues to budget for the reconnaissance study phase, but no local entities step forward to sponsor a feasibility study.
Inspection of Completed Works	Circa 1980	2005	Annual visual inspections of completed project structures by District and local officials are made as part of the Corps Inspection of Completed Works Program. But these visual inspections have very limited scope. They are not designed to uncover and communicate potential project limitations regarding subsidence or surge modeling information that would raise doubts about the ability of protection works to contain surges from the original SPH parameters.
2006 Budget Justification Sheet	Feb 7, 2005		In the year that Hurricane Katrina makes landfall, the BJS for fiscal year 2006 reports that total project costs to completion will be about $740 million. In the BJS the District continues to report that the completed project will provide protection against the SPH surge. However, after 2003 the budget justification sheets also include the following statement: “The project was initially designed in the 1960s, and a reanalysis was performed for part of the project in the 1980s. Continuing coastal land loss and settlement of land in the project area may have impacted the ability of the project to withstand the design storm. Refinement of existing computer models to assist in determining the impact of these environmental changes on the project will continue.”

Event Name	Start Date	End Date	Notes
Hurricane Katrina	Aug 29, 2005		Hurricane-driven surges breach the LP&VHPP protective structures at 50 different locations, primarily as a result of overtopping.

2.3 Fifty Years of Project Decision-Making

2.3.1 Project Authorization

The project area has been inhabited by European settlers since the early 18th century, but most settlement was on higher ground along natural river levees. Population was drawn into the area with the rise in oil and gas extraction and processing employment at the middle of the last century. Over time, population settlement spread out to the east, north, and the west of the old city of New Orleans, in some cases into low-lying areas exposed to hurricane surges.

The first federal hurricane protection project in the New Orleans area was authorized by Congress on July 24, 1946. That project, called Lake Pontchartrain, LA, provided for the construction of levees along the Jefferson Parish lakefront and along the Jefferson Parish sides of the 17th Street Canal (at the border with Orleans Parish) and the Parish Line Canal (at the border with St. Charles Parish). The levees were constructed to 10 feet above local mean sea level and 25% of the cost was a non-federal responsibility.

The Corps can undertake planning and construction for projects such as the Lake Pontchartrain project only after receiving a specific legislative authorization from Congress. Authorization defines what is to be constructed and the purposes to be served, and establishes the allocation of financial and other responsibilities for the implementation and operation of the project among the federal government (the Corps budget) and one or more local project sponsors.

At the middle of the 20th century, it was unusual, but not unprecedented, for Congress to authorize hurricane protection projects. Mostly, Congress focused the Corps program and its then-substantial budget and expertise on the control of river flooding. For example, after the flood of 1927, Congress expected the Mississippi River Commission (MRC) to build levees along the river all the way to the Gulf for the purposes of flood protection. The MRC maintains the oversight and maintenance cost responsibility for these flood control levees to this day.

The Corps' broadest flood control planning and construction authority was given by the Flood Control Act of 1936. The Congress in that act recognized flooding as a threat to the nation's well-being and affirmed the provision of flood protection projects to protect the "lives and social security of the people."

World War II diverted the nation's attention from flood control works, but by about 1950, water development projects for flood control were being built at a rapid pace. One measure of the significance of the Corps civil works program is that Corps projects accounted for 5% of total federal spending in the 1930s, and even after World War II ended, the program budget represented 2% of federal spending. At this time of robust budget support a series of severe hurricanes struck the Atlantic and Gulf coasts. In response, the Congress on June 15, 1955, in Public Law 84-71, authorized studies of projects to protect areas along the eastern and southern coasts from hurricane storm surges. That study authorization included the area that ultimately came to encompass the Lake Pontchartrain and Vicinity Hurricane Protection Project (LP&VHPP).

A related development in 1958 was Congress's establishing cost-sharing requirements for local beneficiaries of hurricane protection projects that departed from traditional cost-sharing rules for federal civil works projects. At that time, planning for civil works projects was to be a full federal cost responsibility (and this remained the case until the 1986 Water Resources Development Act required local sponsors to pay 50% of the cost of project feasibility studies). Generally, the cost-sharing requirement for implementing a flood control project was that non-federal sponsors would provide all lands, easements, and rights of way (LERW) necessary for project construction, and these same entities were to assume long-term responsibility for the operation and maintenance of the completed project.

However, Congress in 1958 (PL 85-500) said that hurricane project construction costs were to be a shared financial burden, with one or more non-federal sponsors expected to sign agreements assuring that they collectively would pay for 30% of project construction costs. If the value of LERW did not reach 30% of total project cost, then the non-federal sponsors would need to agree to make cash payment until the total value of the non-federal contribution reached 30% of the cost of a hurricane protection project.

This 30% non-federal cost responsibility for hurricane protection projects represented a significant local cost burden that was in many ways without precedent at the time. Indeed, it was not until 1986, nearly three decades later and following 10 years of dispute between successive congresses and administrations, that non-federal cost-sharing for all project purposes was increased to reflect the kind of local financial responsibility that had already been in place for the LP&VHPP and other federal hurricane protection projects.

As a result, the Corps New Orleans District (hereafter called the District), when planning and then implementing the LP&VHPP and other hurricane protection projects under PL 85-500, became especially cognizant of the acceptability and affordability of any plan to the local sponsors of the project. Nonetheless, the District still had to be responsive to the expectations and requirements of the hierarchical organizational structure of the Corps as well as Executive Branch leadership and the Congress.

Several changes to the original project authorization were made over time, mostly related to project cost-sharing. Congressional authorizations for the LP&VHPP are shown in Box 2-1.

Box 2-1: Congressional Authorizations for the LP&VHPP

Flood Control Act of 1965 (PL 89-289), HD 23/89/1: A program for protection from hurricane flood levels in New Orleans, LA and surrounding areas by means of levees, floodwalls, control structures, navigation structures, locks, dams, and drainage structures.

Water Resources Development Act of 1974 (PL 93-251), Section 92: A modification of the FC Act of 1965 to provide that non-federal public bodies may agree to pay the unpaid balance of the cash payment due with interest, in yearly installments.

Water Resources Development Act of 1986 (PL 99-662), Section 805: A modification of the project to include construction of a floodwall with sluice gates or other necessary means to ensure that hurricane-flood protection within Jefferson Parish will be unimpaired as a result of any pumping station construction by local interests.

Water Resources Development Act of 1990 (PL 101-640), Section 116(k): A restudy of and report on project benefits to determine whether or not sponsors have received expected benefits and whether or not there should be a reallocation of costs as a result of any unrealized expected benefits. No non-federal payment for the St. Bernard Parish portion of project required during the study period (November 28, 1990 – November 28, 1991).

Water Resources Development Act of 1992 (PL 102-580), Section 102(j)(2): A reevaluation of the reallocation of project cost based on the benefit study required by the WRDA 1990 Section 116(k).

Water Resources Development Act of 1992 (PL 102-580), Section 102(j)(1): A modification to the project to include conveying landside runoff from the Jefferson Parish Lakefront levee from the levee right-of-way to the street drainage system.

Water Resources Development Act of 1996 (PL 104-303), Section 325: A modification to the project to provide that St. Bernard Parish, Louisiana, and the Lake Borgne Basin Levee District, Louisiana, shall not be required to pay the unpaid balance, including interest, of the non-federal cost-share of the project.

Water Resources Development Act of 2000 (PL 106-541), Section 432: A post authorization change report to include structural modifications to the seawall providing protection along the south shore of Lake Pontchartrain not later than 180 days after WRDA enactment.

Source: Project Budget Justification Sheet for fiscal year 2006 (20050207)

2.3.2 The Planning and Design Process

Multiple reorganizations within the Corps Headquarters as well as in the Division and District field offices over the 50-year period of project planning and implementation sometimes changed the responsibilities of the different offices. Generally, technical work was completed in the District and then reviewed at the Division, but in the early 1990s the Division technical review (quality control) responsibilities were shifted to the District offices who often reviewed the design work done by private contractors. The Division role then became more one of quality assurance, i.e., ensuring that District reviews were accomplished. The hierarchy of the agency itself also changed over time. For example, during the 50-year LP&VHPP history, the Office of the Assistant Secretary of the Army for Civil Works was established and the Board of Engineers for Rivers and Harbors that had been in place since 1902 was eliminated.

Despite these changes, the broad responsibilities of the different Corps offices have remained largely the same over time. The District office has the lead responsibility for project conception, planning, design and implementation. First, the District prepares a report for what it sees as the best way to address the problem identified for solution in the congressional study authorization. That report, once it passes a technical review and is deemed consistent with policies, is the basis on which the administration requests authorization for construction. The District Engineers' report could be modified, if need be, based on the reviews. This planning process for the LP&VHPP stretched over about five years, leading to the 1962 Interim Survey Report that presented the District's preferred plan—the so-called Barrier Plan. Between 1962 and 1965, few refinements were made to the plan (19650706).

The initial planning reports for the LP&VHPP leading up to project authorization were reviewed at the time by the Lower Mississippi Valley Division (now known as the Mississippi Valley Division, and hereafter called the "Division"), the Board of Engineers for Rivers and Harbors, the Office of the Chief of Engineers at Corps Headquarters, the Secretary of the Army for Civil Works [ASA9CW)], and the administration budget office. Various state and federal agencies also commented on the report. All of these reviews focused on planning methods and whether the District plan complied with Corps, administration, and congressional policy. Broad engineering matters were also reviewed; however, the engineering analysis was at a "planning level" of detail. The final report transmitted to Congress by the Chief of Engineers (the "Chief's Report") endorsed the District's plan for the LP&VHPP. With the Chief's Report in hand and the concurring recommendation of the Secretary of the Army, Congress in 1965 authorized construction of the Chief's recommended plan (19651027).

Once authorized, the project entered into the post-authorization design phase. Following Corps practice, the District worked with the Division over the years to refine the project engineering and prepare design memoranda following prescribed guidelines, and then final plans and specifications that would guide project construction. Dozens of design memoranda were issued over the decades-long project design process. The District engineering office would, through the Division, provide these documents to Corps Headquarters for review, and the District programs office annually would provide Headquarters, the administration, and Congress with estimates of budget requirements to complete the project.[6]

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[6] Different units of the Corps organization are referenced throughout this report, including the New Orleans District (the District), the Lower Mississippi Valley Division (the Division), and the Office of the Chief of Engineers (Headquarters). Within each of these units there are various branch offices such as engineering, hydrology and hydraulics, and planning. This report uses the terms District, Division, and Headquarters to describe project decision-making entities, although it is recognized that these Corps units are not homogenous entities with one internal and unified point of view for any matter. A project decision made within any Corps unit is the product of interplay among their various branch offices and the people within them, as well as with other Corps units and members of Congress. When the available evidence indicates that a specific source document was prepared within a specific branch office of a Corps unit, that

As a general matter, it is expected that after authorization and during design, new information that may have a bearing on the performance of the project plan will be recognized and accommodated to ensure that the purposes of the project as authorized will be realized. Any needed changes are identified by the District office since that office is responsible for any post-authorization design and construction work. The District is expected to provide the rationale for any changes, and may be expected to secure the necessary approval for proposed changes depending on their significance.

Changes made to the LP&VHPP during the design phase may increase costs, reduce costs, and lower or increase the project's ability to protect against the storms it had been authorized to address. Major changes to the project purposes and scope beyond what was authorized may require a new congressional authorization. Other changes may be made by the District with the concurrence of the Division alone. Still other changes may be deemed significant enough (e.g., those that entail significant cost increases or changes in project design approach) to warrant approval of the Chief of Engineers in a post-authorization change report that is also submitted to the congressional appropriations committees. Some changes might require going back to the Congress for a new authorization (see Box 2-2).

For the LP&VHPP, there were two post-authorization change reports that will be outlined later in this chapter. The first was for adding the Chalmette Extension to the project in 1967. The second was for the switch to the High Level Plan made in 1985.

2.3.3. Budgeting for Construction

The Corps Headquarters, the administration, and Congress are engaged in project decision-making by appropriating funds in the annual budget process, after project authorization and in parallel to the design process that is the responsibility of the District. At the Washington, DC level, the appropriation is the result of an administration's budget request and congressional approval of, or modification or addition to, that request. The process results in allocating the Corps construction general (CG) budget among competing projects across the nation. The Corps national CG budget increased only slightly in nominal terms after 1980. An overview of the federal budget development and appropriations process for civil works projects is presented in Box 2-3.

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information is noted. In some cases the evidence suggests that there were different professional points of view within some units regarding project decisions. However, in the end such disagreements must be resolved for project planning and implementation to move forward. Accordingly, this report refers broadly to Corps decision-making entities as the District, Division, and Headquarters.

Box 2-2: Corps Policies for Project Modifications (excerpts from 1999 Corps Policy Digest)

"Congressional authorizations of Corps projects normally include a provision for implementation of the recommended plan with such modifications as the Chief of Engineers may deem advisable, in the interest of the purposes specified. …

Procedures for adoption of proposed project changes differ depending on whether they may be approved by the Chief of Engineers using such delegated discretionary authority or must be submitted to Congress for consideration and legislative modification of the existing authorization. To a limited extent, approval authority for some changes which are within the Chief's discretion has been redelegated to the division commanders. Where proposed changes are more significant, they are documented in a Post Authorization Change (PAC) Notification Report submitted to HQUSACE (unless timely coverage can be provided in a design memorandum or other routine preconstruction planning document submitted to HQUSACE). If it is determined, after review, that the proposed changes are not within delegated authority but are of sufficient importance to warrant a recommendation for modification of the project authorization, procedures and further reporting requirements for processing such a recommendation to the Congress will be selected as best suits that specific case. …

a. Modification Authority Delegated to the Chief of Engineers. Modifications and changes of a project necessary for engineering or construction reasons to produce the degree and extent of flood protection or the extent of navigation improvement or other purpose intended by the Congress are within the latitude delegated to the Chief of Engineers. Examples of such changes are shift of a dam to a nearby better foundation location; changes in channel alignment and dimensions indicated by more detailed studies; changes from a concrete to an earth structure because of lack of proper concrete aggregate; or moderate extensions of project scope, such as necessary to provide flood protection to adjacent urban areas developed since the project was authorized. The Chief of Engineers recognizes that this latitude for changes and modifications of authorized projects is an important delegation of authority which must be exercised carefully. Changes involving the addition of project purposes, significant changes in project cost, scale, features, benefit, location, and costs allocated to reimbursable project purposes require notification of OMB.

b. Modifications Beyond Delegated Authority. A proposed modification of an authorized project is brought to the attention of Congress if study after authorization shows that: the scope of functions of the project will be changed materially; the plan of improvement will be materially changed from that originally authorized by Congress; special circumstances exist which were not known to the Corps or recognized by Congress when the project was authorized…Decisions regarding project modifications are made on an individual case basis. Questionable cases are reported to HQUSACE in a PAC report (if not as one subject in a routine preconstruction planning document of broader project coverage) with the views and recommendations of the division and district commander. Recommendations for modifications beyond the authority delegated to the Chief of Engineers are submitted to the ASA(CW) with supporting documentation suitable to the case, for review and subsequent transmittal to Congress for authorization."

The development of the annual administration budget request for civil works projects sent to the Congress begins with the Corps district field offices. The budget justification sheet (BJS) for any project, which is first drafted by the relevant District, is the document that results from a year-long budgeting process. The BJS prepared for the annual budget request to Congress is developed in the programs (budgeting) offices of the districts and passed through similar division and other Corps offices that have budget responsibilities. The specific purpose of the BJS is to justify requested federal appropriations for continuing implementation of a project in the next fiscal year; it also serves as an instrument of communication among the field offices, the Headquarters, the administration, and the Congress for conveying budget information about individual projects. The BJS also includes a justification statement for the proposed spending, and a short statement on the expected value of the project to the area and the nation. Moreover, the BJS also provides information on project authorization history and the status of local cost-sharing. A formal statement on the status of project completion is also provided in each BJS. Therefore, tracking these reports over time indicates how progress toward finishing the project was being reported to the administration and the Congress.

Box 2-3: The Federal Budget Development and Appropriations Process

Over the years the broad approach to federal budget development for civil works projects has not changed. The process begins in Washington when the Office of the President develops an overall agency budget target for the Corps and sets forth certain policy guidelines that will govern the President's budget request to the Congress. The Corps Headquarters reviews ongoing activities and possible new starts and makes an allocation of this overall cap to the divisions. The divisions inform the districts of their allocation and are asked to prepare a budget that fits within the cap. Within the districts, the planning, the engineering and construction offices track ongoing project construction and possible funding for new starts and for operations and maintenance. These offices prepare information for the district programs office that it then uses to prepare district spending requests. Based on this information, the district may request, with justification, funds that exceed the assigned cap. The district request is sent back through the division programs office to Corps headquarters, where the total spending requested by all field offices is likely to exceed the President's cap. The headquarters prepares a budget that is responsive to the requests from the field and the administration's budget limits and priorities and sends it to the administration budget office through the Office of the Assistant Secretary of the Army for Civil Works [ASA(CW)]. The budget office reviews the request and works with the Corps and the ASA(CW) to reach agreement on the President's budget submission to the Congress. That submission includes project-specific budget justification sheets.

The Congress takes the President's budget request under advisement and holds hearings in both the House and the Senate. Each chamber develops its own budget and in the conference process reconciles the three budgets and prepares a final budget that the President may sign or veto. The congressional appropriation can differ from the President's submission in two ways. First, the total appropriation amount may differ. Second, the projects supported within that appropriation, and the amounts directed to individual projects may differ from the president's request. Related to this second possibility is that there may be language in the law itself or in a conference report directing the Corps to spend money in specific ways. Through this process the Congress could choose to accelerate the completion of a project by adding funds to the President's annual budget request, if there were an indication that the Corps had the ability to efficiently spend those added funds and that the required local cost-share monies were also available.

The BJS is not a vehicle for communicating and elevating critical project design decisions, although the BJS does include a statement about the effectiveness of the project in meeting its authorized purposes, if the funds requested are provided towards project completion. Annual congressional hearings provide opportunities for Corps representatives to highlight for the Congress the agency's funding needs and suggested policy modifications regarding such matters as cost-sharing. The authors of this report reviewed 35 project BJSes and the information these documents provided was central to the development of this report.

2.3.4 Developing the Federal-Local Partnership (1955-1970)

The District began planning the LP&VHPP with no formal cost-share partners yet secured. The District held a series of public hearings in the New Orleans area in 1956 to assess local needs and interests in hurricane protection. These early meetings drew little attention and provided no technical advice for engineers and planners. The District, exercising its leadership in project conceptualization and design following Corps polices and planning procedures, defined the problem to be addressed, developed and analyzed plan alternatives, and recommended a preferred alternative.

The District developed a vision for a plan to provide protection against the Standard Project Hurricane (SPH) surges for the study area, and local preferences were taken into account when formulating a specific project design to provide that protection. For example, the District noted local opposition to high levees along the lakefront as a compelling reason for favoring the Barrier Plan. As had been required during most of the 20th century, some form of benefit-cost evaluation was required to justify the provision of the project purpose, in this case SPH surge protection, with the chosen design.

As the preferred alternative was identified and then justified, the District had to seek out non-federal sponsors who would be willing and able to pay the 30% non-federal share of project cost as required by Public Law 85-500. The Chief's report for the project stated:

> "Hurricane protection plans. The apportionment of costs of the proposed plans for hurricane protection is based on the cost-sharing formula adopted in the Flood Control Act of 1958…This act specifies that first costs, including the costs of lands, easements, rights-of-way, and relocations, but excluding the cost of preauthorization studies, shall be apportioned at lest 30 percent to non-Federal interests and not to exceed 70 percent to the Federal government. Lands, easements, rights-of-way and relocations shall be provided by non-Federal interests without cost to the United States and will be credited to the local contribution. Operation and maintenance costs of all levees, structures, and drainage facilities, except the modified Seabrook Lock, shall be the responsibility of non-Federal interests. The Rigolets Lock and navigation channel will be operated by the Federal government with funds to be contributed by local interests…" (19650706, page 96)

Securing non-federal cost-sharing agreements would prove to be a challenge for the LP&VHPP. The project area that was to receive hurricane protection crossed boundaries of many political jurisdictions, as well as special-purpose levee and drainage districts that had been formed over the previous century to lead and finance land reclamation and flood protection projects (levees, floodwalls, drainage networks and pumps) essential to settlement of the region. Initially, there was no project plan or cost estimate that could be used to explain to local sponsors what they might be asked to pay. For this reason and for purposes of project authorization, the State of Louisiana affirmed that cost-sharing would be provided. The project authorizing language stated:

> "Assurances of cooperation. The State of Louisiana, Department of Public Works, the agency designated to act in such matters on behalf of the Governor of the State of Louisiana, has concurred in the suitability of the plans of protection, and has stated that assurances from local interests will be provided when required." (19650706, page 100).

Another matter that was resolved prior to authorization was whether any of the 30% local cost requirement could be met as a credit for project work undertaken by local sponsors. The final cost-sharing provisions of the authorization allowed local sponsors to provide toward their cost-shares any in-kind project contributions (e.g., project design or construction work done by local interests) in lieu of cash payments. The 1964 Chief's report for the project included a letter from the Chief of Engineers to the State of Louisiana, which stated:

> "Federal policy as set forth in recent Congressional authorizations for hurricane protection projects, provide that local interests bear not less than 30 percent of the construction cost. Lands, easements, rights-of-way, and relocations shall be provided by non-federal interests and will be credited to the local contribution. When the fair value of these items is less than 30 percent of the construction cost of the project, the difference shall be borne by non-federal interests as a cash contribution payable at the time of project construction. *This policy has also included a provision that part of the local cost may be contributed in equivalent work in lieu of cash, but such work would be limited to that specifically undertaken as an integral part of the project after its authorization, and in accordance with approved construction schedules. No provision has been made for a reduction of the local contribution because of costs incurred for the construction of existing protection that might subsequently become an integral part of a hurricane protection project.*" [italics added] (19650706, page 13)

In later years, some local sponsors, particularly the Orleans Levee District (OLD), would take the lead in hiring private firms for project design and construction work, and would be given credit for those expenditures toward their local cost-shares. All project work by local sponsors would be completed according to Corps requirements and would be reviewed and approved by the District.

The assurance by the State of Louisiana that local cost-sharing would be forthcoming needed to be made operational once a plan was proposed and its cost estimated, since it was necessary to allocate costs to the separate benefiting local entities so that the total local financial commitment was equal to 30% of the project cost. In 1966, the OLD was designated by the Governor of Louisiana to lead the local cooperation effort for the Orleans, Jefferson, St. Charles, and St. Tammany Parishes. The OLD signed a local cooperation agreement (LCA) with the District in that year. By 1971, other local sponsors became involved since it was unrealistic to expect the OLD to provide requirements for lands located in the other parishes. Acting independently, the Pontchartrain Levee District (PLD) was constructing interim lakefront protection in Jefferson Parish. There was also interest in 1967 to initiate work on a levee in St. Charles Parish; the State of Louisiana and the PLD took the lead in that activity.

The local funding commitment was most readily secured for the Chalmette area because the proposed work was a separable element within the larger LP&VHPP, and specific government entities that represented beneficiaries were readily identified. In August 1966, the Lake Borgne Basin Levee District and St. Bernard Parish became joint local sponsors for Chalmette project work in St. Bernard Parish. The OLD served as a local sponsor for project works in Chalmette that fell within its jurisdiction. Construction within Chalmette was reported (in budget justification sheets) as 98% complete by 1990, and the focus then shifted to completing the lakefront protection and addressing protection designs for the outfall canals.

2.3.5 Planning Moves Forward: The Design Hurricane and Barrier Plan (1958-1965)

When the LP&VHPP was being planned, Corps policy for providing protection for urban areas from river flooding required levees to have structure heights that contained flows from the Standard Project Flood (SPF), a flood derived by routing flows generated by the runoff from the Standard Project Storm (SPS). This policy goal focused on the protection of human life and not maximization of net economic benefits. This is demonstrated by the following excerpt from the applicable Corps engineering manual (EM 1110-2-1411), as revised in 1965:

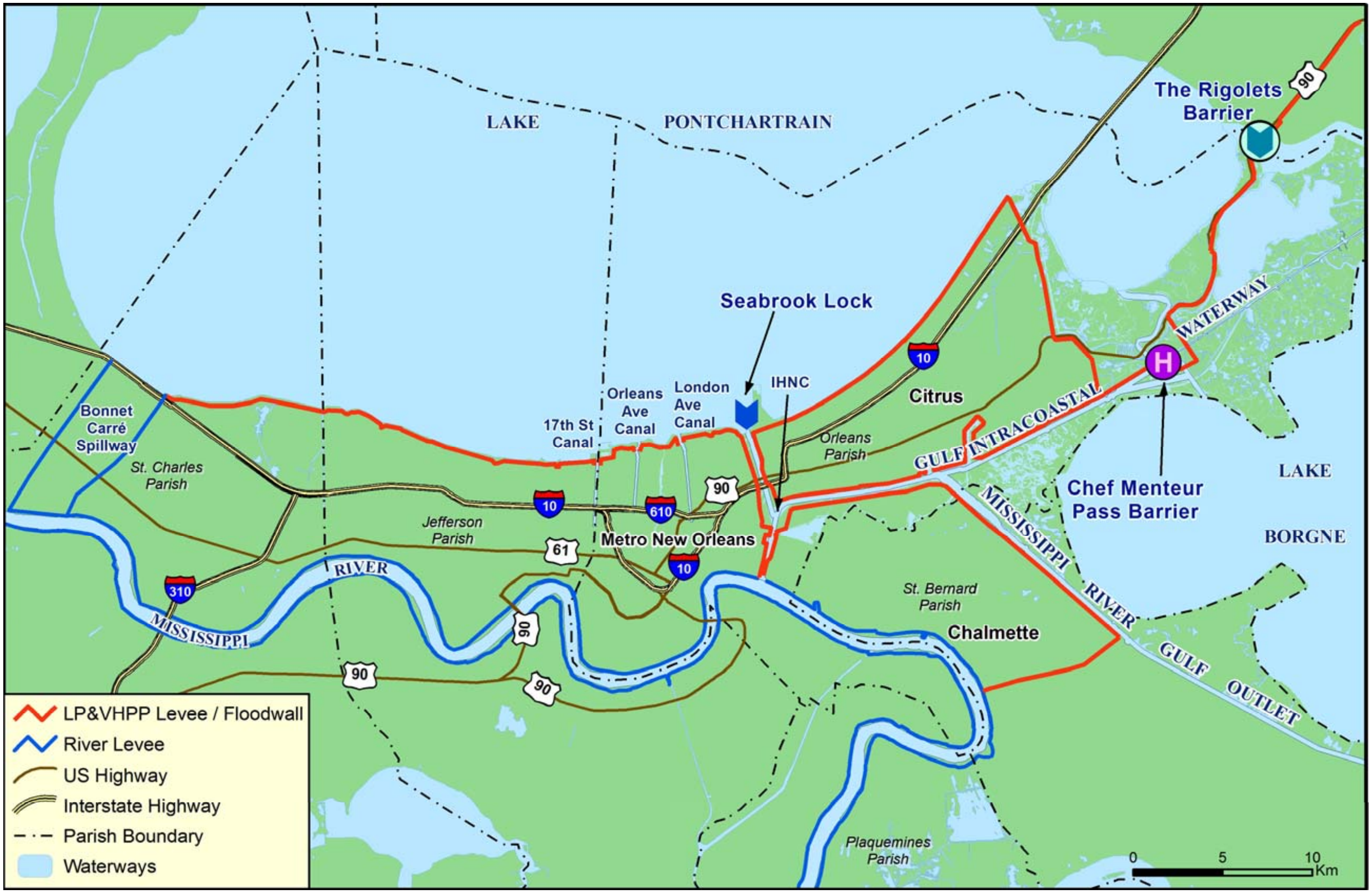
> "… selections (of project performance) should not be governed by estimates of average annual benefits of a tangible nature alone, nor should construction difficulties that may prove troublesome but not insurmountable be allowed to dictate the design flood selection, particularly where protection of high class urban or agricultural areas is involved. Intangible benefits, resulting from provision of a high degree of security against floods of a disastrous magnitude, including the protection of human life, must be considered in addition to tangible benefits that may be estimated in monetary terms." (19650301, page 7)

A similar performance target would be set for the LP&VHPP using a parallel construct that called for protection against the stillwater surges and wave action created by the Standard Project Hurricane (SPH). The policy goal of providing SPH surge protection was made operational by modeling the track of the SPH (a hurricane that developed offshore) over the water and wetlands to different points of landfall. The LP&VHPP design was expected to contain the storm surge (akin to river flood flows) driven by the SPH within the project area. This SPH would also be called the "design hurricane."

A second concept, also adapted from project planning for protection against river flooding, was the surge from the Probable Maximum Hurricane (PMH), as analogous to the flows from Probable Maximum Flood (PMF). This construct recognized that storm surges were possible that were larger, although less likely, than the design storm. In fact, as a concept, the PMF and PMH are recognized to be storms that have an infinitely small likelihood of happening.

In the late 1950s, the Chief of Engineers engaged the United States Weather Bureau (USWB) in preparing a report to define the SPH for different parts of the Atlantic and Gulf coasts. The USWB report defined the SPH as "the most severe storm that is considered *reasonably characteristic* of the region." The PMH was the “hurricane that may be expected from the most severe combination of meteorological circumstances that are *reasonably possible* in the region.” At landfall, in each location, the SPH surge height and wave action would need to be rebuffed by the protective structures at that location. With the design storm surges at locations throughout the region identified, the next task was to identify and then prepare “planning level” designs (suitable for project authorization) for protective structures.

The result for the LP&VHPP was what came to be known as the Barrier Plan. The Barrier Plan included several types of protective structures (see Map 2-2). Central to the protection were tidal gates at Chef Menteur Pass and The Rigolets, which would be closed during storms to hold back surges that otherwise would enter Lake Pontchartrain. The Citrus area would have a new, low-level levee along the lakefront, floodwalls at the Inner Harbor Navigation Canal (IHNC), and levees and floodwalls along the Gulf Intracoastal Waterway (GIWW). The Metro New Orleans area would have levee enlargement and floodwalls at the IHNC and the Seabrook lock at the mouth of the IHNC. The portion of Orleans Parish bordering St. Bernard Parish would get levees and floodwalls along the GIWW and the IHNC. The Chalmette area would get levees along the Mississippi River Gulf Outlet (MRGO) that would provide direct protection from SPH surges from Lake Borgne. By 1967, the area would be further protected by adding the Chalmette Extension to the project. St. Charles Parish was to receive a new levee along the lakefront that would accommodate surges dampened by the surge barriers; in later years, as a result of new environmental laws, the alignment of the St. Charles levee would be moved inland to prevent the filling of lakefront wetlands. The original Barrier Plan did not include any work for the Jefferson Parish lakefront, however, because that area was thought to be sufficiently protected by the surge barriers in conjunction with the existing lakefront levees that were constructed under a separate federal project authorized in 1946.



Map 2-2: The LP&VHPP Barrier Plan Authorized in 1965

Among the requirements for project authorization was an estimate of the project costs to provide the SPH surge degree of protection (DOP), as well as an analysis to demonstrate that costs were justified by the narrow benefit metric of property damages avoided (see Box 2-4). The 1965 letter report used for authorization estimated costs of $65 million for the Barrier Plan, and $15 million for the Chalmette area, a separable unit of the project also designed to provide SPH surge protection. The benefit-to-cost ratio for the Barrier Plan was reported as 14:1; the Chalmette area had a reported ratio of 4:1. (19650706)[7]

Box 2-4: Benefit-Cost Analysis is not the same as Financial Cost and Affordability Analysis

Benefit-cost analysis (today in the Corps called "National Economic Development analysis") represents the calculation and comparison of estimated project benefits with estimated project costs. Benefits are representations of the positive outcomes from the project measured in monetary and non-monetary terms. Costs include financial outlays for project construction and operations by governments, and expenditures by private individuals necessary for them to realize project benefits. Costs may also include forgone benefits from activities displaced by the project.

Financial outlays by governments are a narrower concept of cost. Financial costs to government, in relation to available government budgets, are a factor in public decision-making. Comparing costs required of a government to its budget represents a financial cost analysis, sometimes referred to as "affordability analysis." Benefit-cost analysis and financial cost analysis are often both described as "economic analysis" even though they represent very different types of analytical concepts and procedures.

Statements have been made in the press and in other reports that a narrow economic analysis (meaning benefit-cost analysis) that ignored potential loss of life was used to select the protection level to be provided by the LP&VHPP. However, Corps policy dating to the 1950s called for a degree of protection for urban areas that was for the Standard Project Flood (SPF), and by analogy the Standard Project Hurricane (SPH), or greater. Benefit-cost analysis was a final screen to justify the SPH protection. Interestingly, benefit-cost analysis was at times used to argue for greater-than-SPH protection. For example, in 1965 the District requested PMH protection based on the surges experienced during Hurricane Betsy, arguing that net economic benefits justified going beyond the SPH minimum requirement. Structure heights were later raised by 1-2 feet, but not to secure PMH protection. An economic analysis included in the 1984 Reevaluation Report called for SPH protection in response to local interests' request for a review of project plans providing lesser protection. That report argued for SPH protection since it was economically justified and in compliance with Corps policy. Conversely, as is described in much detail throughout this report, financial costs (project affordability) were a significant consideration in many of the project decisions made.

Calculating expected project benefits in terms of property damages avoided required an estimate of the return frequency for the SPH stillwater surge, as well as the frequency of stillwater surges from smaller storms. The return frequency for the SPH surge is commonly called the "level of protection" (LOP), which the District used to communicate the intended project protection and residual risk. A 200-year LOP meant that the project would withstand a storm surge that had a 1/200 or 0.5% chance of occurring in any year (in the 1980s, local sponsors requested an analysis of plans providing protection for the 100-year, or 1% chance, storm event).

[7] The 1965 letter report from the Secretary of the Army (19650706) includes the 1962 Interim Survey Report as well as the 1964 Chief's report.

There is some difficulty with this characterization of SPH surge risks, especially for the LP&VHPP. First, the return frequency conveys information about the magnitude of the storm event, because as a general matter a rarer event is likely to be a larger storm for a particular location, but it is not possible to say how much larger. Also, the LOP was at best an approximation, given the limited data to support the estimated return intervals. As rough as these calculations were, it remained common practice to communicate protection offered by the project as “X-year” level of protection. Over the initial years the statement was made that the project provided 200-year protection; later the District began to report that the project provided 300-year protection for the lakefront.[8] After development of the Saffir-Simpson Hurricane Scale (SSHS), the project was sometimes described as providing protection against a “fast-moving, Category 3 hurricane.” However, that characterization of intended project protection is imprecise because there is no close relationship between the SSHS classification system—which is based largely on wind speed—and protection against SPH tidal surges that the project was intended to provide.

On the opposite side of the LOP is the possibility of storm events that would exceed the project SPH design storm. The likelihood and consequences of those events happening would be explained in terms of “residual damages.” Residual damages are the adverse consequences from storm surges larger than the design storm surge. If there are no storms that can exceed the SPH surge, then there still may be some relatively small residual damages from minor wave overtopping.

When the 1962 Interim Survey Report reported that the stillwater surges from the PMH and SPH were relatively close in size, the resulting design heights of project structures, once consideration for the effects of wave action and/or freeboard were included, would contain PMH as well as SPH stillwater surges. For this reason, flooding from all then-conceivable storms would be limited to that caused by minor wave overtopping and was considered to be of minimal significance. Residual damages were reported as being limited to such wave overtopping.

In later years, new storm parameter data and enhanced surge modeling capabilities would suggest that the SPH and the PMH were stronger storms with higher surge elevations than originally thought, and that the difference between the SPH and PMH in intensity was larger than the 1962 analyses suggested. These factors meant that, unless structure design heights were raised, there would be an increased probability of a storm surge significantly overtopping those structures (and not simply minor wave overtopping). Thus, simultaneously the actual project DOP fell below the SPH surge protection standard and the LOP provided by the project became less than 1/200 (the original estimate).

[8] The fiscal year 1995 “Data for Testifying Officers” (a project information sheet used to prepare Corps officials for congressional hearings) reported that the storm of record for the project area was Hurricane Betsy in 1965 (similar to the 1915 storm on which the SPH was based); that storm had a return frequency of 1/100. The SPH was a larger storm and had a return frequency of 1/250 (19940101). It is difficult to reconcile this statement of the project LOP with other project documents.

Adding to this lessening of the project DOP and LOP over time was the problem of land subsidence in the project area. Levees throughout the LP&VHPP would be built in a sequence of "lifts" that would accommodate expected settlement; settlement was expected when constructing levees in the area. However, general land subsidence was not a consideration in the design of project structures.

2.3.6 Authorization, Post-Authorization Change, and Construction Begins (1965-1975)

The 1962 Interim Survey Report recommended the Barrier Plan as the District Engineer's preferred alternative for providing SPH stillwater surge protection. The District Engineer's logic and recommendation had been reviewed throughout the Corps review hierarchy and by the administration (Bureau of the Budget). The report included assurances from the State of Louisiana that commitments for required non-federal cost-sharing would be secured. An alternative to the Barrier Plan, called the High Level Plan, was reported to be an inferior alternative based on technical feasibility, cost, and acceptability to lakefront communities.

Included with the 1962 report were comments by fish and wildlife agencies that expressed concerns about the possible effects of the barrier complexes on salinity regimes and habitat in Lake Pontchartrain. These comments would, it was assured by the 1962 report, be taken into consideration in compliance with the Fish and Wildlife Coordination Act. Under that act, the District had more leeway in doing the analyses to respond to the resource agency comments than it would have in later years under the 1969 National Environmental Policy Act.

The economic analysis included in the 1962 report showed a benefit-cost ratio of 14:1 for the areas outside of Chalmette, and 4:1 for the Chalmette area. Some of the benefits were attributed to protection for prospective new development reflecting increasing population trends in the area. Project benefits anticipated from new development was permitted under the Corps planning procedures of the time and was the reason that some local entities, especially St. Bernard Parish, were willing to agree to the required project cost-sharing. Unlike elsewhere in the project area, the predicted development never occurred in St. Bernard Parish, and parish leaders subsequently sought and received relief from the parish's project cost-sharing obligations in the Water Resources Development Act of 1996.

The Congress, in the Flood Control Act of 1965 (PL 89-298), passed a few days after Hurricane Betsy struck the project area, authorized the LP&VHPP along with numerous other hurricane protection projects along the Atlantic and Gulf coasts. The authorizing language stated:

> "The project for hurricane-flood protection on Lake Pontchartrain, Louisiana, is hereby authorized substantially in accordance with the recommendations of the Chief of Engineers in House document Numbered 231, Eighty-ninth Congress, except that the recommendations of the Secretary of the Army in that document

> shall apply with respect to the Seabrook Lock feature of the project. The estimated cost is $56,235,000." (19651027, page 5)

Understanding what was authorized beyond this terse statement requires a reading of the Chief's report, dated March 4, 1964 (that was in effect the same as the 1962 Interim Survey Report). The Chief of Engineers in that document, citing reviews of the Board of Engineers for Rivers and Harbors, the Division and District Engineers, and the concurring reports of the Mississippi River Commission, recommended provision of the SPH surge DOP for the study area through the Barrier Plan, as had been recommended by the District. The report is unambiguous about the project DOP; it states:

> "a. <u>Selection of the design hurricane</u>. The standard project hurricane was selected as the design hurricane (Des H) due to the urban nature of the study area. A design hurricane of lesser intensity which would indicate a lower levee grade and an increased frequency would expose the protected areas to hazards to life and property that would be disastrous in event of the occurrence of a hurricane of the intensity and destructive capability of the standard project hurricane.
>
> b. <u>Characteristics</u>. The characteristics of the Des H's for the proposed plan of protection are identical to the standard project hurricane described in detail in paragraph 9. However, due to transposition of the regional SPH to the smaller study area the design hurricane would have a probability of recurrence of only once in about 200 years in the study area. The paths of the Des H's were located successively to produce maximum hurricane tides along the entire length of the proposed structures. The Des H's are theoretical hurricanes but ones of similar intensity have been experienced in the area…" (19650706, page 156)

The District understood this authorization as providing for project protection against the stillwater surge from the SPH design storm. More precisely, the District interpreted the authorization as providing for project protection against the stillwater surge height associated with the specific SPH parameters for central pressure index and wind speed defined in the Chief's report. That report defined the project SPH as follows:

> "A standard project hurricane, SPH, is one that may be expected from the most severe combination of meteorological conditions that are considered reasonably characteristic of the region. The general SPH that is characteristic for Louisiana … corresponds to one having a frequency of once in about 200 years in the study area … Each of the specific SPH's for the study area has a central pressure index, CPI, of 27.6 inches, and a maximum wind velocity of 100 mph at a radius of 30 nautical miles. These parameters define a hurricane which is similar in intensity to the September 1915 hurricane. Various translation speeds, rates of hurricane forward movement, and paths are necessary to produce SPH effects with maximum winds perpendicular to the shores at different locations in the study area. The occurrence of an SPH for any location in the study area would produce maximum surge heights of 11.2 feet along the south shore of Lake Pontchartrain, 12.5 feet at Mandeville, 11.9 feet in the Chalmette area, 12.5 feet at Citrus and

> New Orleans East back levees, and 13 feet in the Rigolets and the Chef Menteur Pass." (19650706, page 67)

The report recommended the Barrier Plan as the means to secure the specific SPH surge protection described above. However, the report also recognized that to secure SPH protection the Chief would need to have discretion to make post-authorization changes, stating, "… in accordance with the plan of improvement described herein (Interim Survey Report) and as shown on the accompanying plates and with such modification thereof as in the discretion of the Chef of Engineers may be advisable…"

The structure design heights, including freeboard, set out in the original project plan were expected to contain the surge from both the SPH and the PMH. Thus, at the time of project authorization it was thought that no possible storm surge could result in the significant overtopping of planned project structures. This assurance is described in the following passage from the project report:

> "b. <u>Average annual damage prevention benefits.</u> … The projects are designed to protect against flooding from the standard project hurricane (SPH) which has a frequency of about 200 years. The residual damages consist of damages resulting from hurricane occurrences less frequent than once in about 200 years….Within the section of New Orleans located between Jefferson Parish and the Inner Harbor Navigation Canal there would be no residual damage of consequence from hurricanes less frequent than the SPH. The wind tide level on the lake side of the seawall fronting this area would vary with hurricane intensity. However, average water levels between the seawall and the back levee paralleling it would be controlled by the crest elevation of the seawall. The combination of structures, seawall and back levee will provide essentially complete protection from all hurricanes.…" (19650706, page 192)

In addition, the report made specific recommendations regarding project cost-sharing with non-federal project sponsors and related matters. The report specified that, among other requirements, non-federal project sponsors were to:

> "(1) Provide all lands, easements, and rights-of-way, including borrow and spoil-disposal areas, necessary for construction of the project;
>
> (2) Accomplish all necessary alterations and relocations to roads, railroads, pipelines, cables, wharves, drainage structures, and other facilities made necessary by the construction works;
>
> (3) Hold and save the United States free from damages due to construction works;
>
> (4) Bear 30 percent of the first cost, to consist of the fair market value of the items listed in subparagraphs (1) and (2) above and a cash contribution presently estimated at $14,384,000 for the barrier plan and $3,644,000 for the Chalmette plan, to be paid either in a lump sum prior to initiation of construction or in

> installments at least annually in proportion to the Federal appropriation prior to the start of the pertinent work items, in accordance with construction schedules as required by the Chief of Engineers, or as a substitute for any part of the cash contribution, accomplish in accordance with approved construction schedules items of work of equivalent value as determined by the Chief of Engineers, the final apportionment of costs to be made after actual costs and values have been determined…" (19650706, page 32)

In 1965, estimated project costs for areas outside of Chalmette were more than $65 million, and the structural designs included in the recommendation of the Chief of Engineers were about to be modified in response to what was learned during Hurricane Betsy, when many parts of Chalmette were massively inundated. In the aftermath of that experience, District concerns over the ability of the structure design heights to secure the authorized SPH surge protection were communicated to the Division in 1965 only two days after authorization. The District Engineer requested that PMH surge heights be considered for the design of project structures. The Division responded within five days that project authority was "broad enough to allow reconsideration of the degree of protection in light of conditions and data available during definite project studies." (19651104) As will be elaborated on below, the final design grades of project structures were increased in the aftermath of Hurricane Betsy, although that change was not based on the replacement of the SPH with the PMH as the design hurricane, as had been requested by the District.

Project documents report that after Hurricane Betsy the design heights of project structures were raised 1-2 feet to accommodate more-intensive SPH wave action. This was accomplished as a design modification approved at the Division and by the Engineering Directorate of Corps Headquarters. Also, a new project reach, known as the Chalmette Extension, was requested and approved to provide surge protection along the southern flank of the Chalmette area (19661129). This change was made as a post-authorization change request that was approved by the Chief. These changes together increased project cost for providing protection in Chalmette by about $13 million, nearly doubling the original cost for the Chalmette Unit. The text of a 1985 project information sheet recounting these changes states:

> "In accordance with the desires of local interests the project was again modified under the discretionary authority of the Chief of Engineers to provide protection to a larger area in the vicinity of New Orleans known as the Chalmette area. This change incorporated the need to increase levee heights to accommodate the new hurricane parameters. This modification will provide protection for an additional 18,800 acres. The letter report recommending this modification was submitted to OCE on 12 December 1966. The Director of Civil Works by letter of 27 November 1967 informed the Chairman of the Committees on Appropriations of the House and Senate that the above changes in scope had been approved by the Chief of Engineers." (19850101, page 31)

The above passage indicates that the increase in design grades across the project network was deemed needed “to accommodate new hurricane parameters.” However, Hurricane Betsy’s primary parameters for central pressure index and wind speed were very similar to those defined for the project SPH, and those SPH parameters were not recomputed in the aftermath of Hurricane Betsy. Rather, the increase in design grades by 1-2 feet across the project network was based on revisions to SPH wind field patterns made following Hurricane Betsy that led to a re-computation of possible wave action that could accompany an SPH surge; the calculated stillwater SPH surge did not change for project design purposes, however.

Another effect of Hurricane Betsy was to call into question the original determination that, with the planned barrier structures in place at the Rigolets and Chef Menteur passes, the existing local levees along the three outfall canals would provide sufficient hurricane protection. This recognition set in motion over 20 years of debate between the District and local entities over how to best provide project protection along the canals.

By 1968, some local assurances had been secured, some structure designs finalized, and construction had begun in the Chalmette area and along the GIWW and the IHNC. Ongoing refinements were being made to the Barrier Plan design to mitigate some of the effects that motivated the resource agency concerns. Five years later, in 1971, estimated costs for the LP&VHPP were approaching $200 million. This was nearly three times the cost at authorization in 1965. Local sponsors and the District were concerned about local sponsors’ ability to make cost-share payments, and there were still local assurance agreements to be executed (19720908). Meanwhile, some local jurisdictions were objecting to providing LERW (i.e., land rights) for the barriers due to their opposition to the barrier structures, and state bond referenda to provide financial support for the Barrier Plan were being defeated.[9] The Water Resources Development Act of 1974 relieved concerns among local sponsors and the District that project implementation would be slowed by project financing issues (19740307). That act authorized balloon payments at a future date in order to ensure that the local sponsors’ cash payment requirements would not delay project implementation.

The National Environmental Policy Act (NEPA), a federal law enacted in 1969, required the preparation of an environmental impact statement for the project, even though parts of the project were already under construction. As required by this new law, the District filed a draft Environmental Impact Statement (EIS) for the project in January 1975.

The 1976 Budget Justification Sheet (BJS), prepared at the same time the EIS was submitted, reported that project costs were then over $350 million, and that little progress toward project construction had been made in project areas other than the Chalmette Unit (which was then reported to be 45% complete). Five years earlier, the 1971 BJS had reported that the project would be completed by 1978. The 1976 BJS now projected a 1991 completion date. Project implementation was falling behind schedule, in part as a result of project execution delays related to securing project lands and rights-of-way, and

[9] 19721207; 19720908; 19721208

variable and often poor soil conditions were extending the time between levee lifts in order to accommodate settlement.[10]

Hurricane Camille was another significant 1969 event. An internal memorandum from the District Hydraulics Chief reported to the District Engineering Chief that Hurricane Camille was a more severe storm than the PMH for the project area reported in the 1962 Interim Survey Report (19690929). As a result, the PMH and SPH stillwater surges were no longer as close in size as believed to be when they were first defined in 1962, and it was no longer the case that the plan as originally conceived would contain all possible storm surges. This meant that there was an increased likelihood of a large storm surge occurring that would exceed the structure heights designed to contain the SPH as first established in 1965, and then adjusted in subsequent post-authorization changes. Residual flood risk was now higher and involved the potential for more than simply minor wave overtopping of project structures—major flooding and even structure failure was possible because the structures had not been designed with the expectation of sustained overtopping. Also, as a result of the Camille experience, some local sponsors urged more rapid completion of the project.[11] With construction underway, this new knowledge of potential storm surges in the project area was not folded into another project redesign.

One factor in understanding how the District responded to new information such as that provided by Hurricane Camille, as well as new information that would later become available on revised storm parameters, possible surge heights, and subsidence in the project area, relates to the time at which that information became available. For example, when significant design changes were requested and approved under the Chief's discretionary authority following Hurricane Betsy, project construction was not yet underway. At that time the increase in project costs associated with the design change might have appeared readily affordable by project sponsors, and the change involved virtually no delay in project implementation. In later years, however, the accommodation of new information into project design and construction would have required adjustments to ongoing construction activities, as well as retrofitting project components that had already been constructed. Such changes would have significantly increased project costs, and the District would have had to request added project funding at a time when local concerns about project costs were paramount and the overall Corps budget was in decline. Moreover, changes to the project in response to the new information would have further delayed project implementation at a time when local sponsors were expressing increasingly urgent concern for project protection.

[10] Implementation delays also resulted from another environmental law that did not exist at authorization. Section 404 of the 1972 Federal Water Pollution Control Act Amendments created a regulatory review of impacts to wetlands. Resolution of the wetlands impacts for the St. Charles area caused delays in design and execution of that project unit.

[11] Local sponsors may have also believed that the project as authorized would withstand the surge from a storm like Camille, not recognizing that Camille was outside the storm experiences that were used as the basis for the initial project design. 19690929; 19720908; 19760718; 19771123

2.3.7 Construction Delays and the Shift from the Barrier Plan to the High Level Plan (1975-1985)

In 1985, the Chief of Engineers approved a District recommendation to replace the surge barriers with the High Level Plan involving higher levees along the lakefront; other elements of the original Barrier Plan were unaffected by the decision and were incorporated into the High Level Plan. The change was justified by District analysis showing that the cost of the High Level Plan was now less than the cost to build the barriers as redesigned to accommodate environmental concerns. However, the shift was motivated by matters other than cost savings.

While the barriers had strong support among federal and local project sponsors, there also was significant local and national-level opposition.[12] Opposition to the barriers was expressed by state government elected officials, congressional representatives, and various local citizen and interest groups. Some opponents feared the barriers would adversely affect navigation access to the lake, and others cited the possible flooding of the North Shore of the lake when the barrier gates were closed. The operations and maintenance cost of the barriers was also an issue. But the concern that the barrier opponents cited most broadly was its potential adverse effects on the lake environment.

As noted earlier, the first indication of environmental concerns appeared in the comments in the 1962 Interim Survey Report. The Fish and Wildlife Coordination Act required the Corps to receive and consider the comments of the natural resources agencies and to respond to those comments; however, it did not require the Corps to accept and be fully responsive to expressed concerns, and the commenting agencies had no appeal process. Nonetheless, the District was responsive in the sense that it continued to refine the barrier designs to address their operations and effectiveness, to accommodate navigation, and to mitigate their effects on lake salinity regimes and fish populations.

After 1969, the District, because it had already been addressing fish and wildlife concerns, shifted its environmental assessment into the preparation of an Environmental Impact Statement (EIS) for the project as required by NEPA. Hearings held after the draft EIS was filed were a forum for the general public to express opposition to the barriers. The District prepared a revised EIS but the adequacy of that document was challenged in federal court by Save our Wetlands, Inc., an environmental advocacy group. The court review found that the Corps had not met NEPA analysis requirements, citing inadequacies in: 1) the analysis of possible effects of the surge barriers on lake salinity regimes and habitat, 2) the economic evaluation of project alternatives, and 3) the financial capabilities of local sponsors. In December 1977, the court placed an injunction on further construction of the project (19771230). Later, in March 1978, the court lifted the injunction for all project elements except the barrier structures at Chef Menteur Pass, the Rigolets, and the Seabrook lock, noting that the non-barrier elements of the plan had no adverse effects on the lake and thus could move forward. However, the court injunction effectively placed on hold certain project work on the lakefront levees and on

[12] 19720908; 19750222; 19760405; 19770227; 19771028; 19770714; 19780309

the outfall canals, since their design and construction would be influenced by the final resolution of the proposed barriers.

The District, in the BJS for years 1978-1984, continued to report that the barrier complexes were going to be modified to accommodate the concerns of the court and the opponents of the barriers, and continued to defend the need for the barriers as part of the authorized project. Nonetheless, during this same period an alternative High Level Plan (that is, higher lakefront levees to protect the lakefront area from surges) was being designed and evaluated.

In 1978, the District, in consultation with the Division, initiated an engineering and environmental reevaluation of the Barrier Plan and the alternative High Level Plan.[13] Of note is that the scope of the analysis in response to the injunction was limited to only those changes needed to prevent damage from surges along the Lake Pontchartrain shore, either by modifying the barriers or replacing them with higher lakefront levees; other elements of the Barrier Plan away from the lakefront were not reevaluated (19800600). During this period, the expected completion date for the overall project continued to be moved out in time, project costs were increasing, and those local sponsors who had remained steadfast in support of the barriers became more open to the alternative High Level Plan. Meanwhile, the District itself was moving towards a recommendation to replace the Barrier Plan with the High Level Plan.[14]

The District reported to Corps Headquarters in July 1984 that the Barrier Plan was no longer the District-preferred plan.[15] The change to the High Level Plan was authorized by the Chief of Engineers in 1985 under his discretionary authority. A matter that was not addressed in 1984 was the best way to address surges into the outfall canals; this was particularly important since barriers would no longer be used to dampen storm surges into the lake. A debate between the District and the OLD (the local sponsor for project works in Orleans Parish) over treatment of the outfall canals would persist until finally resolved by congressional action in the early 1990s.

The District did not come easily to the recommendation to switch to the High Level Plan, and so the time from the filing of the EIS to the final decision to abandon the original Barrier Plan extended for nearly six years. During the time that the project reanalysis was being completed, total project costs for the barrier alternative increased significantly due to general price inflation and design changes made to mitigate the environmental and other adverse effects of the barriers cited by critics. Total project cost was $378 million at the time of the court injunction (1977) and was $600 million by January of 1984. The Government Accounting Office (GAO), in a 1982 report (19820817), noted (as it had in its 1976 report on project status) that project costs were escalating at rates that could be unaffordable to local sponsors. As part of the project reanalysis study, local sponsors

[13] 19780424; 19780822; 19780911

[14] 19760406; 19770401; 19770718; 19800409; 19801008; 19801215; 19810723; 19820817; 19840412; 19850207

[15] 19840425; 19840808

asked the District to identify and evaluate another project plan providing “100-year protection”—a lower level of protection than SPH surge protection.

Meanwhile, construction of other project structures was falling behind schedule at the same time that project costs were escalating rapidly. The 1971 BJS predicted that the project would be finished in 1978; however, in 1982, the New Orleans East Unit (which includes the Citrus and metro New Orleans areas) was reported to be 44% complete (the same as that reported in 1978, the year in which the court injunction affecting this area was modified), and the Chalmette Unit was reported to be 33% complete (this was a lesser completion percentage than was reported in the year that the court injunction was modified). Construction in the New Orleans West Unit (which includes Jefferson Parish and St. Charles Parish) and on the barriers had not yet begun. (Map 2-3 shows the geographic extent of the project “units” used for the reporting of project completion status in the annual BJS). The start of project work along the lakefront was delayed until resolution of the fate of the barriers.

The GAO in 1982 reported not only the concerns of local sponsors about increasing project costs, but also their frustrations with the pace of project implementation. However, the District did not need a GAO report to be made aware of these local concerns. Box 2-5 reproduces part of the text of a 1978 letter from the OLD to the Louisiana Department of Transportation and Development expressing its concerns about project delays, costs, and affordability. Box 2-6 reproduces part of the text of a 1980 letter from the OLD to the District Engineer expressing urgent concern that the project plan be resolved.

The GAO attributed project implementation delays in part to poor internal management within the Corps. The District response to this GAO critique provides clear insight into how the District’s leadership viewed its efforts as of the fall of 1982. That response was provided in a memorandum from the District Chief of Engineering to the Division (19820908), portions of which are reproduced in Box 2-7 (these District comments were forwarded on to Corps Headquarters in the official Division response to the GAO report). In that memorandum the District Chief of Engineering agreed that there had been project delays, but vigorously defended the progress that had been made to date. The memorandum illustrates District sensitivity to the criticism by GAO and project local sponsors that District planning and budgeting procedures were the cause of delay in project implementation. That criticism was rejected on several different grounds that were repeated in the official ASA(CW) response to the GAO report that would come later (19831109). Nevertheless, ongoing concerns about project implementation delays became part of the context for District decision-making after 1982, as choices were made to finish the project as currently budgeted before seeking post-authorization changes.

Box 2-5: Orleans Levee District Expression of Concerns About Project Delays, Costs, and Affordability

Letter from the OLD President to the Louisiana Department of Transportation and Development, dated January 4, 1978 (19780104)

"Federal Judge Charles Schwartz has issued an injunction against further work on the LP&VHPP until the US Corps of Engineers prepares a supplemental environmental impact statement. This supplemental EIS will probably require a minimum of two years to complete and I feel confident that upon its completion we face another series of lengthy court suits before any further work can be done on the major portions of this protection plan for Orleans, Jefferson, St. Bernard, St. Tammany Parishes and other parishes that surround the lake.

This project was originally estimated, in 1965, to cost approximately $85 million. Because of construction delays and inflation the project's cost is now estimated in excess of $400 million.

St. Tammany Parish has refused to pay its share of the project and Governor McKiethen, by Executive Order, assigned this share of the costs of the protection plan to the Department of Public Works. The Pontchartrain Levee District has exhausted its funds that were available for the project and Governor Edwards has signed assurance with the USCE that the state will pay for portions of the project. The Lake Borgne Levee District is in arrears on its share of the project and it is questionable whether it will be able to make its payments.

The Orleans Levee Board's share of the project approximates 67% of local participation. As of this date, if there are no further delays in the project, we estimate that we will have just enough money to pay our share, which at this time is estimated to be $88,380,000. Any delay which will inflate the cost of the project in excess of the $400 million now estimated will place the cost beyond our ability to pay.

What this probably means is that the project as it has been developed by the USCE by Congressional mandate is no longer viable…"

The decision to switch to the High Level Plan was made against this background, and that decision was presented to the ASA(CW) on Nov 10, 1982. However, a question that remained was whether the decision to approve the change fit within the discretionary authority of the Chief of Engineers. If it did not, then a new congressional authorization would be required. At the time, the standing view of the District and others, including the ASA(CW), had been that any replacement of the Barrier Plan with some other plan would require new authorization (19821117). To seek new authorization would mean further delay in project implementation, especially given that there had not been a Water Resources Development Act authorization bill since 1976, and there was no prospect for a bill on the horizon (the next WRDA would not come until 1986). The Corps Chief Counsel, in March 1983, after consultation with the Division, offered an opinion that became the basis for approving the switch to the High Level Plan as a post-authorization change (PAC) in February 1985 under the discretionary authority of the Chief of Engineers. The opinion rested on three determinations that followed from the limited scope of the proposed project changes. Specifically, the Chief Counsel found that the change would not involve: "a) a material alteration of the function of the project; b) a material change in the scope of the authorized plan of improvement; and c) a change in legal relationships" with non-federal sponsors.[16]

Box 2-6: Orleans Levee District Expression of Urgency for Resolution of the Project Plan

Letter from the OLD President to the Corps New Orleans District Engineer, dated November 20, 1980 (19801120)

"On September 24, 1980, Orleans Levee Board staff members attended a briefing on the LP&VHPP. During the course of the day ample evidence seemed to be surfacing regarding the ability at this time to make a decision regarding the barriers. The numbers postulated by your staff apparently make a case for the high level plan; i.e., a) optimal barrier plan -- $445,089,000 to $552,465,000; b) optimal high level plan -- $416,000,000.

The latest official time we have been given for the EIS completion is December of 1982, however we understand it could slip at least a year. This means not only 24 to 36 months of cost escalation for whatever project is finally approved and constructed, but 24 to 36 more months of environmental studies needed to complete an already staggering EIS cost in which we have to share.

As the assuring agency for Orleans Parish, the president of the Board having a responsibility to the local taxpayers and also a taxpayer I urge you to seek a speedy conclusion to what appears to be an impasse in deliberations concerning the ultimate fate of the LP&VHPP.

We are now fifteen years past Betsy and while we can point to the many improvements in the flood protection system, it is inconceivable at this time that we still don't know what the final product will look like. I know there are many reasons for this but I might add that we are three years past Judge Schwartz's decision with what looks like another three years before we'll know.

More importantly than the soaring costs of both the project and EIS is the fact that many individual projects hinging on the outcome of the EIS are not being done and the ultimate protection the project is supposed to afford the taxpayer is pushed further and further away.

It is getting difficult to explain to the concerned citizen why it takes so long to come to an answer and how this translates into delayed protection.

The National Weather Service just unveiled the results of their SLOSH (Sea, Lake and Overland Surges from Hurricanes) model forecasts. The results are freightening [sic] to say the least. I don't feel protection should wait. We must get on with a plan of action. It is my feeling that if there is a possibility that the answer in three (3) years would be the same as one that could be issued today, it makes no sense to proliferate the cost of the project and the EIS under those conditions. I sincerely hope that the gravity of the situation will provide the impetus for a concentrated effort to reach a decision now if that is possible…"

[16] 19821124; 19830106; 19830223; 19830302; 19830718; 19830804; 19840829

Box 2-7: Excerpts from the Response of the District Chief of Engineering to the 1982 GAO Report

"… The GAO report suggests that the Corps has not prosecuted the project with the vigor and effectiveness that it deserves, and that as a result, the metropolitan New Orleans area does not presently enjoy the degree of hurricane protection that it should. While we regret that progress has not been faster, and view with deep concern the residual threat to the area after 17 years of work on the project, we don't believe that the report—or more importantly the record, support such findings. The project was authorized and funded for design in the same fiscal year (1966), a rarity among civil works projects. Designs were pressed with vigor and expedition, and the system was exploited, bent, twisted and innovatively interpreted to permit the earliest practicable completion of design and start construction. The resources of local interests, particularly the Orleans Levee District, were pressed into service to permit construction of the project to proceed before Federal construction funds were made available. As a result of these efforts, when Hurricane Camille visited Breton Sound in 1969—less than 4 years after project authorization—and generated stages in the critical Industrial Canal-MRGO area within 6 inches of those of Hurricane Betsy in 1965—no significant flooding occurred, and it is estimated that $100 million in damages, or about the total estimated cost of the project at that time, were prevented….It must be borne in mind that circumstances have influenced design and construction progress in very different ways on the barrier and levee portions of the project. The former has involved extremely complex issues of public policy, issues which raised strong emotions and ultimately spawned legal action. Progress on the remainder of the project has been influenced by those concerns more readily dealt with and solved in technical engineering terms. While progress on the barriers has been agonizingly slow for reasons which are both obvious and set forth in the GAO report, this is not true of the remainder of the project, which remainder is now 70% complete….Schedule delays on the project have not, in the main, been driven by factors amenable to amelioration by more intensive management. The prominent cause for schedule changes has, in fact, been an increased appreciation of the nature of foundation conditions in the area, and the corresponding escalation in the number of lifts and intervals between successive lifts required to achieve final levee grades in some areas. As the GAO report and the record reflect, other factors which caused schedule delays include non-receipt of rights-of-way and insofar as the barrier portion of the project is concerned, environmental matters and litigation. But insofar as the non-barrier portions of the project—and particularly those portions exclusive of the St. Charles Parish levee—are concerned, these factors were not important drivers of schedule delays for that portion of the project prior to that time. The recommendations of the GAO report are very broad and certainly the objectives they are intended to achieve is [sic] desirable. However, many of those objectives comprise procedures which have been ongoing since the authorization of the project. We are, for example, 'working closely with local sponsors to acquire the necessary rights-of-way, easements, and construction priorities for the remaining portions of the project.' Insofar as the high level plan is concerned, this work now includes the elucidation to local interests of the impacts inherent in changing from the barrier to the high-level plan; exploring with local interests the implications of those impacts; and eliciting their views and concerns. We are currently moving forward with the change in plan as rapidly as procedural requirements, and sound engineering, economic, and environmental considerations will permit. We expect to provide recommendations regarding a change in plan to higher authority this December. Approval of such recommendations will remove any constraints to project completion in this regard. In the meantime, we are pursuing completion of those features common to both the high level and barrier plans, and as the GAO report notes, preparing design memoranda for those elements of the high level plan which differ from the barrier plan." (19820908 and 19820910)

The project record reviewed in this section shows that the switch to the High Level Plan involved those limited project changes that were necessary to move the project forward. The reanalysis of the project following the 1977 court injunction against the barriers was limited to the project lakefront area and to how high levees there would need to be to protect against the stillwater surges in the lake that would be realized without the barriers. The need to consider project protection for the outfall canals was recognized and proposed for future study. For the reanalysis, the stillwater surges along the lakefront were calculated with different models than had been used for project authorization, but the original 1962 SPH parameters were used, even though the NWS in 1979 had made a slight downward revision of the SPH central pressure index (more severe). The 1984 Reevaluation Report acknowledged but did not use the revised SPH parameter. Finally, the switch to the High Level Plan involved no material change in the financial or legal relationship with the local sponsors.

Map 2-3: Project Units for which Percent Completion was Reported in the Annual Budget Justification Sheets

2.3.8 The Outfall Canals: Costs and the Congress (1965-1993)

The three outfall canals (17th Street, London Avenue, and Orleans Avenue Canals) front on Lake Pontchartrain and penetrate southward into metro New Orleans. These canals are part of the New Orleans drainage system that had been constructed beginning in the latter part of the 19th century to remove rainwater from low-lying areas in metro New Orleans. In general, the system works by pumping interior drainage into the three canals. As the pumped water causes head in the canals to increase, the water flows into the lake. This system requires walls of some height along the canals, pump stations at the canal heads and at other places along the canals, and unobstructed canal mouths at the lakefront.

The 1965 LP&VHPP authorization specified that the development and maintenance of interior drainage works was to be a non-federal responsibility. However, during hurricane events these canals could act as conduits for surging lake water to enter the city. Accommodating the local imperative for reliable interior drainage, while preventing surging water from entering the city, was an ongoing challenge in reconciling local and federal interests.[17]

The District determined soon after Hurricane Betsy that the existing local levees along the outfall canals were not sufficient in either grade or stability to contain SPH surges even with the planned lake barrier structures in place. The District, working in consultation with local agencies that had responsibility for interior drainage, began to discuss two basic alternatives for providing hurricane protection at the canals—raising and strengthening the existing canal levees (termed "parallel protection"), or installing floodgates along the canal mouths at the lakefront (termed "frontage protection"). New and relocated pumps also might be part of a solution. In the 1970s, the District developed protection alternatives for the outfall canals, but detailed development and consideration of those alternatives had to wait for the final design of the barriers. Challenges to the barriers delayed the selection of an alternative for the lakefront, and they also delayed a decision on the outfall canals. When the District in the 1984 Reevaluation Report recommended the High Level Plan, it noted that a solution to the outfall canals was still being developed, but indicated the District preference for frontage protection.

The District developed a butterfly valve gate concept as a means of providing frontage protection that also would allow the Sewerage and Water Board (SWB) of New Orleans to continue pumping rainfall into the canals during storms until the lake rose to the point where lake waters began flowing back into the canals, at which time the gates would close automatically.[18] The Corps Waterways Experiment Station did model testing of the concept to assure its viability. With the butterfly gate frontage alternative, the District felt that the SWB would be able to pump rainfall into the canals for as long as possible during storm events, but any modification to the canal levees and pump system for interior

[17] 19770819; 19781116; 19791128; 19800825; 19821207; 19830606
[18] 19830624; 19831128; 19831212; 19840620

drainage would be considered a local responsibility and expense. However, the parallel protection plan was strongly preferred by SWB and the OLD.[19]

Two policy interpretations influenced the District's recommendation to pursue the frontage plan and its resulting position on cost distribution. First, by Corps policy set by Headquarters in the 1980s, the District was required to select the most cost-effective alternative to address the surge protection project purpose. Analysis contained in the 1984 Reevaluation Report indicated that frontage protection was a significantly less costly means of preventing overtopping of the canal levees during a storm event than raising and strengthening the canal levees under the parallel protection plan. Second, internal drainage was understood to be a local responsibility in accordance with project authorization language.[20] Since the frontage protection plan was less expensive, parallel protection was described by the District as a "betterment," meaning that the incremental cost for its implementation (over the cost of the least-cost butterfly gates plan) would be a local financial responsibility. For reasons unique to the 17th Street Canal, the District found that parallel protection would cost approximately the same as frontage protection; accordingly, the District recommended parallel protection for that canal as preferred by the local sponsor (the OLD). But the District continued to recommend frontage protection for the London Avenue Canal and the Orleans Avenue Canal. There is no evidence in the project record that the District felt that there were differences between the approaches in providing reliable surge protection.

At the same time, the SWB and the OLD made it clear to the District that frontage protection was unacceptable to them, and they continued to push for the parallel protection alternative. These local agencies viewed the butterfly gates plan as incompatible with their interior drainage responsibilities, and they also questioned whether the gates would always work properly during storm events. Also, costs were a matter of great concern. The SWB and OLD were already planning to drive sheet pile along the existing levees of at least one canal to increase interior drainage capacity. Thus, if the gates were installed as part of the LP&VHPP, then the OLD as the local sponsor would be responsible for 30% of its cost, and the SWB and the OLD would bear the full costs of improving the canal levees for interior drainage purposes (as well as the costs of any local decision to install auxiliary pumps at the canal mouths to allow for continuous pumping when the gates were closed during storm events). From the local perspective, the parallel protection plan was the best way to address both hurricane protection and interior drainage objectives and secure 70% federal funding toward those ends. However, the District position was that if parallel protection were implemented as the locally-preferred plan, then the federal financial contribution would be limited to 70% of the costs of the least-cost butterfly gates frontage alternative. There is no evidence that the local sponsor felt that there were differences between the two approaches in providing reliable surge protection.

[19] Another alternative that would accommodate both interior drainage and surge protection, which included the butterfly gates and pumps relocated to the lakefront, was the most costly option, and one that would require the greatest financial cost to local entities; that alternative was mentioned in the 1984 report but was never developed further since it was deemed to be "prohibitively expensive."
[20] 19701113; 19760130; 19831212

The OLD pursued a political strategy to persuade Congress to authorize the parallel protection plan and require federal assumption of 70% of total plan cost. The Congress, in the WRDA of 1990 (19901027) and the Energy and Water Development Appropriations Act of 1992 (19910817), directed the Corps to implement parallel protection and made the federal government responsible for 70% of that cost. The result was to shift roughly $45 million for the completion of the parallel protection plan (as costs were estimated in 1992) from the local sponsor to the federal government. The administration considered that action to be in violation of its policies on project cost-sharing, and subsequently did not budget for parallel protection throughout the 1990s; the Congress had to add the necessary federal funds in annual appropriations bills each year, which the District then used to implement the work.[21]

Cost and affordability concerns also influenced project design decisions other than the choice of parallel protection over frontage protection. The OLD, as the local sponsor, was responsible for obtaining the required rights-of-way for hurricane protection works at the canals. Cost and local acceptability dictated the choice of primarily I-walls for parallel protection at the 17th Street Canal and London Avenue Canal, since I-walls allowed for greater design elevations without the need to acquire significant additional lands, easements, and rights-of-way as would have been the case with levees.

I-walls require the driving of sheet pile walls below ground. Parallel protection designs, whether developed by District staff or contractors working for the District or the OLD, were expected to follow existing Division guidance for I-wall design. That guidance would, after taking into account loadings, soil conditions and other matters, dictate I-wall sheet pile of certain penetration depths, thickness, and strength for different cases. Deeper, thicker, or stronger sheet pile would come at increased cost.

The so-called E-99 Sheet Pile Wall Field Load Test was initiated by the Division in the mid-1980s after consultation with the District. The test was motivated by an interest in determining whether existing design guidance for I-wall sheet pile penetration depths could be modified to accommodate cases where loading is short-term (as would be the case during a hurricane) without compromising I-wall reliability, while at the same time reducing construction costs. A justification offered for the test was that an anticipated extensive future use of I-wall structures for hurricane protection projects throughout the region could have significant cost implications in an increasingly tight budget environment.[22] The test results were used to conclude that, beyond a certain sheet pile penetration depth, there was little additional increase in the reliability of the I-wall structures under short-term loading conditions (19871223). This interpretation ultimately led to new Division guidance on sheet pile penetration depth requirements for hurricane protection, resulting in significant project cost savings.

The District and Division were not alone in their concern over the cost implications of I-wall sheet pile design criteria. The OLD in 1986 rejected an I-wall design developed by

[21] 19920129; 19920429; 19921228
[22] 19841029; 19841113

its contractor for the London Avenue Canal that was developed using then-existing Corps geotechnical design standards, which the OLD deemed to be "too stringent." (The London Avenue Canal designs based on those standards specified sheet pile penetration depths significantly deeper than the depths of the sheet pile walls that were eventually installed at that canal). The cost of the canal design to meet Corps standards was of paramount concern to the OLD, which expressed concern that its available budget for the London Avenue Canal was considerably less than the cost of the 1986 design (19900050, page 6).

2.3.9 Accelerating Construction in a Budget-Constrained Environment (1985-2005)

Project construction moved ahead following the long delay that accompanied the dispute over the Barrier Plan. In 1984, the BJS reported that the Chalmette Unit and the New Orleans East Unit (that includes metro New Orleans except for the outfall canals), were about 70% complete, but there had been no construction progress anywhere else. By 1991, both of these project units were reported to be nearing completion (but for reasons that are not clear to the study team, these units were never reported as 100% complete up to the present day).[23] In 1991, construction in the New Orleans West Unit was just getting started; that unit was reported to be 50% complete by 2001 (20010403), and 65% complete by 2005 (20050207).

This project construction occurred in a challenging fiscal environment. After 1984, external forces that were constraining the Corps national budget, and local sponsors' concerns about their ability to afford the project, kept a focus on expeditious completion of the project within the budget estimates provided in the BJS. The Corps national

[23] Perhaps the reported incomplete project status is partly related to the requirement for local assumption of maintenance for completed works. The Local Cooperation Agreements (LCA) developed for each local sponsor of the LP&VHPP specify that the local sponsor is responsible for maintenance after construction of the project, or a functional portion of the project (project feature), has been completed within their jurisdiction. A 2005 report by the Government Accountability Office reported that, according to the Corps, "most of the levees included in the Lake Pontchartrain project had been completed and turned over to the local sponsors for operation and maintenance." In interviews conducted for this study, District Operations staff indicated that the District has written numerous "turnover" letters to local sponsors for individual project features, such as specific levee reaches. The authors of this report reviewed several dozen interim notification and final turnover letters. The interim notification letters inform local sponsors of partial completion of a project feature, such as when the first or second of three planned levee lifts have been completed. These letters also say that formal notification of turnover to local sponsor for maintenance will occur upon completion of the project feature (some notification letters also request that local sponsor perform interim maintenance on a levee reach prior to the next planned lift, such as grass mowing and prevention of wild growth). The final turnover letters inform the local sponsor of completion of a project feature when no additional work is planned for that piece of the project. They specify that, in accordance with the signed LCA, the local sponsor is now responsible for maintenance of that project feature, where "maintenance is construed as keeping all completed works in first-condition to serve the purpose for which they were designed." It is worth noting that, in interviews, District Operations staff indicated that some local sponsors have verbally refused to assume maintenance responsibilities for completed project features until the entire portion of the project within their jurisdiction is completed. And interviews with local sponsor representatives—conducted for a separate report on local sponsor project roles and considerations commissioned by IWR for the HPDC (20060800)— indicated that, the local sponsors had accepted completed project features (apart from major water control structures) for "grass and weed control" only.

construction budget was holding steady in nominal terms, as the estimated costs of project completion rose from $80 million at the time of the 1965 authorization to over $800 million by 1982 (although by 1989 the cost estimate had settled at about $700 million and remained at around that level afterwards). Difficult budget choices had to be made to allocate limited federal funds among projects across the nation and for projects within Louisiana. During the 1980s and 1990s, when the Corp's national Construction General (CG) budget was static in nominal dollars, the Louisiana delegation secured a significant share of those limited funds. Louisiana's share of the federal civil works budget grew after 1980 to as much as 17% of all federal CG spending. It then declined to a smaller percentage in the mid-1990s. These funds allowed the LP&VHPP to move ahead. However, until 1994, navigation projects accounted for roughly 75% of all federal CG appropriations spent in Louisiana, mostly for the Red River Waterway. The priorities appeared to change toward flood and storm protection after 1994, but total federal funds going to the state also fell.

Local sponsors for the LP&VHPP also faced significant budget pressures to meet the 30% cost-share requirement, and after the injunction against the barriers, wanted the promised protection provided without further delay (19780104). This concern for delay was especially strong in areas along the lakefront that had to wait for the resolution of the barriers before designs for protective works could even be prepared. The cost concerns cited in the preceding section did not diminish with time. Any efforts to set tax rates, sell bonds, or secure grants to pay for an expected cost-share requirement would be wasted if there was going to be continuing cost escalation, even if the main cause was inflation.

In fact, some local sponsors wondered whether District designs for the project were excessively costly, even to the extent of questioning whether the SPH surge was a real possibility. Some argued that the District analysis had exaggerated the threat of hurricane-induced surges from the lake.[24] The District found itself defending the possibility of lakefront flooding and the SPH protection standard as it had been defined for the 1965 project authorization.[25] In one instance, a local sponsor asked for a District analysis of possible project cost savings if the SPH surge protection standard were relaxed.

The concerns over federal and local funding constraints recognized by the District were occurring in the context of a national debate over guiding principles for funding and justifying water development projects. At the national level, the 1986 Water Resources Development Act (WRDA) came at the end of a decade in which no new projects were authorized. The principal reform of the 1986 WRDA was its requirement for increasing local cost responsibility for project studies and implementation. Accompanying this requirement was an emphasis on greater sharing of decision responsibility with local cost-sharing partners. The planning and decision-making for the LP&VHPP had always required significant local cost contributions, so the 1986 WRDA did not represent significant change in that regard. And the 1986 WRDA also raised attention to

[24] 19760405; 19760308, paragraph 24
[25] 19771123; 19780404; 19780822; 19780707

environmental compliance, but the LP&VHPP project had already been subject to intensive environmental reviews in earlier years.

The 1986 WRDA ushered in another fundamental change in federal policy toward the Corps of Engineers program. Specifically, the act provided a congressional sanction to what had been an aggressive program of administration budget oversight on the Corps program. This oversight program had begun with the Carter administration and was continued through the Reagan and George H. W. Bush administrations when many decisions on the LP&VHPP were being made.

An increase in administration attention to justifying the federal interest in water projects began with the Carter administration revisions to the *Principles and Standards for Water and Related Land Resources Planning* (P&S), and that administration's proposal that the revised P&S be published as a rulemaking in the *Federal Register*. The revised standards were especially stringent on project formulation (sizing) and justification, stressing the requirement for rigorous adherence to specific economic benefit and cost calculation procedures, and the need to justify project size and cost in terms of the project's contribution to National Economic Development (NED), to Environmental Quality (EQ), or to a combination of the two. The Reagan administration chose to issue the resulting standards as guidelines instead of rules, and to limit the federal interest test to a project's contribution to NED (i.e., net economic benefits), consistent with meeting all applicable environmental laws. The result was the *Principles and Guidelines for Water and Related Land Resources Planning* (P&G).

The LP&VHPP had been designed to withstand the surge of the 1962 SPH (akin to the SPF) and not to maximize net economic benefits. By the time the P&S was being revised, and then later when the P&G was put in place, successive administrations stressed what they deemed to be needed for a compelling project justification. A Carter-era report reflects doubts about the fiscal, economic, and environmental justification of the SPF as a design standard (19790100), and suggests a rule of maximizing NED as the preferred way to choose the degree of protection to be provided by a flood damage reduction project. And Corps Headquarters guidance that originated in the Reagan administration extended this skepticism into new evaluation requirements that challenged the logic of budgeting for project protection against a design storm, unless compelling economic and non-economic arguments were made. [26] By the mid-1980s, more stringent analytical requirements for the application of risk assessment methods were being developed and might have been expected to accompany any evaluation requesting more project funding.[27] It was against this background of concerns for project delays and cost, and increased emphasis on justifying project changes that the District had to make decisions about how it would respond to new information relating to the DOP that could be provided if the project were completed at a cost no more than that provided in the current BJS estimate.

[26] 19840227; 19840608

[27] 19860416; 19861104; 19861208

The 1985 “datum benchmark” decision that has been highly publicized after Katrina was made in the context described above.[28] Project construction to that point had relied on the 1964-era local benchmark elevations for the National Geodetic Vertical Datum (NGVD) to ensure that structure elevations were built to intended design grades. After the National Geodetic Survey adjusted benchmark elevations in the area (reflecting subsidence in the area over the previous twenty years), the Division asked the District to develop a course of action for incorporating changes in vertical control benchmark elevations in the District’s projects and studies. The District Chief of Engineering, in a letter reply on August 7, 1985, announced the District’s intention not to switch to the latest published benchmark elevations for remaining project construction based on the argument that to do otherwise would result in varying levels of protection across the project area. Other parts of the policy statement suggest that this policy was motivated largely by concerns relating to the impracticality and cost of modifying already-constructed project features.

The 1985 datum benchmark decision exacerbated a more fundamental error with respect to the District’s use of the NGVD as the reference point for project construction. The NGVD datum was originally established in 1929 using mean sea level (MSL) measured at 21 tide stations in the U.S. (including one in the Gulf Coast, but not in Louisiana) and five stations in Canada. Project structures were constructed relative to this datum under the erroneous assumption that this datum corresponds with local MSL, the reference point used for the design of project structures. However, the datum was actually lower than local MSL; the result was that project structures were constructed to grades that were below intended design heights.

Project records indicate that, by 1993, the District had been alerted to the datum error. Nevertheless, project construction moved forward using NGVD, and according to existing designs to provide a degree of protection that could be secured within the budget reported in the current BJS, and within the existing revenue capabilities of the local sponsors. The annual BJS continued to report that the project, once completed as budgeted, would provide SPH protection, even though the datum error and benchmark decision made that unlikely.

Meanwhile, as outlined earlier, in 1979 the National Weather Service (NWS) concluded that storms with parameters more severe than the SPH were more likely in the project area than previously thought possible. The NWS also reported that the parameters of Hurricane Camille (1969) were more severe than those of the PMH for the project area reported in the 1962 Interim Survey Report. (This had already been determined by the District.) This meant that overtopping of project structures designed in the late 1960s would be more likely during the project life.

By the early 1990s, the District recognized that accumulated new knowledge—including that related to subsidence, sea level rise, revised SPH central pressure and more severe PMH, as well as advances in computer surge modeling and understanding—meant that the project that could be constructed within the estimated cost might not provide the authorized degree of protection (19931100). In 1993, the District contracted with the

[28] 19850807; 19850916

Corps Coastal Engineering Research Center (CERC) to perform a pilot model study to assess the impacts of changes in the SPH central pressure index parameter on design stages, and the effects of the relationship between local MSL and NGVD with respect to the required elevations of structures designed to prevent overtopping. The CERC study used an early version of a more sophisticated long-wave surge model, the Advanced Circulation (ADCIRC) model, to validate the original storm surge estimates for the project under the original SPH parameters. That application of the ADCIRC model reinforced findings using the 1980s-era WIFM and SLOSH models indicating that the 1962-era surge estimates may have underestimated SPH surges along the IHNC and GIWW corridors and the eastern portion of Chalmette. With respect to the 1979 revised SPH central pressure index parameter, CERC used the ADCIRC model to conclude that the change produced an increase in SPH surge heights of 1-2 feet for certain storm tracks under one set of assumptions, while under another set of assumptions the new SPH parameter had little effect on previously estimated surges. The CERC study also concluded that local MSL was approximately one foot higher than NGVD. Based on these findings, the CERC recommended a thorough hydrodynamic modeling of the basin and reevaluation of project protection using the ADCIRC model (19930000).

The District, in 1994, citing the CERC pilot study findings and recommendations, requested permission from the Division to conduct a numerical model study of existing project protection using the ADCIRC model and modern data (19940920). However, at that time the District was not sufficiently confident in the validity of the early ADCIRC model results, and noted problems with the model related to its inability to reproduce the surges associated with known storm events. Accordingly, the District decided to pursue further model refinement and testing before applying the model for a project reevaluation that could form the basis for justifying a PAC or a new authorization for changes in project design and construction. That is, the District felt that a refined and better validated model would be required for justifying any proposed project changes to higher authorities. Between 1995 and 2004, the District spent $1-2 million on ADCIRC model refinements and validation.[29]

By about 2000, the ADCIRC and other available surge models were being applied by others to highlight in general terms storm hazards faced by the region, given what was then known about storm parameters. Newspaper reports on hurricane dangers in New Orleans were publicized in June 2002 in a five-part series ("Washing Away") published by the New Orleans *Times Picayune*. Various other professional and popular press articles made the same arguments relying on the ADCIRC and other surge models.

At the same time, there was another, broader-scale District assessment of hurricane threats underway. After Hurricane Georges in 1999, the State of Louisiana strongly supported, and through its congressional delegation helped secure, federal authorization and appropriations for the so-called “Cat 4/5” reconnaissance study to establish if there was a federal interest in entering into an agreement with one or more local sponsors to determine the feasibility of providing upgraded hurricane protection for Southeast Louisiana. The 2001 Energy and Water Appropriations Act included $100,000 to initiate

[29] 19950000; 19990400; 20040131

a General Reconnaissance Study specifically for “category 4/5” hurricane protection in the region. At that time, the original project SPH parameters were being categorized as reflecting a “fast moving, category 3 storm,” so in effect this study recognized that storms with parameters more severe than the originally authorized SPH parameters could occur.

The reconnaissance study report completed in 2002 provided justification for conducting a more detailed feasibility study of upgraded hurricane protection for Southeast Louisiana. Soon after, the LA Department of Transportation and Development signed a Letter of Intent to sponsor the feasibility study (a requirement that had been put in place by the 1986 WRDA). More specifically, the letter indicated the state’s intention to form a coalition of Southeastern Louisiana communities to provide the local sponsor share of the feasibility study costs. The reconnaissance study phase received additional funds from the administration and the Congress, and was expanded in duration during later budget cycles. The District continued work on the reconnaissance phase into 2005, and was still working on a project management plan for a possible feasibility study and negotiating with the state regarding local sponsor cost-sharing for the study.[30]

In 2002, District representatives met with state and local officials to review the content, cost, and duration of a detailed Cat 4/5 feasibility study and to solicit local sponsors for that study. Many local officials expressed frustration that an array of authorized hurricane protection projects in the region had not yet been completed, and noted that securing the federal and local funds to do so is an ongoing struggle. They argued that, given that areas such as St. Charles Parish and the West Bank now have very limited protection, the District, the state, and local sponsors should concentrate on finishing already-authorized projects before embarking on a new feasibility study that would draw resources away from current projects, take up to seven years to complete, and conclude with a recommended project that, if authorized, would take decades to fully construct. A common thread throughout all the comments was lack of money. Local officials maintained that they alone could not come up with the resources needed to cost-share the feasibility study. And even if state funding for the study were secured, project implementation would be cost-prohibitive for the state and southeastern Louisiana communities. The final speaker noted that the only way that such a multi-billion-dollar project could move forward would be for the federal government to assume full project financing.

During this time period the District continued its support for ADCIRC model refinement for eventual use to reevaluate project protection. By 2005, when Katrina made landfall, the limitations of the LP&VHPP project were generally understood in the District. This said, it is notable that even as model development funds were being provided, the recognized deficiencies in the project warranted only a brief mention in the project budget justification sheet. Beginning in 2003, the BJS included the following note:

> “The project was designed in the 1960s, and a reanalysis was performed for part of the project in the mid-1980s. Continued coastal land loss and settlement of land in the project area may have impacted the ability of the project to withstand the

[30] 20010130; 20010200; 20010309; 20020619; 20020628; 20020701; 20020805; 20020816

> design storm. Refinement of existing computer models to assist in determining the impact of these environmental changes on the project will continue." (20020204, page 4)

However, this wording is not included in the main BJS justification statement for the project, which still promises that the project, once completed, will provide SPH surge protection.

2.4 In Retrospect

Ten years of planning preceded the 1965 authorization of the LP&VHPP. At authorization, the project was expected to provide protection from the stillwater surges and wave action generated by the Standard Project Hurricane (SPH). Once authorized, design and construction lasted 40 years, and when Katrina made landfall in August 2005, the budget justification sheet for that year reported that the Chalmette Unit was 98% complete and the New Orleans East Unit (that includes metro New Orleans) was 92% complete. These were the areas within the LP&VHPP where structures were overtopped and where breaches on outfall canals occurred before water reached the tops of the floodwalls.

With the benefit of hindsight, several engineering reviews of the project's performance during Katrina have concluded that project engineering decisions should have raised doubts about the ability of the project to provide its authorized DOP, as well as the project's ability to withstand storms more severe than the SPH as authorized in 1965. This chapter's summary of the 50-year-long process of project planning, design, and construction has focused on those project decisions, from among the thousands of engineering, budgeting, and legal decisions made, that affected the DOP provided by the project in place when Hurricane Katrina hit the project area.

The process began by selecting the wind speed and central pressure parameters to define the SPH. The modeled surges using the state-of-the-art methods of the time justified the District's vision for the original Barrier Plan to dampen surges into the lake and to protect other areas with levees and floodwalls. After authorization in 1965, the District estimated that completion of the project would take 10-15 years. The original design vision was quickly tested by Hurricane Betsy's wave action. As a result of Betsy, the District requested and received permission to increase structure design heights across the project network.

Next, the Barrier Plan vision was challenged by protracted local opposition to the barriers for preventing hurricane surge into Lake Pontchartrain. In 1985, the Chief of Engineers approved the switch to a plan that replaced the barriers with increased levee heights along the lakefront (the High Level Plan); other features and designs of the Barrier Plan, as modified after Betsy, were unaffected and incorporated into the High Level Plan, with one important exception.

The switch to the High Level Plan meant that even higher stillwater surge heights could threaten the outfall canals. A protracted debate between one local sponsor and the District over how best to address surges into the outfall canals was resolved by congressional action in the early 1990s. Meanwhile, Division interpretations of the E-99 Sheet Pile Wall Field Load Test resulted in cost-reducing Division guidelines governing the design of the I-wall sheet pile penetration depths that were used to implement parallel protection along the canals.

Later, in 1994, the District requested from the Division the authority to reevaluate the project in light of new information on subsidence and storm intensity and frequency on the existing project DOP. Beginning at about the same time, improved models, and analyses with those models that included new information on storm parameters and subsidence, suggested that if the project were implemented as originally designed, the structures might not withstand the originally-estimated SPH surge, or the surge that might accompany storms stronger than those that were envisioned when project planning began in the 1950s. However, the District determined in 1995 that further refinement and testing of a relatively new, state-of-the-art surge model was needed for that project restudy. The model development work proceeded for the next nine years and received a positive independent technical review in 2004, but little progress had been made on project reevaluation by the time that Hurricane Katrina hit the project area.

All project design, construction, and communication decisions were made through existing organizational vehicles such as the PAC request process and the BJS. Consistent with the decentralized nature of the Corps organization, technical analyses were competed by the District with Division oversight. Key technical decisions were identified and evaluated at these field offices, and depending on circumstances and requirements, decision-making might be shared with Corps Headquarters. Decision influences included consideration of cost increases in relation to budget availability, the desire for expeditious project completion as estimated construction dates extended out in time, and concern for the validity and the sufficiency of surge model results for designing detailed project modifications and justifying the budget requests that would be needed if such modifications were approved.

Completed project structures were inspected annually as required by law, but in a very limited way (see Box 2-8). Meanwhile, no systematic Corps procedure required or created an opportunity to communicate the general recognition that the promised SPH surge protection was increasingly unlikely to be provided by a project completed within the estimated budget for project completion (see Box 2-9). The next three chapters examine in greater detail the project decisions described in this chapter as well as the contexts for those decisions.

Box 2-8: Corps Inspection of Completed Works Program

Federal regulations governing the maintenance and inspection of flood protection works constructed by the federal government and turned over to local sponsors are set out in Title 33, Part 208.10 of the Code of Federal Regulations. For levees, the regulations require the relevant local jurisdiction to provide all necessary maintenance to ensure intended performance, including measures such as promoting the growth of sod, extermination of burrowing animals, routine mowing of grass and weeds, removal of wild growth and drift deposits, and repair of damage caused by erosion. (Similar types of maintenance measures are specified for floodwalls.) The regulations also require local sponsors to perform periodic inspections to ensure that required maintenance measures are being effectively carried out, and to identify indicators of potential problems such as areas of unusual settlement, seepage, and sand boils. The annual inspections of levees and floodwalls involve visual verifications of local sponsors' compliance with required maintenance; they do not, however, include the types of engineering assessments that would be needed to verify structure stability and performance. Thus, the Inspection of Completed Works Program would not be expected to uncover and communicate potential problems with the ability of the completed LP&VHPP protection works to perform as intended (protect against SPH surge) due to area-wide subsidence that compromised structure design heights, changes in possible storm frequency and intensity, or any of the original engineering design decisions, such as the choice of parallel over frontage protection for the outfall canals.

Box 2-9: Purpose and Limitations of the Annual Project Budget Justification Sheet

It is important to recognize that the limited purpose of the BJS is to justify federal appropriations for continuing implementation of a project in the next fiscal year. The BJS is not the vehicle to report new information as it becomes available over time, such as new knowledge about datum issues (reflecting continuing subsidence in the project area) that raised doubts about the ability of the project as constructed to meet the authorized DOP. The BJS is not the vehicle to report that new surge modeling using the original SPH parameters indicated the possibility that structure design heights might not achieve the authorized degree of protection. The BJS is not the vehicle to report that refinements to the surge models were underway to assess this possibility. The BJS is not the vehicle to report that new storm parameters suggest that the DOP as authorized might not provide protection against more likely and larger storms than were deemed possible at the time of authorization. Nonetheless, all of the annual BJS reports on the LP&VHPP include boilerplate language stating that, once completed, "the project will provide protection against flooding from the Standard Project Hurricane," even though it was known by the District that the completed project might not provide protection against the revised SPH parameters—or even the original SPH parameters given that at least some project structures were constructed using datum elevations that did not reflect local mean sea level—and that new surge analysis using the old SPH parameters raised doubts about the adequacy of design heights for some project structures. But starting in 2003, limited wording appears in the project BJS—separate from the main justification statement which promises SPH surge protection once the project is completed—suggesting that the SPH protection might not in fact be provided upon project completion.

Chapter 3. Project Performance Decisions

3.1 Introduction

This chapter presents a series of topics related to LP&VHPP performance decisions, including decisions that led to the design elevations (grades) of project structures, as well as decisions that affected the correspondence between structure elevations as constructed and intended design grades. A major focus of the chapter is on the extent to which new information on hurricane parameters, surge modeling, and subsidence in the project area was incorporated into project design and construction as it became available over time, and the effects of those decisions on the elevations of protective structures when Hurricane Katrina made landfall. In those instances when the District did not incorporate relevant new information into project design and construction, the reasons for that exclusion are discussed, along with a review of whether the new information and potential consequences for the project were communicated to the Corps hierarchy, the administration, the Congress, and local sponsors of the project.

Section 3.2 characterizes and explores project decisions and calculations relating to the intended *degree of protection* to be provided by the project, which is represented as a three-step process involving selection of the "design hurricane," estimation of the "design surge," and determination of the final design elevations of project structures. This section defines basic concepts such as the "standard project hurricane" and the "probable maximum hurricane," and explores the rationale for the choice of the former as the design hurricane for the LP&VHPP. It then explains estimation of the design surge, called the "stillwater" or "wind tide" level, and finally the setting of design elevations for structures. Representation of these decisions and calculations as a three-step construct aids in understanding the role that new information played in project design and how it changed the performance expectations for the project over time, which is reviewed in Section 3.3. Section 3.4 reviews issues relating to the translation and communication of project protection in terms of hurricane surge return frequencies, termed the *level of protection*. Section 3.5 provides a summary chronology of key events relating to project performance decisions and reflections on the factors underlying those decisions. Finally, Section 3.6 illustrates in part the outcomes of project performance decisions by comparing the design elevations for project structures, the actual elevations of those structures at the time that Hurricane Katrina made landfall, and the heights of Hurricane Katrina-induced stillwater surges for different project reaches.

3.2 Planning for Performance: A Three-Step Process

Performance design for the LP&VHPP, as reflected by the final design grades for protective structures, involved three distinct steps: 1) Selection of the design hurricane, 2) Estimation of the design surge, and 3) Engineering of final design elevations for project structures.[31] In Step 1, planners select the type of hurricane that the project is to be designed to protect against. In Step 2, planners estimate how high the floodwaters associated with the design hurricane would reach in different parts of the project area. In Step 3, planners determine how high project structures must be engineered in order to hold back the design surge. Taken together and given consideration for routing, precise structure elevations for each segment of the geographic area to be protected are established. These are the design elevations that appear in early documentation.[32] These three steps are outlined in Box 3-1 and reviewed in more detail below.

Box 3-1: Performance-Based Project Design: A Three-Step Process

<u>Step 1: Select the Design Hurricane</u>

- Identify empirical record of storms in project area
- Apply probability statistics to storm records
- Apply planners' judgments on storm severity to protect against

<u>Step 2: Estimate Design Surges</u>

- Transpose the design hurricane to the project area
- Account for topography and other localized conditions
- Forecast stillwater surge levels

<u>Step 3: Engineer Design Elevations for Structures</u>

- Estimate wave and pressure runup or freeboard requirements.
- Add wave runup or freeboard to design surge.
- Design final structure elevations

3.2.1 Step 1: The Standard Project Hurricane Was Selected as the Design Hurricane

The design hurricane is an abstraction. Once selected it constitutes the performance target for all further project planning and engineering. The November 1962 project planning document—the Interim Survey Report (19621121), which was submitted to the Secretary of the Army by the Chief of Engineers on behalf of the District, Division, Mississippi River Commission, and Board of Engineers for Rivers and Harbors, defined the design hurricane as "that hurricane selected by the reporting office as a basis for design of the

[31] It should be noted that Corps guidance at the time of project authorization did not subdivide the determination of design grades for project structures into three steps. The three-step process presented here is a construct provided by the study team for the purpose of explaining the different types of information and analytics used for project design.

[32] The development of more-precise alternative structural and non-structural protective measures followed in the various design memoranda and in final plans and specifications for project features.

proposed plan of improvement."[33] The concept of the design hurricane is further discussed in a 1986 Engineering Manual (EM 1110-2-1412). The following passage from that manual illustrates that early and later interpretations of the design hurricane were consistent:

> "A representation of a hurricane with specified characteristics that would produce hurricane storm surge hydrographs and coincident wave effects at various key locations along a proposed project alignment. It governs the project design after economics and other factors have been duly considered. The design hurricane may be more or less severe than the SPH [Standard Project Hurricane], depending on economics, risks and other considerations." (19860415, page 51)

The design hurricane includes two primary parameters—central pressure index and wind speed. Corps policy at the time that the original authorized project was designed allowed the reporting office to consider a wide range of possible recurrence intervals for these parameters. The design hurricane could be based on statistical interpretation of known historical events likely for the area, including an estimate of the worst that could possibly occur given the national body of knowledge. Importantly, the selection of the design hurricane from the historical record was within the discretionary authority of the reporting office.

Conceptually, the Standard Project Hurricane (SPH) was chosen as the design hurricane for the LP&VHPP as early as 1956. Although numerical parameters for the SPH had not yet been identified, the degree of protection implied in the concept was theoretically consistent with that associated with flood protection provided for urban areas along rivers. The choice of the SPH was a policy-driven decision meant to ensure the protection of human life; it was not based on an analysis of economic benefits and costs realized from securing protection against storms with different parameters. In fact, benefit-cost analysis for the project had not been completed at the time that the SPH was chosen as the design hurricane.

At the time of the 1962 Interim Survey Report, federal policy for protecting against riverine flooding allowed projects to be larger or smaller than the Standard Project Flood (SPF), but in areas where there was a potential threat to human life, the SPF was considered the minimum standard.[34] Selection of the SPH for the LP&VHPP was based on this same logic, as evidenced by the following passage from the 1962 Interim Survey Report:

> "Areas to be protected are highly developed for residential, commercial and industrial use, or have immediate potential for such development. Because of the

[33] In this case the reporting office is the Corps New Orleans District. The plan for the authorized project is set out in the 1962 Interim Survey Report. That report was the basis for subsequent recommendations made in the 1964 report of the Chief of Engineers sent to Congress.
[34] The SPF is a flood flow derived from the Standard Project Storm (SPS); the SPS is analogous to the SPH, and the SPH design surge is analogous to the SPF.

> serious threat to human life and property involved, the design of the protective plan must be based on the standard project hurricane for the region…" (19621121, page 51)

That report defined the Standard Project Hurricane as:

> "A hurricane that may be expected from the most severe combination of meteorological conditions that are considered reasonably characteristic of the region involved." (19621121, page 10)

3.2.1.1 Origins of the Standard Project Hurricane Concept

The SPH concept was first approved for use by the Corps in 1953 as applied to a design study for the Lake Okeechobee Hurricane Protection Project. In November 1955, the Chief of Engineers sent a letter to the U.S. Weather Bureau in which he described their joint participation in a hurricane study (19591100). Development of SPH parameters for different locations along the east coast of the United States was one of seven subprojects.

The major product of that overall study was the *National Hurricane Research Project (NHRP) Report No. 33*, published in 1959 (19591100). That report was co-authored by Howard Graham of the U.S. Weather Bureau (USWB) and Dwight Nunn of the Corps. Being a joint project, it was tailored for use by the Corps and consistent with Corps terminology regarding storm events and frequency intervals. The following description of the SPH concept comes from that report:

> "The name 'Standard Project Hurricane' is analogous to the 'Standard Project Storm' defined by the Corps of Engineers for a particular drainage basin and season of the year as …the most severe storm that is considered reasonably characteristic of the region in which the basin is located. Like the Standard Project Storm precipitation, the SPH index is based on enveloping the records of meteorological events with elimination of a few extreme events. The first SPH was approved by the Corps of Engineers in a design study for Lake Okeechobee, Fla. The SPH index parameters discussed in this report and the Lake Okeechobee SPH are consistent within the limits imposed by regional variation of climatological features." (19591100, page 7)

Two facts stand out from the above definition of the SPH. First, the SPH is analogous to the Standard Project Storm (SPS) performance standard used in designing flood protection for river basins. The SPH concept was a derivative of policy guidance as it related to riverine flood events. The Corps had a long history of providing protection for such events. The SPS results from synthetic calculations based on the most severe combinations of conditions that are "reasonably characteristic of the region." Typically, on an empirical basis, the SPS has been exceeded by approximately 10% of the most severe storms in its region. Moreover, Corps policy dictates that the Standard Project Flood (SPF), as derived from the SPS, be the minimum design standard in urban areas where catastrophic losses are possible. What is noteworthy is that hurricane protection planning for the nation and the Corps was in its infancy with regard to the LP&VHPP,

but it drew on and was consistent with standards as applied to other flood events (see Box 3-2).

Box 3-2: Choice of Protection from the Standard Project Flood

The standard project flood and the maximum probable flood were the precedents for the SPH and PMH. These were defined in a 1952 Corps of Engineers Engineering Manual, as revised in 1965 and again in 1980. The following are excerpts from the 1965 version of EM 1110-2-1411 (19650301) with parts of the text emphasized in italics.

"… Standard Project Flood (Abbrev. SPF) Estimates representing flood discharges that may be expected from the most severe combination of meteorologic and hydrologic conditions that are *considered reasonably characteristic* of the geographical region involved, excluding extremely rare combinations." (19650301, page 5)

"… Maximum Probable (or "Maximum Possible)" Flood Estimates representing flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are *reasonably possible in the region*." (19650301, page 6)

"… In the design of flood control projects it would of course be desirable to provide protection against the maximum probable flood, if this were feasible within acceptable limits of cost. However, it is seldom practicable to provide absolute flood protection by means of local protection projects or reservoirs: usually the costs are too high, and in many cases the acquisition of adequate rights-of-way for the purpose would involve unreasonable destruction or modifications of properties along the floodway. *As a rule, some risk must be accepted in the selection of design flood discharges. A decision as to how much risk should be accepted in each case is of utmost importance and should be based on careful consideration of flood characteristics and potentialities in the basin, the class of area to be protected, and economic limitations.*" (19650301, page 7)

"…. The Standard Project Flood is intended as a practicable expression of *the degree of protection* that should be sought as a general rule in the design of flood control works for communities when protection of human life and unusually high-valued property is involved. Inasmuch as SPF estimates are to based on generalized studies of meteorologic and hydrologic conditions in a region, *the SPF estimate provides a basis for comparing the degree of protection provided by flood control projects in different localities, thus promoting a more consistent policy with respect to selection of design flood giving a comparable degree of protection for similar classes of property.*" (19650301, page 7)

There are several points to note in these quotations. First, the standard project flood was not the most severe flood that might occur; there was the maximum probable flood (MPF) that was a less frequent event. For levees in urban areas, the Corps policy was to provide no less than SPF protection. Also, the policy allowed for protection against flows larger than the SPF if costs were not excessive in relation to incremental protection benefits. Nonetheless, the EM provided no firm guidelines for defining the "most severe combination of meteorological and hydrologic conditions that are considered reasonably characteristic" of the area. It is possible to interpret the MPF as being at least as large an event as what had occurred in the historical record, although a synthesized MPF from a coincidence of plausible weather scenarios was a more likely basis for the calculations. In either case, it appears that the SPF and MPF might be revised with new information and storm experiences. Second, the degree of protection would be chosen in consideration of necessary tradeoffs between cost and risk reduction. Here again the principles are clear, but there are no firm guidelines on how this tradeoff would be analyzed or where it would be made. In this regard the guidance is permissive, allowing for discretionary authority for these decisions to be left to experts in the agency who would perform analyses applying expert judgment, and then communicate the degree of protection to the public and local sponsors. Finally, setting the degree of protection as the SPF would provide comparability of performance among the many flood protection projects.

The second fact of note is that the analytical approach is based on "enveloping the records of meteorological events with elimination of a few extreme events" consistent within the limits imposed by regional variation. Under this method, the coastline of the United States is plotted on the horizontal axis as a continuum from Port Isabel, Texas to Eastport, Maine. Then, on the vertical axis, measured hurricane characteristics such as central pressure index or wind speed are plotted for known severe events in history at their specific horizontal location on the continuum. The envelope for the SPH characteristics is drawn to mold itself around the major events, while leaving out the extreme cases.

At the time of project planning, it was believed that the most severe storm to be characteristic of the region occurred in 1915. It had wind speeds of 106 mph, Central Pressure Index (cpi) of 27.87, and tidal surges of up to 13 feet (19621121). Characteristics of the SPH design storm used for LP&VHPP planning were similar to the 1915 event. While this unnamed 1915 storm event fell within the envelope curve used to define the SPH for the LP&VHPP, Hurricane Camille, which occurred in 1969 after the project SPH empirical work had been completed, would have fallen outside the envelope. The SPH was a steady-state, synthetic storm, which means that storm characteristics would be maintained through the project area for its duration; consequently, in the Gulf, wind speed would be expected to be higher than 100 mph. For the purposes of comparing the SPH in the Gulf of Mexico to the modern hurricane Saffir-Simpson Hurricane Scale, one would have to assume wind speeds significantly higher than 100 mph in the Gulf in order to achieve 100 mph throughout the project area after landfall. Indeed, the approach of the USWB and the Corps to define the SPH in 1959 was based on a very limited database of historical storms, but resulted in defining SPH parameters that reflected those of an actual storm that was as severe as any that had been experienced in the region up to that time.

Indicative of the limited database was the fact that, at the time NHRP Report #33 was published in 1959, only 42 hurricanes had been recorded in the prior 57 years for the 400-mile, mid-Gulf coastal zone (referred to as “Zone B”) in which New Orleans was located for analytical purposes. Figure 3-1 reproduces Plate A-6 from the Appendix to the 1962 Interim Survey Report that plots central pressure index data for storms of record in Zone B (19621121, page 149).

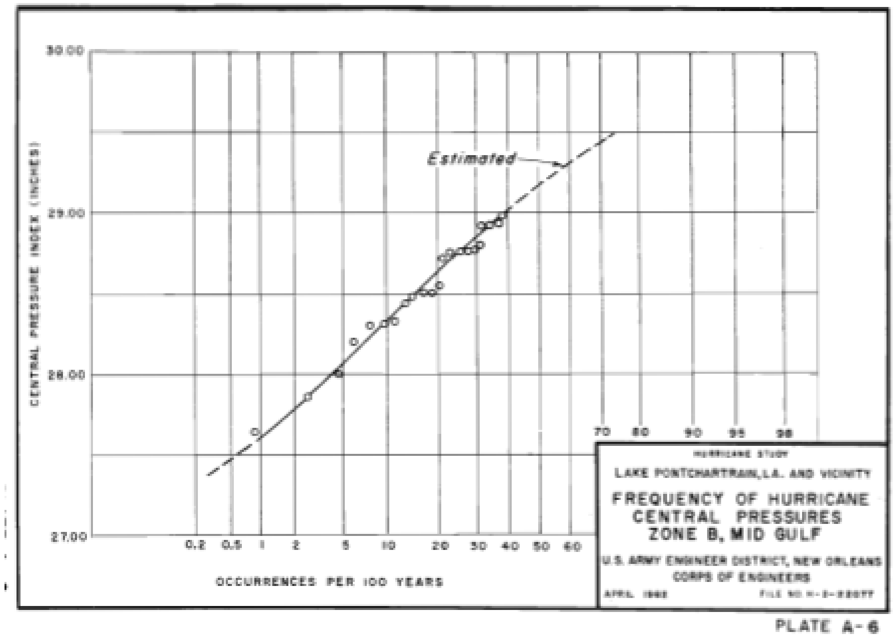


Figure 3-1: Frequencies of Central Pressure for Storms of Record in Zone B

Analysis of the data was largely done with arithmetic, as indicated by the following quotation from the appendix to the Interim Survey Report:

> "Frequencies for hurricane central pressure indexes that were presented in the report (USWB #33), as shown on Plate A-6, reflect the probability of hurricane recurrence from any direction in the mid-Gulf Coastal region. In order to establish frequencies for the localities under study, it was assumed that … the average projection along the coast of this 50-mile swath for the azimuths of 42 Zone B hurricanes is 80 miles…. Thus, 20% of the Zone B frequencies shown on Plate A-6 was used to represent the CPI frequencies in the 50-mile subzone that is critical for each study locality." (19621121, page 136)

In 1979, the National Weather Service (formerly the U.S. Weather Bureau) published Technical Report NWS 23 (19790900). Based on new statistical information, central pressure for the SPH was revised downward (more severe) to 27.35. The new SPH information was reported in the project 1984 Reevaluation Report. However, as will be discussed later in more detail, subsequent project design memoranda (DM) continued to use the same SPH parameters reported in the 1962 Interim Survey Report for determining design surges, and thus the design grades for protective structures. For example, DM #20 for the 17th Street Outfall Canal, published in 1990, applied the SPH central pressure of 27.6 inches (19900300). Table 3-1 shows the 1959 SPH parameters as reported by the 1962 Interim Survey Report (and which became the basis for the project authorized in 1965), and the 1979 revised SPH parameters reported in the 1984 Reevaluation Report (19840700). The change in SPH central pressure could manifest itself as a change in stillwater surge.

Table 3-1: SPH Parameters Reported in 1959 and 1979

SPH Parameters	1959 SPH (Included in 1962 Interim Survey Report)	1979 SPH (Included in 1984 Reevaluation Report)
Wind Speed	100 mph @ 30 nautical miles	100 mph @ 30 nautical miles
Central Pressure Index	27.6 inches	27.35

The Probable Maximum Hurricane (PMH) is a meteorological worst-case scenario. It has an infinitesimally small likelihood of occurrence and represents the upper boundary for hurricane severity in any project area. It is based on empirical evidence and scientific extrapolation. The PMH was defined in the 1962 Interim Survey Report as, "the hurricane that may be expected from the most severe combination of Meteorological conditions that are *reasonably possible* in the region."[35]

LP&VHPP planners could have selected the PMH as the design hurricane if they deemed that greater-than SPH protection was justified for the project area. The PMH for the project area was identified and considered but not chosen for designing the LP&VHPP. As outlined earlier, the envelope used to define the SPH included the worst storms of record in Zone B to that point in time; the derivation of the original PMH for Zone B apparently relied on more-severe storms recorded for the Atlantic Coast.

The 1962 Interim Survey Report reported PMH parameters for the project area that were derived in the NHRP Report No. 33 published in 1959. In 1979, the National Weather Service (NWS) reported revised PMH parameters for the project area that indicated the possibility of more-severe hurricane events than what was reported in 1959. The updated PMH parameters were not reported in the 1984 Reevaluation Report, however. Table 3-2 shows the PMH parameters reported in 1959 and in 1979.

Table 3-2: PMH Parameters Reported in 1959 and 1979

PMH Parameters	1959 PMH (Included in 1962 Interim Survey Report)	1979 PMH (Not included in 1984 Reevaluation Report)
Wind Speed	115 mph	133 mph
Central Pressure Index	26.9 inches	26.2

The increase in estimated severity of the reported PMH between 1959 and 1979 is largely due to the experience of Hurricane Camille and other large storms that occurred in Zone B in the intervening twenty years, and that were added to the database.[36] Of critical importance to understanding the performance of the project during Hurricane Katrina is the fact that the *difference* between the SPH and the PMH estimated parameters grew

[35] The PMH thus differs from the SPH through replacement of the phrase "reasonably *characteristic* of the region" with "reasonably *possible* in the region."
[36] Generally, it can be argued that the longer the period of record, the better the understanding and quantification of the SPH and PMH.

dramatically in the period between the 1962 Interim Survey Report and the 1984 Reevaluation Report. The SPH parameters used for LP&VHPP design calculations remained the same during the life of the project, while the estimated PMH parameters increased dramatically over that same period. The differential had implications for the likelihood of storm events larger than the original SPH, and hence for project performance if a storm more intense than the SPH were to occur. However, the new PMH data and its potential implications for project performance were not reported in the 1984 Reevaluation Report.

3.2.2 Step 2: Estimation of the Design Surge

Once the design hurricane had been selected, then its associated surge levels were calculated for different locations within the project area. In LP&VHPP planning documents, the surge is referred to as the "stillwater level" in some documents while in others it is referred to as the "wind tide level." The design surge is the sum of tide, pressure setup, wind setup, buildup and other formulaic adjustments. That is, it represents the elevation of storm surges without consideration of potential wave action. The LP&VHPP stillwater level hydrograph was adjusted for rainfall, and marshland in the project area was assumed to be submerged. Storms were hand-routed in such a way as to expose each area within the project boundaries to the greatest surge effects of the SPH.

The calibration process used historical storms that occurred in 1915 and 1947 and for which isovel patterns, central pressure, radius to maximum winds, and forward speed were known. Agreement between known storm surges and modeled surges was established with the application of a mathematical "surge adjustment factor (Z)."

For project areas such as the Chalmette Loop that contained significant wetlands, adjustments were made for the dampening effect of marshes on surge levels. Empirical evidence derived from prior storms indicated that the effects of wetlands on hurricane forward speed, wind speed, and direction were neutral, but that surge heights were reduced at the rate of one foot per 2.75 miles inland from the "synthetic" coastline. All modeling was undertaken using a one-dimensional technique that was appropriate at the time; modern two-dimensional models and computing capabilities now provide much better estimates of the impact of marshes on storm surges.

Table 3-3 presents the SPH surge elevations for different project reaches reported in the 1962 Interim Survey Report and included in the plan recommended by the District Engineer. Most notable from the table is that the lakefront design surge was 11.2 feet, and the Chalmette design surge along the Mississippi River Gulf Outlet (MRGO) was 11.9 feet (19621121, page 36). The design surges for the PMH were also calculated and reported in the 1962 Interim Survey Report. They were given for the Lakeshore at 12.7 feet, and for Chalmette along MRGO at 13.8 feet (19621121, page 37). As indicated by the data presented in the next section, both the SPH and PMH design surges fell below the final design elevations of structures reported in the 1962 Interim Survey Report. No information for the PMH surges at any project reach was provided in the 1984 Reevaluation Report, however.

Table 3-3: Design Surge Levels by Project Reach, 1962 and 1984

Project Reach	1962* Design Surge Elevation (Ft.)	1984** Design Surge Elevation (Ft.)
Jefferson Parrish Lakefront	11.1	11.5
New Orleans Lakefront	11.2	11.5
Citrus lakefront	11.2	11.5
New Orleans East, back	12.5	Not Addressed
Citrus, back	12.2	Not Addressed
Chalmette, back	11.9	Not Addressed
IHNC	12.0	Not Addressed

* Design surge is also referred to as "stillwater" or "wind tide" level
** The 1984 report did not provide analysis of any project reaches other than those affected by the switch to the High Level Plan

3.2.3 Step 3: Engineering of Final Design Elevations for Structures

The final design elevations for LP&VHPP protective structures were calculated as the sum of the design surge (stillwater level) associated with the SPH (Step 2) and either "runup" or "freeboard." In areas where the project would be subject to interaction with waves, runup was considered to be the ultimate height to which water in a wave ascends the slope of a structure. Overall runup depends on wave steepness, relative depth, and structure slope. The design elevations for the LP&VHPP structures were expected to be sufficient to prevent all overtopping by the "significant wave," which is a statistical concept applied to wave trains. Fourteen percent of the waves were higher than the significant wave, but overtopping from these were not expected to endanger protective structures or cause significant interior flooding (19660800, pages 23-24).

Final design elevations (sum of design surge and runup or freeboard) were determined in the various design memoranda that followed the 1965 project authorization.[37] Design elevations by reach and project component vary greatly in the various documents. Moreover, design elevations for some project components changed through different design memoranda depending on whether those components were affected by the adoption of the High Level Plan in 1985. Final design elevations for LP&VHPP structures are given in Table 3-4 exactly as they were reported in their respective design memoranda.

[37] These include: DM1, DM2, DM14, DM15, DM16, DM17, DM17A, DM19, DM19A, DM20, & DM22, published between 1966 and 1993. These documents are all available at: https://ipet.wes.army.mil.

Table 3-4: Final Design Elevations for LP&VHPP Structures, by Project Reach

Project Reach	Design Surge* (stillwater) Ft.	Design Elevation* (stillwater + runup or freeboard) Ft.	Source
St Charles	10-11 NGVD	12-12.5 NGVD	DM18, Feb 1989
Jefferson-St Charles Parish Return Levee	11-11.5 NGVD	14-14.5 NGVD	DM 17A, Jul 87
Jefferson Lakefront	11.5 NGVD	16.0 NGVD	DM 17, Nov 87
Orleans Lakefront	11.5-12.9 NGVD	16.5-20.0 NGVD	DM13, Nov 84, DM22, Apr 93
17th St Outfall Canal	11.6-12.63 NGVD	13.66-14.66 NGVD	DM20, Mar 90
Orleans Ave Outfall Canal	11.5-12.1 NGVD	13.64-18.0 NGVD	DM19, Aug 88
London Ave Outfall Canal	11.69-11.85 NGVD	13.69-13.85 NGVD	DM19a, Jan 89
Citrus Lakefront	11.5 NGVD	14.5 NGVD	DM14, Jul 84
New Orleans East Lakefront	11.5 NGVD	18.0-18.5 NGVD	DM15, Apr 85
Southpoint to GIWW	11.5-12.8 NGVD	13.5-17.5 NGVD	DM16 Sep 87
New Orleans East Back levee	13.0 MSL	14.0-23.0 MSL	DM2, Sup 4, Mar 71
Citrus Backlevee	13.0 MSL	14.0-18.0 MSL	DM2 Aug 67
IHNC	11.4-13.0 MSL	13.0-14.0 MSL	DM2, Sup 8, Feb 68
Chalmette Loop	12.5-13.0 MSL	14.0-17.5 MSL	DM1, Aug 66
Chalmette Extension	11.8-12.5 MSL	16.5-17.5 MSL	DM1, Aug 66

* Early project DMs cited mean sea level (MSL) as the reference point for designs, while later DMs cited the NGVD (datum) as the reference point. These two reference points were apparently assumed to be equivalent by project engineers (see Section 3.3.3).

3.3 Effects of New Information on LP&VHPP Design and Construction

This section reviews the extent to which new information on hurricane parameters and potential surge levels were incorporated into project design over time. It also reviews whether updated information on subsidence in the project area was factored into project construction decisions, which bears on the correspondence between the constructed elevations of project structures and their intended design elevations.

3.3.1 New Hurricane Data

The first significant new information came in 1965 shortly before the project was authorized. That was the experience of Hurricane Betsy, which had characteristics much like those of the SPH design hurricane (105 mph winds and minimum central pressure at 27.76 inches in New Orleans). Hurricane Betsy-induced flooding in the project area caused project planners to rethink the needed degree of hurricane protection for the project area, as evidenced by a letter written by the District Engineer to the Division Engineer on October 29, 1965, only two days after project authorization. That letter is reproduced in Box 3-3.

The letter indicates that, based on the Hurricane Betsy experience, the District sought Division approval to increase the degree of project protection during the detailed design stages for project structures. As will be discussed below, the final design grades for project structures were increased in the aftermath of Hurricane Betsy, although that change was not based on selection of a new design hurricane (Step 1) and a re-computing of the design surge (Step 2). And when the NWS revised the SPH cpi parameter downward in 1979, it was not factored into subsequent design memoranda.

Box 3-3: 1965 District Recommendation to Increase LP&VHPP Degree of Protection

Letter from the District Engineer to the Division Engineer, dated October 29, 1965 (19651029)

1. "Reference is made to the Interim Survey Report, Lake Pontchartrain, La. And Vicinity, dated 21 November 1962.

2. During the recent hurricane Betsy, extremely high wind tides overtopped existing levees in areas for which hurricane protection projects were recommended in the Lake Pontchartrain Report. This overtopping was responsible for the loss of about 70 lives and it caused widespread flooding and extensive damage in residential areas. The protective system recommended in the report was designed to provide protection from an occurrence of the SPH (standard project hurricane). If the protective system had been constructed as recommended, overtopping of the levees during Betsy would have been minor. However, area southeast of New Orleans on the east side of the Mississippi River experienced wind tides greater than those expected to accompany a SPH. Therefore, had Betsy been on a track more critical to the Lake Pontchartrain area, wind tides greater than those used for design purposes would probably have resulted. This means that a future hurricane similar in intensity to hurricane Betsy and on a track critical to the Lake Pontchartrain area would cause overtopping of the proposed SPH protection.

3. Assuming the possibility that Betsy may have been a lower frequency than the SPH, it is considered that a degree of protection greater than that recommended in the report should be provided. The modification would be made during the detailed planning stage. PMH protection would have ample justification even though the benefit to cost ratio would be lower..."

3.3.1.1 Structure Design Elevations Increased by 1-2 Feet in 1966

A 1967 design memorandum includes the following description of one departure from the LP&VHPP plan as authorized in 1965:

> "Grade revisions. The net grades of most of the protective structures included in the plan were revised upward by 1 to 2 feet in accordance with the results of tidal hydraulic studies utilizing more severe hurricane parameters developed by the U.S. Weather Bureau subsequent to project authorization." (19670800, page 2)

It goes on to note that partial results of these studies are contained in a series of design memoranda for hydrology and hydraulics published or to be published between 1966 and 1968. Those sources in turn indicate that the determination that higher structure elevations were needed was based on revisions to the SPH wind field patterns made by the U.S. Weather Bureau in 1965; however, the original primary SPH parameters for wind speed and central pressure index remained unchanged. This suggests that the increase in structure grades was based on re-computations of wave action in Step 3. [38] Here we are careful to distinguish these re-computations from calculations for the design hurricane (Step 1) and the design stillwater surges (Step 2), which apparently did not change, and the final design elevations (Step 3), which did change.

The study found no official project Post Authorization Change (PAC) documentation relating to the reporting or authorization of this design change for the project, with the exception of the Chalmette area. For Chalmette, the design changes for project structures were incorporated into the Chief's approval of adding the Chalmette Extension to the project. The Data for Testifying Officers[39] dated January 1, 1985 contained the following passage:

> "In accordance with the desires of local interests the project was modified under the discretionary authority of the Chief of Engineers to provide protection to a larger area in the vicinity of New Orleans known as the Chalmette area. This change incorporated the need to increase levee heights to accommodate the new hurricane parameters. The letter report recommending this modification was submitted to OCE on 12 December 1966." (19850101, page 31)

The letter report cited above included design elevations for the Chalmette area that were generally 1-2 feet higher than those reported in the 1962 Interim Survey Report. Moreover, Design Memorandum 01, Part I, which includes 1-2 foot grade revisions for Chalmette, was approved by the Office of the Chief of Engineers on October 27, 1966. The addition of the Chalmette Extension, including grade revisions for the larger Chalmette area, was approved by the Chief of Engineers on January 31, 1967, and this change was approved by the Office of Management and Budget on March 25, 1969 (19820915). The Chief's 1967 approval of the grade increase for the Chalmette area was cited in later design memoranda for other project reaches as providing discretionary authority for increasing design grades for those reaches beyond the grades specified in the original authorizing documents.[40]

3.3.1.2 Initial Design Surge Levels Remain Unchanged

As outlined earlier in Section 3.2, the NWS in 1979 issued a slightly revised cpi parameter for the SPH (more severe), which was reported in the 1984 Reevaluation

[38] A District reviewer of an earlier draft of this chapter pointed out that additional surge calculations were performed after Hurricane Betsy using its storm surge high water marks and wind fields to recalibrate the one-dimensional model.

[39] The "Data for Testifying Officers" is a project information sheet that was formerly prepared annually for Corps officials to use in responding to questions at congressional hearings on federal appropriations for civil works.

[40] For example, in the 1962 Interim Survey Report, design grades were set at 13 feet along the IHNC and the GIWW between the Chalmette and Citrus areas, and the southeast-facing levees along MRGO in Chalmette and along the GIWW in New Orleans East were set at 16 feet. During the detailed design phase for these areas between 1966 and 1968, elevations for these areas were increased to 14 and 17.5 feet, respectively.

Report. However, this revision to the project SPH apparently was not used to update the design hurricane (Step 1) or its associated design surge, termed the stillwater or wind tide level (Step 2), for incorporation into project design. In the 1984 Reevaluation Report, which recommended that the High Level Plan be adopted and addressed only the lakefront project reaches that would be affected by abandonment of the barriers, design surge levels were not recomputed for project structures. Table 3-3 shows that roughly the same surge levels computed in 1962 were also used in the 1984 reevaluation.[41]

It is interesting to note, however, that the 1983 response by the Assistant Secretary of the Army for Civil Works [ASA(CW)] to the 1982 GAO report on project delays (discussed in Chapter 2) indicated that the need to incorporate revised SPH parameters in project design was one cause of delay. Specifically, that response included the following language that apparently originated at the Division (19830818):

> "Since authorization of the project, it has, as alluded to above, become necessary to reevaluate the design hurricane as developed by the US Weather Service. These revisions had the effect of increasing the intensity of the design hurricane, and hence the height of the hurricane surge. The higher levees needed to protect against these higher surges require more lifts and hence more time to be brought to final grades." (19831109, page 3)

One possible interpretation of this statement is that the District recalculated the design surges based on the revised SPH parameter for cpi made by the NWS in 1979, and factored that new information into ongoing project design and construction. However, as indicated earlier in this section, the 1979 SPH parameters were not in fact used to recalculate surge levels for project design; the original project SPH parameters and estimated surge levels continued to be used for project design and implementation after 1979. The project record supports an alternative interpretation—that the above quote refers to the 1-2 feet increase in design grades made for the project during 1966-1968 following Hurricane Betsy. As reported earlier, that change was not based on a recalculation of the SPH surge, but rather was based on a recalculation of possible wave action associated with the SPH surge as originally estimated for the project.

3.3.1.3 Divergence between SPH and PMH Over Time

The experience of Hurricane Betsy was soon followed in 1969 by that of a more intense storm, Hurricane Camille. Hurricane Camille is generally considered one of the worst storms to strike the Gulf Coast, a mere 100 miles from New Orleans. It had 190 mph winds, a central pressure index of 26.84 inches, and measured tidal surges between 22 and 25 feet. As with Hurricane Betsy, District engineers noted the importance of Hurricane Camille. The District Chief of Hydraulics reported in a memo dated September 29, 1969 that Camille had higher wind speeds and lower central pressure than the PMH reported in the 1962 Interim Survey Report (19690929). Thus, within four years after

[41] The three to four inch difference in surge levels for lakefront project reaches reported in the 1962 and 1984 planning documents and shown in Table 3-3 cannot be tied to revisions to SPH characteristics in the aftermath of Hurricane Betsy.

project authorization, the Gulf region experienced higher tidal surges with an actual storm (Hurricane Betsy) than had been computed for the nearly identical theoretical SPH event, and higher hurricane parameters (Hurricane Camille) than had been estimated as the worst that could possibly happen (that is, it was thought in 1962 that a storm like Hurricane Camille could never happen given an infinite period of time).[42]

The 1979 NWS Report #23 applied new guidelines for estimating the PMH. The resulting new PMH parameters for the project area were not reported in the 1984 Reevaluation Report, however, even though these revised PMH parameters indicated the potential for much more intense storms in the project area than the SPH. In a relatively short period of time (from 1962 to 1984), the initial close relationship between the SPH and PMH for the project area had widened significantly.

Based on the 1979 NWS report, the revised PMH for the New Orleans area would have had a significantly higher wind speed and lower central pressure than the initial PMH reported in the 1962 Interim Survey Report. Most importantly, tidal surges for the PMH were now significantly different, suggesting a dramatic divergence from the tidal surge differentials between the SPH and PMH reported in 1962. The data included in the Interim Survey Report indicate that, in 1962, estimated tidal surge associated with both the SPH and the PMH would fall within the design elevation of project structures. By 1984, however, the PMH surges were well above structure design elevations. As the PMH diverged from the SPH, this meant that storms larger than the SPH were more likely in the project area, and that empirically, it could be inferred that the level of protection (return frequency for the SPH) provided by the project had decreased.

3.3.2 Advances in Surge Modeling and Application to the LP&VHPP

Surge modeling capability improved over the course of project implementation with the rapid increases in computing power and improved database to support such modeling. By the 1980s, modeling had become two-dimensional, and computer simulations run using modern programs gave more-vivid interpretations of possible surge elevations as the characteristics of the topography were more accurately accounted for. Advances in surge modeling over time and their application to the LP&VHPP are reviewed below.

3.3.2.1 Early 1980s-Era Surge Modeling

One new surge model was the Sea, Lake and Overland Surges from Hurricanes (SLOSH) model developed by the NWS in 1978. Early reference to the SLOSH model is found in a letter from the Orleans Levee District (OLD) to the Corps New Orleans District in November 1980 (19801120). Among the concerns registered about continued delays in project implementation, the OLD cited SLOSH model surge forecasts that were “freightening [sic] to say the least.” The letter does not describe the specific nature of the

[42] It should be noted that Hurricane Camille was not on a critical path to the LP&VHPP and did not create higher flood stages in the project area than those predicted for the project SPH. The hurricane did, however, severely flood Plaquemines Parish and the Mississippi Gulf Coast.

modeling purpose and results. Nonetheless, the letter illustrates that, by 1980, new modeling was being used to forecast hurricane surge possibilities for New Orleans.

Another two-dimensional surge model that came into use in the 1980s was the Implicit Flooding Model (WIFM) developed by the Corps Waterways Experiment Station (WES). WES undertook an ambitious restudy of hurricane surges using the WIFM model in the early 1980s when the project was being reevaluated due to the 1977 litigation opposing the Barrier Plan (19780000). The District initiated the restudy to answer questions about the influence of the proposed barrier structures on hurricane surges along the north shore of Lake Pontchartrain (outside the project area). A significant byproduct of that work was reported findings that surge levels for some reaches of the project were different from calculations developed in 1962 using the original one-dimensional model and SPH parameters. The new modeling indicated that, if the project were fully built as designed, certain reaches would provide a degree of protection against a storm surge greater than that created from the original SPH parameters, while other reaches would provide less than the SPH degree of protection. The 1984 Reevaluation Report did not indicate that the WIFM model results were used to redesign structure elevations for any of the project reaches during the 1984 reevaluation, however. Once the Barrier Plan was replaced by the High Level Plan, further analysis with the WIFM model appears to have been discontinued. No other references to the WIFM model were found in project documentation published between 1984 and 1994.

3.3.2.2 The ADCIRC Model and 1993 CERC Storm Surge Pilot Study

A more significant improvement in surge modeling capability occurred with the Corps-sponsored development of the Advanced Circulation Model (ADCIRC) in the early 1990s. The Corps employed experts from the Universities of Notre Dame and North Carolina to modify the model to make it more representative of conditions in Southeast Louisiana.

In 1993, the District contracted with the Corps Coastal Engineering Research Center (CERC) to use the ADCIRC model to assess the impacts of the 1979 change in SPH cpi parameter on design surges, and the effects of changes in the relationship between NGVD (the datum used for project construction) and local mean sea level (19930000). The original (1959) project SPH parameters were used for the purpose of validating the original surge estimates for the project area. That application of the ADCIRC model reinforced the WIFM modeling findings that the 1962-era surge estimates may have overestimated the SPH surge along the lakeshore, and underestimated the surge associated with the SPH along the GIWW/IHNC corridor and the eastern boundary of Chalmette along MRGO. With respect to the new 1979 SPH cpi parameter, the CERC pilot study found that it produced an increase in surge heights of 1-2 feet for certain storm tracks under one set of assumptions, while under another set of assumptions the new SPH parameter had little effect on the original estimates of SPH surge heights.[43] Based on

[43] The lower SPH central pressure was extracted from the April 15, 1986 version of EM 1110-2-1412 (198604015). The CERC study modeling results with respect to the new SPH cpi parameter were included

these results and the study conclusion that local mean sea level was approximately one foot higher than NGVD, CERC recommended a thorough hydrodynamic modeling of the project using ADCIRC and a statistical procedure making use of the full database on historical storms within a joint probability approach or empirical simulation technique.

3.3.2.3 1994 District Request to Reevaluate Project Protection

In 1994, the District wrote to the Division requesting authority to conduct a numerical model study of the LP&VHPP, citing the Division's statement as part of its approval of the District's 1985 datum benchmark policy (discussed in the next section) that "consideration should be given to reanalyzing and modifying (if needed) hurricane protection work in high density urban areas where the datum changes will drastically reduce the level of protection." (19850916)

As background for the request, the District described the CERC pilot storm surge pilot study and the 1980s-era modeling using WIFM. The background statement also included the following language:

> "The project was formulated in the 1950s and 1960s using the technology available at that time. Numerical models and high speed computers now allow for the more complete analysis of the physics of hurricane storm surge and wave action. Many reaches of the project are nearing completion. Because of the extensive use of freeboards of 1 and 2 feet, phenomena such as sea level rise, deltaic subsidence and datum changes give cause for reanalysis. Our benchmark policy, discussed in Enclosure 1, when applied to project construction exacerbates the problems associated with sea level rise, deltaic subsidence and datum changes. These factors were not accounted for in the project formulation and have detrimentally affected the project's performance. Their combined effects approach a net change in the order of 1 foot over the past 30 years. The trend in subsidence will continue. The degree of protection afforded by the project appears to be deficient in some reaches with the prospect of further deterioration over the remaining 100 year project life. In addition, topographic changes attributable to levee construction may have affected the hurricane stage relationship in Lake Pontchartrain." (19940920, pages 1-2)

In describing the plan for the restudy, the District wrote:

> "The restudy will be conducted with a view toward insuring that, as a minimum, the authorized degree of protection is uniformly designed and constructed throughout the system. The potential for loss of life, cost savings and reduced future maintenance mandate accuracy and reliability in storm surge forecasting. The uncertainties associated with datum adjustments and our extensive use of 1 and 2 feet of freeboard require a comprehensive and vigorous effort… Results from the numerical model will produce a grid of storm surge magnitudes for the

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as an enclosure but were not emphasized by the District in its 1994 request for authority to reevaluate project protection using the ADCIRC model (see Section 3.3.2.3).

> project area based on existing topography referenced to a consistent datum. The wave analysis will yield proper wave heights for design. The statistical analysis will indicate the appropriate frequency of the SPH Hurricane as well as a few less frequent events." (19940920, page 3)

3.3.2.4 1995-2005 ADCIRC Model Refinement and Testing

The District intended to use the ADCIRC model for project reevaluation. However, the District decided that further refinement and testing of that model would be needed before using it for a detailed project reevaluation that might eventually be used to recommend project design changes. The District had concerns about the reliability of the early ADCIRC modeling results, and believed that the model did not satisfactorily address wetting and drying, and grid topography was not complete. Most importantly, the existing grid became unstable when the District tried to simulate the surge associated with Hurricane Betsy. Recommended work to refine the ADCIRC model was funded, and work on model refinement has continued up to the present day.

In 2003, the District employed a team of independent technical reviewers to review the years of work on model improvement. That technical review committee submitted its report to the District in January 2004 (20040131). The District, then assured of the model's reliability, began using the model to assess the project protection relative to the original and new SPH parameters, although funding for this effort was limited.

3.3.2.5 Surge Modeling Perspectives for the LP&VHPP

Advances in storm surge modeling over the project history were used in two ways for the evaluation of project protection. One focused on running the original SPH parameters as reported in the 1962 Interim Survey Report through each generation of new models. The project record indicates that, starting in 1980, there were several assessments made using multiple models that indicated that the 1962-era design surge estimates were too low by about one foot for the southeastern portion of the project and along both the IHNC and the GIWW. Although those results were preliminary, they had important potential implications because structure designs called for only one foot of freeboard throughout the entire IHNC/GIWW corridor.

The second perspective focused on using the surge models to predict surges associated with more-severe storm parameters for central pressure and wind speed. Starting in 1979, there was clear evidence that the appropriate SPH called for lower central pressure than that defined with the original project SPH, and that the PMH was significantly more severe than estimated in 1962. The state-of-the-art in surge modeling in each time period demonstrated that the LP&VHPP could be overwhelmed by storms greater than the 1962 project SPH, which were then known to be more likely to occur than originally thought possible in 1962.[44]

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[44] It is worth noting that other entities have used the ADCIRC model to assess and communicate hurricane risks in New Orleans. The Louisiana Water Resources Research Institute at LSU, prompted by Hurricane Georges in 1998, used the ADCIRC model to assess risks associated with hurricane events more severe

3.3.3 New Information on Subsidence and Vertical Datum

The entire Gulf Coast is a topographically dynamic environment, which makes planning, constructing, operating and maintaining hurricane protection projects difficult in the New Orleans area and throughout coastal Louisiana. There is general subsidence of the region and localized settlement of structures. The sea level is rising. Importantly, issues related to subsidence and vertical control datum can affect the extent to which the constructed elevations of project structures correspond with their intended design heights. Project decisions relating to the use of vertical control for project construction are reviewed below.

3.3.3.1 Vertical Datum and Control Benchmarks Not Updated Over Time

A geodetic vertical datum is a land-based reference system for determining geospatial coordinates—such as the heights of hurricane protection structures—with respect to some consistent reference surface. They are vital to civil works programs, the general construction industry, and flood insurance programs that require precision in measuring the elevations of structures relative to a consistent reference point.

Only two official national geodetic vertical datums have been established in the United States. The first was the Sea Level Datum of 1929, which in 1973 was re-named the National Geodetic Vertical Datum of 1929 (NGVD) to avoid confusion since it did not truly reflect local Mean Sea Level (MSL) at any location (19730507). The constructed elevations of LP&VHPP structures were largely referenced to this datum, although a variety of other datums were also employed to varying degrees. In 1993, the national geodetic datum was redefined as the North American Vertical Datum of 1988 (NAVD88) (19930624). This new national datum was intended to remove inconsistencies and distortions in the previously defined datum and does not purport to represent MSL.

Because of continuous changes in the earth's surface at different locations caused by land subsidence, sea level rise, and other factors, local vertical control points referenced to any geodetic-based datum such as NVGD are dynamic and must be periodically adjusted for local surface conditions. This is particularly true in coastal Louisiana where lands are composed largely of accumulated sediments delivered by the Mississippi River, and are influenced by many factors that cause land subsidence, including consolidation, faulting, and groundwater and minerals extraction. Such adjustments are accomplished through periodic survey adjustments to the elevations of spatially distributed, marked vertical control points, called "benchmarks," which are referenced to vertical datums. These periodic adjustments (which may not extend to the full set of benchmarks in any area) are referred to as datum "epochs." There have been many adjustments associated with the various datums used in coastal Louisiana over the last fifty years.

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than the 1962 SPH, to dramatic effect. The "Hurricane Pam" emergency planning exercise conducted in 2004 was based on ADCIRC model results assuming a "slow-moving, Category 3 storm." And over the last several years numerous articles on New Orleans hurricane risks have appeared in journals, magazines, and newspapers.

The National Geodetic Survey (NGS) used 2004 survey data to develop an adjusted vertical reference framework for Southeast Louisiana, termed NAVD88(2004.65). This framework established a new relationship between local MSL and latest benchmark elevations for the NAVD88 datum, and its application to New Orleans found that local MSL in the city is about ½ foot above the last published benchmark elevations.

The IPET study used the new reference framework to evaluate the actual pre-Katrina elevations of LP&VHPP structures, finding that the pre-Katrina heights of structures were significantly below intended design levels. The IPET reported that deficiencies in the project were largely because the heights of protective structures were *designed* relative to local MSL, but were *constructed* relative to a geodetic vertical datum (NGVD) that was erroneously assumed to be equivalent to local water surface levels. The IPET reported that this mistake resulted in the three outfall canals, for example, having structure elevations that were constructed 1-2 feet below intended design heights, which were further reduced over time by settlement of the structures since construction.[45]

Some project design memoranda reference design elevations to MSL, while others reference design elevations to NGVD.[46] This suggests that project engineers did indeed mistakenly believe that these reference points were equivalent. Nevertheless, the project record indicates that, by 1993, the District was aware of the general elevation difference between NGVD and local MSL and its potential implications for the performance of the project as constructed. One objective of the District-sponsored 1993 CERC pilot storm surge study (discussed in the previous section) was to preliminarily assess the effects of changes in the relationship between MSL and NGVD with respect to the required elevations of project structures designed to prevent overtopping from a storm surge derived in the MSL frame of reference. On this question the CERC study report concluded:

> "Construction of the levee is referenced to NGVD; however, because storm surges are referenced to MSL, the levee elevations should be referenced to MSL. The assumption used in the original flood protection project was that MSL was equal to NGVD. This assumption was correct according to the original concept of the 1929 NGVD datum, however, the relationship between sea level and NGVD in the Lake Pontchartrain area has been documented to be continuously changing. The relative sea level changes shown in Table 3 have been documented over the period 1931-1977 … As indicated in Table 3, either seal level has risen with respect to NGVD or there has been subsidence in the land. In either case, the crest of the levee is approximately 1.0 foot nearer to MSL than it is to NGVD, i.e., NGVD is now approximately 1.0 foot below MSL. Therefore, if the design freeboard for the levee system is x-ft, then the levee should be constructed to x + 1.0 ft NGVD." (19930000, page 7)

In addition to the mistaken equivalence of NGVD with local MSL, significant parts of the project were constructed using outdated benchmark elevations referenced to NGVD,

[45] IPET Volume II: Geodetic and Water Level Datum (https://ipet.wes.army.mil).
[46] Project documents prior to 1984 reference to MSL while later documents reference to NGVD.

which exacerbated the problem caused by the erroneous equivalence of these reference points. As events stretched out project implementation over decades, the District faced a dilemma with respect to the use of NGVD benchmark elevations for project construction that were changing significantly with each round of adjustments (performed by NGS every ten years or so) due to subsidence. By the mid-1980s, no major part of the overall project had yet been completed, and construction of significant portions had not yet even begun. At that point the District announced a policy not to switch to the latest published benchmark elevations for remaining project construction.

Although the IPET study found that contract plans for different project portions often do not explicitly note the specific datum epoch used, the study data and calculations suggest that project features implemented prior to the 1985 District datum policy were apparently referenced largely to the NGVD 1964/65 epoch. After the NGS in 1982/83 significantly adjusted local benchmark elevations, the Division and District solicited NGS confidence in the new benchmarks and advice on their use.[47] Following that dialogue with NGS, the Division in 1985 requested that the District "propose a course of action for incorporating the changes in elevation into your projects and studies and for defining in a more reliable manner the subsidence in your area."[48] In 1985, the District responded with a proposed policy (19850807) that was approved by the Division in that same year.[49]

The District policy froze the benchmark elevations used for project construction to those that were applied at the start of project construction, based on the argument that to do otherwise would result in varying levels of protection across the project area. It stated:

> "Hurricane protection projects which are partially complete will use the NGS benchmarks current at the time of construction of the first increment of the project. To shift to the latter NGS data without altering the heights of previously constructed portions would make 'fuseplugs' of those portions and thus impose a gratuitous servitude on the lands and facilities they protect. And altering previously constructed works would not be practicable." (19850807, page 3)

Other parts of the policy statement suggest that the expressed concern with the practicality of altering already constructed LP&VHPP structures at least partly reflected concerns about the high costs that such a change would entail. Specifically, with respect to other (non-LP&VHPP) projects within the District, the policy statement said,

> "Modification of projects which have been completed will not be considered. The level of precision in the current data, and the practical difficulties and cost of changing such projects combine to mandate this course of action, at least for the foreseeable future." (19850807, page 2)

[47] 19830000; 19840410; 19841100; 19841102; 19850305; 19850329; 19850412
[48] 19850501; 19850524
[49] In the Division approval of this course of action, it commented, "Consideration should be given to reanalyzing and modifying (if needed) hurricane protection work in high density urban areas where the datum changes will drastically reduce the level of protection." (19850916)

It is important to recognize the historical context in which the 1985 District datum benchmark policy was adopted. At that time, much of the project was incomplete, and the District was under intense pressure from local sponsors and their congressional representatives to move forward with providing protection. Further, estimated project costs had been steadily increasing since 1965, and by the mid-1980s federal budgets were being squeezed and local sponsors were expressing concerns about their ability to meet cost-share requirements. The 1985 datum benchmark decision allowed the project to move forward without increasing project costs, and without extending project completion even further into the future.

At the time that the datum benchmark policy was adopted, the District presumed that frontage protection would be the alternative used for providing protection for the three outfall canals. Because frontage protection involves floodgates at the canal mouths at the lakefront, these plans would not be as significantly affected by the datum benchmark policy. When the District was later directed by Congress to implement parallel protection at the outfall canals, the District datum benchmark policy, if applied to floodwall construction, would have affected the constructed elevations of those floodwalls. The data gathered by the IPET study indicate that the District datum policy was not evenly applied to the outfall canals, however.

In 1993, the OLD wrote to the District noting that construction of the Orleans Avenue Canal floodwalls is based on a 1983 NGVD epoch, while construction of the London Avenue Canal floodwalls is based on a 1964 NGVD epoch. The letter requested that the District "adjust as may be required to provide maximum protection for both canals." (19930813) No documentation of District response to this request was uncovered during this study. However, the IPET study confirmed that the constructed elevations of most of the London Avenue Canal floodwalls were based on the 1964 NGVD epoch, while most of Orleans Avenue Canal levees and floodwalls were based on the 1983 NGVD epoch.

No project documentation secured for this study indicates the Corps Headquarters was involved in or even made aware of the 1985 District datum benchmark policy. And when in 1994 Headquarters issued guidance to the field for conversion from NGVD to the new NAVD88 datum in studies and projects (19940101), the District did not follow it. It was not until the year 2000 that the District proposed to the Division to switch to NADV88, noting, "it is becoming untenable to maintain the existing [1985] policy." (20001026)

3.4 Communication of Intended Project Protection

As outlined in Section 3.2, the project was designed to provide protection against SPH tidal surges defined by a three-step process that culminated in final design heights for protective structures. That is, the intended *Degree of Protection* to be provided by the project was the SPH surge protection standard. There has been some confusion regarding communication of this intended project protection, however. One point of confusion relates to the translation and communication of SPH surge protection using the term

Level of Protection or storm return frequency (recurrence interval). Another point of confusion relates to an imprecise characterization of the project as providing protection against a “fast-moving, category 3 hurricane” as classified by the Saffir-Simpson Hurricane Scale. These two alternative ways that have been used to communicate the intended project protection are reviewed briefly below.

3.4.1 Level of Protection (Return Frequency)

During the various stages of project design according to the SPH *Degree of Protection*, planners also represented project protection to the public as the *Level of Protection*. Specifically, SPH protection was translated in the form of recurrence intervals, such a 1 in 100 or 1 in 200 year protection, for purposes of economic analysis of alternative plans as well as for communication of intended protection. However, while in a given location larger storm surges would occur less frequently than smaller storm surges, the difference in return frequencies for these surges does not convey any information on the difference in surge heights. Furthermore, storms in different areas with different surge heights may have the exact same return frequency for each area.

Both the 1962 Interim Survey Report and the 1984 Reevaluation Report reported the project-intended SPH surge protection in the form of SPH surge return frequencies; however, the District noted that these calculations of level of protection were only rough approximations (see Box 3-4). In the 1962 report, the project SPH performance design was reported to provide 200-year protection for all parts of the project area. The SPH was the design storm. It had .01 probability of striking “Zone B” in any given year, where Zone B, as identified by the U.S. Weather Bureau (USWB), extended over a 400 mile-stretch of the Gulf Coast. The USWB also concluded that the SPH had a .005 probability of striking the more limited area of New Orleans.

Box 3-4: Approximate Translation of SPH Surge Protection into Estimated Return Frequency

The LP&VHPP was designed to provide SPH surge protection. This surge protection was then translated into estimated return frequencies (or "level of protection" described as 1 in 200 years, for example) for purposes of project economic analysis and communication of intended protection. However, the calculations of project return frequencies were only rough approximations, as suggested by the following passage from the 1962 Interim Survey Report:

"Although damaging floods caused by hurricane tides have been experienced throughout the study area on numerous occasions in the past, it was not possible to establish adequate stage-frequency relationships for the entire study area because of the sparse records of observed maximum high water elevations. Observed stages were analyzed and adjustments made where necessary to reflect stages that would have occurred along the south shore of Lake Pontchartrain had existing protective works been in place. It was found that adjustments were required for only the 1893 and 1901 hurricanes, both of which stalled over the area. In addition, a synthetic method for computing stage-frequencies was derived by relating central pressure frequencies and stages that were computed for selected hurricane tracks. After computing hurricane frequencies for the south shore of Lake Pontchartrain by the synthetic frequency procedure, the two relationships were combined, using the synthetic data to establish shape and the observed data to establish placement of the final stage-frequency curve. This procedure, verified in other study areas for which sufficient data were available, was applied to all sections in the Lake Pontchartrain study areas. A detailed discussion of methods used in the computation of hurricane stage-frequencies is presented in appendix A."(19621121, pages 33-34)

For the calculation of project benefits, the Interim Survey Report stated:

> "The projects are designed to protect against the standard project hurricane which has a recurrence frequency of about 200 years. Residual Damages with projects in place would be annual damages from the less frequent great hurricanes." (19621121, page 60)

The 1984 Reevaluation Report, under the section titled "Plan Formulation Rationale," used different language, terminology, and logic regarding the level of protection provided by the project. It stated:

> "The alternative plans are not based upon one theoretical SPH event, but upon several SPH events, each of which would be critical to a given project reach… While a SPH event does not have a specific frequency, the design SPH storm for protection bordering Lake Pontchartrain has a return frequency of approximately 300 years. The return frequency of the design SPH critical to Chalmette, Inner Harbor, Citrus back, and New Orleans Back levees is approximately 200 years. Protection from the SPH was the minimum level of protection considered appropriate for recommendation due to catastrophic impacts which would result from overtopping of levees and floodwalls protecting such densely-populated urban areas." (19621121, page 68)

The authors of this report were not able to find any explanation in the 1984 Reevaluation Report for the change in characterization of the level of protection between 1962 and

1984 for the project lakefront reaches. No available documents during the time period addressed that specific subject. However, if one recognizes that the SPH storm surges for different locations within the project area were not adjusted in 1984, but design elevations were increased disproportionately for the lakeshore levees in comparison to other levees in the project, then logically the level of protection would have to be different for those areas. Moreover, this presumption can be traced through the economics section in the appendix to the 1984 Reevaluation Report, as a stage-damage curve reported in that document used the 300-year return interval for benefits calculations in New Orleans (the levees were to be higher in relation to storm surge probabilities).

3.4.2 Saffir-Simpson Hurricane Scale Classification

The District has not always been consistent in describing intended project protection in terms of the degree of protection (SPH surge) or the level of protection (SPH surge return frequency). In recent years, the District and other Corps officials have at times characterized the project as providing protection against a “fast-moving, category 3 hurricane,” which refers to a hurricane class defined by the Saffir-Simpson Hurricane Scale (SSHS). Although used by the District in an effort to communicate the degree of protection in terms that the public might better understand, that characterization of intended project protection is imprecise because there is no close relationship between the SSHS classification system, which is based largely on wind speed, and protection against SPH tidal surges that the LP&VHPP was specifically designed to provide (see Box 3-5).

Box 3-5: Relationship between the SPH, PMH, and the Saffir-Simpson Hurricane Scale

The Saffir-Simpson Hurricane Scale (SSHS) was developed in 1969 by Herbert Saffir, a civil engineer. It divides hurricanes into five categories based on sustained wind speed and the structural damage that might be expected within each wind speed category. For example, a Category 1 hurricane has wind speeds of 74-95 mph and causes “no real damage” to structures. On the other end of the scale, a Category 5 storm has wind speeds in excess of 156 mph and can cause complete building failure. Bob Simpson, who was Director of the U.S. National Hurricane Center at the time, added the effects of storm surge to the SSHS. Central pressure is a connecting thread between wind speed and storm surge. Although the scale provides useful information, flood surges often depend on a number of additional factors such as the slope of the continental shelf, shape of the coastline, size of the storm, and landfall region. The table below compares the parameters of the SPH, the PMH, and Hurricane Katrina to the SSHS. It shows that the SPH and PMH parameters as reported in the planning documents used for project authorization and reevaluation do not have high levels of consistency with the SSHS hurricane categories. SPH and PMH parameters are used primarily for designing structure elevations, while the SSHS is primarily for potential wind damage forecasts. Indicative of the problem of crossover comparisons between the design storm and the SSHS is the experience of Hurricane Katrina, which made landfall as a Category 3 storm based on wind speed, and then diminished from that point forward. But the surge associated with Hurricane Katrina at landfall had been generated while the storm was in the Gulf of Mexico, at which point it was classified as a Category 5 hurricane. The physical properties of the surge, carried by impetus, did not dissipate at the same rate as wind speed and slammed into the southeast portion of the project with inundation levels consistent with a Category 4 storm at some locations and a Category 5 storm at others. Although hurricane surges are highly location dependent, the IPET study reported that Hurricane Katrina had higher storm surges than Hurricane Camille, which was judged to be a Category 5 storm at landfall. The data provided below suggest that the storm surge that hit the Chalmette Loop along some stretches was in excess of 18 feet (the lower boundary of a Category 5 hurricane surge), indicating that the entire southeast portion of the project was subjected to Category 4/5 surges. (Stillwater surge data for Hurricane Katrina are provided in Table 3-5.) Areas along the Mississippi coast that were directly in the path of the storm experienced significantly higher surges.

Comparison of SPH, PMH and Hurricane Katrina Parameters at Landfall with the SSHS

Criteria	SPH	S-S	PMH	S-S	Katrina	S-S
Wind (mph)	100 (1962/84)	2	115	3	125	3
Barometer (cpi)	27.6 (1962) 27.35 (1984)	4	26.9(1962) 26.2(1984)	5	27.17	4/5
Maximum Surge (ft)	13(1962)	3/4	15.2	3/4	18.7	4/5

The 1984 study includes wind effect on surges.

3.5 Summary and Reflections on Project Performance Decisions

The chronology presented at the end of this section outlines the sequence of the key project events relating to project performance decisions reviewed in this chapter. The authors' reflections on that record follow below.

As a general review, it is the case that the District, following Corps policy for flood protection in urban areas, intended to build project levees and floodwalls that would not be significantly overtopped by the most severe storm event reasonably characteristic of the region, as represented by the selected project SPH. The original SPH for the LP&VHPP reflected the worst storm on record for the project area as of 1962, while the project PMH (a more severe storm) was based on storms of record for the Atlantic Coast. Only a small portion of the significant waves associated with the SPH would be expected to overtop protective structures, and they were not expected to compromise the integrity of those structures.

Of special note is that the data included in the 1962 Interim Survey Report indicate that estimated stillwater surges for the project PMH (as reported in that document) would also be contained by the design grades of project structures. This meant that it was believed that significant overtopping of structures could not happen under any circumstances, and higher structure elevations, or armoring of structures so that they could withstand overtopping, were not considered.

However, over time new information on storm parameters, potential surge levels, and datum errors suggested that significant overtopping of project structures as designed and constructed was increasingly likely to happen during the life of the project. Such overtopping could create flooding much greater than from wave action alone, and if sustained, could result in failure of the structures. But this new information was not factored into project design and construction; once project construction had begun, the District focused on finishing the project as originally authorized and designed.

This focus was the result of concerns for the affordability of the project and the urgency to get authorized protection in place. As noted in Chapter 2 and further discussed in Chapter 5, project costs were increasing dramatically and pressures in the federal government for cost control were strong as new information became available over time. Meanwhile, some local sponsors were seeking cost relief from having to repay historically incurred debt associated with the project. Moreover, the 1982 Government Accounting Office report and the 1984 Reevaluation Report indicated that, in the period prior to adoption of the High Level Plan, some local sponsors asked the Corps to analyze the benefits and costs of 100-year protection along the lakefront, a level of project protection that was less than that dictated by the design storm (and hence would dictate lower structure grades), arguing that the Corps tended towards overly-conservative structure designs.

The assertion has been made in post-Katrina reporting that neither higher structures nor designs including armoring to withstand overtopping were proposed for the LP&VHPP,

because they could not be justified by evidence that the benefits of these measures outweighed the costs. However, project documents show that benefit-cost analysis did not dictate structure designs established in the project plan authorized in 1965. And the project record provides no evidence that armoring of project structures was ever considered.

In fact, it appears that planning and design to prevent sudden and catastrophic failure of levees (most were on rivers) was uncommon throughout the Corps organization. There was a Corps Engineering Technical Letter suggesting consideration of the possibility and consequences of levee overtopping, but the solutions were not expected to be higher structures or armored structures (19870822). Structures for urban areas were built to contain massive storm flows. In the highly unlikely event that larger flows were to occur, there were options of flood-fighting, controlled breaching of downstream levees in less populated areas to reduce flood peaks, and organized and planned evacuation, since there would be ample warning time before the floodwaters crested. Opportunities for taking such actions were largely unavailable for levees and floodwalls designed for hurricane protection; however, no project documents were found suggesting that this difference was recognized.

In hindsight, the 1984 project reevaluation could have included strategies to protect against the increased likelihood of overtopping. At that point there had been adequate time to consider and assimilate the 1979 NWS report that reported revised and more divergent parameters for the SPH and PMH, and earlier memos within the District that had reported on similar changes in understanding of possible storm events. However, the 1984 reevaluation focused narrowly on justifying the replacement of the barrier elements with higher lakefront levees. In the 1984 report, the protection provided by the rest of the project network (which was not affected by the abandonment of the barriers) was not reevaluated.[50] There was no explicit acknowledgment in the 1984 report that storm events greater than the project SPH were then recognized as more likely than originally thought, and that such storms could overwhelm project structures as designed.

In later years, the potential implications of new storm information, surge modeling, and subsidence problems were recognized in the District, but no request for authority and budget to raise the heights or armor project structures was forthcoming. It is the case that significantly higher levees or armoring against a storm bigger than the original SPH would have required a new authorization, or at least a post-authorization change approval, not to mention agreement by local sponsors to meet the requisite cost-sharing. However, no new authority for project upgrades was sought after the early post-authorization change that allowed structures to be raised 1-2 feet to accommodate new analyses of SPH wave action. The logic for this approach can be found in the 1989 design memorandum pertaining to the St. Charles Parish portion of the High Level Plan, which reported the following:

> "The SPH for the Louisiana coast was derived by the National Weather Service from a study of 42 hurricanes that occurred in the region over a period of 57

[50] This statement is based on the materials available to the study team (19800600).

> years.... Based on subsequent studies of more recent hurricanes, the national weather service has revised the SPH wind field patterns and other characteristics over the years. Wind field patterns were revised after Hurricane Betsy in 1965 to reflect intensified wind speeds. After Hurricane Camille in 1969 the weather service completely revised hurricane characteristics for the SPH, including wind speeds, central pressure, and radii. In their (1979) publication NOAA has expanded and generalized the latest SPH characteristics. For the design of the Lake Pontchartrain and Vicinity Hurricane Protection Project High level plan, the SPH, as defined after Hurricane Betsy, was used. To assure that all the segments of the project were compatible, SPH parameters have not been changed since construction began." (19890200, page 132)

This passage indicates that the decision to use the original SPH parameters for the High Level Plan, rather than the updated SPH parameters provided by the NWS in 1979, was based on the same rationale as applied in the 1985 decision to maintain the use of the 1964-era datum benchmark elevations for remaining project construction.

In the mid-1990s, the District established a plan to reevaluate project protection in light of new information and the availability of improved data and surge modeling capabilities. However, the District decided that further refinement and testing of a relatively new, more sophisticated surge model (ADCIRC) was needed before it could be confidently applied for a detailed project reevaluation that might eventually be used to recommend project design changes. Work on refining the ADCIRC continued up to the arrival of Hurricane Katrina.

And importantly, the project documentation available to the study team provides no evidence that the new information indicating that project degree of protection was falling over time was communicated outside the District and Division. From 1965 to 2005, the District continued to report in annual Budget Justification Sheets sent to Congress that the project, once completed, would protect against the SPH surge and provide roughly a 200-year level of protection.

Chronology of Key Project Events Relating to Project Performance Decisions

Event Name	**Start Date**	**End Date**	**Notes**
Sea Level Datum of 1929, Later Renamed the National Geodetic Vertical Datum (NGVD)	1929		The U.S. Department of Commerce Coast & Geodetic Survey establishes the first official national vertical datum using mean sea level (MSL) measured at 21 tide stations around the U.S. (including one in the Gulf Coast) and 5 stations in Canada. This becomes the datum to adjust all vertical control in North America. LP&VHPP structures were constructed relative to this datum under the erroneous assumption that the datum corresponds with local MSL, the reference point used for the design of project structures. In 1973, the National Geodetic Survey changes the name of this datum to NGVD to avoid confusion, since it represents a land-based reference system that does not truly reflect local MSL at any location.
The first Standard Project Hurricane (SPH) Design Approved by the Corps for the Central and Southern Florida Project	Dec 31, 1953		"Partial Definite Project Report, Central and Southern Florida Project for Flood Control and Other Purposes." Lake Okeechobee report uses SPH concept for the first time.
Chief of Engineers Letter to the U.S. Weather Bureau (USWB) Describing Participation in Hurricane Study	Nov 25, 1955		Letter from the Chief of Engineers to the USWB describing participation in hurricane study. The USWB is given seven subprojects related to hurricanes.

Event Name	Start Date	End Date	Notes
National Hurricane Research Project (NHRP) Report #33 sets SPH parameters for the Project Area	Nov 1959		Document produced by the U.S. Weather Bureau in conjunction with the Corps provides methods for calculating SPH parameters for Atlantic and Gulf Coasts of the United States. Defines SPH as "the most severe storm that is considered reasonably characteristic of the region." The SPH is analogous to Standard Project Storm (SPS) concept used for river basin flood control projects. "The SPH index is based on enveloping the records of meteorological events with the elimination of a few extreme events." The issue of excluded events is important due to the limited database at the time. States that the SPH has a recurrence interval of one in 100 years for the 400-mile length Gulf coastline, termed “Zone B.” The recurrence interval for a storm along a critical path for New Orleans, a more limited area within Zone B, is calculated to be one in 200 years.
Interim Survey Report, LP&VHPP	Nov 1962		The SPH is chosen as the "design hurricane" for the project. This is a policy decision designed to prevent potential "serious threat to human life and property." Reasoning is similar to urban flood control policy for river basins that called for Standard Project Flood (SPF) protection. Based on NHRP Report 33, the project SPH has central pressure index (cpi) of 27.6 inches (storm intensity is inversely related to the cpi value) and a maximum wind velocity of 100 mph at 30 nautical miles. Design hurricane surges are derived from the SPH parameters and along with wind setup are used to determine the "hurricane tide" (stillwater surge level + wind setup) and structure heights required to contain it. (Example: estimates for stillwater surge levels for the lakefront and Chalmette were 11.2 and 11.9 feet, respectively. Structure heights were to be at higher levels because of wind setup and freeboard.) The document also provides parameters for the “Probable Maximum Hurricane” (PMH), or “the most severe storm that is reasonably possible in the region.” PMH parameters are given as cpi = 26.9 inches and wind speed = 115 mph. In 1962, modeling was more labor-intensive than it is today and hand drawings for storm-routing and use of rules-of-thumb were the norm.

Event Name	**Start Date**	**End Date**	**Notes**
SPH Parameters Remain Unchanged for Project Design Throughout the Project History	Nov 1962	Aug 2005	The original SPH parameters for cpi and wind speed set out in the 1962 Interim Survey Report continue to be used for project design throughout the project history, despite a slight lowering of cpi for the SPH (more severe) made in 1979.
Hurricane Betsy	Sep 9, 1965		The storm's cpi and wind speed parameters are similar to those chosen for the SPH in the 1962 report. However, the wave action from Betsy is more intense than what the District calculated for the project SPH and included in the 1962 planning report. The storm seriously damages six thousand homes near the Port of New Orleans and inundates the Lower Ninth Ward with twelve feet of water.
LP&VHPP Barrier Plan Authorized	Oct 1965		Based on the 1962 Interim Survey Report as approved by the Mississippi River Commission, the Board of Engineers for Rivers & Harbors, and the Chief of Engineers. Authorization language states that the project is in accord with the Chief's Report, which recommends the project in accordance with the District Engineer's recommendation in the 1962 report. Subsequent project documentation indicates that the District interprets this authorization as providing for protection against the original SPH parameters for wind speed and central pressure set out in the 1962 report.
The District Requests Authority to Increase Project Degree of Protection to the PMH	Oct 29, 1965		The District notes that Hurricane Betsy, despite having central pressure that was roughly equal to the 1962 SPH, had wind tides that would have overtopped many proposed project levees had it been on a path more critical to the project area. Based on this, the District requests authority to increase the project degree of protection to the PMH standard. Within one month the District is informed by the Division that project authority is broad enough to allow reconsideration of the degree of protection during "definite project studies."

Event Name	Start Date	End Date	Notes
Final Design Elevations of Structures are Established 1-2 Feet Higher than Original Designs	Aug 1966	Sep 1968	Design Memorandum 01, Parts I-IV Hydrology and Hydraulic Analysis. Based on new wind field parameters associated with Hurricane Betsy, the design elevations of all structures are raised by 1-2 feet during the detailed design phase in comparison to those recommended in the 1962 Interim Survey Report.
Post-Authorization Change Approved by the Chief of Engineers	Jan 31, 1967		This change is specifically for the Chalmette Extension, and documentation indicates that the levees along the eastern portion of the Chalmette unit will be 1-2 feet higher than designs presented in the 1962 Interim Survey Report.
Hurricane Camille	Aug 14, 1969		The District Hydraulics Chief reports in a September 29, 1969 memo that Camille had higher wind speeds (150 mph) and lower cpi (26.85) than the PMH reported in the 1962 report. This new data indicates that storms more severe than the SPH are now more likely than previously thought possible in the 1962 report.
Chalmette, IHNC, and Citrus Back Levee Structure Design Heights Remain Unchanged	Dec 1969	Aug 2005	With the exception of the design elevations of lakeshore levees that are raised with the official adoption of the High Level Plan in 1985, all design elevations remain unchanged after 1969
Implicit Flood Model (WIFM) Developed and Applied to the LP&VHPP	1978	1980	The WIFM computer model is developed by the Corps Waterways Experiment Station (WES) and applied to SPH surges from Lake Pontchartrain under the Barrier Plan. An analytical byproduct of that effort indicates that the 1962-era hurricane storm surge estimates for the lakefront may have been too high, and that surge estimates along MRGO, Citrus Back Levee, IHNC, and GIWW may have been too low. Further analysis using WIFM is discontinued when the Barrier Plan is later abandoned. This new information generated by the WIFM is not applied to those portions of the project that are not subject to reevaluation in 1984.

Event Name	Start Date	End Date	Notes
National Weather Service Technical Report #23 Revises Parameters for the SPH and PMH	Sep 1979		"Meteorological Criteria for SPH and PMH Wind fields, Gulf and East Coasts of the United States." Major new analysis of storm events. Continues enveloping methodology and leaves out major storm events from SPH. Events such as Camille are not included within the envelope. SPH cpi for the project area is lowered (more severe) to 27.35 from 27.6 as in 1962 report. No changes are made to wind speed estimates for the SPH. However, the PMH calculations for cpi are changed more dramatically, to 26.2 from 26.9, since the PMH is affected by the inclusion of Camille data. The new calculations show that the difference between the project SPH and PMH has increased from 1959 to 1979. At this time there are two issues: 1) the new SPH central pressure is now somewhat more severe than at project authorization, and 2) storms greater than the original SPH are more likely than previously thought possible.
Reevaluation Report Recommends Switch to the High Level Plan	Jul 1984		Recommends the High Level Plan (HLP) over the original Barrier Plan recommended in 1962 and authorized in 1965. The HLP plan involves higher levees along all areas exposed to tidal action along the shores of Lake Pontchartrain, as they would no longer be protected by the previously recommended barrier structures. Lakefront levee heights are adjusted upward to take into account higher lakefront surges without the barriers, but are not adjusted for the new SPH central pressure calculation provided in NWS Report 23. Although the new SPH central pressure parameter is reported in the Reevaluation Report, it is not applied in any design memoranda after 1984.

Event Name	Start Date	End Date	Notes
The District Freezes Datum (NGVD) Benchmark Elevations Used for Remaining Construction	Aug 07, 1985		Project structures had been constructed to this point using the NGVD 1964-era benchmark elevations as the reference point. After the National Geodetic Survey in 1983 adjusted local NGVD benchmark elevations (reflecting subsidence in the project area since 1964), the Division in 1985 requests that the District propose a course of action for incorporating the changes in its projects and studies. In response, the District adopts a policy to freeze the benchmark elevations used for remaining project construction to those that were applied at the start of project construction, based on the argument that to do otherwise would result in varying degrees of protection across the project area. The policy statement also notes concerns with the practicality and cost of altering already constructed project features. The Division approves the policy in that same year, noting that, "Consideration should be given to reanalyzing and modifying (if needed) hurricane protection work in high density urban areas where the datum changes will drastically reduce the level of protection."
Corps Publishes Updated Criteria for the Calculation of SPH Parameters	Apr 15, 1986		Engineer Manual (EM) 1110-2-1412 presents new criteria for determining central pressure based on an improved database. The EM also gives guidelines for using statistical procedures that use a longer storm history. (A 1994 report by the Corps Coastal Engineering Research Center used the new EM approach to conclude that an updated understanding of SPH central pressure would be 27.3 as opposed to 27.35 as reported in 1979 by NWS—see next entry).

Event Name	Start Date	End Date	Notes
The Corps Coastal Engineering Research Center (CERC) Conducts Lake Pontchartrain Storm Surge Pilot Study	1993		The District contracts with the CERC to perform a model pilot study to assess the impacts of changes in SPH parameters on design stages, and the effects of changes in the relationship between MSL and NGVD with respect to the required elevations of structures designed to prevent overtopping from a SPH surge derived in the MSL frame of reference. The CERC study uses an early version of the more sophisticated Advanced Circulation (ADCIRC) surge model to validate the original storm surge estimates for the project under the original SPH parameters. That application of the ADCIRC model reinforces the 1980s-era WIFM modeling findings that the 1962-era surge estimates may have overestimated the surge associated with the SPH along the lakeshore, and underestimated the SPH surge along the IHNC/GIWW corridor and the eastern boundary of Chalmette. With respect to the new 1979 SPH cpi parameter, the CERC uses the ADCIRC model to conclude that the change produces an increase in surge heights of 1-2 feet for certain storm tracks under one set of assumptions, while under another set of assumptions the new SPH parameter has little effect on estimated SPH surge elevations. The CERC study also concludes that local MSL, the reference point used for project design, is approximately one foot higher than NGVD, the reference used for project construction. Based on these preliminary findings, the CERC recommends a thorough hydrodynamic modeling of the basin and reevaluation of the project, using ADCIRC and a statistical procedure making use of the full database on historical storms within a joint probability approach or empirical simulation technique.
The District Requests Authority to Conduct Model Study to Determine Existing Degree of Project Protection	Sep 20, 1994		The District, citing the CERC pilot surge study results and recommendations as well as earlier WIFM modeling results, requests from the Division authority to conduct a numerical model study of project protection using modern models (ADCIRC) and data. The District notes that the restudy would be conducted with a view toward ensuring that the authorized degree of protection is uniformly designed and constructed throughout the protection network.

Event Name	Start Date	End Date	Notes
ADCIRC Surge Model Refinement and Testing	1995	2004	The District notes problems with the ADCIRC model due to its inability to calibrate to past storm events, and decides to pursue further model development and testing before applying the model to reevaluate project protection. An effort to improve the model is funded between 1995 and 2004, and the model is subjected to Independent Technical Review in 2004.
Newspaper Reports on Hurricane Dangers in New Orleans	Jun 2002		Five-part series ("Washing Away") published in New Orleans Times Picayune. One of many published reports on hurricane dangers. Some observers of the public reaction to the series write that public interest was not aroused and that the articles were viewed by many as "scaremongering."

3.6 Comparison of Structure Elevations and Hurricane Katrina Surge Heights

In this final section, the outcomes of project performance decisions are partly illustrated by comparing structure design heights, actual structure elevations when Katrina made landfall (pre-Katrina elevations), and Katrina stillwater surge heights. Table 3-5 provides these data for different project reaches. That information is also provided geographically in two different ways in Map 3-1 and Map 3-2. All elevations are based on a consistent and up-to-date vertical control reference framework [NAVD88(2004.65)].[51]

The data indicate that the intended design heights for much of the project were tested by Hurricane Katrina surges. The Chalmette Loop, IHNC, Citrus Back Levee, and New Orleans East Back Levee components each experienced storm surges that exceeded design elevations of structures in at least some reaches. Those reaches experienced overtopping. This can be inferred by comparing the “Katrina Stillwater Elevation” range to the “Structure Design Protection Elevation” range for each project component. In the case of the Chalmette Loop, for example, the storm surge was between 15.5 and 18.7 feet, while the design elevation of structures was between 14.5 and 18 feet. Considering that the reported Katrina stillwater elevations do not include wave runup, the degree of overtopping along the southeastern portion of the project was more severe than the table would indicate.

The pre-Katrina structure elevations were affected by the use of NGVD instead of MSL as the reference point for construction, and by the District’s 1985 decision to continue referencing project construction to the NGVD 1964-era benchmarks. Many project

[51] The data presented in Table 3-5 were provided by the Corps New Orleans District. It should be noted that the structure design elevations in Table in 3-5 differ from those reported in Table 3-4, because the former have been adjusted to a consistent vertical control reference framework.

reaches also experienced settlement and subsidence since construction.[52] All of these factors are not separated in the table, but the combined effects are observed by comparing the design elevations to the actual pre-Katrina elevations for project structures. As shown in Map 3-2, the differences are substantial for the Citrus Back Levee, IHNC, East and West, New Orleans East Back Levee, and the Chalmette Extension, in some instances at least three feet. Consequently, Katrina-induced overtopping of structures was worse than would have been the case had all structures been constructed and maintained at the originally intended design heights. The degree to which the differences between design and actual pre-Katrina elevations contributed to the flooding of New Orleans cannot be inferred from the data in the table, however.

The three outfall canals experienced surges during Katrina that were just below the stillwater design surges for the structures. They were not overtopped. Thus, performance decisions resulting in final design grades do not appear to be a factor in the breaches at the 17th Street Canal and the London Avenue Canal. (The next chapter considers design decisions for the outfall canals in some detail.)

The available data indicate that it is questionable whether the project, had it been built and maintained to original design intent, would have prevented to a significant extent the flooding of New Orleans that resulted from Hurricane Katrina. When Katrina was in the Gulf of Mexico it had central pressure and wind speed measurements that were more severe than storms thought to represent either the SPH or the more severe PMH for the project area defined when the LP&VHPP was authorized in 1965. The surges at landfall resulting from Hurricane Katrina, generated while the storm was in the Gulf, exceeded the original design stillwater surge levels along the entire southeast-facing perimeter of the project.

Moreover, based on flood modeling included in the IPET report, had the originally authorized barrier structures been in place at the time of Hurricane Katrina and had they worked effectively, floodwaters would still have entered the city through the breaches at the nexus of the IHNC and GIWW. And the abandoned barriers would have provided no protection for the Chalmette project area. Further, if frontage protection at each outfall canal had been in place and worked effectively, the residual inundation from overtopping and breaches at other locations would have resulted in significant flooding in New Orleans during and immediately after Hurricane Katrina. And if the line of parallel protection along the outfall canals had held fast, much of the city would have flooded from the surge entering through breaches that occurred along the IHNC. Essentially, the city was at risk along its entire perimeter because much of the land is significantly below sea level and any breach in the network of project structure that encircles the city had the potential to cause flooding over much of the project area.

[52] Settlement occurs when soils/strata underneath a structure become compacted by the weight of the structure, while the term subsidence refers to a general sinking of land in the area.

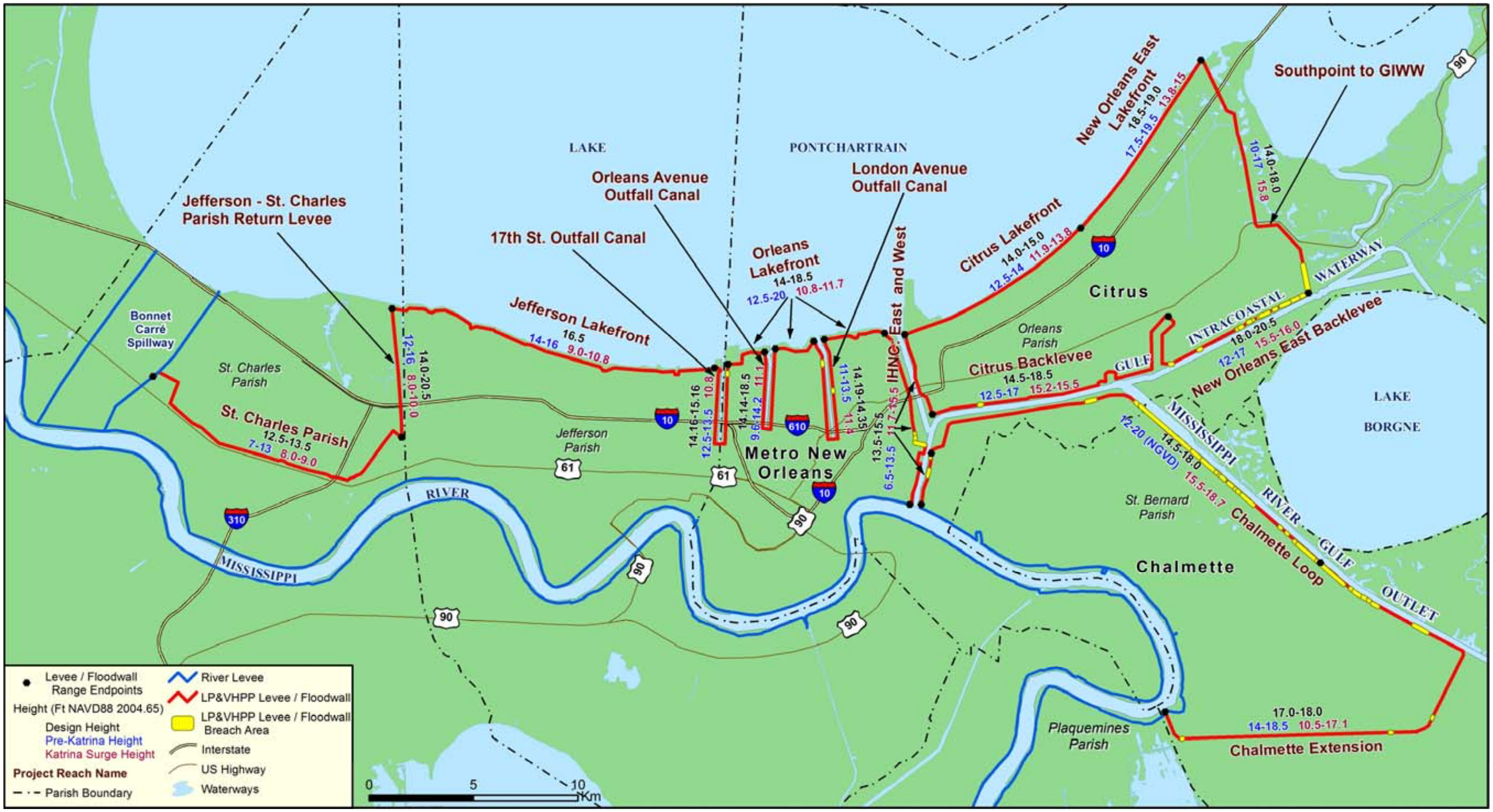
Table 3-5: LP&VHPP Structure Design Elevations, Pre-Katrina Structure Elevations, and Hurricane Katrina Surge Heights (excluding Katrina wave runup)

Project Reach	Structure Design Elevations *			Structure Pre-Katrina Elevations**		Katrina Surge Elevations (excluding wave runup)***	
	Stillwater Elevation FT NAVD88 2004.65	Protection Elevation FT NAVD88 2004.65	Source	Protection Elevation FT NAVD88 2004.65	Source	Stillwater Elevation FT NAVD88 2004.65	Source
St Charles Parish	10.5 11.5	12.5 - 13.5	DM18, Feb 1989	7-13	levee assessment	8.0 - 9.0	IPET HWM profile at lakefront
Jefferson-St Charles Parish Return Levee	11.5 12.0	14.0 - 20.5	DM 17A, Jul 87	12-16	levee assessment	8.0 - 10.0	IPET ADCIRC
Jefferson Lakefront	12.0	16.5	DM 17, Nov 87	14-16	levee assessment	9.0 - 10.8	IPET HWM profile at lakefront
Orleans Lakefront	12.0 - 13.4	14 - 18.5	DM13, Nov 84 and DM22, Apr 93	12.5-20	levee assessment	10.8 - 11.7	IPET HWM profile at lakefront
17th St Outfall Canal	12.1 - 13.13	14.16 - 15.16	DM20, Mar 90	12.5-13.5	IPET report, fig 1-83,91,92	10.8	IPET HWM at lakefront
Orleans Ave Outfall Canal	12.0 - 12.6	14.14 - 18.5	DM19, Aug 88	9.6-14.2	IPET report, fig 1-74, 80,81	11.1	IPET HWM at lakefront
London Ave Outfall Canal	12.19 - 12.35	14.19 - 14.35	DM19a, Jan 89	11-13.5	IPET report, fig 1-99, 100	11.4	IPET HWM at lakefront
Citrus Lakefront	12.0	14.0 - 15.0	DM14, Jul 84	12.5-14	levee assessment	11.9 - 13.8	IPET HWM profile at lakefront
New Orleans East Lakefront	12.0	18.5 - 19.0	DM15, Apr 85	17.5-19.5	levee assessment	13.8 - 15	IPET HWM profile at lakefront and ADCIRC
Southpoint to GIWW	12.0 - 13.3	14.0 - 18.0	DM16 Sep 87	10-17	levee assessment	15.8	IPET HWM Chef Menteur
New Orleans East Back Levee	13.5	18.0 - 20.5	DM2, Sup 4, Mar 71	12-17	levee assessment	15.5-16.0	IPET HWM GIWW MRGO and Chef Menteur
Citrus Back Levee	13.5	14.5 - 18.5	DM2 Aug 67	12.5-17	levee assessment	15.2 - 15.5	IPET HWM GIWW
IHNC, East and West	11.9 - 13.5	13.5 - 15.5	DM2, Sup 8, Feb 68	6.5-13.5	levee assessment	11.7 - 15.5	IPET HWM IHNC
Chalmette Loop	13.0 - 13.5	14.5 - 18.0	DM1, Aug 66	12-20 NGVD	TF Guardian files, 1998 survey	15.5 - 18.7	IPET HWM GIWW, MRGO and Shell Beach
Chalmette Extension	12.3 - 13.0	17.0 - 18.0	DM1, Aug 66	14-18.5	levee assessment	10.5 - 17.1	IPET HWM along MRGO and near Caernarvon and ADCIRC results

* Structure design elevations have been adjusted to the new datum NAVD88 2004.65 and thus do not match the design elevations as reported in design memoranda and cited earlier in this chapter.

** The reported protection elevations represent final grades that include stillwater elevations plus extra grade for wave runup or freeboard.

*** The comparison of structure elevations with Katrina flood elevations understates the extent of Katrina flooding since the former include wave runup (or freeboard) while the latter do not.



Map 3-1: LP&VHPP Structure Design Heights, Actual Pre-Katrina Structure Heights, and Katrina Surge Heights, by Project Reach

Map 3-2: Deficiencies in Pre-Katrina Structure Elevations with Respect to Original Design Elevations, by Project Reach

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Chapter 4. Design Decisions for the Outfall Canals

4.1 Introduction

This chapter focuses on project design decisions for the three outfall canals in metro New Orleans. It is divided into five sections. Section 4.2 provides background information on the determination that the LP&VHPP would need to address hurricane surges into the outfall canals. Section 4.3 reviews the consideration and choice of alternative protection approaches for the outfall canals during the period 1975-1992. It is largely chronological and explains why the District developed and recommended a “frontage protection” plan (floodgates across the canal mouths), why the local sponsor opposed that plan and sought an alternative “parallel protection” plan (lateral levees/floodwalls along the canal lengths), and the eventual resolution of these different preferences by Congress in favor of the local sponsor. Section 4.4 reviews the consideration and use of alternative types of protective structures for implementing parallel protection, and provides the rationale for understanding the choice of I-Type floodwalls (I-walls) as the dominant type of project structure used for the outfall canals. Section 4.5 outlines design decisions relating to I-wall sheet pile penetration depths. It reviews District and Division efforts to investigate whether reduced sheet pile penetration depths for I-walls subject to short-term loading conditions could reduce costs without compromising engineering reliability of I-wall structures. Section 4.5 describes the resulting changes in design criteria for I-walls constructed for hurricane protection, and the effect of the new design criteria on final sheet pile penetration depths included in plans and specifications for the London Avenue Canal. Section 4.6 provides a summary of design decisions for the outfall canals and the authors’ reflections on the key factors and considerations underlying those decisions.

4.2 Incorporation of the Outfall Canals into the LP&VHPP

Interior drainage has always been a serious issue in New Orleans. The three main outfall canals with large pumping stations at their heads—the London Avenue Canal, Orleans Avenue Canal, and 17th Street Canal—have long been in place to drain rainfall from the city into Lake Pontchartrain (see Map 4-1).[53] Early efforts to drain the city during rainfall events required pumping stations placed at locations well within the present city limits south of the Lake Pontchartrain shoreline. Land north of the pumping stations was undeveloped wetlands. Trenches running from the stations to the lake accommodated flowage during periods of use. In the 1920s, the Orleans Levee District (OLD) undertook a major land development effort along the northern transition zone between the shore of Lake Pontchartrain and the city. It had multiple purposes. A 5.6-mile seawall was constructed well offshore in 1930. It was a stepped concrete barrier to storm surges. Sand from the lake was pumped behind the wall, creating property for economic development, thus extending the effective city limits to the north. The outfall canals were incorporated

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[53] *Time and Place in New Orleans: Past Geographies in Present Day* by Richard Campanella provides an excellent history of the city’s efforts to manage interior drainage.

into the wall with sweeping concrete-lined inlets, thus providing three continuous 2.5-2.9 mile channels between the pumping stations and the lakefront. Simple earthen berms made from excavated material helped contain flows in the outfall canals. At the time that the seawall was built, it was presumed that there was little economic incentive to move the pumping stations to the lakefront, as existing channel capacity was adequate to contain all pumped water, and the new seawall was expected to provide protection from hurricane-driven surges that might be pushed into the canals. After the land development project was completed, houses were constructed on available property in zones planned for such use, most without protective features against flooding. The area eventually became so densely populated that, by the 1950s, the outfall canals no longer passed relatively harmlessly through wetlands, but instead passed through a major new settled portion of the city where land had subsided. The simple berms that had contained the outfall canals were raised in order to contain water flow through the populated areas.

4.2.1 Outfall Canals Were Not Part of the 1962 Project Plan

The analysis supporting the 1962 Interim Survey Report concluded that, with the recommended Barrier Plan in place, the existing local levees along the outfall canals would be adequate to contain barrier-dampened SPH surges coming from Lake Pontchartrain. Those local levees were then at 9.5 feet elevation and the SPH surge with the barriers in use was predicted to be no more than 6 feet along the lakeshore. Consequently, early (1962-1964) planning documents made no specific references to consideration of the outfall canals as part of the LP&VHPP.

4.2.2 Surges into the Outfall Canals Emerge as a Concern after Hurricane Betsy

The District determined soon after the project was authorized that the existing outfall canal levees did not meet the design height or design stability required for the LP&VHPP under the recommended Barrier Plan or the alternative High Level Plan. This was due to revised wind field estimates of wave runup based on information derived from post-Hurricane Betsy analysis undertaken by the U.S. Weather Bureau. The District used that analysis to determine that project levee grades should be increased by 1-2 feet throughout the project area. The higher overall lakeshore levees deemed necessary in the aftermath of Hurricane Betsy meant that, even with the barriers in place, the outfall canals would require additional project protection.

The first significant reference to the need for enhanced hurricane protection along the outfall canals was a 1976 Government Accounting Office (GAO) Report to Congress on cost, schedule, and performance problems encountered with the LP&VHPP (19760831). Although that report focused on project cost overruns and construction delays, it pointed out that additional protection for the outfall canals would be “necessary,” and that it could “cost as much as $60 million” and “have to be authorized by Congress.”

The GAO report stated that the District was then considering different protection alternatives for the canals, and mentioned two basic options—either move pumping stations to the lakefront, or continue “with the present pumping stations which are remote from the levees and raise the outfall canal’s embankments from each pumping station to the lakefront levee.”

Between 1977 and 1980, the District devoted considerable effort to developing protection alternatives for the outfall canals, spurred by the recognition that the barriers might have to be abandoned and the lakefront levees would have to be even higher than originally planned (19770819). In 1977, the Sewerage and Water Board (SWB) of New Orleans continued to express its preference for the Barrier Plan because of concern for the extreme threat posed by a hurricane of the magnitude of Camille. The SWB also noted that, in the absence of the barriers, levees along the outfall canals would have to be significantly higher or a “safer” alternative of moving the canal pumps to the lakefront would need to be pursued (19771123).

The District developed seven alternatives for the outfall canals and, in 1980, briefed the OLD and the SWB on the alternatives. By 1982, the OLD had expressed a willingness to consider all alternatives for the outfall canals, while the SWB argued that the choice of protection alternative must preserve its ability to drain rainwater from the city to Lake Pontchartrain via the canals under hurricane conditions (19821207).

4.2.3 Consideration of the Outfall Canals in the 1984 Reevaluation Report

The 1984 Reevaluation Report recognized that the outfall canals were a significant unresolved issue. By then it was clear that the environmental issues that precipitated the court injunction against the proposed barriers meant that the Barrier Plan would not go forward and the High Level Plan was by default the only viable option. Indeed, at that point the High Level Plan was reported to be the most economically-justified approach based on a remaining-net-benefits analysis. Without the barriers, the High Level Plan (involving levees/floodwalls exclusively) would have to rebuff a significantly higher storm surge that could approach the city from the north with the SPH passing to the east and engorging Lake Pontchartrain. This necessitated higher lakefront levees than would have been required as part of the Barrier Plan. Moreover, an SPH event along a critical path would be expected to send lake surges into the outfall canals through their lake outlets in the seawall, and in turn overtop existing interior canal levees. The mention of the outfall canals in the 1984 Reevaluation Report represented an explicit recognition that preventing surges into the outfall canals was a necessary part of the LP&VHPP.

The Reevaluation Report described five alternatives for the three outfall canals that the District had developed. Alternative one would involve raising and strengthening the existing canal levees to provide SPH surge protection "without concern for the number of house relocations necessary"; it was estimated to cost about $200 million. Alternative two was the same as the first except that house relocations would be avoided; it was estimated to cost about $250 million. Alternative three would provide for floodgates at the mouths of the canals, which could be closed during hurricane events; it was estimated to cost about $20 million. The report states that residual damages (in dollar terms) from interior flooding when the gates were closed during storm events would be minimal because "during times of high lake levels...the capacity of the existing pumping stations already would be greatly reduced." Alternative four was the same as the third, but added auxiliary pumping stations at the lakefront to allow pumping to continue while the gates were closed during hurricane events; it was estimated to cost about $124 million. The report noted that the SWB as well as District engineers had doubts about the workability of alternative four because of potential surging problems between pumping stations. The fifth alternative would relocate the existing pumping stations from the canal heads to their mouths at the lakefront, and improve the interior drainage network; no cost estimate was provided for this alternative since it was presumed to be "prohibitively expensive." Although the Reevaluation Report recommended no specific protection alternative, the report's overall economic analysis for the project used the estimated cost of alternative four (19840700).

4.3 Choice of Protection Approach for the Outfall Canals

4.3.1 Frontage versus Parallel Protection

The first four protection alternatives outlined above reflect two different protection approaches—frontage protection and parallel protection. Frontage protection focused on placing gates across the mouths of each canal to prevent lake surges front entering the canals. Parallel protection focused on augmenting lateral protective structures along both sides of the entire lengths of the canals, while leaving the canal mouths open to Lake Pontchartrain at all times. With parallel protection, hurricane-driven lake surges would enter the canals where they would be contained by the lateral protection structures.

The primary advantage of the frontage protection approach was that it would prevent lake surges from entering New Orleans via the canals. The primary disadvantage of the frontage approach was linked to the internal drainage function of the canals. If heavy rains were to accompany a hurricane event, the pumping and drainage capability of the canals would be compromised when the gates were shut—unless significant added investments were made in the drainage system to allow for continuous pumping. For example, auxiliary pumps could be installed at the mouths of the canals to allow continuous pumping when the gates were closed, but this would add significant expense (and involve technical challenges relating to the coordination of pumping stations).

Map 4-1: LP&VHPP Structures and Breach Areas on the Outfall Canals and the Inner Harbor Navigation Canal

The parallel protection plan would raise and strengthen the existing levees along the outfall canals to levels adequate to contain SPH-driven surges from Lake Pontchartrain that entered the canals. The advantage of the parallel protection approach rested on the fact that the existing pumping stations and canals, with modifications, could continue to operate to drain rainfall from the city during a hurricane or lesser storm. Thus, internal drainage capacity during a hurricane would be greater with parallel protection than with frontage protection. The primary disadvantage of parallel protection was that the overall protection system, and its exposure to flood surges, would be increased by nearly eleven miles in comparison to the frontage protection approach. Moreover, the bridges that crossed the canals would have to be either flood-proofed or raised, and the existing pumps protected. Another potential difficulty with the parallel protection approach related to the concentrated urban development that had occurred along the canal corridors; raising the existing levees would entail significant costs as well as potential local political consequences associated with the need to acquire the necessary lands, easements, and rights-of-way (19770819).

Cost was the major factor in the consideration of frontage versus parallel protection. There is no record that there was any concern expressed about the engineering reliability of the different approaches with respect to SPH surge protection. However, as outlined above, there were differences of view between the District and local agencies over the effects of the different approaches on the operational reliability of the drainage system.

4.3.2 District Recommends Frontage Protection (Butterfly Gates)

The District considered frontage protection to be the most straightforward and cost-effective protection approach for providing reliable SPH surge protection along the outfall canals. And in an effort to accommodate local concerns, the District expended considerable time and money to develop a frontage alternative that would be compatible, to the maximum extent possible, with the expressed desire of local agencies to preserve interior drainage capability of the canals during a hurricane event. Specifically, the District focused on developing and testing an innovative frontage design in which the gates would stay open to the lake as much as possible during a hurricane.

Early design work by the District focused on two types of gates—vertical lift gates and vertically-pinned gates. The pinned gates, called butterfly gates, were ultimately chosen for detailed design, and then model-tested for operational evaluation by the Corps Waterways Experiment Station (WES, now known as the Engineer Research and Development Center). Designing such a frontage protection alternative for the outfall canals represented a challenge, as the Corps had never developed and used a similar type of structure. Box 4-1 includes a description of the butterfly gates and their operation.

Box 4-1: The District-Recommended Butterfly Gates for the Outfall Canals

"The proposed structure would consist of reinforced concrete components and steel butterfly valves (gates). Operation of the structure is based on the theory of vertical self-operating, eccentrically pinned, butterfly valves. Under normal circumstances, the valves would be maintained in a passive, open position to allow pumping of interior drainage into Lake Pontchartrain. When a hurricane approaches, the valves would be placed in the active (automatic) mode. In this case, the valves would remain open when the water level in the outfall canal exceeds that on the lake side of the structure but would close when the water level on the lake side of the structure is greater than that in the outfall canal. Closure of this type would normally be in response to the lake side water level rising due to a hurricane driven surge. In the open (trimmed) position, the axis of each valve would be rotated 12 degrees from the center line of the gate bay. During a surge flow, the eccentricity of the pin and the 12 degree offset (trim) would induce closure. This self-operating feature would permit continuous operation of the pumping station during a hurricane. This would be possible because the valves would prevent surge flows from entering the outfall canal and would automatically reopen when the water level on the lakeside of the control structure recedes to a level below that in the outfall canal. When the threat of further hurricane induced surge had passed, the valves would be returned to their passive, open condition. Along with the above described self-operating feature, machinery would be provided to permit manual operation of the valves. This would only be required in the event of a malfunction of the proposed automatic operating system."

Source: London Avenue Outfall Canal, GDM 19A, Volume I (19890100, pages 64-65)

4.3.3 Local Agencies Adamantly Favor Parallel Protection

After 1984, the OLD and SWB were consistent in their preference for parallel protection. The issue of which protection approach to pursue for the outfall canals sparked vigorous debate between the SWB and OLD on one side and the District on the other, and remained unresolved until late 1991. This debate arose from the different objectives and constraints of the local agencies, and the federal government as represented by the District.

On the one hand, the District's sole objective was to identify and recommend the least-cost, reliable design for providing SPH surge protection for the outfall canals. Nevertheless, the District made a considerable effort to devise and model test a frontage protection alternative for the outfall canals that would maximize local agencies' ability to continue to drain rainfall from the city via the canals during hurricane conditions. The District concluded that this frontage alternative (the butterfly gates) was the most cost-effective solution to the vulnerability of the outfall canals to lake surges, would operate reliably, and would preserve to the maximum extent possible the ability of local agencies to continue to drain rainfall from the city during hurricane conditions. This District conclusion was stated in Design Memoranda 19 and 19A for the Orleans Avenue Canal and London Avenue Canal, respectively, and was presented in a number of different forums at different times. In the design memorandum for the 17th Street Canal, however, the District recommended a parallel protection plan because its estimated cost was comparable to the cost of the butterfly gates plan, and it was the locally-preferred plan. These design memoranda all stated that the OLD (the local sponsor) as well as the SWB had gone on record in support of the parallel protection plan (see Box 4-2).

Box 4-2: Post-1987 Outfall Canal Design Memoranda

Orleans Avenue Canal: GDM #19 (August 1988) included a detailed description of alternative plans and recommended fronting protection with butterfly gates based on cost-effectiveness/least-cost analysis (at a cost of $15,100,000). It described the alternative locally-preferred parallel protection plan, with a cost of $43,800,000. The document stated the facts of the disagreement between the District and OLD (An August 11, 1988 letter from District Chief of Engineering to the OLD indicated that the parallel protection plan was a "betterment") and asserted that design work done under contract for the locals on the parallel protection plan had been coordinated with the District and met Corps standards. Moreover, it stated that the federal contribution to the parallel protection plan, if implemented, would be limited to 70% of the cost of the recommended fronting protection plan (19880800).

London Avenue Canal: DM #19A (January 1989) included a detailed description of alternative plans and recommended fronting protection with butterfly gates based on a cost effectiveness/least-cost analysis (at a cost of $9,110,000). It described the locally-preferred parallel protection plan, with a cost of $43,800,000, and specified that it was to be treated in the same manner as the Orleans Avenue outfall canal should the local sponsor pursue that alternative on its own (19890100).

17th Street Canal: GDM #20 (March 1990) recommended the locally-preferred parallel protection plan (at a cost of $20,700,000). This plan was recommended by the District because the cost of the frontage plan ($20,500,000) was almost equivalent, and the local sponsor preferred the parallel protection plan (19900300).

Local agencies had two objectives when choosing the protection alternative for the outfall canals—enhancement of hurricane protection and the capacity to drain rainfall from the city via the canals during hurricane conditions. The local sponsor's opposition to the District-recommended frontage protection plan was based on these dual objectives and the distribution of project costs to local agencies and the federal government under the different alternatives. One local concern with the butterfly gates related to possible operational problems that could impede interior drainage; for example, OLD engineers who had observed the WES model in operation voiced concerns that, when the gates were closed to hold back lake surges, floating debris could potentially snag on the gates and prevent them from automatically reopening when lake waters receded below the level of water in the canals. More generally, the OLD and SWB were concerned that the canals could not be used for internal drainage when the butterfly gates were closed during times when the lake head was greater than water levels in the canals. According to OLD and SWB logic, if a hurricane simultaneously produced lake surges and severe rainfall, New Orleans would be flooded with the butterfly gates in place because the closed gates would prevent the pumping of rainfall out of the city via the canals. In their view, the frontage protection alternative would reduce the overall reliability of the interior drainage system.

That reliability could be assured if, in addition to the butterfly gates, new auxiliary pumps were installed at the mouths of the canals to allow continuous pumping even when the gates were closed. However, such auxiliary pumps would cost over $100 million and the District had informed the local agencies that, since the pumps addressed drainage and not hurricane protection, this cost would be a local responsibility in accordance with national civil works policy and the authorizing language for the project. Thus, if the frontage protection were pursued as part of the LP&VHPP, the OLD as the local sponsor would be required to pay the local cost-share for the butterfly gates, and local agencies would also have to pay the full cost of any new auxiliary pumps added to preserve internal drainage capacity when the gates were closed during hurricane conditions.

The local sponsor's concerns for cost and drainage system reliability were accentuated because the OLD and SWB were already taking steps to improve the existing canal levees and implement other measures to increase canal pumping capacity to accommodate heavy rainfall events (see Box 4-3). From the standpoint of these agencies, if the parallel protection plan were implemented as part of the LP&VHPP, they would not have to install and pay for new auxiliary pumps, and their already-planned efforts to improve existing canal levees could be accorded in-kind credit toward the local sponsor cost-share for the federal hurricane protection project. (In-kind credit toward meeting local cost-sharing obligations was part of the original project authorization language.)

However, the District maintained that, if the local sponsor insisted on pursuing parallel protection within the LP&VHPP, then any incremental costs of this plan above the cost of the least-cost alternative plan for providing SPH surge protection (which the District had determined was the butterfly gates frontage plan) would be considered a drainage "betterment."[54] Such betterments, by Corps policy, are the full financial responsibility of the local sponsor. Thus, if the locally-preferred parallel protection plan were pursued, the federal government would restrict its financial contribution for the plan to 70% of the total cost of the butterfly gates plan (or about $17 million for the London Avenue and Orleans Avenue canals). That District stance is stated in correspondence accompanying the London Avenue Canal and Orleans Avenue Canal design memoranda, and was endorsed by the District Chief of Engineering and cleared by the Division. The local sponsor nevertheless moved forward with its efforts to implement the parallel protection plan. There is no evidence in any available project documents indicating that either the District or the local sponsor believed that parallel protection was a less reliable alternative to frontage protection.

[54] The District also informed the local sponsor that any local efforts to implement parallel protection would have to meet Corps design and construction standards to be accorded in-kind credit toward the local sponsor cost-share.

Box 4-3: Local Efforts to Dredge and Install Floodwalls at the 17th Street Canal

In 1983, the Sewerage and Water Board (SWB) of New Orleans submitted to the District Regulatory Branch an application for a permit to dredge the 17th Street Canal and install sheet pile walls along its existing levees for the purpose of improving the drainage capacity of the canal (19830623). The permit application was forwarded to the District Engineering Division for review and comment, following District policy relating to permit actions that could impact a federal flood control project. The District Engineering Division evaluated the proposed work for its possible effects on the grade and integrity of the existing federal levee on the west bank of the canal, and provided numerous technical comments to the applicant on additional data needs and concerns to be resolved before it would report to the Regulatory Branch that it had no objections to granting the permit (19830111). District engineers worked with SWB consulting engineers to resolve their concerns, one of which related to the potential for uplift pressures to cause blow-out failure at the landside levee toe under high water conditions (19840130). The SWB consulting engineers conducted a test section for this potential (19840112), which satisfied the concerns of the District engineers (19840313). The permit was granted on June 13, 1984 after all the concerns of the District Engineering Division had been addressed and resolved (19840613).

The SWB had completed work on some project phases by 1989, but it was not until 1990 that it entered into an agreement with the Orleans Levee District for combined dredging and flood protection works for the east bank of the canal. With work proceeding on that side of the canal, the SWB pursued a similar agreement with the East Jefferson Levee District (EJLD) for work on the west bank. To that point, the EJLD had been uninterested in pursuing this project, seeming content to wait for the Corps to do the floodwall work as part of the LP&VHPP. However, EJLD signed an agreement with SWB for combined dredging and floodwall work on the west bank in November 1991 (19920527).

With the timeframe for the SWB permit about to expire, SWB requested that the District grant a permit time extension to complete the work (19920527). The District in June 1992 granted the permit time extension to June 1997, and informed SWB that no more time extensions would be forthcoming (19920622). The project documentation available for this study ends in the 1992 timeframe, so it is unclear to the study team whether dredging work on the west side of the canal was ever initiated or completed.

4.3.4 Orleans Levee District Initiatives

The OLD, in pursuing enhancements to the existing canal levees before a plan for the outfall canals was finalized as part of the LP&VHPP, hired its own contractor to develop a plan for the London Avenue Canal. The result was an April 1986 design memorandum (DM) prepared by Burke & Associates, Inc. (19860400). At that time, the OLD was proceeding on its own with the hope of incorporating and receiving in-kind credit for the work as part of the LP&VHPP. The OLD-sponsored design work was based on providing SPH surge protection, which, in terms of return frequency, the District had estimated would provide roughly 300-year protection. The OLD plan included some levees but mostly floodwalls, including over 26,000 feet of cantilever steel sheet I-walls, and a section of T-walls (these floodwall designs are described in the next section). Cost estimates of $38 to $44 million were reported for this plan in various documents. (These cost estimates were lower than the preliminary costs for parallel protection estimated by the District and reported in the 1984 Reevaluation Report) The design memorandum noted that the OLD-sponsored design work had been coordinated with the District so that the plan would provide SPH surge protection, and noted that it adhered to all Corps engineering regulations and manuals. The OLD ultimately decided the plan was too expensive, however, and directed the contractor to stop further development of the plan.

The OLD subsequently contracted again with Burke & Associates to prepare an "interim" parallel protection plan for the London Avenue Canal that would provide 100-year protection, and the resulting design memorandum was published in May 1990 (19900500)). That document stated that the interim protection plan would protect against the design surge for a 100-year storm, included an extra two feet of freeboard, and was developed according to geotechnical standards set by the American Society of Civil Engineers (ASCE). The sequence of events that led to this new design for the London Avenue Canal was summarized in the 1990 design memorandum as follows:

> "In April 1986, a general design memorandum was prepared for this flood protection (protection for a 300 year storm plus two feet of free board with the Corps' current geotechnical design standards) which indicated a cost of 44 million dollars. At the time, the available budget for the London Avenue Canal was considerably less that this amount. Therefore, the [OLD] Board decided to upgrade the existing system for interim flood protection to a level within the budgetary limits. Also, with the Corps standards being too stringent, the Board decided to follow the ASCE's state of the art geotechnical criteria and standards for structural design." (19900500, page 6)

On a separate track, the OLD pursued an aggressive strategy to garner political support among state government officials and the Louisiana congressional delegation for incorporating parallel protection for the outfall canals into the LP&VHPP. A resolution passed by the Board of the OLD during a meeting on October 17, 1990 expressed its commitment to the parallel protection approach and encouraged the Corps to support it (19901017). The resolution also empowered the Board President to take steps to bring this to the attention of government officials at all levels; specifically, the Board President was given the authority to spend money on a "consultant" to help "inform" Congress. The minutes to the meeting include a long narrative expressing the importance of parallel protection to the OLD and the financial stakes involved if the costs for parallel protection could be allocated between the federal and OLD budget differently than the allocation that the District said would be necessary pursuant to Corps policy. The minutes show that the worth of hiring a consultant to support the congressional delegation was debated, and it was decided that the investment in a consultant was small in light of the potential gain from securing congressional support for incorporating the parallel protection plan into the LP&VHPP and authorizing federal financing for a full 70% of its cost.[55]

The choice of protection approach and cost-sharing allocation for the outfall canals involved very high financial stakes for the local sponsor. If the District prevailed in its position that the incremental cost of parallel protection (over the cost of the least-cost butterfly gates plan) was a betterment, then the federal government would contribute

[55] The tone of the OLD meeting was respectful to the Corps (a high-ranking representative of the Corps New Orleans District was present at the meeting).

about $17 million to the London Avenue Canal and Orleans Avenue Canal protective structures. On the other hand, if the parallel protection plan were incorporated into the LP&VHPP with the federal government contributing a full 70% of its cost, then the federal contribution would be $62 million. The $45 million difference in federal contribution under the two scenarios was of extreme importance to the OLD, particularly in light of the financial setback it experienced with the 1984 Bohemia Spillway decision (see Chapter 5) and its continuing concern over escalating local cost-share requirements, as project costs had increased substantially over time when compared with the original cost-share expectation. Indeed, at the time of the 1985 shift to the High Level Plan, the costs to provide project protection at the outfall canals had not yet been determined, but even without those costs overall project cost had increased significantly during the previous decades (see Chapter 5).

4.3.5 Engineering Reliability Was Not Part of the Outfall Canal Debate

The long debate over which of the two protection approaches to pursue for the outfall canals did not reflect any evidence of concern about differential reliability of the alternatives for providing protection against the SPH surge (i.e., engineering reliability). The District viewed the butterfly gates as the most elegant as well as the most cost-effective plan for providing SPH surge protection at the canals, and noted practical difficulties with the alternative parallel protection approach (relating to limited rights-of-way and poor foundation soils). However, none of the design memoranda and other project documentation related to the outfall canals that were reviewed for this study indicate that the District or local sponsor viewed the parallel protection approach as involving potentially greater failure risk than the frontage protection approach. Such greater risk could arise because of the much greater length of protective structures that would be exposed to hurricane surges using the parallel protection approach and that could introduce many more points of potential vulnerability to failure. But the available project records relating to the outfall canals do not indicate any recognition by project engineers that the parallel protection approach was potentially inferior to frontage protection approach in terms of risk and reliability.

At the time when this debate was occurring, engineering reliability assessment methods were not highly developed by the engineering community, outside of a few areas such as nuclear plant safety. It was not until the mid-1980s that the political and technical leadership of the Corps began to recognize and stress the utility of formal analyses of risk and reliability. And in 1988 the Corps was just beginning its risk assessment applications research program, and field guidance was still years away.[56]

4.3.6 Congress Mandates Parallel Protection and 70% Federal Financing

In the early-1990s, Congress resolved the choice of protection approach and plan cost-sharing distribution for the outfall canals in favor of the local sponsor. Congress first weighed in on the protection approach in a conference report accompanying the Water

[56] 198604016; 19861104; 19861208

Resource Development Act of 1990. Under the section entitled "Joint Explanatory Statement of the Committee of Conference," the conferees:

> "[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 to be borne by both the Federal and local assuring authorities." (19901027, page 3)

But this conference report did not require choice of the parallel protection approach for the outfall canals or specify how the costs of implementing parallel protection should be split between the federal government and the local sponsor. The Congress finally resolved the protection approach and cost distribution for the outfall canals in the Energy and Water Development Act of 1992.[57] The legislation stated:

> "That with the funds appropriated herein and hereafter for the Lake Pontchartrain and Vicinity, Louisiana Hurricane Protection project, the Secretary of the Army is authorized and directed to provide parallel hurricane protection along the entire lengths of the Orleans Avenue and London Avenue Outfall Canals by raising levees and improving flood protection works along and parallel to 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." (19910817, page 4)

4.3.7 Tensions in the Federal-Local Partnership as Plan Implementation Begins

Correspondence between the District Engineer and the OLD from late 1990 to 1993 regarding who would control plan contracting and design work indicates that the federal-local partnership was strained. Project documentation includes numerous letters between the two parties relating to contracting arrangements and the adequacy of private engineering firms under contract to the OLD. Other difficulties between District leadership and OLD engineering staff are referenced in OLD board meeting minutes (19930319).

With the cost-sharing distribution mandated by Congress in 1992, the OLD could now afford and was ready to move forward with implementing parallel protection. On the other hand, consistent with administration budget policy guidance, the Corps Headquarters did not budget for the parallel protection work after 1992.[58] Nevertheless, federal funding for parallel protection was provided annually by congressional adds to the

[57] For a characterization of the views of certain members of Congress, the District, and OLD on the outfall canals set out in correspondence among these parties just prior to this legislation, see: 19910318.
[58] See the Chapter 2 discussion of the administration policy decision regarding budgeting for the parallel protection plan.

administration's requested appropriations. The District then used these monies to implement the work.

4.4 Choice of Parallel Protection Structures

Three types of protective structures were considered and used to varying degrees to implement parallel protection along the outfall canals: earthen levees and two types of floodwall designs—I-walls and T-walls (see Figure 4-1). Each type of structure can be constructed effectively and safely and each has specific advantages and disadvantages. Indeed, there are tradeoffs between them that are particularly sensitive to different cost considerations (see Box 4-4).

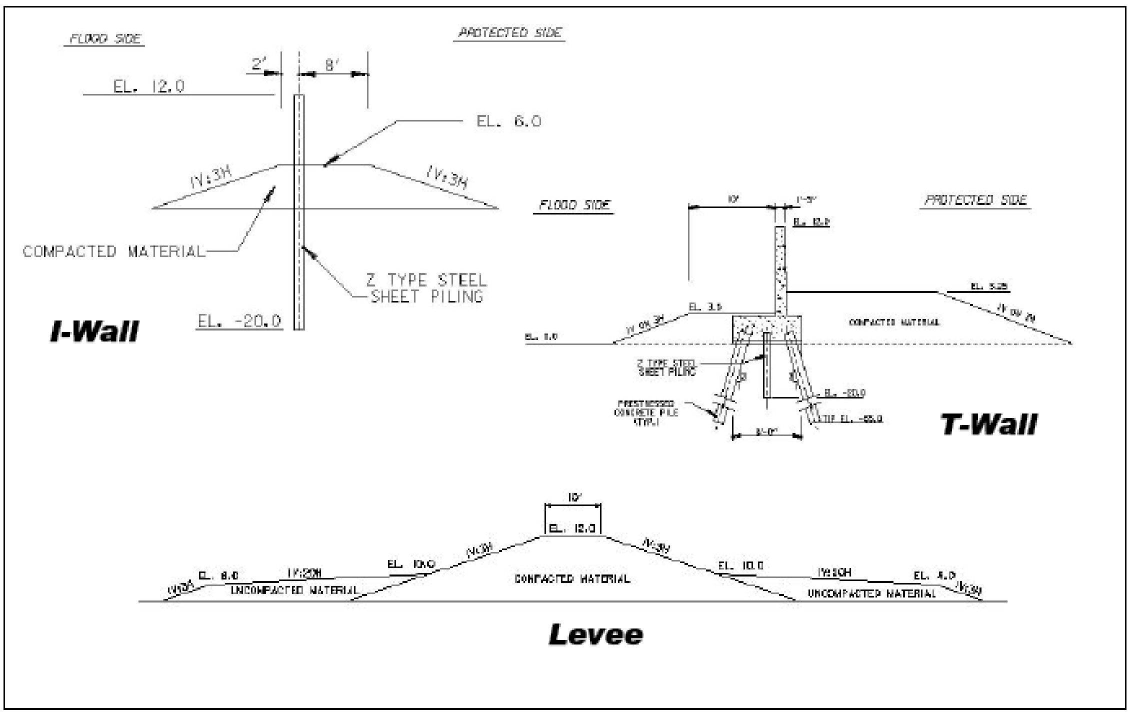

Figure 4-1: Illustration of Levees, T-Walls, and I-Walls

4.4.1 Use of Levees, T-Walls, and I-Walls for the Outfall Canals

4.4.1.1 Levees

Levees are earthen embankments. The OLD had originally built levees along the outfall canals to provide flood protection before significant urban development had occurred in adjoining corridors.[59] The original canal levees set property boundaries on the land side and lots were marketed by the OLD accordingly. It was eventually determined that these

[59] Levees along the west bank of the 17th Street Canal in Jefferson Parish were first raised as part of a federal protection project that predated the LP&VHPP.

levees would have to be higher and their bases wider if they were to be used to implement the LP&VHPP parallel protection plan. But wider levees would encroach on private property and necessitate significant land acquisition and related costs for the OLD, as required under their project cost-sharing agreement. The OLD did not want to take land away from citizens and believed that the costs of doing so (estimated in 1994 to approach $30 million per canal) were unacceptably high. Thus, in the case of the 17th Street and London Avenue Canals, the OLD favored alternative floodwall structures that would require less land and cost less to construct. Levees were used as part of the project parallel protection plan primarily along the Orleans Avenue Canal where space constraints were not as great as for the other two canals.

4.4.1.2 T-Walls

T-walls are concrete cantilever structures that allow designers to go higher without necessarily requiring a wider base. Sheet pile walls are driven through existing embankments to prevent seepage. Multiple pilings provide lateral stability and guard against tipping. They also include "skirts" to block scouring and stop water from penetrating along sheet pile to foundation layers. T-walls were used only selectively along the outfall canals as part of the project plan.

4.4.1.3 I-Walls

I-walls are constructed by driving sheet pile walls into foundation soils (often through existing levees) and then cutting off the sheet pile at top elevations to a consistent height. The sheet pile is then typically capped with concrete for uniform appearance and for the protection of exposed metal. The penetration depth of the sheet pile (or "tip elevation") depends on the quality of foundation materials among other factors. All else equal, when foundation materials are poor, uncertain, or inconsistent, sheet pile is driven to deeper tip elevations and/or more soil tests are conducted to establish the necessary safety factors. Sheet pile characteristics and dimensions such as length and thickness are subject to design variation, and the cost per 100 feet of protection depends heavily on those characteristics and dimensions. I-walls were the dominant structural approach used to provide protection along the outfall canals largely because they could be constructed within the very limited existing rights-of-way.

4.5 Choice of I-Wall Sheet Pile Penetration Depths

Cost consideration played a role not only in the emphasis on I-wall structures, but also in how those structures came to be designed. Project documents from the period 1984-1993 indicate that sheet pile penetration depths, as well as sheet pile thickness and other properties, were closely scrutinized in the design of I-walls for the project. In the early 1980s, the District and the Division were discussing design options for I–walls in recognition of their potential extensive future use for the LP&VHPP and other projects in Southeast Louisiana. District and Division staff were curious about whether existing Corps standards for sheet pile design were appropriate for hurricane protection projects, and whether design changes might reduce costs without compromising engineering reliability (19841029). Some design engineers believed that there should be a distinction between cases in which water pressure would be on the structures for only a short period of time, as was thought to be typical during a hurricane, and long-term loading as is often the case with riverine flooding. At that time, a 1948 Preliminary Engineer Manual provided Corps guidance for floodwall design.[60] Although that manual was limited to T-wall design, a manual supplement dated March 15, 1961 provided additional criteria as a result of full-size floodwall tests conducted by Ohio River Laboratory. Certain test findings were applicable to I-walls upon the judgment of the designing engineer, but were aimed at preventing leaks and channeling. A Division Regulation relating to I-wall design was subsequently released in November 1966.[61]

[60] Preliminary Engineering Manual 1110-2-2501 (January 1948). Part CXXV, Chapter 1, Wall Design, Floodwalls.
[61] Lower Mississippi Valley Division DIVR 1110-1-400 (November 1966). Part 5: I-Type Floodwalls, Item 1 (Introduction and General Design Procedures) and Item 2 (Design Charts for I-Type Floodwalls).

Box 4-4: Pros and Cons of Alternative Parallel Protection Structures

The following text was developed by the report authors using multiple sources.

Levees: Pros - Levees are less costly when there is a readily available source of quality construction material. In cases in which foundation conditions are subject to subsidence, compaction and settling, additional lifts can be added over time, thus maintaining intended design elevations. Levees can be "overbuilt" to account for expected settling and subsidence. The ratio between the vertical height and horizontal base is a function of the quality of construction material and foundation conditions. Where foundation conditions are less certain, or when seepage is expected, bases must be wider to achieve a given height and the slopes of the levees flatter. Very high levees require special design considerations, and duration of water stresses become more critical to overall strength and stability. When runup or wave action is expected, the extended and relatively flat slopes of levees generally dissipate wave action and require lower overall structural elevations in comparison to floodwalls. Cons – Levees can be relatively expensive when building materials are not readily available and must be hauled long distances. When foundation conditions are uncertain or unstable, construction must be scheduled in multiple lifts at least three years apart and sometimes longer depending on actual settlement rates. Very high levees can take decades to construct. Wide bases for high levees impose larger geographic footprints and require more extensive lands, easements, and rights-of-way. In urban areas the costs of acquiring such land rights can be prohibitive. Infrastructure in highly-populated areas, which can not be compromised and/or acquired, imposes problematic design requirements when configuring levee alignment.

T-Walls: Pros –In cases where urban development has reached the lateral limits of existing hurricane protection structures, T-walls allow planners to avoid expensive acquisition of property as would be required under a levee plan. They are robust and can be built higher as needed. Multiple pilings provide lateral stability and guard against tipping, and skirts block scouring and also stop water from penetrating along sheet pile to foundation layers. Settlement is much less problematic than with levees and therefore construction timing can be shortened to single lifts. Mobilization and demobilization requirements are minimal in comparison to levees. Projects can be designed to conform to existing urban development patterns. Cons – They are expensive, particularly in comparison to I-walls. Construction of the wall requires multiple materials acquisition and contracts. They have higher fixed costs per linear foot. T-wall construction is more invasive to a community than I-wall construction, and when completed can impose visual disamenities in densely populated areas. In areas where they are exposed to wave action and/or runup, they must be higher than levees. When no wave action is expected, freeboard is added to the stillwater surge elevation to get final design elevations. When planners deem that higher freeboard is needed, costs go up accordingly.

I-Walls: Pros– I-walls can be constructed in places where there are existing levees. They allow planners to go higher without necessarily going wider. As with the case of T-walls, I-walls minimize the need to acquire additional lands, easements, and rights-of-way. In urban settings this can result in a significant cost reduction when compared to levees. Construction costs are highly correlated with sheet pile requirements; therefore, engineers must balance reliability against cost, at times under conditions of uncertainty regarding soil conditions. I-walls can represent a reasonable compromise between T-walls and levees. They have smaller footprints than levees and can cost less to construct than T-walls. As with T-walls, settlement due to consolidation is much less problematic than with levees; however, if settlement occurs, the cost of restoring the proper elevation can be substantial. Cons - By virtue of design, I-walls lack the self-protective accoutrements of T-walls. Skirts are not present, and the I-walls can potentially be compromised by seepage along the water-side sheet pile face, and by scouring along the protected backside in cases of overtopping. When foundation conditions are uncertain, planners must undertake more soil boring tests and/or build margins of safety into the design in order to ensure structural integrity, all of which add costs. When wave action is not anticipated, freeboard is added to stillwater surge levels to establish the final design elevations of structures. And it is difficult to add additional sheet pile onto existing piling to compensate for subsidence because sheet pile dimensional tolerances prohibit matching across sections when welding.

4.5.1 The E-99 Sheet Pile Wall Field Load Test

In September 1984, a Division representative met with District staff to discuss conducting an I-wall field load test to determine the appropriate sheet pile penetration depths for I-walls used in Southeast Louisiana. The results of the meeting and initiation of a sheet pile depth test are provided in an October 1984 letter from the Division to the District (19841029). Excerpts from that letter are provided in Box 4-5. The results of the test ultimately factored significantly in I-wall design decisions for the LP&VHPP.

The E-99 Sheet Pile Wall Field Load Test was conducted in 1985. A 200-foot floodwall section was constructed on the landside berm of the E-99 East Atchafalaya Basin Protection levee on Avoca Island near Morgan City, Louisiana (see Figure 4-2). The foundation soils were considered relatively poor, consisting of soft, highly plastic clays, and were expected to be a "near worst case condition in the New Orleans District." A test wall penetration of 23 feet was selected for an 8-foot maximum head using conventional limit equilibrium Q-case (i.e., “Quick” or short-term loading case) undrained analysis and a factor of safety of 1.25. This penetration depth was much less than the 44-foot penetration depth that would be required by normal design criteria using an S-case (i.e., “Sustained” or longer-term loading case) factor of safety of 1.5. (The S-case factor of safety for the 23-foot penetration and 8-foot head was less than 1.0.) The results of the test were reported in June 1988 (19880600).

The test report indicated that the S-case 1.0 factor of safety and the Q-case 1.5 factor of safety correlated well in accordance with CANWAL[62] based on required sheet pile penetration depths. (Figure 4-3 shows a graph of the test results from that report.) Therefore, the report concluded that "no significant decrease in wall deflection would result from increasing sheet pile penetration beyond that required to achieve an S-case factor of safety of 1.2.” (19880600). In other words, the test was interpreted to mean that, when foundation soils were poor, sheet pile penetration depth beyond a certain point would not significantly increase I-wall stability under the type of short-term loading conditions believed to characterize hurricane events. Thus, it was determined that reduced sheet pile penetration depths could reduce costs but would not compromise the engineering reliability of I-wall structures used for the LP&VHPP.

[62] Conventional criteria for static equilibrium of a cantilever wall.

Box 4-5: Excerpts from Division Correspondence to the District on the E-99 Test

Letter from the Lower Mississippi Valley Division to the New Orleans District, dated October 29, 1984 (19841029)

1. "The most appropriate method of analyses for determining the optimum depth of penetration for the cantilevered sheet pile walls has been the subject of considerable discussion among design engineers for many years. The required depth of embedment of I-type sheet pile floodwall is governed by the magnitude of the water load on the wall and the lateral earth pressure acting on the embedded part of the wall. The current method of analysis used to determine sheet pile penetration within LMVD [the Division] is somewhat conservative, i.e. "S" strength is used, in order to account for uncertainties in sheet pile and soil behavior. We are not aware of any existing field load test data that could be used to verify our methods of analysis on I-Type floodwalls and little performance data is available of existing floodwalls since these walls have seldom been loaded to any degree by flood waters…

3. Over the next few years, there are many I-Type floodwall projects, with an estimated cost of over $100 million to be conducted within NOD. These include floodwalls for the Mississippi and Atchafalaya River flood protection projects and also hurricane projects. Considering the high cost of a sheet pile I-wall, we consider it appropriate and advisable at this time to reevaluate our design procedures for determining the depth of sheet pile penetration required for I-wall stability considering the duration of loading imposed on these walls. The reevaluation can best be accomplished by instrumenting a section of I-wall in the field, ponding water against the wall, analyzing the instrumentation data, and then revising our current analytical procedures as necessary…

5. Using current design procedures, the long term or "S" case often governs the design penetration. The instrumentation data from the proposed test may show that the "S" case, in fact, is not applicable and that the classical methods of analysis using the "Q" case will result in adequate penetration and performance. Alternative analytical methods, such as soil structure interaction, should also be investigated to determine whether they would yield results closer to that observed in the test sections…"

Figure 4-2: E-99 East Atchafalaya Basin Protection Levee Sheet Pile Wall Test

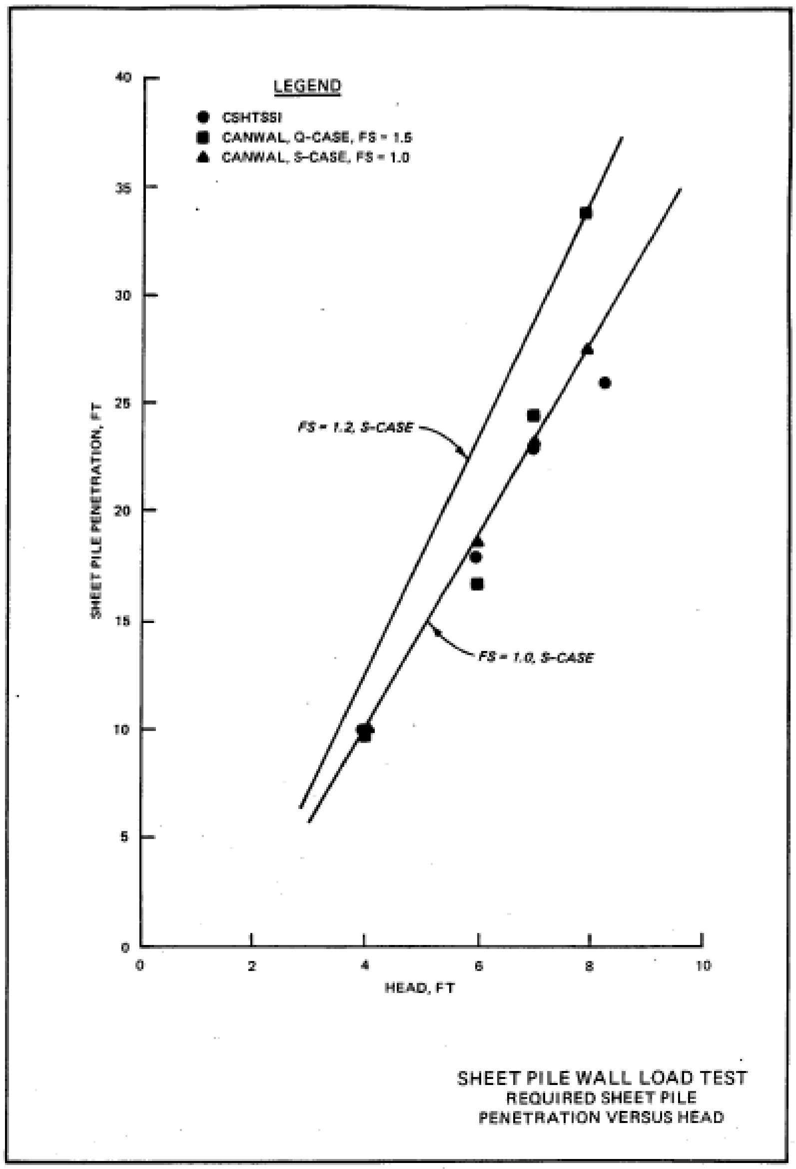

PLATE 44

Figure 4-3: Results of the E-99 Sheet Pile Wall Test

4.5.1.1 The Q-Case Summary

The “Q” (for “Quick”) case represents a short-term loading scenario. The short-term loading scenario reflects water surges lasting generally less than 24 hours, as the District expected would be the case under hurricane conditions. Soil properties would be expected to be different under short-term duress. Clay soils would resist shear based on cohesion. All else equal, design requirements are lower than in cases with long-term loading, and involve sheet pile tip elevations at lesser depths. Prior to the E-99 Sheet Pile Wall Field Load Test, the so-called Q and S cases were treated similarly with regard to design standards in the New Orleans District. Draft guidance issued by the Division in

1987 included revised, less stringent design standards for the Q-case scenario. The Q-case was applied to I-walls in the three design memoranda for the outfall canals published by the District between 1988 and 1990.

4.5.1.2 The S-Case Summary

The “S” (for “Sustained”) case represents a longer-term loading scenario. At the time of the E-99 test, the method of analysis and criteria used by the New Orleans District to determine the required sheet pile penetration depths was the conventional limit equilibrium fixed-end method with minimum factor of safety of 1.5 with respect to soil shear strength and using consolidated–drained shear strengths. As the current method at the time, it was based on long-term or sustained loading conditions as would be the case during flood conditions that may last several weeks. This procedure was recognized to be somewhat conservative for relatively short-term loading believed to reflect hurricane events.

4.5.2 Implementation of New I-Wall Design Criteria

Draft guidance for sheet pile wall design was sent by the District to the District on December 23, 1987 (19871223). The draft guidance stated that, based on the E-99 test and the related finite element study, new criteria set out in the draft should be followed to determine the required penetration depths for sheet pile floodwalls founded in soft clays. It specified:

> "For sheet pile wall driven into a levee founded on very soft to soft clays, the majority of lateral sheet pile movement during flood loading will likely be due to deep seated foundation movement and not due to sheet pile flexoral deflection. Driving the sheet pile deeper has little effect on overall levee stability, or after some limiting depth, on flexoral deflection at the top of the wall. The primary intent of these revised criteria is to prevent excessive sheet pile penetrations which do not improve either sheet pile or overall levee stability.” (19871223, page 2)

It is important to note that new guidance was based on an interpretation of the test results by the Division to mean that sheet pile penetration beyond a certain depth would not improve wall stability and therefore was a wasteful expenditure. In other words, the new criteria were not viewed as a risk-versus-cost tradeoff. Representatives from the District and Division met on January 6, 1988 to discuss phasing in the new draft I-wall design criteria issued by the Division (19880126). The meeting was hosted by the District, which recommended that the new criteria be applied to ongoing design and construction work for levees and floodwalls in four projects: LP&VHPP, New Orleans to Venice, LA, Mississippi River Levees, and Atchafalaya Basin. Specifically, the plan to phase-in the new I-wall design criteria was endorsed for the Orleans Avenue, 17th Street and London Avenue outfall canals because there was a “high potential for savings.” The minutes of the meeting were approved by the Division, subject to comments, on February 22, 1988 (19880126).

Representatives from the District and Division met again at the District offices on October 28, 1988 to discuss issues related to the E-99 test, the new I-wall design criteria, and analyses of deflections using finite elements (19881118). The discussion addressed deflection in soft clays, sheet pile length, and sheet pile thickness. It was reported that the new December 1987 draft I-wall design criteria were being used by the District and “it has resulted in substantial reductions of sheet pile penetration.” Use of the findings from the June 1988 WES report was endorsed by the Division, subject to comments (19881118).

4.5.3 Final 1989 Division Guidance on Sheet Pile Penetration Depths

The final guidance on sheet pile wall design criteria was represented by a letter sent by the Division to the District on July 24, 1989 (19890724). It provided background information on the E-99 test and the WES model application to the data derived from the test (19890900), and referenced the December 23, 1987 draft guidance, associated follow-up guidance, and the WES final report on the E-99 Sheet Pile Wall Field Load Test. Along with the new criteria, the final guidance noted, “Engineering judgment should be exercised in selecting appropriate loading cases and penetration to head ratios," and "Due to sensitivity of the computed and actual deflections of soil stiffness, the actual deflections experienced in the field can only be estimated with limited accuracy.”

Table 4-1 presents the 1989 design criteria for determining penetration depths for sheet pile floodwalls founded in soft clays, which mirror those included in the earlier draft guidance issued by the Division in 1987 (19890724, page 2). These criteria were applied to I-wall designs for the parallel protection alternative considered in the design memoranda for the outfall canals issued after 1987.

Table 4-1: 1989 Division Design Criteria for I-Wall Sheet Pile Penetration Depths

Q-Case (Short-Term Load Conditions)
F.S. = 1.5 with water to flowline or stillwater level. F.S. = 1.25 with water for flowline plus freeboard for river levees or with stillwater level and waveload for hurricane protection levees. F.S. = 1.0 with stillwater level plus 2-ft freeboard for hurricane protection levees.
S-Case (Long-Term Load Conditions)
F.S = 1.2 with water to flowline or stillwater level and waveload. If a hurricane protection floodwall has no significant waveload, determine the penetration using Q-case criteria only. F.S. = 1.0 with water to flowline plus approved freeboard for river levees.

4.5.4 Effect of New Guidance on Sheet Pile Penetration at the London Avenue Canal

Several design documents for the London Avenue Canal that establish I-walls specifications were developed over the period 1986-1993 and thus help illustrate the effect of the new guidance criteria on final sheet pile depths and cost. This period of project I-wall design evolution overlaps with the new sheet pile guidance first issued in draft form in 1987, and then finalized in 1989, as a result of the E-99 Sheet Pile Wall Field Load Test. Box 4-6 outlines the I-wall sheet pile design specifications defined by these design documents for those parts of the London Avenue Canal that breached during Hurricane Katrina.

Table 4-2 uses the data in Box 4-6 to compare I-wall sheet pile specifications included in the design documents developed with and without the new guidance criteria for sheet pile penetration depths that resulted from the E-99 test. Specifically, the table compares sheet pile penetration depths (tip elevations) and total lengths for the two sites along the London Avenue Canal where breaches occurred during Hurricane Katrina. This comparison shows that early design specifications, which were based on design criteria in place prior to the E-99 test, called for much greater sheet pile penetration depths than those specified in final 1993 plans and specifications used for construction. For example, the 1986 design memorandum specified that, for the two canal sites that breached during Hurricane Katrina, sheet pile penetration depths should be -31 feet and -46 feet, respectively, to provide SPH surge protection. However, in the final 1993 plans and specifications, the tip elevations at these sites had been uniformly reduced to -16 feet.

Box 4-6: Design Documents for the London Avenue Canal That Did and Did Not Apply New Criteria for I-Wall Sheet Pile Penetration Depths

Did Not Apply the Post E-99 Test Sheet Pile Guidance Criteria

April 1986, OLD Design Memorandum **-** Prepared for the Orleans Levee District by Burk and Associates, Inc. At the Hurricane Katrina “South Breach” site at East Station 71-71.6 (Mirabeau) and the “North Breach” site at West Station 116-119 (Robert E Lee)], this DM defined I-wall sheet pile design specifications of BZ-42 sheet pile at 60 ft. length and -46 ft. tip elevation, and PZ-27 sheet pile at 45 ft. length and -31 ft. tip elevation, respectively (19860400).

May 1990, OLD Interim Plan for 100 Year Protection – Prepared for the Orleans Levee District by Burke & Associates, Inc. At the North Breach site, this document defined sheet pile specifications of PLZ-25 sheet pile at 37.5 ft. length and -24 ft. tip elevation. At the South Breach site, the document defined sheet pile specification of PLZ-25 sheet pile at 41 ft. length and -27 ft. tip elevation (19900500).

Did Apply the Post E-99 Test Sheet Pile Guidance Criteria

January 1989, Corps General Design Memorandum 19A **–** Prepared by the District. At the South Breach site, this GDM called for called for a T-wall. At the North Breach site, this GDM defined I-wall sheet pile design specifications of PZ-22 sheet pile at 26 ft. length and -11.4 ft. tip elevation (19890100).

November 1993, Plans and Specifications (Contract #3) **–** Prepared for the District by BKI and Eustus Engineering under contract. At both the North and South Breach sites, this document defined I-wall sheet pile design specifications of PZ-22 sheet pile at 31 ft. length and -16 ft. tip elevation (19931100).

Note: All of these design documents except the 1990 OLD Interim Plan were based on SPH surge protection that the District estimated would provide, in terms of return frequency, roughly 300-year protection. It is presumed, based on the tip elevations included in the 1990 OLD Interim Plan, that the post E-99 test revised design criteria for sheet pile penetration were not used for plan development

Table 4-2: London Avenue Canal I-Wall Sheet Pile Specifications in Various Design Documents, 1986-1993

	Did Not Apply the Post E-99 Test Guidance Criteria		**Did Apply the Post E-99 Test Guidance Criteria**	
Location	**1986 OLD DM**	**1990 OLD Interim Plan***	**1989 District DM #19A**	**1993 District P&S (Contract #3)**
North Breach Site (Robert E. Lee)	45 ft. length, -31 ft. tip elevation	37.5 ft. length, -24 ft. tip elevation	26 ft. length, -11.4 tip elevation	31 ft. length, -16 ft. tip elevation
South Breach Site (Mirabeau)	60 ft. length, -46 ft. tip elevation	41 ft. length, -27 ft. tip elevation	NA (called for a T-wall)	31 ft. length, -16 ft. tip elevation
* All of these design documents except the 1990 OLD Interim Plan were based on SPH surge protection that the District estimated would provide, in terms of return frequency, roughly 300-year protection. It is presumed, based on the tip elevations included in the 1990 OLD Interim Plan, that the post E-99 test revised design criteria for sheet pile penetration were not used for plan development				

The significant reduction in sheet pile penetration depths from early design documents to the final plans and specifications used to construct parallel protection at the outfall canals involved substantial cost savings for project sponsors. As discussed in some detail in Chapter 5, there was a strong financial reason for the District to carefully evaluate sheet pile specifications and seek project cost efficiencies more generally. Consideration for the cost of parallel protection plans can be found within almost every document and every key decision regarding the outfall canals. And the design criteria governing sheet pile penetration depths is only one of several sheet pile designs issues that were examined for cost efficiency.

Perhaps most illustrative of the potential cost savings achieved from these efforts is the difference between initial and final cost estimates for parallel protection at the outfall canals. The 1984 Reevaluation Report provided a preliminary estimate of the cost for parallel protection at the outfall canals of $200-$250 million. By the time the District design memoranda for the canals were published (between 1988 and 1990), the estimated total cost of implementing the parallel protection plans at the three canals was $107 million. This suggests that the District may have found over $100 million in costs savings for parallel protection work at the outfall canals from all design and construction efficiencies combined.

As a final note, the Division expressed some initial concern about the sheet pile penetration designs for the 17th Street Canal that the District had set out in its 1990 general design memorandum for the canal. Correspondence on this topic between the Division and District was the subject of post-Katrina news articles and investigations seeking evidence regarding decisions that may have contributed to the breaches at the 17th Street and London Avenue Canals. However, that discussion involved an issue that apparently was relatively minor in terms of its potential bearing on final sheet pile penetration depths for the canals, and was readily resolved. Attachment A to this chapter reproduces the relevant correspondence between the Division and District on the topic.

4.6 Summary and Reflections on Design Decisions for the Outfall Canals

The chronology presented at the end of this section outlines the sequence of key project events relating to project design decisions for the outfall canals. The authors' reflections on that record follow below.

The project record indicates that the three main outfall canals in metro New Orleans were not part of the project plan adopted in 1965, but soon after were recognized to be a necessary part of the project. The choice of protection approach for the canals was a matter of dispute among local agencies on one side and the District on the other and remained unresolved between 1984 and 1992. The District recommended a frontage protection alternative, butterfly gates at the lakefront, which it had determined was the least-cost, reliable plan. Local agencies opposed the butterfly gates and pushed for an alternative parallel protection plan involving levees and floodwalls along the entire lengths of the canals, because it served their dual hurricane protection and interior drainage goals and could maximize the federal government financial contribution toward those ends. The Congress in 1991 resolved the choice of protection approach and its cost-sharing distribution in favor of the local sponsor.

Cost considerations also were a factor in the choice of parallel protection structures for the canals; I-walls were the dominant type of protective structure used largely because they could be constructed within the very limited existing rights-of-way, thus obviating the need for expensive and politically-sensitive land acquisition for the project by the local sponsor. Project documents from the period 1984-1993 indicate that the District and Division closely scrutinized I-wall sheet pile penetration criteria and designs because of the sensitivity of sheet pile penetration depths to cost, and a concern that existing Corps criteria for sheet pile penetration depths might be too conservative for the type of short-term loading conditions believed to characterize hurricane events. The District and Division conducted a test to investigate the latter and found that when foundation materials were poor, sheet pile penetration depths beyond a certain point would not significantly increase I-wall stability under short-term loading conditions. That test resulted in new design criteria for sheet pile penetration depths, which were used in the final plans and specifications for I-walls at the outfall canals. Application of the new design criteria resulted in a significant reduction in the final sheet penetration depths from that specified in early design documents, resulting in substantial cost savings for project sponsors.

In sum, cost considerations at both federal and local levels played a significant role in design decisions for the outfall canals. Indeed, the authors of this report believe that the decisions to choose parallel protection over frontage protection, to use I-walls to provide that protection, to conduct the E-99 Sheet Pile Field Wall Load Test, and to develop revised guidance that reduced sheet pile penetration depths, all illustrate how the local sponsor and the District were sensitive to the cost consequences of the outfall design decisions. However, in all of these decisions, design changes were made only when the analysis was interpreted to allow reduced cost or redistributed cost without compromising engineering reliability. There is no evidence in the available written project record that design engineers and decision-makers believed that these cost savings came at the expense of engineering reliability. The cost and budget context for the LP&VHPP is discussed in detail in the next chapter.

Chronology of Key Project Events Relating to Outfall Canal Design Decisions

Event Name	Start Date	End Date	Notes
LP&VHPP Barrier Plan Recommended and Authorized	Nov 1962	Oct 27, 1965	The 1962 District Interim Survey Report recommends the Barrier Plan, which is then approved by the Chief of Engineers in 1964 and authorized by Congress in 1965. The Barrier Plan does not include any project protection for the three outfall canals in metro New Orleans, because surge modeling indicated that the existing local levees along the canals would be sufficient to contain the SPH surge as dampened by the project barrier complexes at Chef Menteur Pass and the Rigolets.
The District Determines Project Protection for the Outfall Canals is Needed	Aug 1966	Sep 1968	Design Memorandum #1 (Hydrology, Parts I-IV) uses revised wind field parameters calculated following the Hurricane Betsy experience in 1965 to conclude that all project structures should be raised by 1-2 feet over those recommended in the 1962 planning report in order to contain the SPH surge and wave action. At the same time, the District concludes that, in consideration of the new wind field parameters, the existing local levees along the outfall canals are of insufficient grade and stability to contain the barrier-dampened SPH surges, and thus must be addressed by the project.
Preliminary Alternatives Analysis	Aug 19, 1977		An internal District meeting leads to the conclusion that an alternatives analysis is needed before preparing GDM No. 2 for the Orleans Parish outfall canals. This would consist of preliminary designs and cost estimates for seven preliminary alternatives
Results of Soil and Geodetic Research	Sep 16, 1977		District analysis of soil and geodetic data "indicate the presence of a buried beach sand deposit that underlies the outfall canals. This sand deposit approaches the bottom of each outfall canal, creating the potential for excessive and dangerous hydrostatic uplift pressures during high stages in the canals. Additionally, there are reaches in each of the outfall canals that presently do not meet minimum stability requirements even during normal stages. Therefore, no matter which alternative is selected for the GDM, if return levees are part of federal hurricane protection, we anticipate some modification of existing levees."

Event Name	Start Date	End Date	Notes
District Briefs Local Interests on Alternatives Analysis	Aug 22, 1980		The District briefs local interests on the District's alternative plans under study for the outfall canals and solicits their input and recommendations for a preferred alternative. The District notes its intention to prepare a letter report to its higher authority that would present alternative plans and recommend a plan of action. The report would include input from the local sponsor, the Orleans Levee District (OLD). At the meeting, a representative of OLD states that a plan that would allow abandonment of existing lateral levees would be highly desirable to OLD, since the levees imposed a considerable maintenance problem.
Sewerage & Water Board (SWB) Comments on Protection Approach	Dec 7, 1982		In a letter to the District, the SWB of New Orleans informs the District of 1) its planned capability at pumping station No. 6 on the 17th St. Canal, and 2) the SWB position that the choice of protection alternative for the outfall canals must preserve their capability to pump into the canals under all conditions.

Event Name	Start Date	End Date	Notes
District Requests Authorization for Model Study of Butterfly Gates	Oct 1, 1983		The District in a letter to the Division requests authority and funding to conduct a model study of the newly-developed butterfly gate design for frontage protection at the mouths of the canals. Says that existing local levees do not meet design height or design sectional stability required for either the Barrier Plan or the High Level Plan. It notes, "Finding a solution has been made difficult because, on the one hand, raising and strengthening the levees would be extremely expensive and disruptive of existing developments along the canals, while on the other hand, solutions which would eliminate the need to raise the levees are acceptable to SWB only if they preserve the ability of the Board to pump into the canals under all conditions. With the exception of the vertically pinned butterfly control valves, all plans proved either excessive in cost, unacceptable to the Board, and/or presented intractable operational problems." Says that SWB, OLD, and Jefferson Parish are favorably disposed toward butterfly gate concept pending further study. "The favorable reaction from the SWB insofar as the 17th St. Canal is concerned is tempered, however, by the fact that they are rather far advanced with plans to increase the capacity of the 17th St. Canal and the pumping station which discharges into it, and these plans involve raising the lateral levees. They believe that this can be done for about the same cost as we currently estimate for the control valves. Since the SWB would, of course, be desirous of having the work credited to the OLD under the project, we are following their studies with interest, but on the basis of our previous work, we believe that hurricane project standards will be difficult to achieve at that cost. Accordingly, we propose to continue with efforts to develop the control valve concept."
Division Comments on District Request for Model Study	Nov 28, 1983		The Division notes the District "should furnish additional supporting documentation to include an economic analysis reasonably demonstrating that the butterfly valve solution would provide greater net benefits than the roller gate solution." The Division returns the request for additional study noting, "These studies should also serve to verify whether or not costly model studies are necessary for an adequate design." With regard to the preferences of SWB, the Division notes "impossible situation in that a scheme must be developed for keeping

Event Name	Start Date	End Date	Notes
			hurricane surges out of the drainage canal while preserving for SWB the option to pump at all times." The Division also notes, "local sponsors might be anticipating credit for the work being done on the 17th St. Canal and that the District presently doubts that the locals' new levees will meet our standards. The District would be remiss if it does not impress locals with the fact that not only will credit not be allowed for this work, if deficient, but the Corps will still have to construct a gate in this canal and that the locals will be expected to cost-share the structure cost."
District Replies to Division Comments on Proposed Model Study	Dec 12, 1983		The District reiterates that any plan that uses frontage protection must also satisfy to the fullest extent possible the operational drainage requirements of SWB. It notes, "The District would not recommend an expensive model test of a plan that it did not believe enjoyed a high probability of satisfying design objectives for the Lake Pontchartrain project and operational constraints of the SWB...We do not agree that the situation presented is impossible...Also, the SWB is of the opinion that regardless of whether or not gated structures are placed at the Lake end of the outfall canals, that they must provide sufficient freeboard to allow them to pump throughout the design storm...local interests are for the 17th St. Canal currently attempting, through the permit process to meet our hurricane protection design criteria for their proposed upgrade of the canal and levees. This office has been working closely with SWB in an effort to insure that their designs are compatible with the Lake Pontchartrain project...We remain cautiously optimistic that these designs may be incorporated into the project. However, independent study conducted by the District leave us with sufficient doubt about the economic feasibility of the SWB plan when compared to fronting protection...It is important to understand that if the project ultimately adopts a fronting protection plan, the responsibility of the lateral parallel levees along the outfall canals is solely the responsibility of the SWB."

Event Name	Start Date	End Date	Notes
District Issues Permit to SWB to Dredge the 17th St. Canal	Jun 13, 1984		In 1983 the SWB had applied to the District regulatory branch for a permit to dredge the 17th St. Canal and install sheet pile walls along its existing levees to improve the drainage capacity of the canal. The District engineering branch evaluated the proposed work for its possible effects on the existing federal levee on the west bank of the canal, and provided numerous technical comments to the applicant on additional data needs and studies required before the permit could be granted. District engineers work with SWB consulting engineers to resolve the concerns, and the permit is granted after those concerns had been resolved.
Reevaluation Report	Jul 1984		The report describes five project alternatives for the outfall canals developed by the District and their estimated costs: 1) raise and strengthen the existing canal levees without concern for the number of house relocations necessary ($200 million); 2) same as alternative one except house relocations would be avoided ($250 million); 3) floodgates at the mouths of the canals ($20 million); 4) same as alternative three but with added auxiliary pumping stations at the lakefront to allow pumping to continue when the gates were closed ($124 million), and; 5) relocate existing pumping stations to the canal mouths at the lakefront (presumed to be prohibitively expensive).
Planning for the E-99 Sheet Pile Wall Field Load Test	Sep 18, 1984	Oct 29, 1984	District and Division representatives meet in September to discuss the proposed test. A follow up letter from the Division to the District Engineer states 1) the proposed sheet pile test is justified, 2) the current method of designing and determining optimum depth for sheet pile has been the subject of discussion among design engineers for many years, 3) over the next few years I--wall projects with an estimated cost of over $100M will be constructed in the District for the Mississippi and Atchafalaya Rivers and for hurricane protection throughout the region, and 4) considering the high cost of sheet pile I-wall it is felt appropriate and advisable to reevaluate procedures for determining depth of penetration for stability with consideration for duration of loading on those walls.

Event Name	Start Date	End Date	Notes
E-99 Sheet Pile Wall Field Load Test	May 1985	Sep 1985	A 200-foot floodwall section is constructed on the landside berm of the E-99 East Atchafalaya Basin Protection Levee near Morgan City, LA. A test wall penetration of 23 feet was selected for an 8 foot maximum head using conventional limit equilibrium Q-case (short-term loading case) undrained analysis and factor of safety of 1.25. This penetration is much less than the 44-foot penetration that would be required by normal design criteria using S-case (sustained loading case) factor of safety of 1.5.
Orleans Levee District (OLD) GDM for the London Avenue Canal	Apr 1986		Parallel protection I-walls providing SPH (300 year) protection designed by Burk and Associates, Inc. under contract to the OLD. The designs adhere to existing Division design criteria for I-walls, and are estimated to cost $38-$44 million. The OLD deems this plan too expensive and cancels further work on the design.
Division Draft Guidance Letter on Sheet Pile Wall Design Criteria	Dec 23, 1987		The Division letter to the District presents draft revised design criteria for sheet pile wall penetration depths based on the results of the E-99 test and the related finite element study. It states that the revised criteria should be followed to determine the required penetration depths for sheet pile floodwalls founded in soft clays, and notes, "for sheet pile wall driven into a levee founded on very soft to soft clays, the majority of lateral sheet pile movement during flood loading will likely be due to deep seated foundation movement and not due to sheet pile flexoral deflection. Driving the sheet pile deeper has little effect on overall levee stability, or after some limiting depth, on flexoral deflection at the top of the wall. ... The primary intent of the revised criteria is to prevent excessive sheet pile penetrations which do not improve either sheet pile or overall levee stability.”
E-99 Sheet Pile Wall Field Load Test Report	Jun 1988		States that method of analysis currently used in the Division to determine sheet pile penetration has minimum factor of safety of 1.5 and is "somewhat conservative in order to account for uncertainties in sheet pile and soil behavior." The test found that S-case analysis for long-term loading (FS = 1.5; 44 foot penetration) is too conservative for design with short loading periods, and found no significant decrease in deflection from penetration beyond 28 feet (FS = 1.2; 28 feet penetration). These results are interpreted to mean that when foundations soils are poor, sheet pile penetration beyond a certain point would not significantly increase I-wall stability under the type of short-term loading conditions believed to characterize hurricane events.

Event Name	Start Date	End Date	Notes
GDM #19 -- Orleans Avenue Canal	Aug 1988		Includes detailed descriptions of alternatives and recommends frontage protection using butterfly gates as the least-cost plan ($15.1M). The locally preferred parallel protection plan is estimated to cost $43.8M, and the report states that if this plan is implemented, the federal cost contribution would be limited to 70% of the cost of the recommended frontage protection plan.
GDM #19A – London Avenue Canal	Jan 1989		Includes detailed descriptions of alternatives and recommends frontage protection using butterfly gates as the least cost plan ($9.1M). The locally preferred parallel protection plan is estimated to cost $43.8M, and the report states that if this plan is implemented, the federal cost contribution would be limited to 70% of the cost of the recommended frontage protection plan.
Final Division Guidance on Sheet Pile Design Criteria	Jul 24, 1989		A letter from the Division to the District presents final guidance on sheet pile wall design criteria; these criteria mirror those set out in the 1987 draft guidance. The letter references the 1987 draft guidance, associated follow-up guidance, and the WES final report entitled "Development of Finite Element-Based Design Procedures for Sheet Pile Walls." It provides background information on the E-99 test and WES model application to the data derived from the test, and states, "Due to sensitivity of the computed and actual deflections of soil stiffness, the actual deflections experienced in the field can only be estimated with limited accuracy," and "Engineering judgment should be exercised in selecting appropriate loading cases and penetration to head ratios." The new design criteria are applied to floodwall designs in the outfall canal GDMs developed after 1987.
GDM#20 – 17Th Street Canal	Mar 1990		Recommends the parallel protection plan for this canal since the cost difference between this alternative and the frontage protection (butterfly gates) alternative is minimal, and the local sponsor (OLD) prefers the parallel protection plan. Parallel protection designs for the west side of the 17th St Canal include I-wall specifications similar to those included in DM#19A for the London Avenue Canal.
OLD Interim Plan – London Avenue Canal	May 1990		The plan prepared by Burk and Associates for the OLD is for 100 year ("interim") protection along the canal. The plan references that the previous plan developed for the OLD to provide SPH (300 year) protection was deemed by OLD to be too expensive.

Event Name	Start Date	End Date	Notes
Orleans Levee District Board Resolution for Parallel Protection	Oct 17, 1990		The OLD Board resolution expresses commitment to parallel protection, encourages the Corps to support parallel protection, and empowers the President of the Board to take steps to bring this to the attention of government officials at all levels.
Water Resources Development Act of 1990 Conference Report	Oct 27, 1990		The report states, "One option under consideration is the construction of structures which will close the outfall canals at London and Orleans Avenues during periods of hurricane conditions. Local authorities have raised legitimate concerns that this would result in flooding within the City because water discharged from drainage pumps would not flow into Lake Pontchartrain when the structures are closed. The conferees do not believe it was the intent of Congress in authorizing this project to compound flooding or drainage problems in the City of New Orleans. Therefore, the conferees direct 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 the standard project hurricane with costs to be borne by both Federal and local assuring authorities."
Energy & Water Appropriations Act of 1992	Aug 17, 1991		Congress finally resolves the choice between parallel protection and frontage protection by mandating construction of the parallel protection plan. The legislation states, "…the Secretary of the Army is authorized and directed to provide parallel hurricane protection along the entire lengths of the Orleans Avenue and London Avenue Outfall Canals by raising levees and improving flood protection works along and parallel to 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."
District Grants Time Extension for the SWB Permit to Dredge the 17th St. Canal	Jun 1992		The SWB had completed work on some project phases by 1989, but it was not until 1990 that it entered into an agreement with the OLD for combined dredging and flood protection works for the canal east bank. With work proceeding on that side of the canal, the SWB in 1991 signed an agreement with the East Jefferson Levee District for combined dredging and floodwall work on the canal west bank. With the timeframe for the SWB

Event Name	Start Date	End Date	Notes
			about to expire, SWB requests that the District grant a permit time extension to complete the work. The District grants a permit time extension until June 1977.
District Begins Parallel Protection Work	1993		Consistent with administration policy to fund only the most cost-effective alternative, Corps Headquarters does not budget for the parallel protection work after 1992. Federal funding for the work is nevertheless provided annually by congressional adds to the administration’s requested appropriations, which the District uses to implement the work.

Attachment A
Division-District Correspondence on Sheet Pile Penetration for the 17th Street Canal

After the District completed the 17th Street Outfall Canal GDM in 1990, the Division reviewed it (19900300). The Division Chief of Engineering raised several concerns in the first endorsement about designs for sheet pile penetration. However, this concern was relatively minor in terms its potential bearing on final sheet pile penetration depths, and was readily resolved. The design memorandum, including endorsements, was sent to Corps Headquarters. Relevant portions of the Division-District correspondence are reproduced below.

August 8, 1990 Letter From Division Chief of Engineering to the District Engineer (19900300, page 21)

> c. Para 29b. Due to the critical nature of this project and the close proximity of the adjacent canal, a minimum penetration to head ratio of 3 to 1 should be used for sheet pile design for this project. We note that the 3 to 1 minimum ratio has been used on less critical projects in the New Orleans area. In addition, the sheet piles shown on I-wall penetration plates 101 to 105 and 110 to 113 will serve as permanent bulkheads retaining as much as 4 ft. of soil. To ensure adequate bulkhead stability toward the floodside, these sheet pile bulkheads should be analyzed using the "S" case soil strengths, a sheet pile penetration in this DM should be increased as necessary. If there is a potential for erosion at the floodside toe of the bulkheads, some protection should be considered.
>
> h. Para 69. (1) This schedule indicates that the construction contract for the east side floodwall will be awarded in Oct 95. However, we understand that the Orleans Levee Board has already awarded a contract to drive sheet pile for the east bank floodwall and also perform some dredging work, and the work under this contract was to commence in early Jul 90. These sheet piles are to be driven full length and not capped with concrete until the scheduled contract award in Oct 95. We understand the plans and specifications for the current sheet pile contract were reviewed and approved by you and the sheet pile lengths specified are the same as shown in this DM. (2) Compliance with comment c above will result in additional sheet pile penetration in some reaches over that shown in this DM. The fact that a construction contract was awarded for the east side sheet pile work prior to our review of this DM results in an undesirable situation for this office and the Corps. The current Orleans Levee Board contract should either be modified to provide the additional lengths or the sheet piles should be driven as shown in the DM and later driven to the revised penetration just prior to capping. The Orleans Levee Board should be advised that there is some risk involved with waiting 5 years to achieve the revised sheet pile penetration. The sheet pile lengths for the west side floodwall should be revised prior to preparation of plans and specification.

October 22 response from the District Chief of Engineering (19900300, pages 3-4)

> c. Comment on Para. 29b. Do not concur. Reference CEMRC-ED-GS memorandum dated 24 July 89, para. 3. A penetration to head ratio of 2.5 to 3:1 is recommended in the referenced memorandum. For certain projects a penetration to head ratio of less than 2.5 was authorized. The factors stated in the memorandum which cause the tip to be arbitrarily increased by a penetration to head ratio are unknown variations in ground surface elevations and soil conditions. The 2.5: 1 penetration to head ratio was used because of the following: (1) The ground surface elevations are based on surveys at 100 ft. intervals. (2) Two surveys along the canal were done in the last 10 years. (3) The velocities in the canal are too low to cause scour. (4) Borings were taken at 350 ft.

intervals by the A/E on both sides of the canal and were supplemented by USACE check borings. (5) The existing levee is over 30 years old.

All hurricane protection in urban areas is critical in nature; however, no other hurricane protection project has had the level of borings or survey as the 17th St. Canal project. The 3 to 1 minimum ratio was used on other New Orleans projects because the CEMRC-ED-GS memorandum dated 23 Dec 87 which required the 3 to 1 ratio. No GDM has been submitted for a 3 to 1 ratio in an existing levee since the July 89 criteria.

The sheet pile sections on plates 101 through 103 and 11 and penetration ratios of 2.8 to 1 and an S-CASE F.S. of 1.2 for canal water level of 0.0. Sections on plates 104 through 105 and 112 have tip elevations deeper than required for an S-CASE F.S = 1.5 or 3:1 ratio for the bulkhead case. The existing sheet pile has served as a permanent bulkhead retaining as much as 4 ft. of soil for at least 19 years (Orleans Levee Board 1971 Surveys). We will monitor the sheet pile wall being constructed by the local interests on the Orleans side of the canal. We will consider driving the sheet pile deeper instead of cutting the sheet pile in 1994 during capping.

Final Division Concurrence with District Stance (19900300, page 2)

The responses in the enclosed 2nd endorsement are satisfactory subject to the following comments:

Para c, 2d End. In view of the information presented, we concur in your proposal to utilize the 2.5:1 minimum penetration ratio for the floodwall penetrations on this project. In addition, analyses performed by this office indicate that in most cases the penetrations derived using the 2.5:1 ratio appear about the same as those required using the conservative “S” case, F.S. = 1.5 criteria. However, during the 1994 capping of the Orleans side floodwall, the sheetpile between B/L stations 554+00 and 614+00 should be driven deeper to achieve a tip elevation of -15. This will ensure that these walls will have an “S” case factor of safety of 1.5 for the bulkhead analysis.

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Chapter 5. Project Cost Growth, Funding, and Completion Delays

5.1 Introduction

The 1965 legislation authorizing the LP&VHPP established the degree of protection to be provided by the project, and the cost allocation and other responsibilities of the federal government and local project sponsors in securing that protection. Chapters 2-4 described the significant project decisions affecting the intended degree of protection and the design and construction of protective structures. This chapter reviews trends in project cost growth, funding, and completion delays over time that shaped the environment in which key project decisions were made. The interplay of these factors helps to explain the culture of cost-consciousness for the project displayed by the District and local sponsors as project design and implementation stretched on over time.

5.2 Project Cost Growth and Federal Appropriations

The estimated total cost for the LP&VHPP as authorized in 1965 was $80 million. In subsequent years the estimated project costs rose dramatically. Figure 5-1 shows the estimated total cost of the LP&VHPP as reported in the project budget justification sheets (BJS) for fiscal years 1971-2006, with the distribution of cost between federal and non-federal sponsors noted. The project cost shown is the sum of what was spent in previous years plus projections of future funds that would be required to complete the project. The future budget requirement includes a projected rate of inflation.

Figure 5-1 shows that by 1982 the District was reporting that project costs had risen to over $800 million, or about ten-fold above the originally estimated price. One cause of rising costs was the changes in project designs that were being contemplated to comply with the 1978 court injunction against the original Barrier Plan, and to overcome opposition to that plan. A second reason for the cost growth was that the nation experienced a period of dramatic price inflation that coincided with this time of project reevaluation. While other design changes were being made at the time, and while the outfall canal design issue had yet to be resolved, the cost growth shown is largely attributable to the projected inflation rate included in the BJS and for the redesign of the surge barriers.

It is not possible to document how much of the growth in estimated project costs over the full project history was due to price inflation versus project design changes. This type of separation was not routinely made by the District because it is not relevant for budget decision-making. For budgeting purposes, costs will be realized in nominal dollar terms and the budget will need to pay costs in nominal dollars. That is why estimates of future budget obligations included a projected rate of inflation.[63]

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[63] A 1976 report by the Government Accounting Office on cost, schedule, and performance problems with the LP&VHH included data supplied by the District that attempted to show the extent to which growth in

Nevertheless, the drop in estimated project costs to roughly $500 in 1985 can be traced to project design change—specifically, the replacement of the Barrier Plan with the High Level Plan in that year. It was also about that time that the projected inflation rate was adjusted downward. In 1985, the estimated cost for project protection at the outfall canals was not well developed, but the preliminary costs estimates at that time were for the frontage protection plan (the least-cost plan that in the end was not chosen), and these were included in the cost estimate after the approval of the post-authorization change to the High Level Plan. From 1994 onward, however, reported project costs were consistently in excess of $700 million once the full cost for the chosen parallel protection plans for the outfall canals were factored into estimated costs. This also represented a period of relatively low and stable price inflation, so inflation projections did not significantly increase the estimated cost at project completion.

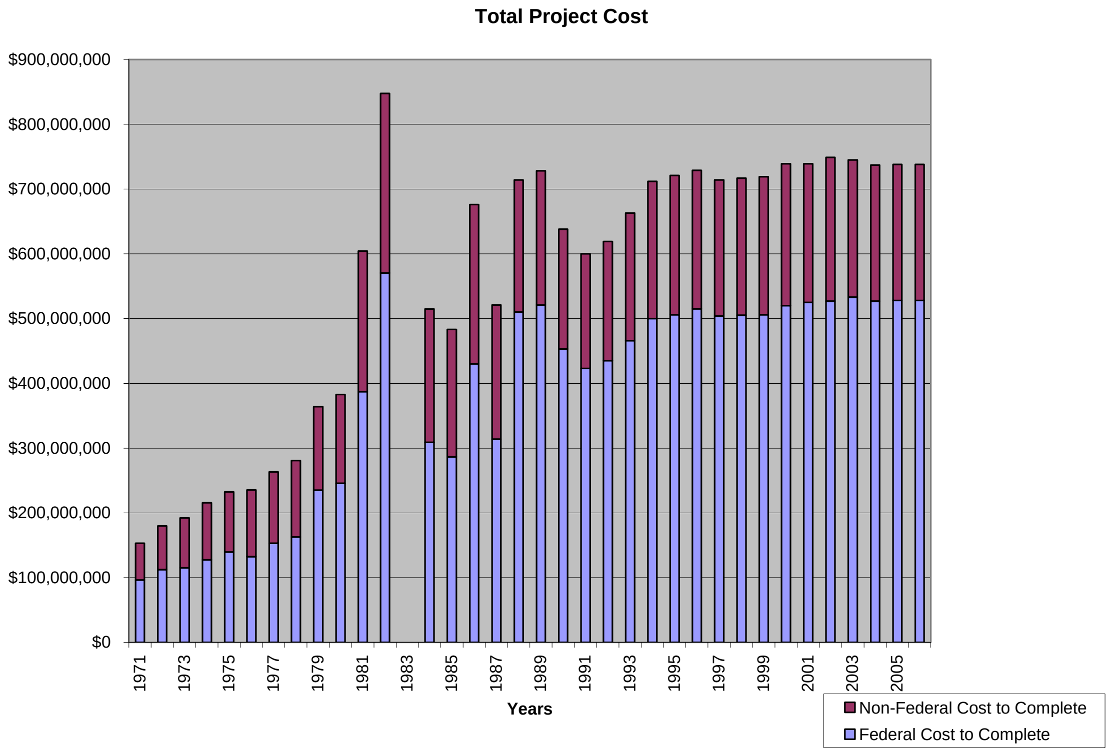

Figure 5-1: Estimated Total Project Cost at Different Points in Time

Table 5-1 provides data on the administration budget request for the LP&VHPP each year from 1979-2006, and the actual dollar amounts appropriated by Congress for the project in those years. The data show that the annual budget requests and congressional appropriations for the LP&VHPP (through multiple administrations and congresses) were the same every year up until 1993. From 1993 onward, however, the Corps did not

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estimated project costs during 1962-1976 was due to price inflation, design changes, and other causes. That data indicated that price inflation was responsible for about 69% of cost growth during 1962-1976.

request funding for parallel protection work at the outfall canals, because of a conflict between the 1992 congressional directive to the Corps to implement the parallel protection plan and Corps policy to budget only for the most cost-effective alternative that could reliably provide the authorized purpose. Recall that the Congress, in late 1991, at the behest of one local sponsor, mandated that the Corps implement and pay 70% of the costs for the parallel protection plan, rather than the least-cost frontage protection alternative favored by the District. In the years following, there was a pattern of the administration, on behalf of the Corps, not budgeting for parallel protection based on an interpretation that the congressional directive on the outfall canals violated federal policy as set forth in the Water Resource Development Act of 1986 (19920129). Thus, Congress was forced to add funding each year for parallel protection at the outfall canals that the District then used to implement the work.

One point of interest on the annual administration budget requests for the LP&VHPP involves how those requests relate to the project budget requested by the Division for those years, as submitted by the Division to Corps Headquarters. However, data on Division budget requests for the project are not available for the full period of project implementation. Nevertheless, data included in the Data for Testifying Officers (DTO) for the nine years that such project information sheets were available to the study team (the last of which is for fiscal year 1994) indicate that the Division budget request to Corps Headquarters was accepted as proposed in every year except one.

5.3 The Larger Federal Budget Context

In this section, the growth in project cost, and thus the funding required to complete the LP&VHPP, is placed in the context of the federal civil works funding both nationally and in Louisiana. [64] These larger budget contexts help to explain why the estimated completion date for the project (which is discussed later in section 5.5) was repeatedly moved further out in time. For example, in 1971 the project BJS reported that the project was expected to be completed by 1978; however, the BJS for FY 2003 (the latest BJS that included an estimated project completion date) reported September 2013 as the expected completion date (The BJS for fiscal year 2006 reported the expected completion date as “to be determined.”)

[64] The data presented in this section were taken from annual Energy and Water Appropriations bill reports.

Table 5-1: Construction General funding for LP&VHPP, 1979-2006

Year	Administration Budget Request (thousands of $)	House Allowance (thousands of $)	Senate Allowance (thousands of $)	Final Appropriation (thousands of $)
1979	$0	$0	$0	$0
1980	$11,000	$11,000	$11,000	$11,000
1981	$10,800	$10,800	$10,800	$10,800
1982	$15,000	$15,000	$15,000	$15,000
1983	$18,800	$18,800	$18,800	$18,800
1984	$16,800	$16,800	$16,800	$16,800
1985	$17,500	$17,500	$17,500	$17,500
1986	$25,000	$25,000	$25,000	$25,000
1987	$16,000	$16,000	$16,000	$16,000
1988	$17,000	$17,000	$17,000	$17,000
1989	$40,400	$40,400	$40,400	$40,400
1990	$39,898	$39,898	$39,898	$39,898
1991	$11,655	$11,655	$11,655	$11,655
1992	$21,491	$21,491	$21,491	$21,491
1993	$11,607	NA	NA	$19,307
1994	$9,619	$24,119	$24,119	$24,119
1995	$10,000	$12,500	$12,500	$12,500
1996	$7,848	$11,848	$11,848	$13,348
1997	$4,025	$18,525	$18,525	$18,525
1998	$6,448	$22,920	$16,448	$22,920
1999	$5,676	$18,000	$10,000	$16,000
2000	$11,887	$16,000	$16,887	$16,887
2001	$3,100	$8,100	$10,000	$10,000
2002	$7,500	$13,500	$15,000	$14,250
2003	$4,900	$9,000	$7,000	$7,000
2004	$3,000	$5,000	$6,000	$5,500
2005	$3,937	$7,500	NA	$5,719
2006	$2,977	$2,977	$7,500	$4,000

5.3.1 Pressures on the Corps Budget

The Corps civil works program was relatively well-endowed by federal budget standards when LP&VHPP planning first began in the 1950s, and the Corps was then an influential federal agency by virtue of that budget authority. Before World War II, civil works accounted for as much as 5% of all federal spending, and just after the war it represented about 2% of the federal budget. Today, however, the Corps budget is but a minute fraction of total federal spending.

Figure 5-2 offers another perspective on the Corps civil works program. It shows the trend in appropriations for national construction general spending by the Corps from 1962 (the date of the first letter report for the LP&VHPP) to 2005 in nominal dollars.[65]

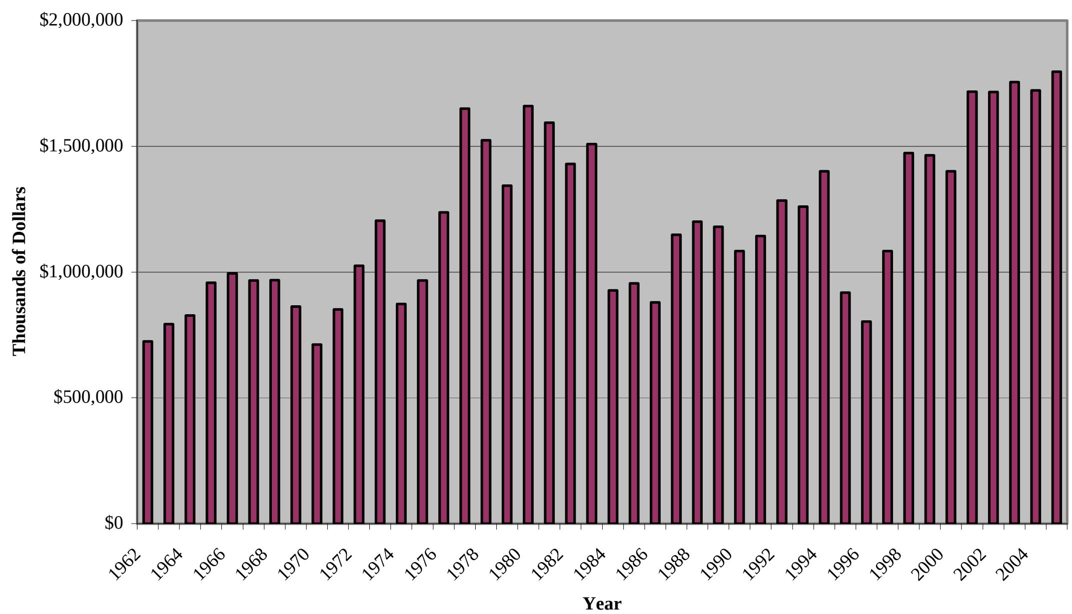


Figure 5-2: Trends in Civil Works Construction General Appropriations

The trend line traces the appropriations in nominal dollars from 1962 to 2005. For over 40 years, nominal appropriations for Corps construction have been unpredictable from year to year and the trend has been nearly flat after about 1980, although there has been some upward trend in the past few years.

It seems reasonable to conclude that in 1965 the District would have viewed as readily affordable the originally estimated $80 million project cost (of which 70% was a federal

[65] Spending for the Mississippi River and Tributaries (MRT) project is not included in these data. While MRT funds can be and have been spent within Louisiana, they were not spent on hurricane protection works.

responsibility). And even as estimated project costs began to rise in subsequent years, the District, at least initially, would not likely have viewed federal project funding requirements to be an obstacle to timely project completion. For example, the BJS for fiscal year 1971 reported that $96 million would be required to complete the project, which it reported would be accomplished by December 1978 (thus requiring about $12 million annually to complete).

Figure 5-2 shows that federal construction general funding in nominal terms (the relevant figures for budgeting purposes) held fairly constant during 1979-1983. It was during this same time period that estimated costs for the LP&VHPP were escalating rapidly (largely as a consequence of price inflation), reaching $800 million by 1982, or about ten times the originally estimated project price. These data suggests that during this period rapidly increasing project costs were placing pressure on a stagnant federal water development budget that had to be spread ever thinner for civil works projects nationwide.

5.3.2 Competing Priorities for a Constrained Federal Budget

Figure 5-3 shows the percentage of the Corps national construction general (CG) funding that was appropriated for all projects within Louisiana each year over the period 1979-2005. The data show that the Louisiana delegation secured a significant share of the funds that were made available for civil works projects nationally during a period when the Corps CG budget was holding fairly constant in nominal terms. The share of the CG budget allocated to projects within the State of Louisiana grew after 1980 to as much as 17%. It then declined to a smaller percentage in the mid-1990s.

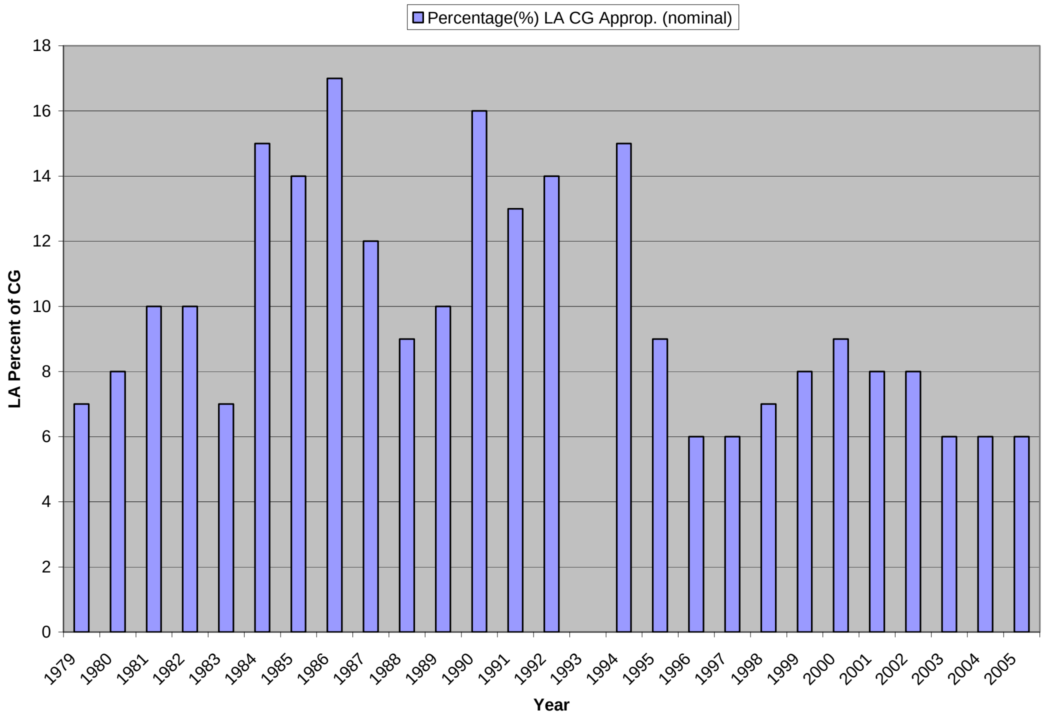


Figure 5-3: Percent of Total Corps CG Funds Appropriated for Louisiana Projects

Figure 5-4 shows total federal appropriations for all civil works projects in Louisiana over time. Annual federal allocations to Louisiana projects peaked at just over $200 million in 1994. Between 1979 and 1994, when demands on the Corps static budget were sharply increasing and after construction of the LP&VHPP was well underway, Louisiana projects received $2.3 billion of the available Corps CG budget. This represented 12% of the national CG budget for that time period.[66]

[66] The calculation of this share excludes 1993 because data on appropriations to LA projects in that year are not available.

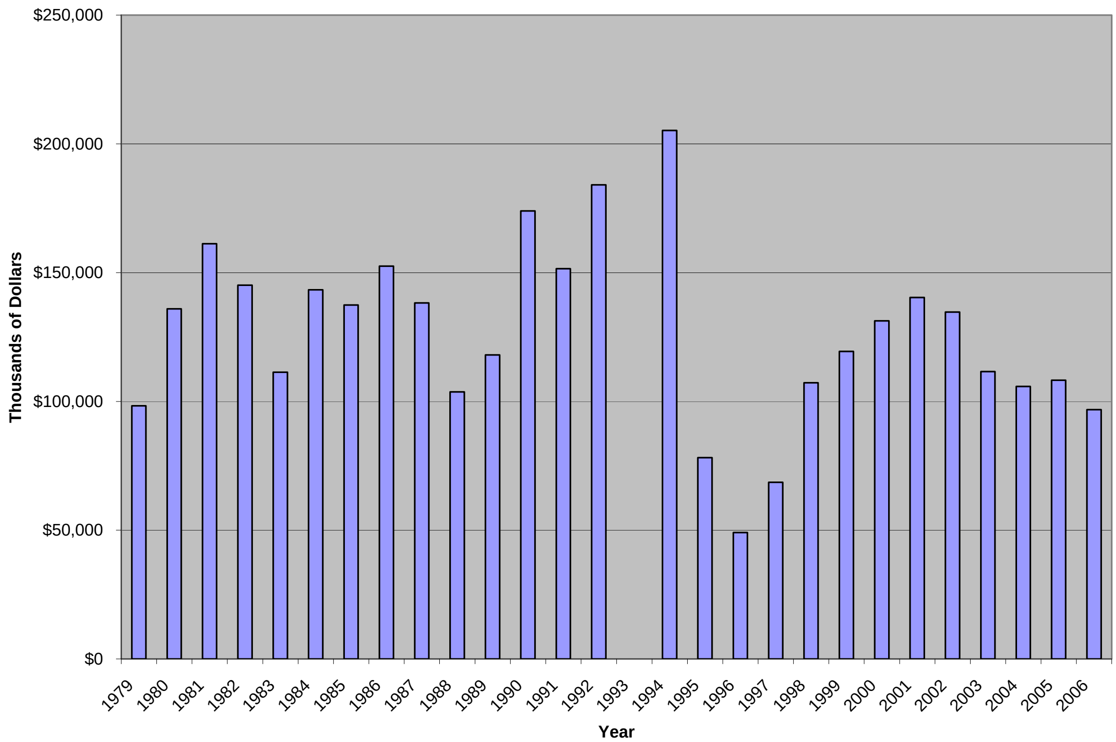


Figure 5-4: Federal Funding for Louisiana Projects Over Time

Figure 5-5 shows the allocation of the funds received by Louisiana projects over time by project purpose. Until 1994, navigation, much of it for the Red River Waterway, was the spending priority for projects in Louisiana. Successive administrations did not budget for the Red River waterway, but Congress added funds each year for that navigation project. In the years after 1994, water resource priorities in the state shifted in favor of flood and storm protection, but total funds going to projects in the state fell. From 1995 through 2005, funding for all flood and storm protection projects in Louisiana totaled $823 million. The Southeast Louisiana (SELA) Urban Flood Control Project received over half (53%) of these funds, while the LP&VHPP received 17%. Figure 5-6 shows that the LP&VHPP accounted for a declining share of federal appropriations to state flood and storm damage protection projects from 1995 onward.

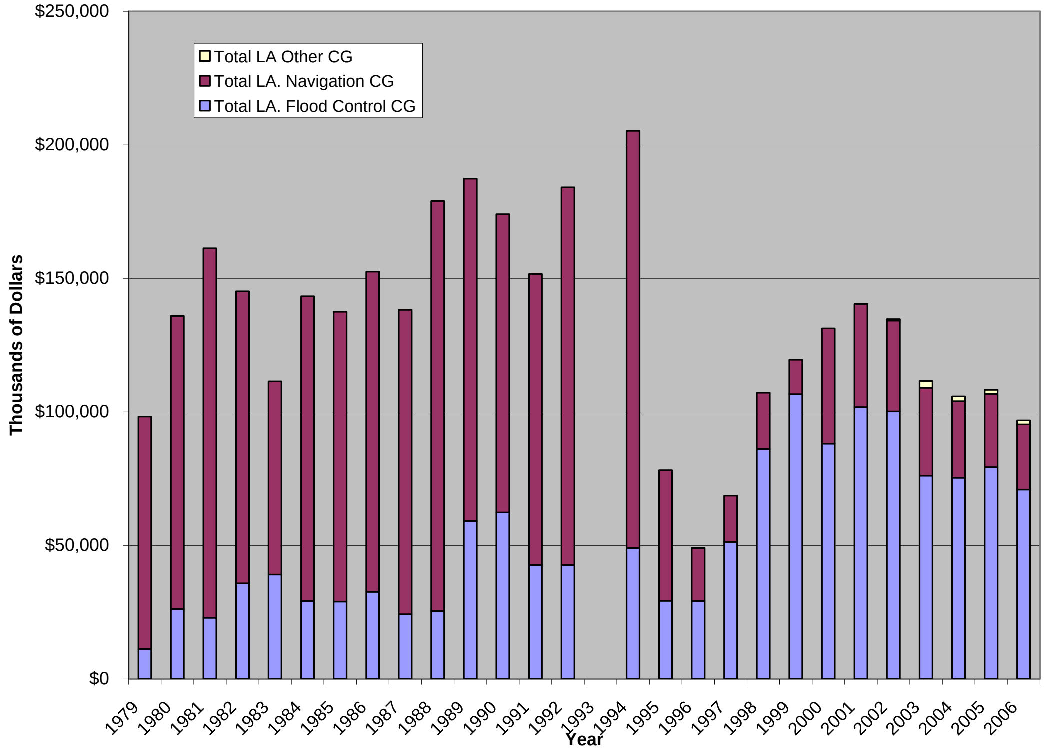


Figure 5-5: Allocation of Federal Funding in Louisiana by Purpose

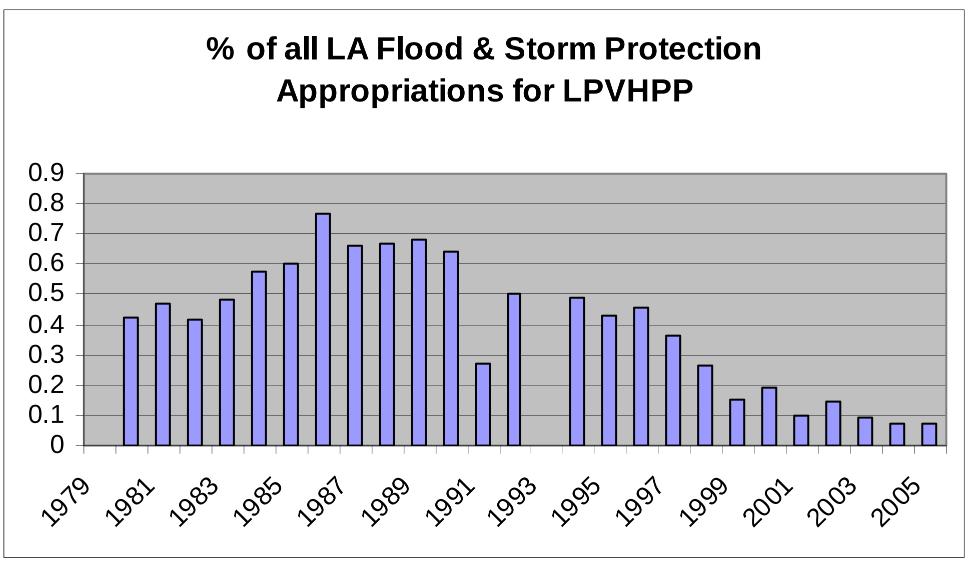


Figure 5-6: LP&VHPP Share of Appropriations for LA Flood and Storm Protection

In sum, successive congresses made appropriations for the LP&VHPP and other projects in Louisiana and across the nation from a total civil works budget that remained fairly static over time. That is, each year Congress had to spread a constrained budget among competing civil works priorities within Louisiana and the rest of the nation. In the end, Congress made budget allocations to the LP&VHPP and other projects within Louisiana and across the nation that it felt balanced competing priorities between navigation, flood and storm protection, and other purposes, and among different storm protection projects. For the LP&VHPP, the result was to stretch out project completion even further into the future, given the high costs to complete the project and the annual federal appropriations made for the project over time. Project completion delays are reviewed further below.

5.4 Delays in Project Completion

The BJS prepared each year for the LP&VHPP included an estimate of the percentage of the project completed to date. This estimate was based on the best professional judgment of the District project manager; there is no standard formula for calculating the project completion percentage based on, for example, a ratio of past costs to future costs or on engineering status, such as the number of levee lifts remaining. Given that this reporting took place over an extended period, several different project managers were involved who may have used varying approaches for estimating progress toward project completion.

The BJS reported percent complete estimates for the project as a whole and for each of three separate project "units." The units are 1) Chalmette, which encompasses that part of the project located within St. Bernard Parish and a small section of Orleans Parish (including the Lower Ninth Ward), 2) New Orleans East, which encompasses all of Orleans Parish that lies on the East Bank of the Mississippi River, except for the Lower Ninth Ward, and 3) New Orleans West, which encompasses those portions of Jefferson Parish and St. Charles Parish that lie on the East Bank of the River.[67] (Map 2-3 in Chapter 2 shows the areas included in the Chalmette, New Orleans East and New Orleans West units). Figure 5-7 shows reported percent complete by project unit for fiscal years 1971 through 2006.[68]

Figure 5-7 indicates that no project unit was reported as fully complete when Hurricane Katrina made landfall. However, the Chalmette Unit, and to a lesser extent the New Orleans East Unit, were reported to be nearing completion by 1990. The reported percent complete then hit a plateau and these units were never reported as fully complete. For example, the Chalmette Unit was reported as 98% complete in every year since 1995. It is not clear to the study team why the units never were reported as complete. New Orleans West was the project unit that was least complete (65% complete) when Hurricane Katrina made landfall (20050207).

[67] The project units were established with the initial project authorization but then modified by the 1984 Reevaluation Report. The original designation included two units, the Barrier Unit and the Mandeville Unit, both of which eventually became inactive when it was decided that work on these units would not move forward as part of the LP&VHPP.
[68] Two of the three outfall canals are included within the geographic area of the New Orleans East Unit and one in the New Orleans West Unit; however, project work along the outfall canals apparently is not included in the reported project completion estimates for these units in the BJS.

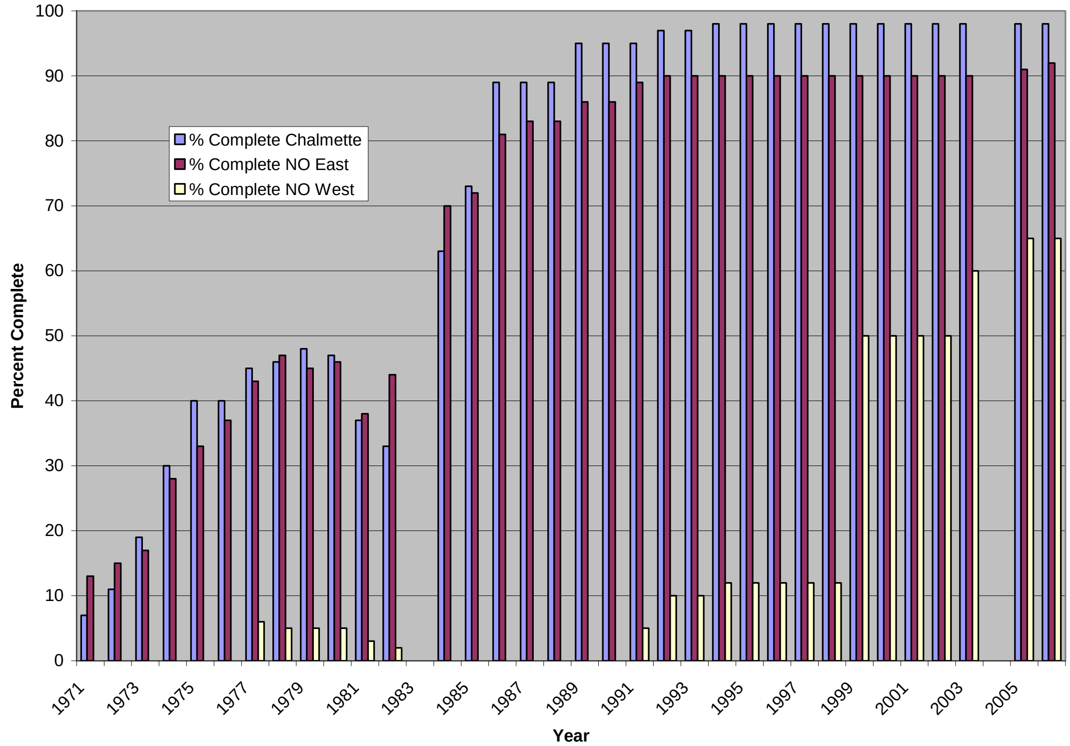


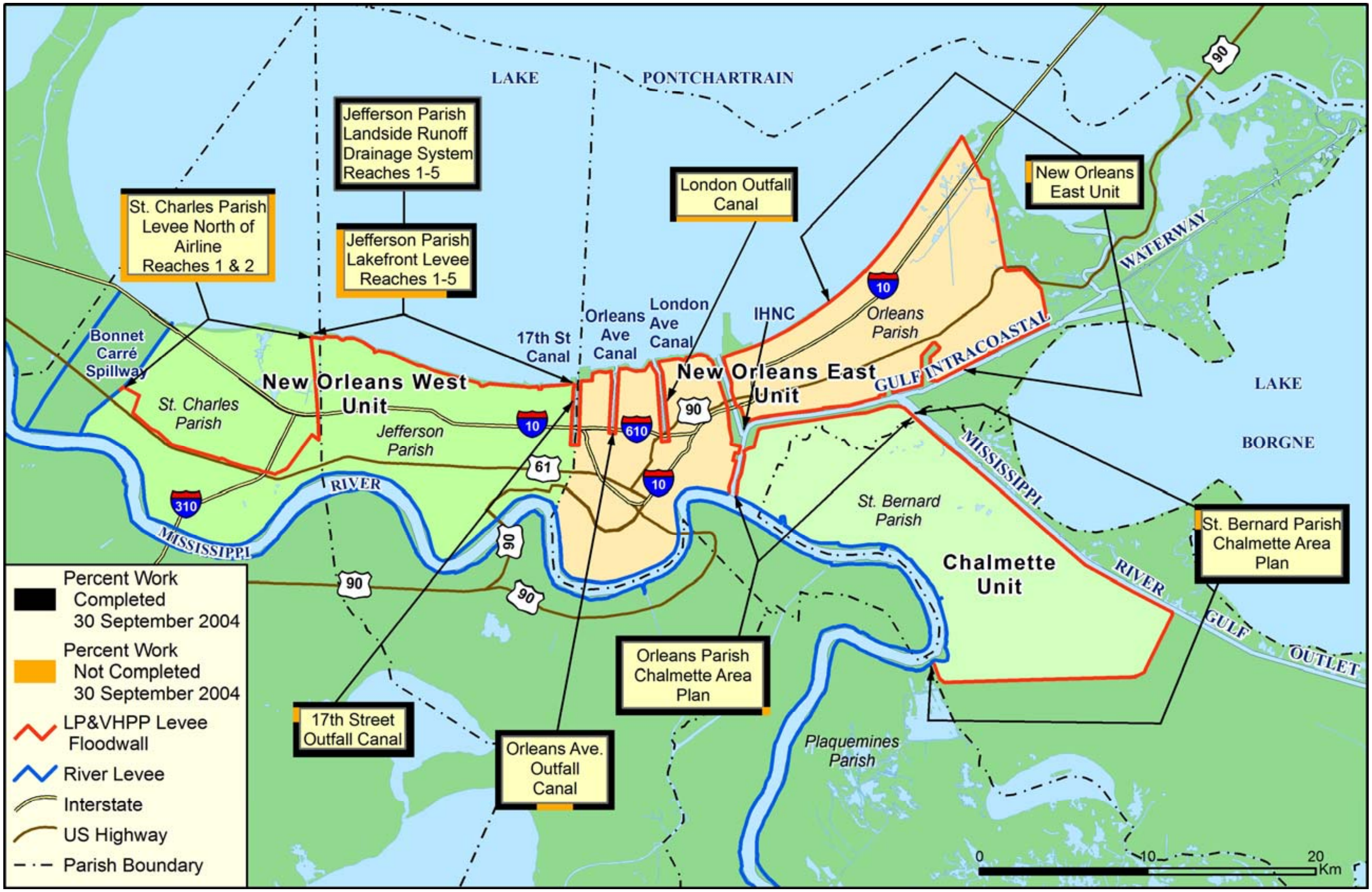
Figure 5-7: Reported Percent Complete by Project Unit

The following passage from a 1994 Project Management Plan prepared by the District for the Division adds useful insight on how the percent project completion estimates would have been understood. Note that those areas where significant work remained were areas that were not affected by overtopping during Katrina.

> "Status of Project. The New Orleans East unit of the project, that includes the City of New Orleans, is about 90% complete. The only major work remaining is raising the parallel protection at the Orleans Avenue and London Avenue outfall canals to about 14 feet above sea level. We will be finished in January 2000. The New Orleans West Unit, Jefferson, and St. Charles Parish is 30% complete and will be completed in November 2013. The major work remaining is in St. Charles Parish. Jefferson Parish has a good level of protection. The Chalmette Unit, St. Charles Parish and Orleans Parish south of the GIWW, is 97% complete with only some small gap closures and final topping left to do. We will finish in January 1997. The entire project is about 80% complete. The major items remaining to be done are the outfall canals and the St. Charles Parish Levee. We started construction on the St. Charles Levee in 1991 and started construction on the outfall canals in 1993." (19940314, page 4)

Another perspective on the status of reported completion comes from examining Map 5-1. This is a partial reproduction of a map on project completion that was included in the project BJS for fiscal year 2006. Two items of note are illustrated by this map and the

2006 BJS more generally. First, those project units, and more specific project components within those units, reported to be nearly complete in 2005 were also areas where LP&VHPP structures were significantly compromised during Hurricane Katrina, for the most part as a result of overtopping. Also, the map shows that project work at the three outfall canals was reported to be less than fully complete in 2005. The BJS for FY 2003 (the latest BJS that included an estimated project completion date) reported September 2013 as the completion date for the entire project. It was this information on project completion status that was provided to the administration and Congress.



Map 5-1: Completion Status for Project Components as Reported in the FY2006 Budget Justification Sheet

Second, the project BJS for fiscal year 2006 includes text stating that the project, once completed as authorized, would provide SPH surge protection. However, that degree of protection could not in fact be provided by a completed LP&VHPP because of the several reasons explored in Chapter 3 of this report. The increased understanding over time of potential storm frequency and intensity, potential surge levels, and subsidence in the project area that indicated that a completed project would provide less than SPH protection were not reported in any BJS or other venue. In retrospect, the budget justification process as well as the Inspection of Completed Works Program were not effective vehicles for assessing and communicating the actual condition of the project protection network, and in fact could not be effective vehicles for this purpose because of their specific limited focus. Indeed, the limited focus of these inspection and reporting instruments might have made their content with respect to project condition and expected performance unintentionally misleading.

The BJS in any year provides an estimate of how much additional funding (in the nominal dollars of the year of the report) would be required to complete the project. Estimated funds needed to complete the project as reported by the BJS trended downward after 1990. Nevertheless, by 2002 the reported funds needed to complete the entire project were in excess of $100 million, and the estimated date of project completion was 2013. Most of the remaining work was in the New Orleans West Unit.

During the first twenty years of project implementation, local sponsors of the project and their representatives in Congress repeatedly expressed frustration about delays in project implementation. Local sponsor complaints were related in part to their concerns over getting protection in place, and in part to concerns over the rapidly escalating cost of the project. By 1992, however, the Chalmette and New Orleans East Units were nearing completion and Congress had acted to resolve the outfall canals debate. At that point, expressions of local sponsor frustrations with project delays mostly related to construction of the New Orleans West Unit in Jefferson and St. Charles Parishes.

Government officials in St. Charles Parish became especially frustrated with project delays over the years. Their requests for protection began in 1949, long before the LP&VHPP was authorized. The area was included in the LP&VHPP as authorized, but after 1965, the District and Division offices questioned the economic justification for that project unit while others criticized it on environmental grounds. In 1980, the District reported that this project unit was no longer justified. Nonetheless, by 1989, the District had completed a design memorandum for the St. Charles lakefront using the original SPH parameters for design. Still, the BJS for fiscal year 2006 reported that the New Orleans West Unit was only 65% complete, and the expected completion date had not yet been determined.[69]

It is worth noting how the BJS estimates of project completion percentage might be interpreted, especially since the project areas for which breaches occurred during Hurricane Katrina (Chalmette and New Orleans East Units) had been reported to be nearly complete for over 15 years. Certainly, if a project unit was reported to be 100%

[69] 19490317; 19730000a; 19740415; 19751001; 19800400; 19890200; 19960930; 20050207

complete and had been constructed correctly, it would imply that the unit was now providing the degree of protection for the authorized SPH parameters. However, it is more difficult to interpret the protection provided by a project unit for which implementation is reported to be only partially complete. The limited available evidence suggests that an almost completed project unit nevertheless provided significant hurricane protection benefits.[70] For example, the BJS for fiscal year 2006 reported, “Between 1983 and 1998, the project has prevented over $11 billion in flood damages in the greater New Orleans Metropolitan Area.” (20050207) This suggests that a project unit reported to be 90% or 98% complete would be understood as providing most of the promised protection benefits.

5.5 Local Sponsors and Project Affordability

Project planning and design could proceed up to construction without a signed Local Act of Assurances (LCA, now referred to as a Local Cooperation Agreement) in place that promised non-federal financial participation. However, a LCA had to be in place by the start of construction. Once construction was underway, there were requirements that local sponsor financial contributions be matched to federal outlays as expenses are incurred. Furthermore, project authorization required that the local sponsors provide all operations, maintenance, and rehabilitation costs for project features once the project was deemed completed.

In the case of the LP&VHPP, securing local cooperation agreements would prove to be a challenge.[71] (A chronology that traces this process and other events relating to local sponsor project financing appears at the end of this chapter.) The project area that was to receive hurricane protection crossed boundaries of many political jurisdictions and special purpose levee and drainage districts that had been formed over the previous century to lead and finance land reclamation and flood protection projects (levees, walls, drainage networks and pumps) essential to settlement of the region. Because of the location of the project’s proposed features, St. Tammany, St. Bernard, Orleans, Jefferson and St. Charles Parishes, the Lake Borgne Basin and Levee District, the Orleans Levee District, the Pontchartrain Levee District, and the State of Louisiana would all serve as local sponsors.

The District had to seek out local units of government that would be willing and able to pay the 30% share of project cost, and assume long-term stewardship for the project structures once completed. In general, potential local sponsors had to demonstrate the fiscal capacity to meet their project financial obligations and have the legal authority to carry out the requisite LCA duties. Each local sponsor of the LP&VHPP funded capital and operations expenses primarily through the annual levy of an ad valorem property tax (or “mil levy”). This basic revenue source could be supplemented by interest earnings, grants, other miscellaneous income, and by the use of bond proceeds.

[70] 19820910; 20050207
[71] 19720908, 19721207; 19721208

The magnitude and complexity of acquiring signed Acts of Assurances are conveyed by the local sponsor chronology presented at the end of this chapter. In all, there were 17 Acts of Assurances reported in various annual Budget Justification Sheets. They spanned a period of twenty years from 1966 to 1987 and involved the entities listed above. Acts were signed after authorization of the Barrier Plan in 1965, and then by necessity, amended after federal legislation in 1970 and 1974. They were also amended after actions taken by the State of Louisiana in 1976 and 1978, and with the adoption of the High Level Plan by the Corps in 1985. In each case, the documents had to include financial plans and be approved by the United States government.

At any point in time, a local sponsor would view the project as becoming less affordable if its budget available for the project at that time (based on tax base and rates, bonds sold, grants, or any other sources of revenue for project funding) were static or expected to grow more slowly than increases in project costs driven by inflation and other factors. It was soon after completion of the long and complicated process of securing the needed local assurances that project costs began to rise with the inflationary period of the late 1970s and early 1980s. Even before then local sponsors had been challenged to secure adequate funds to meet their financial obligations.

Cash payment obligations were a particular concern for local sponsors because large payments might be required over a short construction period. Federal legislation was sought to address this concern. The Congress, in the Water Resources Development Act of 1974, allowed for a future balloon payment to substitute for the requirement that local payments be made in proportion to federal expenditures (19740307). That provision enabled the local sponsors at the time, which included the Orleans Levee District, and jointly the Lake Borgne Basin Levee District and St. Bernard Parish, to defer their payments until 1977. From 1977 to 1990, installment payments including interest were to be made, with a final balloon payment due in 1991. The 1976 Government Accounting Office report on the LP&VHPP reported that, even with this provision, the ability of local sponsors to make required project payments was questionable (19760831).

The delay in project implementation caused by the 1977 court injunction (discussed in detail in Chapter 2) and rapid price inflation around the same time led to significant increases in local cost-share obligations for project completion (see Figure 5-1). Local sponsors' struggles to raise the funds to cover project costs during the 1970s then became even more difficult. In answering project questions posed by the Division in the mid-1970s, the District noted the following perception of local sponsor concerns with project cost and affordability:

> "Question 9: Assuming that the barrier plan were to be abandoned and a high level plan is used to provide the same degree of protection, discuss the following:
>
> ...g. Local support for and opposition to this plan

> RESPONSE: Though the answer to this is for the most part speculative, we would not expect local interests to support any plan more costly than the present plan. Three past special referendums to increase taxes to pay for the local fund requirements toward this project have failed. Local interests have expressed their inability to provide all the funds required for the authorized plan and have pursued congressional legislation to modify their present obligations by reducing their costs and providing for installment payments of their obligations." (19760000, pages 8 and 12)

Statements and actions over time by the Orleans Levee District (OLD), the principal local sponsor for the project, illustrate local sponsor concerns about project cost and affordability. The OLD, in a letter sent to the Louisiana Department of Transportation and Development following the court injunction against the Barrier Plan, noted, "Any delay which will inflate the cost of the project in excess of the $400 million now estimated will place the cost beyond our ability to pay." (19780104) This concern was subsequently alleviated as the OLD was able to stabilize funding sources for the project. Nevertheless, the OLD continued to express concerns about project costs and affordability in the project design process. For example, the OLD in 1986 issued a stop work order to its contractor that was developing parallel protection designs for the London Avenue Canal, noting that the plan cost was too expensive. In the 1990s, the OLD suffered a significant financial setback when it was forced to divest itself of the Bohemia Spillway. This meant a loss of the related royalties and the repayment of $26 million in prior-year royalties. And the OLD led an effort to secure the congressional directive to implement parallel protection for the outfall canals at 70% federal cost, the effect of which was to shift about $45 million of the cost of this locally preferred plan to the federal government.

Despite project financing challenges, local sponsors with the exception of the Lake Borgne Basin Levee District and St. Bernard Parish (see Box 5-1) were able to secure and provide the required funds for project implementation. As of May, 2006, the OLD believed that its available resources plus previously accumulated construction credits were adequate to meet its remaining cost-share. However, these funds would pay for a project that, in consideration of information on project deficiencies that were generally known to the District by the mid-1990s, would provide less than the authorized degree of protection.

Box 5-1: The Lake Borgne Basin Levee District and St. Bernard Parish Obtain Forgiveness for their Joint Project Debt

When the Mississippi River Gulf outlet (MRGO) was proposed for construction, a hurricane levee that was planned for the LP&VHPP was to be constructed along its banks. This levee, by enclosing the wetland areas between the federal hurricane levee and the existing St. Bernard local levee, was predicted to encourage development of port facilities and related economic activity. This was to be the new tax base that would generate the funds to make the local cost-share payments. The Chalmette Unit that included this levee work was reported to be 98% complete in 1994.

Perhaps the environmental laws of the 1970s made development of these enclosed wetlands almost impossible. Perhaps the MRGO simply did not stimulate the predicted economic change. Whatever the cause, the land was not fully developed and St. Bernard Parish and the Lake Borgne Basin Levee District claimed that this limited their ability to pay their share of project costs. They petitioned Congress in 1992 to adjust their local cost-sharing requirements to better reflect realized project benefits, and Congress ordered a study to evaluate the claim. Based on the resulting study prepared by the District, the Assistant Secretary of the Army for Civil Works rejected the claim and did not grant cost relief. However, the Congress in the 1996 WRDA relieved the Lake Borgne Basin Levee District and St. Bernard Parish of their joint project cost obligations incurred to that point in time.

Sources: 19870115; 19901221; 19910211; 19910214; 19910906; 19911000; 19911009; 19940000a; 19961012

5.6 Reflections on Project Cost Growth, Funding, and Completion Delays

This chapter reviewed trends in project cost growth, funding, and completion delays in consideration of the larger context of the national Corps construction budget and the ability of local sponsors to raise the funds to pay their required cost-shares. Project costs were a continuous source of concern for all project sponsors. The first effect of project cost growth within a constrained budget environment was to extend the time to project completion; the simple arithmetic of a growing project cost that had to be funded from a static federal budget spread among competing civil works priorities nationally and within Louisiana meant that the time to project completion had to be extended. Local sponsor complaints about delays in project completion have been evident throughout the project history; in recent years, for example, local officials argued that the LP&VHPP and other hurricane protection projects in the region should be completed before the Corps embarks on a feasibility study for upgraded (Category 4/5) protection for the region.

Another effect of project cost growth and completion delays was to motivate the District to find project efficiencies and to discourage project changes that would increase project costs and extend the time to project completion further out into the future. Local sponsor concerns with project cost, affordability, and completion delays formed the backdrop for project decision-making by the District. Local sponsors may not have been willing or able to secure additional funding for any project changes that would increase costs beyond those already anticipated and budgeted for by project sponsors.

Chronology of Local Sponsor Assurances and Revenue Milestones[72]

Event Name	Start Date	End Date	Notes
LA Governor Designates LA Department of Public Works to Coordinate Local Sponsors	Nov 2, 1965		Department of Public Works (DPW) is designated as the state agency to coordinate the efforts of local interests and to see that the local commitments are carried out promptly. (19670721)
Executive Order Designates Orleans Levee District as the Local Agency to Provide Cooperation	Jan 17, 1966		The Board of Commissioners of the OLD is designated as the local agency to provide the required local cooperation for portions of the Lake Pontchartrain La and Vicinity project in Orleans, Jefferson, St. Charles, and Tammany Parishes. (19670721)
Act of Assurances Signed by Orleans Levee District	Jul 28, 1966		The OLD agrees to comply with all conditions of the Barrier and Chalmette Plans, to include providing lands, easements, and rights of way, 30 percent of first cost, O&M, and capitalized cost of O&M for the barrier structures.
St. Bernard Parish Police Jury Board Signs Assurances	Aug 15, 1966		The SBPJB signs assurances for the original Chalmette area plan. The Chalmette section is considered a separable project element for cost-sharing purposes.
Lake Borgne Basin Levee District Signs Assurances	Aug 16, 1966		Assurances for the original Chalmette area plan are signed by the LBBLD and furnished jointly with the assurances signed by the SBPJB.
Assurances of August 15 & 16 Accepted by the United States	Sep 28, 1966		The joint LBBLD and SBPJB assurances are accepted.
OLD Assurances Accepted for Chalmette Area	Oct 10, 1966		
Chalmette Extension Assurances Signed	Jul 6, 1967		The LBBLD and SBPJB sign assurances for modifications associated with the Chalmette extension
State Constitutional Amendment Fails	1970		Would have provided for local share (19720908).

[72] Unless otherwise noted, all entries were derived from project Budget Justification Sheets, various years.

Event Name	Start Date	End Date	Notes
LA Governor Designates DPW as Coordinating Agency	Mar 5, 1971		Due to "rising non federal cost of participation and widespread benefits to be received by surrounding Parishes," the OLD requested assistance in carrying out assurances. By the Executive Order the OLD, Pontchartrain Levee District (PLD), and the St. Tammany Parish Police Jury (STPPJ) are the assuring entities for the Barrier Plan.
Amended Assurances Signed by OLD	Sept 16, 1971		Based on March 1971 executive order, amended assurances are signed. These were accepted by the U.S. in 1974, but later superseded
Pontchartrain Levee District Assurances	Oct 7, 1971		
Governor Executes Assurances on Behalf of St. Tammany Parish	May 8, 1972		To this point, the St. Tammany Parish Police Jury had been reluctant to grant assurances for participation in the project. Consequently, the LA Governor, in accordance with his authority under Section 81 of title 38 of Louisiana Revised Statutes of 1950, as amended, signs for them. However, these assurances were never accepted formally by the U.S. due to lack of supporting documentation.
State Constitutional Amendment Fails	Nov 7, 1972		Would have allowed the OLD to raise levy by 2.5 mils
Failed OLD Local Election on Mil Increase for Levees	Mar 5, 1973		
OLD Signs Supplemental Assurances	Sept 21, 1973		Based on PL 91-646 - Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, the OLD signs supplemental assurances.
Pontchartrain Levee District Signs Supplemental Assurances	Oct 15, 1973		Based on PL 91-646, the PLD signs supplemental assurances. However, these are not accepted by the U.S. due to lack of supporting documentation.

Event Name	Start Date	End Date	Notes
OLD Mil Levy Increase Approved	Mar 5, 1974		Voters approve the OLD mil levy increase (from 2.5 to 5.5 for an eleven year term). The revenue estimate was for $200 million to be directed to all work, excluding the barrier complexes. Subsequently, the Times Picayune reported in an editorial that the OLD, contrary to voter expectations, had found a way to use the funds for the barriers (19770714)
Water Resource Development Act of 1974	Mar 7, 1974		(PL 93-251) Section 92 states that non-Federal public bodies may agree to pay the unpaid balance of the cash payment due, with interest, in yearly installments...initiated when the Secretary determines that the project is complete ...but not more than 10 years after initiation of construction each payment not less than 4 percent of remaining balance plus interest. The act recognizes increased burden of providing matching local funds and allows deferred payments (19740307).
OLD Assurances Accepted for the Barrier Plan	Mar 29, 1974		The 1971 OLD assurances are accepted, but later superseded due to problems with obtaining acceptable assurances from two other agencies. In the interim, the original October 10, 1966 assurances are considered in full effect for the purposes of moving forward with the project.
Joint Supplemental Assurances for St. Bernard Parish and Lake Borgne Basin Levee District	Feb 28, 1975		Joint Supplemental Assurances based on PL91-646 are accepted by the U.S. on March 17, 1975.
Supplemental Assurances Signed by OLD	May 29, 1975		Supplemental Assurances based on PL91-646 accepted by the U.S. on July 8, 1975.
New Agreement of Assurances, OLD	Mar 30, 1976		New assurances executed by the OLD covering all requirements of local cooperation and a deferred payment plan as authorized by PL 93-251 (WRDA of 1974).

Event Name	Start Date	End Date	Notes
New Agreement of Assurances, St.Bernard Parish and Lake Borgne Basin Levee District	Apr 2, 1976		New joint assurances covering all project costs and deferred payment plan as authorized by WRDA of 1974.
Agreement of Assurances, Pontchartrain Levee District	Sep 20, 1976		New agreement of assurances covering requirements of local cooperation and a deferred payment plan as authorized by WRDA of 1974.
LA Governor Executes Instrument to Lend Financial Assistance	Oct 19, 1976		To be provided through the LA Office of Public Works
LA Office of Public Works Signs Assurances for Pontchartrain Levee District and St. Tammany Parish Policy Jury	Nov 8, 1976		The LOPW executes an act of assurances on behalf of PLD and STPPJ. State office provides financial assistance for costs greater than $100,000 for the portion of the Barrier Plan which is the responsibility of the PLD, and to fulfill the local cooperation requirements for that portion of the project in St. Tammany Parish.
Assurances of April 2, 1976 Accepted by the U.S.	Dec 7, 1977		The new SBP and LBLD assurances are accepted.
Assurance of September 20, 1976 Accepted by the U.S.	Dec 7, 1977		The new PLD assurances are accepted.
Assurances of March 30, 1976 Accepted by the U.S.	Dec 7, 1977		The new OLD assurances are accepted.

Event Name	Start Date	End Date	Notes
St. Tammany Parish Assurances Accepted by the U.S.	Dec 7, 1977		After 1977, there is no further project activity involving St. Tammany Parish. According to the 2005 BJS, amended assurances for the High Level Plan had not been received by the Corps.
Pontchartrain Levee District Partitioned into PLD and East Jefferson Levee District	Sep 13, 1978		
East Jefferson Levee District Formed	Jan 1, 1979		The State of Louisiana forms the East Jefferson Levee District (EJLD) and assigns it responsibility for project levees on the east bank of the Mississippi River in Jefferson Parish. These were previously the responsibility of the Pontchartrain Levee District. Revised assurances are required from the Pontchartrain Levee District for project works in St. Charles Parish, and new assurances are required from the EJLD.
OLD Mil Levy Extension	Nov 19, 1983		A 30 year mil levy extension is approved by voters. It results in the immediate sale of $50 million in bonds for project construction in Orleans Parish.
LA Legislative Order to Return Bohemia Spillway Property to the Original Owners	1984		The state legislature orders the OLD to return property rights in the Bohemia Spillway area to the original owners. This has a major impact on the financial status of the OLD. Ensuing distribution of royalties from mineral rights (oil company leases) to former owners, and legal costs (over 45,000 claims were filed with the Department of Natural Resources) places burdens on the OLD. However, the OLD has other sources of funding for project work, including the special levee assessment. Typically, royalty receipts from the Bohemia Spillway were used for other investment projects such as airport renovation and marina development. The story of the Bohemia Spillway began in 1923. It is located in Plaquemines Parish. The state saw the area as favorable to use as a spillway to protect against flooding upstream as far as New Orleans. Landowners in the rural town of Ostrica, 60% of whom were black, were bought out cheaply or forced out. In 1924 drilling rights were given to Shell, Gulf, Chevron and Bass Oil. In 1929, large amounts of oil

Event Name	Start Date	End Date	Notes
			were discovered. Legal battles began in 1948 to return land rights to original owners (20010521).
OLD Approves $50M Bond Sale for Project Financing	Nov 27, 1984		
Amended Agreement of Assurances, OLD	May 29, 1985		The OLD executes amended assurances for the High Level Plan.
Assurances of May 29 Accepted by the U.S.	Jun 21, 1985		The OLD amended assurances are accepted for the High Level Plan
Supplemental Assurances, East Jefferson Levee District	Jan 16, 1987		Supplemental assurances are for the High Level Plan pertaining to the Jefferson Parish portion of the plan that was formerly the responsibility of the PLD.
Supplemental Agreement of Assurances, Pontchartrain Levee District	Apr 20, 1987		Supplemental assurances for High Level Plan executed by local sponsor. This covers the St. Charles portion of the project.
Assurances of April 20, 1987 Accepted by the U.S.	Aug 07, 1987		PLD assurances for the St. Charles Parish portion of the High Level Plan.
Assurances of January 16, 1987 Accepted by the U.S.	Dec 21, 1987		East Jefferson Levee District assurances for the High Level Plan.
WRDA of 1990	Nov 28, 1990		PL 101-640 requires a restudy of and report on project benefits to determine whether or not sponsors have received expected benefits and whether or not project costs should be reallocated as a result of any unrealized expected benefits. No non-Federal payment for St. Bernard Parish portion of the project is required during the study period (November 1990 to November 1991).

Event Name	Start Date	End Date	Notes
WRDA of 1996	Oct 12, 1996		PL 109-843 includes a modification of the project to provide that St. Bernard Parish and the Lake Borgne Basin Levee District shall not be required to pay the unpaid balance, including interest, of their joint cost-share of the project.

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Chapter 6. Summary Findings and Reflections

6.1 Introduction

The Corps leadership, in cooperation with the Office of the Assistant Secretary of the Army for Civil Works [ASA(CW)], commissioned this report to document project decisions made over the fifty-year history of the LP&VHPP, and explain the factors that influenced those decisions. The report authors focused on those project decisions, among the thousands of technical and policy decisions that were made for the project, that they considered critical to understanding the network of project structures in place when Hurricane Katrina made landfall.

This review of project decisions and the factors that influenced them relied on the facts documented in the available project record. However, no review of this type can be simply a "statement of the facts." The authors chose the project decisions for inquiry, determined how the facts were assembled and presented, and selected the words used to describe project events. For this reason, it is necessary to emphasize that this report is the work of the authors alone and does not necessarily represent the views of the people who commissioned the report or the Corps of Engineers organization.

This final chapter is organized as follows. Section 6.2 provides a brief project summary and initial reflections by the authors of this report that address potential misconceptions about the effects of project decision-making on project status and performance when Hurricane Katrina made landfall. Section 6.3 summarizes report findings on significant historical developments that formed the backdrop for key project decisions. Section 6.4 summarizes the project decisions that were the focus of this review, and relates those decisions to the findings on significant historical developments. The report authors present their own reflections on project decision-making in Section 6.5, and their reflections on lessons learned for hurricane protection efforts are presented in Section 6.5.

6.2 Project Brief and Initial Reflections

In 1962, the District vision of what was necessary to prevent hurricane-induced flooding in the greater New Orleans area led the District to recommend Standard Project Hurricane (SPH) protection, defined by specific wind speed and central pressure parameters, in order to protect human life and avoid catastrophic loss of property. The District justified that degree of protection by demonstrating that the national economic benefits, in terms of property damages avoided, exceeded project costs, and that local project sponsors would be willing and able to pay their share of the estimated costs for the project.

The original Barrier Plan proposed constructing barrier gates to prevent SPH surges from entering Lake Pontchartrain, thus reducing the stillwater height of water along the lakefront and inside the outfall canals that penetrated into metro New Orleans. The barriers would be accompanied with levees and floodwalls in other locations. Also, according to data reported in the 1962 Interim Survey Report, the stillwater surge height from the probable maximum hurricane (PMH) would be contained by the intended structures. In effect, it was believed that, with this degree of project protection, there would be no risk that the area would be inundated by any imaginable storm. After the Barrier Plan was authorized in 1965, the formidable task that remained was to develop the detailed engineering designs for specific plan features, secure the required funding, secure the land rights needed for project implementation, and construct project features. The District at that time estimated that completion of the project would take about a decade.

This original 1962-era design was quickly tested by the size and wave action of Hurricane Betsy, which called into question the planned structure heights. Permission to increase structure heights was requested by the District and approved. Next, the Barrier Plan vision was challenged by protracted local opposition to the barrier gates for preventing hurricane surges into Lake Pontchartrain. In 1985, well after the original date projected for project completion, the Chief of Engineers approved a switch to a High Level Plan that replaced the barrier gates with increased levee heights along the lakefront; however, all other features and designs of the Barrier Plan, as modified after Betsy, were unaffected, with one important exception. The switch to the High Level Plan meant that higher stillwater surges could enter the outfall canals. A protracted debate between one local sponsor, the Orleans Levee District, and the District over how best to address surges into the outfall canals was resolved by congressional action in the early 1990s. Throughout this debate, and for other aspects of the plan, the Corps was responsive to local concerns for cost and project affordability. For example, in the late 1980s, the Division issued new guidance that included revised criteria governing the design of the I-wall structures, as a response to cost concerns.

Clearly, the actual heights of project structures in place in August 2005 were the result of a decades-long sequence of decisions that have been reported in previous chapters and will be further summarized and evaluated in this chapter. However there are three, potentially widely-held, misconceptions that first need to be addressed to set the stage of this summary.

First, it often has been reported that the project was not complete at the time that Katrina made landfall. However, although true in fact, almost all the project areas where breaches occurred were reported as virtually complete in 2005, and had been reported as such for years before that. What is significant, and what will be discussed further below, is that the reported completion was in reference to the original design heights, and did not account for new understanding of subsidence and storm threats that emerged during the project history.

Second, some have argued that Katrina was a relatively small storm when it struck New Orleans, with the implication being that project levees and floodwalls should not have compromised by Katrina's surge. These accounts are misleading, however. It is likely that, had the original design heights for the network of levees and floodwalls been in place in August 2005, the project would still have been overwhelmed by Hurricane

Katrina. Since Katrina, there have been reports and articles noting that Katrina was "only" a category 1 or 2 storm at landfall. But the Saffir-Simpson scale for categorizing storms is generally limited to wind speed at any point in time and location, and does not readily translate to surge height at that same time and location. Hurricane Katrina's surges at landfall were actually determined when the storm was in the Gulf of Mexico, where it had central pressure and wind speed measurements that were more severe than any of the storms in the historical record at the time the project was planned. Thus, the authorized degree of protection for the LP&VHPP was for the stillwater surge created by the central pressure and wind speed parameters associated with both the SPH as well as the severe Probable Maximum Hurricane (PMH), as understood at that time. The surges at landfall resulting from Hurricane Katrina, generated largely while the storm was in the Gulf, exceeded the original design stillwater surge heights along the entire southeast-facing perimeter of the project. Even putting aside the reality that many project structures were constructed to grades that were less than design heights, and were affected by settlement and subsidence since construction, the size of the storm surge was such that, even if project structures had been constructed and maintained at their original design heights, they likely would have been overtopped at many locations. In three places along two of the outfall canals it is known with certainty that breaches occurred before the water reached the tops of the I-wall structures.

Based on flood modeling included in the IPET report, had the originally authorized barrier gates been in place at the time of Hurricane Katrina, and had they worked effectively, flood waters would still have entered the city through the breaches at the nexus of the IHNC and GIWW. In a different hypothetical scenario, if frontage protection at each of the outfall canals had been in place and worked effectively, the residual inundation from overtopping and breaches at other locations would have resulted in significant flooding in New Orleans during and immediately after Hurricane Katrina. Moreover, if the line of parallel protection along the outlet canals had held fast, much of the city still would have flooded from the surge entering through breaches that occurred along the IHNC. Essentially, the city was at risk along its entire perimeter because much of the land is below sea level and any breach in the network of project structures that encircles the city had the potential to cause flooding over much of the project area. To focus on one location within the overall protective network is to lose sight of the systemic nature of the project network and its reliability throughout.

Third, many interested parties have searched for a single project decision that, if it had been made differently, might have avoided the disaster. Some have argued that, if only there had been no NEPA lawsuit, then the barriers would have been built and the disaster would have been avoided. But this argument ignores the fact, already stated, that many of the breach areas would not have been influenced by the barrier complexes. More fundamentally, the record shows that there was much opposition to the barrier gates, and even if there had been no NEPA lawsuit, it is not at all certain that the barriers would have been built. And if the barriers had been built, it is not clear what other project decisions, such as those for the outfall canals, might have been made differently as a result. In the end, all that can be drawn from the record is that the lawsuit delayed project implementation during a period of high price inflation, which changed perceptions of project affordability with the local sponsors, and in turn affected many subsequent project decisions.

None of the aforementioned project decisions occurred in a vacuum, however. On a separate track of reasoning, many have asserted that, if only more money had been budgeted for the project by the federal government, then the disaster would have been averted. Of course, it is true in a larger context that the Corps construction budget was stagnant after 1980 as a result of Executive Branch, congressional, and public opposition to the program's historic emphasis on water project development. But even if this budget stagnation had not been a reality, there is no reason to think that a larger federal budget generally for water projects, or specifically for flood and storm protection, would have—or should have—gone to the LPVHPP, given other flood and storm risks across the nation.

To seek out a single causal event for a result that arose out of a complex series of events over a 40 year period is to assume that all decisions subsequent to that event would have been made no differently. But any change in the past likely would have set off a chain of decisions that would have been made differently, rendering the speculative exercise fruitless.

6.3 Summary of Significant Historical Developments

1. Local sponsor cost-share requirements

In 1958, Congress established cost-sharing requirements for local beneficiaries of hurricane protection projects that departed from traditional cost-share rules applied for other federal civil works purposes. In PL 84-71, Congress said that hurricane protection construction costs were to be a shared financial burden, with non-federal sponsors expected to sign agreements assuring that they would pay for 30% of project construction costs. As with traditional civil works purposes, local sponsors of hurricane protection projects were to provide all lands, easements, and rights-of-way (LERW) necessary for project construction, and these same entities were to assume long-term responsibility for the operation and maintenance of the completed project. But under PL 84-71, if the value of LERW did not reach 30% of total project construction cost, then the non-federal sponsors would need to agree to make cash payments until the total value of the non-federal contribution reached 30% of the cost of constructing a hurricane protection project. This 30% non-federal cost responsibility for hurricane protection projects represented a significant local cost burden that was in many ways without precedent at the time. Indeed, it was not until 1986, nearly three decades later and following ten years of dispute between successive congresses and administrations, that non-federal cost-sharing for all project purposes was increased to reflect the kind of local financial responsibility that had already been in place for the LP&VHPP. For the LP&VHPP, the result was that the District was especially cognizant of the acceptability and affordability of project plans to the multiple local sponsors of the project.

2. Assumed equivalence of the datum used for project construction with local mean sea level

LP&VHPP structures were constructed relative to the National Geodetic Vertical Datum (NGVD) that was erroneously assumed to be equivalent to, but was actually lower than, local mean sea level—the reference point used for the design of those structures. The result was that many project structures were constructed to grades that were below intended design heights. For example, the IPET reported that this error resulted in project structures along the outfall canals being constructed 1-2 feet below intended design elevations.

3. Improved understanding of hurricane threats emerged over time

Beginning soon after Hurricane Betsy in 1965, new information became available to the District over time on a) the potential intensity of storms that might strike the Gulf region and b) the potential severity of hurricane surges based on results from more advanced surge modeling. The new information indicated an increased likelihood and magnitude of higher stillwater surge heights than the original surge estimates, based on the 1962-era SPH parameters, that were used for project designs. Hurricane Camille, in 1969, had wind speed and central pressure parameters that were more severe that those for the project area PMH as defined in 1962. In 1979, the National Weather Service recomputed the SPH and PMH parameters for the project area based on an additional 15 years of storm records. Despite a slight downward revision to the project SPH central pressure parameter (more severe), all project design memoranda continued to use the 1962-era SPH parameters and associated stillwater design surge calculations to establish structure elevations.

4. New surge modeling techniques were developed and applied in the 1980s and 1990s for assessing the degree and level of protection provided by the project

Advances in hurricane surge modeling capability and in statistical analysis of storm data accelerated after 1980 with increased computing power and access to more and better quality data on storms. Hurricane surge analyses at the District using original as well as new storm parameters, and incorporating new understandings of subsidence, suggested that larger storm surges in the project area were more likely than had been thought possible when the project was authorized. A 1993 District-sponsored pilot model study conducted by the Corps Coastal Engineering Research Center using the newly developed ADCIRC surge model indicated that the grades of protective structures adjacent to the MRGO, IHNC/GIWW corridor, and along the Citrus back levee were undersized in relation to the estimated SPH surges in those areas.

5. Project restudy and decision-making extended for eight years following the 1977 court injunction halting construction of the barrier elements of the authorized plan

After the 1977 court injunction that halted further work on the barrier structures (based on a finding that the project EIS was inadequate), the District in consultation with the Division reevaluated the Barrier Plan and the alternative High Level Plan in order to comply with the requirements of the court. In 1978, the Division mandated District economic and environmental studies of these alternatives. By 1980, District analyses indicated that the High Level Plan was less expensive to complete and less damaging to the environment than the original Barrier Plan, although further analyses would be conducted before the District recommended the switch to the High Level Plan. At the same time, a legal determination had to be made regarding whether any proposed changes to the project plan would require a new authorization or could instead be approved under the Chief's discretionary authority.

6. Disagreement between the District and one local sponsor regarding protection approach for the outfall canals persisted after the switch to the High Level Plan

The District determined soon after Hurricane Betsy that the existing local levees along the outfall canals were insufficient in both grade and stability to contain 1962-era estimated SPH storm surges, even with the planned barrier structures in place. In the 1970s, the District developed protection alternatives for the outfall canals, five of which were described in the 1984 Reevaluation Report. That report also noted that treatment of the outfall canals was a significant unresolved project issue. Between 1984 and 1990, the District continued to recommend a frontage protection plan for two of the outfall canals (involving new butterfly gates at the canal mouths), while local sponsors strongly supported an alternative parallel protection plan (involving upgraded lateral protection structures along the entire lengths of the canals). Local agencies strongly preferred the parallel protection plan since it would serve their dual goals of enhanced interior drainage and hurricane protection.

The project record includes no indication that the District and the relevant local sponsor viewed these two approaches as involving differing levels of risk and reliability. Instead of turning on reliability and technical matters, the impasse over the outfall canals stemmed from two interrelated policy perspectives. The first was about the appropriate federal role in enhancing interior drainage. The District considered internal drainage to be entirely a local responsibility in accordance with the District's interpretation of project authorization language and long-standing federal policy. The second policy perspective was the Corps requirement to recommend the least-cost, reliable alternative for providing the authorized project purpose of surge protection. The 1984 Reevaluation Report reported that the District had determined that frontage protection was the least-cost, reliable means of preventing overtopping of the existing canals levees during a storm event.

Since frontage protection was the most cost-effective plan for providing hurricane protection, and since drainage was stipulated by the project authorization to be a local responsibility, the District interpreted the more expensive parallel protection plan to be a "betterment," and determined that if it were pursued as part of the LP&VHPP, the incremental cost for its implementation (over the cost of the frontage protection plan) would be a local financial responsibility.

7. The E-99 Sheet Pile Wall Field Load Test was motivated by concerns for cost-effectiveness in I-wall design

In 1984, the Division supported the idea of a field test to examine I-wall design criteria. In conducting the test, the Division was motivated by concerns about the expected high cost of constructing hurricane protection I-walls throughout the Gulf region, and a belief that current design criteria for I-wall sheet pile penetration depths might be too conservative when applied to I-walls under the conditions of poor foundation soils and short-term loading believed to characterize hurricane events. In 1985, the District conducted the test, which was monitored by the Waterways Experiment Station (WES). Based on the test results as reported and analyzed by WES, the Division concluded that lesser sheet pile penetration depths for hurricane protection could reduce costs without compromising I-wall stability and hence reliability during hurricane surge events.

8. Soon after authorization the project was projected to be completed by 1979, but the expected completion date was repeatedly extended, although most areas where breaches occurred during Hurricane Katrina were reported as virtually complete to the administration and to the Congress.

A variety of factors slowed project completion over time, including 1) local sponsors' difficulty in securing needed rights-of-way, 2) difficulty in unifying the local support and assigning cost-sharing responsibly among the several local assuring agencies for the project, 3) the unanticipated extra length of time required between lifts for certain levee reaches in order to allow for settlement, 4) addressing the requirements of the Barrier Plan litigation, 5) reconciling disagreements over surge protection for the outfall canals, and 6) the significant scope and complexity of project, and the many federal budget cycles in which project construction was funded.

By 1994, the Chalmette Unit was reported to be 98% complete, and the New Orleans East Unit (which includes the New Orleans metro area except for the parallel protection along the outfall canals) was reported to be 90% complete. But the reported completion percentages for these project units did not change significantly in subsequent years. Work at the outfall canals was reported to be nearing completion in early 2004. Project work in the New Orleans West Unit was reported to be only 65% complete in 2005.

9. Estimated costs to complete the project grew nearly ten-fold over the project history due to price inflation and project design changes

The time from 1973 to 1983 is recognized as one of the worst inflationary periods in United States history. Local governments across the nation strained to keep inflation-driven expenditure increases within budgets constrained by established tax rates and policies. Various local sponsors for the LP&VHPP expressed concerns about their ability to pay their cost-shares as project costs grew over time, and Congress acted at different times to relieve part of that cost burden. Meanwhile, after 1980 the Corps construction budget remained nearly stable for over 25 years, even as project costs were increasing. There were competing priorities for that stable budget across the nation and for projects within Louisiana, such as the Red River Waterway and the SELA urban flood control project.

10. The planning and implementation of the LP&VHPP was consistent with the decentralized organizational structure of the Corps

The Corps organization vests significant responsibility in field units for project planning and then detailed project design and construction. Thus, over the years the technical decision-making on the LP&VHPP often was a matter for the District and Division offices alone. After project authorization, Corps Headquarters involvement in the project varied according to the issue and requirements for vertical coordination and review. For example, all design memoranda were sent to Headquarters for review, and there is evidence of Headquarters involvement in the design reviews. However, Headquarters involvement was primarily focused on providing technical guidance as well as policy and budget oversight for the project. Project decisions that did not require any increased budget outlay, or that were not clearly subject to higher-level review, were made at the District with Division concurrence.

6.4. Summary of Project Decisions Reviewed

1. Project designs were developed to protect against surges associated with the Standard Project Hurricane and intended to prevent loss of life and catastrophic damage

In 1955, the Chief of Engineers enlisted the assistance of the United States Weather Bureau in establishing parameters of wind speed and central pressure associated with the Standard Project Hurricane (SPH) for the project area. The SPH was defined as the "most severe combination of meteorological conditions that are considered *reasonably characteristic* of the region involved." The selected SPH parameters were similar to those of the storm that hit the area in September 1915, which at the time of project authorization was the strongest storm on record within a 400-mile zone around New Orleans.

The 1962 Interim Survey Report stated, "Because of the serious threat to human life and property involved, the protective plan must be based on the standard project hurricane for the region." Consequently, the surge that would accompany the SPH was the standard for protection adopted for the project. The project degree of protection, as authorized, was protection against surges associated with the 1962-era SPH parameters for central pressure and wind speed. Project designs continued to be based on the 1962-era SPH parameters throughout the project history.

As of 1962, storms more severe than the 1915 hurricane had been experienced along the Atlantic coast; some of those storms were used to define the parameters of the Probable

Maximum Hurricane (PMH) for the project area. The PMH was defined as the "most severe combination of meteorological conditions that are considered *reasonably possible* in the region." According to data included in the 1962 Interim Survey Report, the stillwater surges associated with the PMH, as estimated in 1962, would be contained by the project design elevations (including freeboard) recommended in that report.

2. Design changes were made to structure elevations between 1966 and 1968

Following Hurricane Betsy, the effects of Betsy's wave action and run-up on proposed structures were used as the basis to increase design elevations of project structures by generally 1-2 feet higher than those specified in the 1962 Interim Survey Report. These increases in the planned heights of structures were made as design changes during 1966-1968 and approved by Corps Headquarters. In 1967, the Chalmette Extension was added to the plan to provide SPH protection over a larger area. This was done as a post-authorization change (PAC) approved by the Chief of Engineers and reported to the administration and the Congress. The District did not update structure design grades after 1969, with one exception. That exception came when the shift to the High Level Plan in 1985 required raising the levee design heights along the lakefront to contain the SPH surge from the lake in the absence of the barrier structures.

3. In 1980, the District, in consultation with the Division, decided to reevaluate only those aspects of the overall plan that would have to change if the High Level Plan were adopted in place of the Barrier Plan

Zero-based budgeting, as an analytical approach to making an investment decision, focuses evaluation on only those aspects of a project or program that are being considered for change. Citing the logic of zero-based budgeting, the District limited all economic and environmental reevaluation analyses to changes in the lakefront structure heights that would be required for the switch to the High Level Plan, and to those necessary to address the NEPA concerns cited in the 1977 court injunction. As a result, all units and reaches of the project were not subject to reevaluation, and the consequences of new SPH parameters and new surge analyses (using the new WES Implicit Flood Model) were not part of the reevaluation study PAC recommendation to switch to the High Level Plan. There is no evidence that Corps Headquarters participated in this decision to employ a zero-based analytical approach for project reevaluation following the 1997 court injunction against the Barrier Plan.

4. The Chief of Engineers in 1985 approved a post-authorization change to the High Level Plan

By the early 1980s, the expected cost of completing the Barrier Plan had increased significantly, making it incrementally less costly to finish the project by raising existing levees and structures around New Orleans (the High Level Plan). In 1985, the decision to abandon the Barrier Plan and to shift to the High Level Plan was approved under the discretionary authority of the Chief of Engineers as a PAC. This decision was communicated to the ASA(CW), the administration, and the Congress. In accordance with the opinion of the Chief Counsel of the Corps, this notification of the PAC was justified with the rationale that the action did not change the scope and purpose of the project nor alter legal relationships with the local sponsors, and thus was within the discretionary authority of the Chief of Engineers. At the time of the 1985 PAC, the means to prevent surges into the outfall canals remained an unresolved issue. Also, the 1985 PAC called only for increasing levee heights along the lakefront. Because no other component of the project was subjected to technical reevaluation, the heights of project structures outside the lakefront areas continued to be based on the original designs, as adjusted by the grade modifications made after Hurricane Betsy.

5. The District in 1985 decided to maintain the use of 1964-era datum benchmark elevations for remaining project construction

As discussed in point 2 in Section 6.3, project structures were constructed relative to the National Geodetic Vertical Datum (NGVD) that was erroneously assumed to be equivalent to, but was actually lower than, local mean sea level—the reference point used for the design of those structures. That error was exacerbated when the District decided to maintain use of the 1964/65 benchmark elevations referenced to NGVD. After the National Geodetic Survey in 1982/83 adjusted benchmark elevations in the project area (reflecting subsidence in the area over the previous twenty years), the Division asked the District to propose a plan for incorporating the new benchmarks in its projects and studies. In 1985, the District made a decision to not adopt the updated benchmarks for project construction. The District recognized that as a result of this decision some project structures would be built to below intended design heights, but concluded that the decision was prudent for several reasons. First, the decision stressed the importance of achieving a uniform degree of protection throughout the project area. Second, the decision noted the impracticality and high cost of modifying already constructed project components.

The District decision came at a time when project costs were rapidly increasing and local sponsors were expressing frustrations about project delays and were unsure of their ability to pay if there were further cost increases. The District 1985 benchmark decision allowed the project to move forward without increasing project costs and without extending project completion even further out into the future.

The Division approved the District decision but noted that, "consideration should be given to reanalyzing and modifying (if needed) hurricane protection work in high density urban areas where the datum changes will drastically reduce the level of protection." There is no evidence in the available project record that the decision and its logic were shared with Corps Headquarters, Congress, or local sponsors.

6. The Division in 1989 issued revised design criteria for I-walls that were applied to parallel protection work for the outfall canals

In 1989, the Division issued revised guidance criteria for I-wall sheet pile design that called for lesser sheet pile penetration depths for I-walls used for hurricane protection in poor foundation conditions. The revision was based on an interpretation of the E-99 Sheet Pile Wall Field Load Test suggesting that costs savings could be realized in hurricane surge protection I-wall design without compromising engineering reliability. Corps Headquarters was aware of the E-99 test and the test results were sent to Headquarters. The decision to issue and apply revised design guidance for I-wall sheet pile design followed issuance of draft guidance in 1987, and significantly reduced the cost of implementing parallel protection along the outfall canals. All project design memoranda related to the outfall canals were sent to Headquarters with all Division endorsements and full discussion of relevant technical and policy issues. Comments by Headquarters were included in the published design memoranda.

7. Congress in the early 1990s directed the Secretary of the Army to implement parallel protection for the outfall canals at 70% federal cost

Responding to a request from the Orleans Levee District, Congress resolved the disagreement between the District and that local sponsor over 1) whether to implement parallel or frontage protection for the outfall canals, and 2) how the cost of parallel protection should be allocated between the federal government and the local sponsor. First, the committee conference report accompanying the Water Resources Development Act of 1990 directed the Corps to treat the outfall canals as part of the overall hurricane protection project, and to favorably consider a plan to implement parallel protection that raised levees along the entire lengths of the canals to grades sufficient to contain SPH surges, with the cost to be shared by the federal government and local assuring authorities. However, this conference report language did not direct the Corps to implement the parallel protection approach or address how its costs should be split between the federal government and local sponsors.

Congress finally resolved the choice of protection approach and cost-sharing distribution in favor of the local sponsor in the Energy and Water Development Act of 1992. That act authorized and directed the Secretary of the Army to provide parallel protection along the entire lengths of the outfall canals, and stipulated that the federal financial cost responsibility would be 70% of the total cost. This congressional action reduced the local sponsor cost for parallel protection by about $45 million, and shifted that cost obligation to the federal government. The administration interpreted this action as a violation of administrative budgetary policy, and accordingly did not budget for the outfall canals after 1993. Nevertheless, federal funding for parallel protection was provided annually by congressional adds to the administration’s requested appropriations, and these monies were used by the District to implement the work.

8. In 1994, the District requested authority to reevaluate project protection, but subsequently determined that surge model refinements were needed before applying the model for project reevaluation that could lead to a PAC or new authorization for structure modifications

The District recognized by the early 1990s that accumulated new knowledge, including that related to land subsidence, sea level rise, storm parameters, and advances in computer surge modeling meant that the authorized degree of protection likely was not provided by the project as it was then being constructed. In the early 1990s, work began on the development of a sophisticated, long-wave surge model, the Advanced Circulation (ADCIRC) model, for use in evaluating existing project protection. A 1993 District-sponsored pilot study of project protection using the ADCIRC model by the Corps Coastal Engineering Research Center indicated that some project reaches were undersized in relation to the estimated SPH surges in those areas. Based on the results of the pilot study, the District in 1994 requested authority from the Division to conduct a numerical model study of project protection using the ADCIRC model and modern data. However, in 1995 the District was not sufficiently confident in the validity of the early ADCIRC model results. The District concluded that use of the model for a detailed project reevaluation that could ultimately provide the basis for justifying a PAC or a new authorization would require a more refined and better validated model. Between 1995 and 2004, the District spent $1-2 million on model refinement and validation, and the results received a positive evaluation by a team of independent technical reviewers in January of 2004.

6.5 Authors' Reflections on the Project Decision Processes

1. **The protracted project planning, design, and construction time period, combined with concerns for cost growth at the District and among local sponsors, focused the District on providing a consistent degree and level of protection throughout the entire project area. Consequently, new information suggesting the possible need for changes in project design and construction to meet the SPH protection standard was put aside for later consideration or subjected to further study.**

Project planning, design, and construction covered a period roughly equal to one-quarter of the history of the United States. There were eight changes in presidential administrations, numerous changes in congressional delegations, and concomitant changes in political philosophy that affected the policies and public attitudes toward water development project spending and the federal funding available for water development projects.

The 1971 project Budget Justification Sheet (BJS) estimated the project completion date as 1978, but when Katrina made landfall, parts of the project—especially to the west of New Orleans proper—were still reported as under construction. Real estate acquisition difficulties, securing local sponsor assurances, and accommodating construction requirements (levee lifts) were among the causes of completion delays. The controversy over the Barrier Plan, followed by the outfall canal dispute, led to more protracted periods of delay. These causes of delay coincided with two other external forces. First, project costs grew dramatically with the rapid inflation of the late 1970s and early 1980s. Second, as project costs were increasing, the Corps construction general budget held virtually constant in nominal dollars from 1980 through 2005 (and fell dramatically in inflation-adjusted dollars over that time).

The reasons for the stagnating Corps budget are many and complex, but there was widespread pressure for civil works reforms that would increase the cost responsibility of local sponsors and increase the sensitivity of water development programs to the environmental concerns reflected in the many environmental laws passed in the early 1970s. The Corps project spending program was challenged in the first days of the Carter Administration in 1977 (the so-called "hit list"). Then there was no new authorization bill signed into law from 1976 until 1986, during the fifth year of the Reagan administration. This time was one of rigorous reviews of project justification in successive administrations; with a stagnant budget, the need to demonstrate the national benefits of a project before it could be offered for funding was indeed a high hurdle. By the late 1990s, expert panels were being convened to study ways to expedite the review process, and organizational changes were made to speed projects through review.

For the LP&VHPP, project cost growth had to be accommodated within a stagnant Corps budget. There were competing spending priorities from other projects across the nation (that also had increased in cost) and for projects to promote navigation and provide flood and storm protection elsewhere within Louisiana. The only way to accommodate growing project costs within a fixed and more competitive budget environment was to extend the time it would take to secure all the funds required for project completion. Nonetheless, prior to congressional actions regarding the design and funding of project work at the outfall canals, the annual administration budget request and the congressional appropriations for the LP&VHPP were identical.

Local sponsors frequently communicated their frustrations with project delays and cost growth to Congress (motivating GAO investigations) and to District and Division offices. One local concern repeatedly voiced was whether the local sponsors would be able to meet future cost-sharing requirements. Although most local sponsors were able to secure the funds needed to meet their cost-share obligations, it was for funds needed to complete the project for the cost as estimated in the BJS after the 1990s period. While the Chalmette area work and work in New Orleans East was near completion, project work in New Orleans West was only 65% complete in 2005, being delayed for a number of reasons, many related to changing environmental requirements that affected the alignment of the protective structures.

The results of a public meeting in October 2002 involving the District and local officials to garner local sponsors for a feasibility study for upgraded "Cat 4/5" protection for all of Southeast Louisiana—at a time when the public perception of the hurricane risk had been heightened by press and professional articles—are instructive. At that meeting local officials argued that the Corps, state, and local governments should focus on completing the LP&VHPP and other authorized hurricane projects in the region before embarking on a study of upgraded protection for the region, and no local entities subsequently stepped forward to sponsor a feasibility study.

It was in this context of a history of local sponsors' frustrations over project delays and costs, federal and local budget limits, and increasing scrutiny of water project investment proposals that new information suggesting the need for changes in project design and construction to meet the SPH surge protection standard was either put aside for later consideration (e.g., the 1985 benchmark decision), or subjected to continuing study (e.g., the 1995 decision to refine the ADCIRC model before using it to reevaluate project protection).

Any changes in project design and construction to accommodate new information might take years to analyze and get approved, especially if the changes required a PAC or new authorization, and thus further cost increases. The District memorandum explaining the decision to not adopt updated datum benchmark elevations reflects these concerns. And the logic for concluding that the Chief under his discretionary authority could make the 1985 switch to the High Level Plan reflected the perceived need to avoid seeking new authorization so that the project could move forward without further delays.

2. **There was no formal Corps-wide assessment process that required the District to routinely track the project's degree of hurricane protection. The only organizational provision for ongoing analysis of the project's ability to provide the authorized degree of protection or consider higher levels of protection was the PAC process**

The Inspection of Completed Works program (ICW) is a Corps program for visual assessment of project conditions. Federal regulations focus the inspection on matters such as the growth of sod cover, extermination of burrowing animals, routine mowing of grass and weeds, removal of trees and drift deposits, and repair of visible damage caused by erosion. The regulations also require a visual inspection looking for areas of unusual settlement, seepage, and sand boils. District and local officials who annually inspected the completed LP&VHPP structures before Hurricane Katrina made landfall typically found no fault with the required maintenance.

Evaluating whether the project's intended degree of protection (protection against the surge associated with the SPH parameters for the project as authorized) was being compromised by area-wide subsidence, or the affect of new hurricane data on the stated level of the project, were outside the scope of ICW review. These kinds of analyses would be completed through studies leading to requests for a PAC or for new congressional authorization.

There was no Corps-wide process for the post-authorization implementation period that required the District to routinely track, and as needed revisit, the project's ability to provide the authorized degree of protection as new information became available. There was no Corps-wide standing program from which the District could request support to initiate such analyses if the District felt they were warranted. Since there was no standing agency process for continuing assessment and reporting of the project's ability to provide the authorized degree of protection (SPH surge protection), and no process to establish the level of justification needed for a PAC, the District was left to make its own determination of whether the analytical foundation was adequate for requesting changes to project designs, and for satisfying higher federal authorities and local sponsors that additional project funding was warranted.

As a result, the District reviews of the ability of the LP&VHPP to provide the authorized surge protection, in consideration of new information, were ad hoc and were largely triggered by external circumstances. Changes to project designs were requested following Hurricane Betsy in 1965 and a modest analytical justification was provided. Changes to structure heights were approved as a design modification and the Chalmette extension was approved as a PAC. The 1977 federal court injunction against the Barrier Plan led to the 1985 PAC switch to the High Level Plan. In that case, the technical as well as legal analyses required to satisfy the court and to get the change approved were quite extensive.

Analyses that raised questions about the degree of protection (DOP) the project provided were an outgrowth of modeling done for other purposes, such as EIS requirements associated with the barrier structures in 1979. Also, concerns about the combined effects on the DOP from regional subsidence, new SPH parameters, and updated surge modeling identified in the early 1990s were an outgrowth of modeling work needed to design new levees for the lakefront with the switch to the High Level Plan. At that time, the District was unwilling to rely on what it considered to be a preliminary application of the ADCIRC model for specifying detailed design changes that might be needed and justifying the cost increases they would entail. Given the long-standing concerns about project cost growth and delays, as well as other factors described elsewhere in this report, the District made the judgment that continued refinement of the ADCIRC model was needed before applying the model to identify project changes required to meet the SPH protection standard, and then secure higher-level approval of those changes.

3. **The only organizational provision for systematically reporting the status of the project to the administration and the Congress was the annual budget justification sheet**

The project Budget Justification Sheet (BJS) is the annual means for communicating to Congress on the status of project implementation. The limited purpose of the BJS is to justify requested federal appropriations for project work in the next fiscal year; thus, the BJS is not recognized by the District and Division offices as an appropriate vehicle for reporting the accumulating information indicating that significant hurricane surge overtopping of at least some project reaches was increasingly likely to happen over the life of the project. On the other hand, the BJS also includes a justification statement that reports on the project purpose and whether it will meet that purpose upon completion.

In the 35 years of project budget justification sheets reviewed for this study, the justification statement was consistent in promising that SPH protection would be provided if that year’s and future budget requests were met towards project completion. But after 2003, a three-sentence statement included in the BJS, but not in the justification statement proper, did report what was known in the District—that project decisions made over time, external changes in the landscape, and modeling studies since the 1980s raised doubts about the project’s ability to withstand the originally estimated SPH surges for the project area.

There were no other standing vehicles for post-authorization communications with Congress. The “Data for Testifying Officers” (DTO) project information memorandum was at one time prepared annually for the development of congressional testimony by Corps officials, and for responding to questions at congressional hearings. The DTOs are no longer prepared, however, and only a few were available to the study team. Those that were available included no information that would have informed the testifying officer that there were possible changes in the project DOP and Level of Protection (LOP, representing the design storm recurrence interval) provided by the LP&VHPP. Instead, on the topic of DOP and LOP, the DTO provided the same information as the BJS. The Chief’s Annual Report is another communication vehicle, but it simply summarized information provided in the BJS.

Beginning soon after project authorization and continuing for the next 40 years, accumulating information was suggesting that hurricane surge overtopping of project structures was increasingly likely over the life of the project. Just the recognition of the 1985 datum benchmark decision is sufficient evidence to conclude that such risk was increasing and that the promised DOP was not attainable by the project as it was being designed and constructed.

Beginning about 2000, many years after the limitations of the project were understood by the District in general terms, there were articles in the popular press and in the professional literature reporting on the limitations of the project protection network if a storm larger than the SPH as originally defined for the project took a critical path to the project area. District officials were quoted in some of these articles as agreeing with the reported analyses and their conclusions. District staff participated in emergency planning exercises with local officials and developed an unwatering plan in the event of significant flooding of the city. And the District completed the Category 4/5 reconnaissance study of upgraded protection of Southeast Louisiana, which included but was not limited to the LP&VHPP area.

It is also true that evidence had been accumulating long before that time period that the project DOP and LOP were less than what was authorized for the project, and that the costs to remedy that deficiency would be significant. To the extent that the District’s understanding of these issues was conveyed in other ways to Corps Headquarters or to local sponsors, no records of such communications prior to 2005 were identified by the study team.

4. There is no documented evidence that the Corps, at any level within the agency, or the Orleans Levee District and other local sponsors and agencies, had access to analyses that described the changes in the risk or reliability of the project protection network as decisions were made over time

The absence of applied risk assessment and engineering reliability analyses for the LP&VHPP has been noted in other post-Katrina reports. It is the case that this review of LP&VHPP planning documents found that the tools of risk analysis were not applied to the project. There was no effort to formally evaluate and report how risks (e.g., populations exposed to flooding under different storm events) were changing with new information; what impact the alternative plans (protective works alone and in combination with evacuation systems, land settlement, and landscape restoration) would have on those risks; and the costs of the alternative plans.

Engineering reliability analysis, as distinguished from risk assessment, is a formal approach for establishing the probability that a complex system will perform its intended function (meet a defined goal such as withstand the SPH surge) during a specified period of time under stated conditions (such as an SPH surge scenario). Evidence of reliability analysis was absent from the available project record. Consider the parallel protection system for the outfall canals. Factors of safety were chosen for the I-walls in particular places, but parallel protection as a system significantly increased the linear feet of floodwalls exposed to storm surges. Therefore, even if the likelihood of failure at any one point is remote, there are many potential failure points, and a failure at one location under an extreme event could have system-wide flooding effects. Increasing the length of the project floodwalls increased the theoretical probability of system failure. For this study, all document reviews and interviews were conducted with the interest in finding reference to decision-makers' perceptions of differential reliability between the parallel and frontage protection alternatives for the outfall canals. None were found, however.

Engineering reliability analysis requires predicting the performance of structures in the network before they are built. For the parallel protection alternative, engineering reliability analysis would have included an integrated consideration of questions such as: 1) What was the difference in the likely ability of T-walls, levees, and I-walls to withstand a quick loading from different surges? 2) Given the particular focus and experimental nature of the E-99 Sheet Pile Wall Field Load Test, what was the likelihood that different penetration depths and thicknesses of sheet pile for I-wall construction would withstand different loadings, and what was the confidence in those estimates? Questions such as these would direct the analyst to consider the adequacy of the data collected to justify new criteria for I-wall design. The interpretation of the data collected from the test then would be critically reviewed over time.[73]

The design decisions for the outfall canals have been criticized in some post-Katrina engineering reports as reducing the reliability of project protection. Ultimately, engineering experts will need to resolve whether the selection of parallel protection, the designs of parallel protection I-walls, or the combination of the two, reduced the reliability of the protection along the outfall canals when compared to the alternative frontage protection approach. The sequence of project events outlined in this report can not answer these questions.

[73] Regarding the E-99 Sheet Pile Wall Field Load Test, the ASCE external review panel report on the IPET work noted, "Thus, at some point USACE researchers clearly recognized the potential for a water-filled gap to develop. This knowledge has now been found to be very important. As research and new information evolved, the design of the existing I-walls was not checked for safety and stability in light of new information."

The available project record does clearly show that cost considerations and policy interpretations, at both local and federal levels, played a significant role in these design decisions for the outfall canals. That same record also includes no evidence that anyone within the Corps had fully evaluated the possible joint effects of the two design decisions on the reliability of the protection network.

However, it is no surprise that the District did not employ formal risk analysis and engineering reliability assessment methods, given the time period when key project decisions were made. Until relatively recently, risk and engineering reliability assessment methods were not highly developed by the engineering community outside of a few areas such as nuclear plant safety. It was not until the 1980s that the political and technical leadership of the Corps began to recognize and stress the utility of formal analyses of risk and reliability. In 1988, the Corps was just beginning its risk assessment applications research program, and field guidance was still years away. Nonetheless, the concepts of risk assessment and engineering reliability would not have been unfamiliar to project engineers and designers, and the nascent state of formal evaluation methods at the time that the project decisions were made can not fully explain the absence in the project record of evidence of risk and engineering reliability considerations.

6.6 Authors' Reflections on the Future

1. Communication and the Corps Responsibility

The District was aware in the most general terms that a project completed with the funds being requested would provide less than the authorized DOP. However, project leaders in the District were not sufficiently confident in the available data and models to use them to estimate precise changes in the actual DOP. Also, the District was not willing to use current models and data to justify requests to local sponsors and higher levels of authority for project modifications.

As stated earlier, concerns over project affordability, completion delays, consistency in protection levels across the project network, and other factors discouraged the District from pursuing significant post-authorization changes under the Chief's discretionary authority or new congressional authorization. Moreover, an organizational process that required continuing project assessment was absent. The District chose to further refine its modeling and analytical capabilities before assessing and reporting on the degree of protection provided by the project when completed, and to possibly use that information to pursue post-authorization changes.

However valid this explanation might be, and however understandable were the decisions made, the way that the Corps shares information must change for the future. The contents of this report and the long history and rich literature on the subject of engineering ethics make clear the necessity for change.

Adcock, writing at the time that many of the project decisions reviewed here were being made, spoke to the obligation of professional engineers and engineering organizations as follows:

> "That engineers have moral and legal obligations beyond those of the ordinary citizen is well accepted. This is because trained engineers can perceive and evaluate hazardous conditions that ordinary persons are not aware of. This is especially true for man-made hazards, because engineers are often involved in making them ... In more basic ethical terms, the moral obligation of the engineer arises from the general philosophy that it is part of a natural relationship between human beings to warn and protect one another from hazards as far as they can be known. Because of his knowledge, therefore, an engineer has a higher moral obligation than one who is not knowledgeable in the field."[74]

More recent scholarship affirms the obligations of professional engineers and their organizations to not only protect but also inform their clients about the limits of the engineering structures they build. In their 2000 book, *Ethics in Engineering*, Martin and Schinzinger note that engineers' "…expertise places them in a unique position to monitor projects, to identify risks, and to provide clients and the public with the information needed to make reasonable decisions."[75]

What the project record shows is that the District knew in at least general terms of the lessening of the project DOP and LOP over time. However, the Corps' reporting requirements did not inform higher authorities or local sponsors that the project, if completed with the estimated required funds, would not provide SPH protection.

This observation is not made to suggest that modified or new project structures would have been funded and built if the District's general understanding of project deficiencies had been shared with higher authorities. Corps leaders have accepted responsibility for the disaster, but it has not been clear what that responsibility was or should be in the future. In fact, it is unlikely given the history told here that the necessary studies, approvals, authorities, funding, and construction sequences all would have rolled out in time to prevent the flooding from Katrina. It is also questionable whether the project, if it had been built and maintained to intended design grades, would have prevented to a significant extent the flooding of New Orleans caused by Hurricane Katrina.

Yet, even if no project changes or other responses were made, the Corps would have fulfilled its obligation to share with all relevant decision-makers whatever knowledge and understanding it possessed. Other decisions might then have been made differently. Perhaps the dissemination of this information would have had effects on decisions regarding land development and use, wetlands/landscape restoration activities, new or

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[74] Adcock, H.N., 1978. "The Engineer's obligation related to man-made hazards." *Pre-prints: ASCE-ICE-CSCE 1978 Joint Conference on Predicting and Designing for Man-Made Hazards*. New York. American Society of Civil Engineers.
[75] Martin, M. and R. Schinzinger. 2000. *Ethics in Engineering*. Fourth Edition. Page 95.

enhanced drainage pumping capability, evacuation planning and emergency response programs, and specialized protection of critical infrastructure.

Moving forward, Corps project evaluation and reporting protocols must be attentive to ensuring that project sponsors and relevant government officials at all levels are as fully informed about project capabilities and limitations as are the technical specialists within the Corps field offices. Further, Corps policies and procedures should seek ways to ensure that the affected public and its political leadership share with the Corps the project decisions that are made in consideration of new information.

2. As future protection of the Gulf Coast is planned, it must be recognized that the vision set forth in any plan will necessarily change during implementation in response to new information, changing costs, and changing stakeholder values, agency missions and policies, and budget priorities.

The Gulf Coast region is a complex and dynamic environment. Project planners must address anticipated design and construction problems associated with poor foundation soils, general land subsidence, and sea level rise. There are unique natural features that are worth protecting and the limited developable urban property has competing uses. Indeed, past decision influences that led to cost increases and completion delays for the LP&VHPP remain endemic in the way the nation manages and directs the Corps program today. There has been an uninterrupted 25-year decline in the federal financial budgetary commitment to water project investment. Meanwhile, this budget stringency has been accompanied by an exploding backlog of authorized projects waiting for federal funding. The Congress continues to separate the authorization and appropriations processes and continues to reserve the right to allocate funds to projects without regard to risk reduction benefits or degree of completion.

At the same time, securing the local funds necessary to meet non-federal, cost-sharing obligations, as a matter of national policy, will continue to be a significant factor in decision-making. The nation has long struggled with how to balance two difficulties with cost-sharing. On the one hand, cost-sharing may create an affordability constraint to building projects that are in the national interest. On the other hand, relaxation of cost-sharing would remove a test of the value of the project to local entities, and also would put further demands on a stagnant federal construction budget. This is a 100-year-old debate that has always resulted in some cost-sharing required for federal projects, and that is unlikely to change in a significant way in the near term as a general policy principle.

The multi-agency review and comment processes, the increased involvement of non-governmental stakeholders, and the federal-local partnering process that has been emphasized were all justified as adding desired checks and balances to decision-making for water project investments. In the view of many observers, this dispersion of decision-making power away from the Corps has brought benefits. And the power of environmental lawsuits has given standing to an important national value.

The diffusion of expertise (in different people, places, and organizations) can benefit decision-making, but will make reaching scientific consensus more difficult, especially for matters where uncertainty remains, such as with the prediction of hurricane surges or the effects of landscape on surge heights. Different technical specialists who ask “what will be the result if X-action is taken” often provide answers that disagree because of model uncertainty, limited data, and even differing conceptual frameworks. It is certain that technical disagreements will persist within agencies, between agencies, and among agencies and other interested parties. The Corps will need to make choices on technical matters after hearing all the relevant arguments, both within and outside the agency.

Decision-making that is the result of competing values, diverse interests, and disagreement between experts gives the appearance of being chaotic. But it is that reality that must be recognized and then orchestrated for providing protection for the Gulf Coast region. Future decisions, whether made within or outside the Corps, will be a continuing process requiring planning and decision-making mechanisms that recognize, accommodate, and then adapt plans to changing values and new information.

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Contracting: Construction Projects or Elements Directed to be Undertaken in the Energy and Water Development Appropriations. USACE. *(pdf, 120 KB).*

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1993 September 16 (19930916) Memo from Headquarters to Division: Comments re Design Memorandum No. 22 - General Design, Orleans Parish Lake Front Remaining Work. USACE. *(pdf, 115 KB).*

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1993 November (19931100a) Memos Recommending Reanalysis of Protection. USACE. *(pdf, 14.0 MB).*

1993 December 22 (19931222) Project Operations Inspection of Completed Works. USACE. *(pdf, 1.3 MB).*

1994	(19940000) FY 1995 Appropriation Construction, General - Lake Protection (Flood Control) Lake Pontchatrain and Vicinity. USACE. *(pdf, 438 KB).*
1994	(19940000a) Letters re St Bernard Debt Payment. St. Bernard Parish. *(pdf, 244 KB).*
1994 January 1	(19940101) Headquarters Guidance Technical Letter 1110-1-152: Engineering and Design: Conversion to the North American Vertical Datum of 1988. USACE. *(pdf, 213KB).*
1994 January 1	(19940101a) Data for Testifying Officers in FY 1995 Civil Works Budget Lake Pontchartrain, LA and Vicinity. USACE. *(pdf, 559 KB).*
1994 March 14	(19940314) District Lake Pontchartrain and Vicinity, LA Hurricane Protection Project, Project Management Plan. USACE. *(pdf, 433 KB).*
1994 September 20	(19940920) District Request for Project Reevaluation. USACE. *(pdf, 783 KB).*
1994 December 19	(19941219) Project Operations Inspection of Completed Works. USACE. *(pdf, 1.6 MB).*
1995	(19950000) FY 1996 Appropriation: Construction General - Local Protection (Flood Control) Lake Pontchartrain and Vicinity. USACE. *(pdf, 432 KB).*
1995	(19950000a) ADCIRC Development Memos - Lake Pontchartrain and Vicinity Model Restudy Data Collection. USACE. *(pdf, 604 KB).*
1995 December 12	(19951212) Annual Inspection of Completed Works Program. USACE. *(pdf, 1.3 MB).*
1996 March 18	(19960318) 1997 Appropriation: Construction, General - Local Protection (Flood Control) Lake Pontchartrain and Vicinity. USACE. *(pdf, 490 KB).*
1996 September 30	(19960930) District Report re Expediting St. Charles Work. USACE. *(pdf, 198 KB).*
1996 October 12	(19961012) Public Law 104-303: Water Resources Development Act of 1996. 104th Congress. *(pdf, 367 KB).*
1996 December 13	(19961213) Annual Inspection of Completed Works Program. USACE. *(pdf, 1.1 MB).*

1997 February 10	(19970210) FY 1998 Appropriation: Construction, General - Local Protection (Flood Control) Lake Pontchartrain and Vicinity. USACE. *(pdf, 548 KB).*
1997 February 18	(19970218) Supplemental Agreement Between The United States of America, The Orleans Levee District, The East Jefferson Levee District and The Sewerage and Water Board of New Orleans. U.S.; Orleans Levee District; East Jefferson Levee District; Sewerage & Water Board of New Orleans. *(pdf, 594 KB).*
1997 February 18	(19970218a) Supplemental Agreement Between The United States of America The Orleans Levee District and The Sewerage and Water Board of New Orleans. U.S.; Orleans Levee District; Sewerage & Water Board of New Orleans. *(pdf, 563KB).*
1997 December 24	(19971224) Annual Inspection of Completed Works Program. USACE. *(pdf, 1.3 MB).*
1998 February 2	(19980202) FY 1999 Appropriation: Construction, General - Local Protection (Flood Control) Lake Pontchartrain and Vicinity. USACE. *(pdf, 414 KB).*
1998 December 15	(19981215) Annual Inspection of Completed Works Program. USACE. *(pdf, 1.8 MB).*
1990 February 1	(19990201) FY 2000 Appropriation: Construction, General - Local Protection (Flood Control) Lake Pontchartrain and Vicinity. USACE. *(pdf, 402 KB).*
1999 April	(19990400) The CERCular article re 1992 ADCIRC 2DDI Model: "Water-Surface Elevation Frequency Estimates for the Louisiana Coast". USACE. *(pdf, 3.2 MB).*
1999 April 21	(19990421) Governor Requests Cat4 Study. State of Louisiana Governor. *(pdf, 99 KB).*
1999 August	(19990800) Hurricane Georges Assessment: Review of Hurricane Evacuation Studies Utilization and Information Dissemination. USACE. *(pdf, 6.1 MB).*
2000 February 7	(20000207) FY 2001 Appropriation: Construction, General - Local Protection (Flood Control) Lake Pontchartrain and vicinity. USACE. *(pdf, 397 KB).*
2000 October 26	(20001026) Policy Letter of 1985; District Proposes NAVD88. USACE. *(pdf, 529 KB).*

2000 December 12 (20001212) Annual Inspection of Completed Works Program. USACE. *(pdf, 1.7 MB).*

2001 January 30 (20010130) District Request for Increased Cat4 Funding. USACE. *(pdf, 189 KB).*

2001 January 31 (20010131) Division Approves NAVD88. USACE. *(pdf, 64 KB).*

2001 February (20010200) Division Endorses Cat4 Recon Funding: Reconnaissance Study, Request for Time and Cost Exception of Planning Guidance Memorandum 99-01, Reconnaissance Phase Guidance. USACE. *(pdf, 47 KB).*

2001 March 9 (20010309) Headquarters Approves Cat4 Recon Funding Increase. USACE. *(pdf, 33 KB).*

2001 April 3 (20010403) FY 2002 Appropriation: Construction, General - Local Protection (Flood Control) Lake Pontchartrain and Vicinity. USACE. *(pdf, 388 KB).*

2001 May 21 (20010521) The Louisiana Weekly Article "Heirs Question Levee Board's Efforts" (Bohemia Spillway). The Louisiana Weekly, Amanda Furness. *(pdf, 225 KB).*

2001 December (20011200) Annual Inspection of Completed Works Program. USACE. *(pdf, 1.8 MB).*

2002 February 4 (20020204) FY 2003 Appropriation: Construction, General - Local Protection (Flood Control) Lake Pontchartrain and Vicinity. USACE. *(pdf, 429 KB).*

2002 April 11 (20020411) District Memo re Vertical Control and Permanent Benchmarks. USACE. *(pdf, 114 KB).*

2002 June 19 (20020619) State of Louisiana Department of Transportation and Development Letter of Intent. Louisiana Department of Transportation. *(pdf, 72 KB).*

2002 June 28 (20020628) Cat4 Recon Report: Section 905(b) of the Water Resources Development Act of 1986. USACE. *(pdf, 1.7 MB).*

2002 July 1 (20020701) District Requests Cat4 Recon Report Approval. USACE. *(pdf, 80 KB).*

2002 August 5 (20020805) Division Memo re Local Funding for Cat4 Feasibility Study. USACE. *(pdf, 120 KB).*

2002 August 16	(20020816) Headquarters Approves Cat4 Recon Report and State Letter of Intent. USACE. *(pdf, 40 KB).*
2002 December	(20021200) Annual Inspection of Completed Works Program. USACE. *(pdf, 544 KB).*
2002 December 20	(20021220) District Memo re Vertical Datum Policy. USACE. *(pdf, 246 KB).*
2003 February 3	(20030203) FY 2004 Appropriation: Construction, General - Local Protection (Flood Control) Lake Pontchartrain and Vicinity. USACE. *(pdf, 398 KB).*
2003 December 8	(20031208) Annual Inspection of Completed Works Program. USACE. *(pdf, 539 KB).*
2004 January 31	(20040131) Review of the Application of the Numerical Model "ADCIRC" for Storm Surge Prediction in the New Orleans, LA Vicinity. USACE. *(pdf, 1.2 MB).*
2004 February 2	(20040202) FY 2005 Appropriation: Construction, General - Local Protection (Flood Control) Lake Pontchartrain and Vicinity. USACE. *(pdf, 400 KB).*
2004 July 23	(20040723) News Release: Hurricane Pam Exercise Concludes. FEMA. *(pdf, 177 KB).*
2004 December 20	(20041220) Annual Inspection of Completed Works Program. USACE. *(pdf, 478 KB).*
2005 February 7	(20050207) FY 2006 Appropriation: Construction, General - Local Protection (Flood Control) Lake Pontchartrain and Vicinity. USACE. *(pdf, 399 KB).*
2006 August	(20060800) Final Report to the Lake Pontchartrain and Vicinity Hurricane Protection Decision Chronology Team on Local Sponsor Considerations & Roles in Decision Making. Prepared by D. Harrison and S. Tucker. *(pdf, 315 KB).*

Appendix A. Master Chronology of Project Events

Event Name	Start Date	End Date	Notes	Source
Unnamed Hurricane	Sep 1915		The most intense hurricane of record to hit the New Orleans area as of the time that the LP&VHPP is planned and authorized. The Standard Project Hurricane (SPH) performance standard used for the LP&VHPP design includes parameters for wind speed and central pressure index that mirror this hurricane.	19591100
Sea Level Datum of 1929, later renamed the National Geodetic Vertical Datum (NGVD)	1929		The U.S. Department of Commerce Coast and Geodetic Survey establishes the first official national vertical datum using mean sea level (MSL) as measured at 21 tide station locations around the country (including one on the Gulf Coast) and 5 stations in Canada. This becomes the datum to adjust all vertical control in North America. LP&VHPP structures are constructed relative to this datum under the erroneous assumption the datum corresponds with local MSL, the reference point used for the design of those structures. In 1973, the National Geodetic Survey changes the name of the datum to NGVD to avoid confusion since this datum represents a land-based reference system that does truly reflect local MSL at any location.	19730507
Unnamed Hurricane	Sep 19, 1947		This hurricane causes extensive damage and flooding of hundreds of acres in New Orleans. The flooded areas, then sparsely inhabited, include much of what is now residential and industrial parts of East New Orleans.	19720908

Event Name	**Start Date**	**End Date**	**Notes**	**Source**
Chief authorizes studies of wind speed effects on shallow lakes	Sep 14, 1948		Studies authorized by the Chief on interrelationship between wind speeds, waves and wind tides in shallow inland lakes. This leads to a series of six Civil Works investigations and corresponding project bulletins for Lake Okeechobee, FL published between 1948 and 1952. These actions come in response to Flood Control Act of 1948 (June), which in turn is linked to the 1947 hurricane.	
Orleans Levee District (OLD) feasibility report on flood control	Oct 1950		"Flood Control and Shore Erosion Protection of City of New Orleans from Flood Waters of Lake Pontchartrain" prepared for the Orleans Levee District by Bedell & Nelson Engineers. Study of impacts of flooding from Lake Pontchartrain and costs to address.	19501000
Corps Engineering Manual sets standard for flood protection in urban areas	Mar 26, 1952		EM 1110-2 1411 establishes Corps policy to provide no less than Standard Project Flood (SPF) protection for river areas where storms may result in catastrophic damage and loss of life. This logic is transferred to hurricane protection projects as requiring Standard Project Hurricane (SPH) protection. The policy is later reaffirmed in 1965 and in 1980.	19520326
The first SPH design is approved by the Corps for the Central and Southern Florida project	Dec 31, 1953		Partial Definite Project Report, Central and Southern Florida Project for Flood Control and Other Purposes, Part IV, Supplement 2, Section 2, DM, Hurricane Winds over Lake Okeechobee. The Lake Okeechobee report uses the SPH design concept for the first time.	Referenced in: 19591100
U.S. Weather Bureau Hydro Meteorological Report #32	1954		Characteristics of United States Hurricanes Pertinent to Levee Design for Lake Okeechobee, FL. (See: Partial Definite Project Report, Central and Southern Florida Project for Flood Control and Other Purposes, Part IV, Supplement 2, Section 2, DM, Hurricane Winds over Lake Okeechobee).	Referenced in: 19591100

Event Name	Start Date	End Date	Notes	Source
Datum (NGVD) benchmarks in New Orleans area	1955		The 1955 re-leveling performed by the US Dept. of Commerce Coast & Geodetic Survey is extended both east and west of New Orleans and finds that benchmarks in New Orleans are settling at varying amounts. Results published October 10, 1957.	19580410
Public Law 84-71	Jun 15, 1955		Following series of severe hurricanes, Congress authorizes and directs the Secretaries of the Army and Commerce to conduct hurricane protection studies for multiple locations along eastern and southern U.S. coasts. One of the studies is for the LP&VHPP.	Referenced in: 19591100
Chief of Engineers letter to U.S. Weather Bureau	Nov 25, 1955		Letter from the Chief of Engineers to USWB describes their joint participation in hurricane study. The USWB given seven subprojects related to hurricanes.	Referenced in: 19591100
District inquires about adjusted datum benchmarks	Jan 5, 1956		Corps asks about recent work by CGS adjusting leveling in the vicinity of New Orleans.	Referenced in: 19580410
Notice of Corps public hearings on hurricane protection.	Feb 1956		Announces public hearings to be held on March 13, 15, 20, 1956 at different locations on problems caused by hurricanes in LA. Cites 1955 congressional study authorization. Public hearings will request public input on project proposals, opposition, damage and physical data, and economics.	19560213
Mississippi River Gulf Outlet (MRGO) authorized and dredging begins	Dec 1956		Plan to provide dredged spoils for levee along MRGO. Levee construction to be done by local interests. No cost-sharing for the levee work is indicated in project documentation Referenced in April 30, 1957 letter from the District Engineer	MRGO DM#1-A, Second Endorsement https://ipet.wes.army.mil

Event Name	Start Date	End Date	Notes	Source
Direction on use of 1955 datum benchmark adjustments	Apr 10, 1958		Direction is from the Coast and Geodetic Survey (CSG). "It is believed that until we have additional releveling to give us a better understanding of what changes have taken place in your area...we should retain the [1955] elevations... the more releveling that is accomplished, the more we lean toward the belief that there is no mark which can be trusted to remain absolutely stable and that any mark may undergo some change due to adjustments in the earth's crust.”	19580410
PL 85-500	Jul 3, 1958		Section 203 of the River and Harbor and Flood Control Act of 1958 establishes a national policy by precedent that local sponsors will be responsible for 30% of construction costs for hurricane protection projects to include LERW, in-kind contributions and cash. O&M is also a local responsibility once the project is completed. This act is cited in the Interim Survey Report under the cost apportionment section for providing the cost-sharing formula applied to the LP&VHPP. (It is the same as the one adopted for the Narragansett Bay, New Bedford, and Texas City hurricane protection projects authorized under the 1958 legislation.) The formula provides the basis for the recommendations of the reporting office and is part of the LP&VHPP authorization. Although total project costs and design change during the life of the project, the same formula is applied throughout.	19580703 and 19621121
National Hurricane Research Project Report #33 sets SPH parameters for the project area	Nov 1959		This National Weather Service (NWS) report defines the SPH as "the most severe storm that is considered reasonably characteristic of the region" and establishes SPH parameters for locations along the Atlantic and Gulf Coasts of the United States. "The SPH index is based on enveloping the records of meteorological events with the elimination of a few extreme events." The report states that the SPH for the New Orleans area has a recurrence interval of 1 in 200 years, and the	19591100

Event Name	Start Date	End Date	Notes	Source
			Probable Maximum Hurricane (PMH) for the project area is also defined. It can be observed that PMH and SPH storm surges used for planning purposes are relatively close in size.	
Barrier Plan model demonstration for local officials	May 1961		Model demonstration is provided for St. Tammany Parish representatives at the Corps Waterways Experiment Station.	Referenced in: 19730905
U.S. Weather Bureau Memorandum 7-61a	Nov 15, 1961		“Hurricane Winds over Gulf Coast Region” establishes relationships between SPH Isovel Patterns and probable maximum events for New Orleans area. A series of memoranda covering the period 1956-1965 give a history of the development of potential hurricane wind patterns and tracks for planning purposes.	Bundled in: 19611115
U.S. Fish and Wildlife Service comments on the LP&VHPP Plan	Mar 1962	Oct 1962	Two letters provide the Fish and Wildlife Service’s comments on the Barrier Plan and the alternative High Level Plan. The comments raise concerns about the effects of the proposed barriers and MRGO on lake salinity and fish and other aquatic habitat.	19620313 and 19621022
LP&VHPP Interim Survey Report	Nov 1962		This is the planning document that is used for project authorization in 1965. The Secretary of the Army, after review of the District’s analysis by the Corps hierarchy, relevant state and federal agencies, and prospective local beneficiaries, transmits a report to the Congress with interim findings and a recommendation of the District Engineer for what will come to be called the Barrier Plan. It will provide a degree of protection (DOP) equivalent to the stillwater surge and wave action predicted to result from the SPH parameters. Economic analysis states that the benefit-cost ratio is 18.9 to 1 for the entire project and 9.0 to 1 for the Chalmette area as an independent project component. The majority of project benefits are derived from future land development	19621121

Event Name	Start Date	End Date	Notes	Source
			and enhancement; however, the B/C ratio remains above unity when land enhancement benefits are excluded. The Barrier Plan has higher net benefits and lower cost than the alternative High Level Plan.	
Corps studies the effects of the barriers and MRGO on Lake Pontchartrain	Nov 1963		The study models the effects of the Barrier Plan features and MRGO on the salinity and hydraulic regimes of Lake Pontchartrain	19631100
Report of the Chief of Engineers on LP&VHPP	Mar 4, 1964		This "Chief's Report" is transmitted to Congress and published as House Document No. 231, 89th Congress, 1st session. It includes the reports of the Board of Engineers for Rivers and Harbors, the District (the reporting office) and Division Engineers, and the concurring reports of the Mississippi River Commission for those areas under its jurisdiction. The report recommends the Barrier Plan, and serves as the basis for project authorization. The report is transmitted to Congress by the Secretary of the Army on July 7, 1965.	19650706
Update of Corps engineering manual on determining the standard project flood	Mar 1, 1965		EM 1110-2-1411 on determination of the standard project flood (SPF) is updated	19650301
Hurricane Betsy	Sep 9, 1965		The storm seriously damages 6,000 homes near the Port of New Orleans and buries the Lower Ninth Ward in 12 feet of water. This storm has cpi and wind speed parameters that are similar to those chosen for the SPH in the 1962 Interim Survey Report (wind speeds = 105 mph and cpi = 27.76 @ minimum). However, the wave action from Betsy is more intense than what was calculated for the SPH in the 1962 project planning report.	19651100

Event Name	Start Date	End Date	Notes	Source
PL 89-298 authorizes the LP&VHPP Barrier Plan	Oct 27, 1965		Congress authorizes the LP&VHPP substantially in accordance with the recommendations of the Chief, except that the recommendations of the 1962 letter report from Secretary of the Army apply to the Seabrook lock. Many other hurricane projects are authorized in the same law using the same broad language. At authorization the expected project cost is $65 million for the barrier complex and related areas and $15 million for the Chalmette area, of which 30% of the cost is a non-federal responsibility. The state of Louisiana assures the federal government that local financial requirements will be met, although local cost-shares have not yet been apportioned and the required legal assurances are still to be signed. The project is authorized to provide protection against the stillwater surge predicted to result from the chosen SPH wind speed and central pressure parameters.	19651027
District requests authority to implement PMH protection	Oct 29, 1965		Two days after project authorization, the District Engineer writes to the Division Engineer to request authority to upgrade the project degree of protection. The District notes that Hurricane Betsy produced wind tides that would have overtopped proposed project levees (had they been in place at the time) in areas southeast of New Orleans, if "Betsy (had) been on a track more critical to the Lake Pontchartrain area." Based on this, the District requests that "authority be granted to modify the recommended plan of protection to provide PMH protection."	19651029
LA Governor designates state Department of Public Works as coordinator of local sponsors	Nov 2, 1965		The LA Department of Public Works is designated by the state as agency to coordinate the efforts of local interests and to see that the local financial commitments are carried out promptly.	Referenced in: 19670721

Event Name	Start Date	End Date	Notes	Source
Division response to District on PMH protection	Nov 4, 1965		The Deputy Division Engineer informs the District that, "The authority for the project is broad enough to allow reconsideration of the degree of protection in light of conditions and data available during definite project studies."	19651104
Division approves lowering the elevation of the Seabrook Lock	Nov 17, 1965		In accord with the wishes of local entities, the Division informs the District, "You are authorized to design Seabrook Lock on a controlling elevation of 7.2 ft. MSL, as recommended, or to use a lower elevation if further studies indicate it to be advantageous to the project. Consideration should also be given to allowing flow through the lock to accomplish additional lowering of the INHC."	19651117
Citizens group petitions for greater protection for Chalmette area	Nov 24, 1965		Citizens group writes to District saying Hurricane Betsy showed the need for adjustments to project plans in Chalmette, and provides suggested amendments. These include raising heights of levees on MRGO and the Gulf Intracoastal Waterway (GIWW) to 30 ft., elimination of Seabrook lock in favor of a floodgate, and the addition of floodgates across the GIWW and MRGO, among others. Notes that the current plan for a levee along south shore of MRGO and north shore of GIWW "would form a funnel channeling all hurricane surges and wind driven water into the Intracoastal Waterway and Industrial Canal."	19651124
State executive order designates OLD for local cooperation	Jan 17, 1966		The Board of Commissioners of the OLD is designated as the local agency to provide the required local cooperation for all portions of the project in Orleans, Jefferson, St. Charles, and St. Tammany Parishes.	Referenced in: 19670721
The US Weather Bureau updates SPH windfields	Feb 17, 1966		Three memoranda dated August 17, 1965, November 3, 1965, and February 17, 1966 provide adjustments to windfields and isovel patterns for SPH established in NHRP #33. These adjustments are used in subsequent project design memoranda	Bundled in: 19651103

Event Name	Start Date	End Date	Notes	Source
OLD assurances for Chalmette Plan	Jul 28, 1966		Assurances are for that portion of the project in Orleans Parish relating specifically to the Chalmette area. Assurances accepted by the U.S. on October 10, 1966.	Referenced in: 19700000
OLD assurances for Barrier Plan	Jul 28, 1966		OLD assures the Corps that the Board is authorized to comply with all the required conditions of local cooperation for the Hurricane Protection Barrier Plan and that it will participate as follows: Provide all lands, easements and rights-of-way; Accomplish all necessary alterations and relocations; Bear 30% of the first cost to consist of the fair market value of the above items and a cash contribution, or as a substitute for any cash contribution, accomplish items of work of equivalent value; Provide additional cash contribution for the estimated capitalized value of maintenance and operation of the Rigolets navigation lock and channel; Provide all interior drainage and pumping plants; Maintain and operate all features of the project. Assurances accepted by the U.S. on March 29, 1974.	Referenced in: 19700000 and 19800128
Design elevations of project structures are established 1-2 feet higher than original designs	Aug 1966	Sep 1968	Design Memorandum 01, Parts I-IV Hydrology and Hydraulic Analysis. Based on new wind field parameters associated with Hurricane Betsy, the design elevations of all project structures are raised 1-2 feet higher than designs set out in the 1962 Interim Survey Report. It is also determined that the locally constructed levees along the outfall canals are not of sufficient grade and elevation to contain the SPH surge when the new wind field data are taken into consideration.	Referenced in: 19670800
St Bernard Parish Police Jury Board and Lake Borgne Basin Levee District assurances	Aug 15 and 16, 1966		Assurances for original Chalmette area plan in St Bernard Parish are signed by the SBPPJB. The Chalmette section is considered a separable element of the project for cost-sharing purposes. Assurances accepted by the U.S. on September 28, 1966.	Referenced in: 19700000

Event Name	**Start Date**	**End Date**	**Notes**	**Source**
DM#1, Part I, LP&VHPP, Hydrology - Chalmette	Oct 1966			19660800
General Design Memorandum #3, Chalmette Area Plan	Nov 1966		The District in this DM reports (as was reported in the 1962 report before the 1-2 foot increase in structure heights) that the SPH degree of protection (DOP) has a return frequency 1/200 years. Termed the level of protection (LOP), this is one way that the District communicates risk; surges from storms less frequent than the 200-year event would exceed structure design heights. The DOP and LOP, and hence the potential for overtopping, would depend on wave action and the height of the storm surge, the stage of project completion, and subsidence of the surrounding land.	19661100
Modification Report - Chalmette Extension	Nov 29, 1966		Report is submitted to the Acting Division Engineer from the District Engineer. Report includes description, justification, economic analysis, and financial report on the modification. Recommends the change on the basis of authority of the Board of Engineers for Rivers and Harbors. Requests to proceed with design modification. States that levee grades along the MRGO will be 17.5 feet.	19661129
Division recommends Chalmette modification	Dec 13, 1966		In memorandum to the Chief of Engineers, the Division concurs with the District recommendations to add the Chalmette Extension to the project.	Bundled in: 19661129
David Levy opposition letters	1967	1976	Levy is a consistent opponent to the Barrier Plan and his letters sent to the Corps over this period provide a comprehensive overview of concerns raised by those who are against the project. Driven by navigation objectives, his focus is on Seabrook Lock and Rigolets Lock/Navigation gates. An August 11, 1971 letter lists 9 reasons for opposition in addition to navigation concerns: (1) tax increase, (2) cloud seeding a better long term plan, (3) would desalt the lake, (4)	19670721 and 19760405

Event Name	Start Date	End Date	Notes	Source
			destroy ship based industry potential, (5) stop pleasure boat use in lake, (6) cause flooding in Slidell, (7) will flood industry outside the flood walls, (8) interior drainage limitations worse than hurricane, (9) no such hurricane has ever happened.	
OLD requests status report on financing and construction schedule for the barriers	Jan 20, 1967		OLD had already provided interim protection until the barrier structures could be built, and now expresses concern that it cannot afford construction delays, and that immediate assistance is needed to get project construction started.	19670120
Post-Authorization Change adding the Chalmette Extension approved by the Chief of Engineers	Jan 31, 1967		This change is specifically to add the Chalmette Extension to the project. Documentation indicates that the levees along the eastern portion of the Chalmette unit will be 1-2 feet higher than original designs in the 1962 Interim Survey Report.	Bundled in: 19661129
Division informs District of approval of Chalmette modification.	Feb 9, 1967		Memorandum from the Division to the District	Bundled in: 19661129
District informs Division that LA has been informed of Chalmette modification.	Feb 23, 1967		On February 13, 1967 the LA Department of Public Works gives assurances that local interest requirements would be met.	Bundled in: 19661129
OLD public information release	Feb 26, 1967		Outlines schedule of project implementation and progress made to date. It notes that OLD has already provided interim protection for Orleans Parish until project structures can be built. Also notes that OLD is the assurance agency of the State of Louisiana for the entire Barrier Plan Unit, and is sponsoring that unit for the several other parishes that are affected (St. Charles, Jefferson, and St. Bernard).	

Event Name	Start Date	End Date	Notes	Source
Jefferson Parish Council resolution for federal reimbursement of funds expended for interim protection	Mar 2, 1967		The Pontchartrain Levee District (PLD) is presently constructing an interim protection 14 foot levee along Lake Pontchartrain on a crash program basis. The resolution states that the Jefferson Parish Council resolves “to request the US Corps of Engineers to reimburse the PLD for funds paid by the said District to construct the interim protection levee of fourteen feet in Jefferson Parish…[and]…resolve further to request the US Corps of Engineers to reimburse the Parish of Jefferson should any funds be expended by this Parish to construct permanent flood protection facilities along Lake Pontchartrain…”	19670302
GDM #2 LP&VHPP Barrier Plan, Advance Supplement, IHNC Levees	May 1967			Document available at: https://ipet.wes.army.mil
DM #1, Part II LP&VHPP. Hydrology -- Barrier Plan	Aug 1967			19670800a
DM #1, Part IV LP&VHPP, Hydrology and Hydraulic Analysis – Chalmette Extension	Oct 1967			19671000
GDM #2 LP Barrier Plan, Advance Supplement, Citrus Back Levees	Dec 1967			Document available at: https://ipet.wes.army.mil
DM#1, Part III LP&V, Hydrology - Lakefront	Sep 1968			19680900

Event Name	Start Date	End Date	Notes	Source
District informs Division of increasing project costs	Sep 13, 1968		This letter speaks to increasing costs for the LP&VHPP and three other authorized hurricane protection projects in the District. Reports that the estimated costs for the authorized projects are 2-4 times as high as the costs presented in authorizing documents, and these are expected to increase further as more detailed design is accomplished. Reasons given include development of new hurricane parameters that increased heights of protective structures, and re-leveling that reduced ground surface levels relative to MSL by 1 foot necessitating a corresponding increase in levee heights.	19680913
Saffir-Simpson Hurricane Scale created	1969	1971	The scale is developed between 1969 and 1971 and provides 5 storm categories based largely on wind speed along with barometric pressure and storm surges. Storm surges are not always reported. The Saffir-Simpson scale does not match well with the SPH used for project design in 1962—SPH cpi would be classified as Category 4 in the gulf; SPH storm surges would be classified Category 3 as they strike the hurricane protection project; and SPH wind speed would be Category 1 in New Orleans. Note: the PMH central pressure reported in 1962 would fall into the Category 5 range, but associated storm surges are below Category 5 elevations.	
Hurricane Camille	Aug 14, 1969		This hurricane, one of the most intense ever recorded, sideswipes New Orleans. Orleans Parish, although not in the direct path of the hurricane, sustains damages of almost $10 million.	19720908
Jefferson Parish resolution urging update of criteria for hurricane protection and construction of barriers	Sep 4, 1969		The resolution states, "The Jefferson Parish Council hereby resolves that an immediate appeal be made to our Congressional Delegation and the Corps of Engineers and the Pontchartrain Levee Board requesting that the critieria of the Corps for hurricane protection on critical paths into this area be immediately updated…"	19690904

Event Name	**Start Date**	**End Date**	**Notes**	**Source**
District compares parameters of PMH and Hurricane Camille	Sep 29, 1969		The District Chief of Hydraulics reports that Camille's central pressure and windspeed parameters are more severe than the PMH reported in the 1962 Interim Survey Report. A minimum pressure of 26.84 inches (PMH = 26.9 inches) was reported in Bay St. Louis, Mississippi, which makes Camille the second most intense hurricane of record to hit the United States. The actual maximum sustained winds will never be known, as the hurricane destroyed all the wind-recording instruments in the landfall area. The estimates at the coast are 200 mph. Columbia, Mississippi, located 75 miles inland, reported 120 mph sustained winds.	19690929
Budget justification, FY 1971	1970		Each year the District Program Office prepares a justification for requested project funding for the upcoming fiscal year that is submitted through the Division and Headquarters Program Offices and published in the Congressional Record. The budget justification includes financial and other project information, including percent of the major project units completed to date and the expected year when those project units will be completed. This year's justification reports that total project costs are now $182 million, more than two times the cost at project authorization five years earlier. In language included in the original 1962 report before Hurricane Betsy and that will be repeated in all subsequent BJS through 2005, this justification asserts that the completed project will provide protection against storms such as Betsy and the 1915 hurricane that was the basis for the SPH parameters. This budget justification also reports that the New Orleans East Unit is 13% complete (expected completion in 1978), New Orleans West Unit is 0% complete (expected completion in 1978), and Chalmette Unit is 7% complete (expected completion in 1978).	19700000

Event Name	Start Date	End Date	Notes	Source
GDM #2 LP Barrier Plan, Supplement #6, St. Charles Parish Lakefront Levees	Nov 1970			Document available at: https://ipet.wes.army.mil
Budget justification, FY 1972	1971		This budget justification reports that the New Orleans East Unit is 15% complete (expected completion in 1981), New Orleans West Unit is 0% complete (expected completion in 1978), and Chalmette Unit is 11% complete (expected completion in 1978).	19710000
LA Governor designates state Department of Public Works as the coordinating agency for local sponsors	Mar 5, 1971		Justification sheet for fiscal year 1977 reports that due to "rising non-federal cost of participation and widespread benefits to be received by surrounding Parishes, the Orleans Levee District requested assistance in carrying out assurances."	Referenced in: 19760121
OLD assurances	Sep 16, 1971		The President of OLD assures Corps that he is empowered to comply with all the required conditions of local cooperation for the project in Orleans Parish.	Referenced in: 19760121
Pontchartrain Levee District assurances	Oct 7, 1971			Referenced in: 19760121
Budget justification, FY 1973	Jan 31, 1972		This budget justification reports that the New Orleans East Unit is 17% complete (expected completion in 1981), New Orleans West Unit is 0% complete (expected completion in 1981), and Chalmette Unit is 19% complete (expected completion in 1978).	19720131
LA Governor executes assurances on behalf of St. Tammany Parish.	May 8, 1972		St. Tammany Police Jury has been reluctant to grant assurances for participation in the project. Consequently, the Governor in accordance with his authority under Section 81 of title 38 of Louisiana Revised Statutes of 1950, signs for them. These assurances are never accepted by the District, however, due to lack of supporting documentation.	Referenced in: 19760121

Event Name	Start Date	End Date	Notes	Source
National Weather Service issues draft revised SPH criteria	Jul 31, 1972		Revised SPH criteria for wind speed, central pressure, and radii are given for the Atlantic and Gulf Coasts after Hurricane Camille. The SPH characteristics are later expanded and generalized in NOAA Technical Report NWS 23 released in September 1979. These new characteristics are reported in later project design memoranda but are not used for design purposes.	19720731
OLD report on the history of the levee district and hurricane protection efforts	Sep 8, 1972		"Nature Changes from Moment to Moment" recounts OLD development and hurricane history and efforts to secure necessary increase in millage levy rates to pay for improved hurricane protection. Cites failed constitutional amendments of 1970 and early 1972 to raise local share of project costs. Suggests that the LP&VHPP will protect against all future storms.	19720908
Statewide election on constitutional amendment for OLD to raise mil levy	Nov 7, 1972		A series of letters and status reports involving the District, the New Orleans Mayor, and the LA Governor provide background information on the failed amendment and efforts by the local sponsors to secure the necessary funding for the project. The District remains confident that the local sponsors will be able to fund their share of the project.	Referenced in: 19721207 and 19721208
GDM #2 LP Barrier Plan, Supplement #5B N.O. East Lakefront Levees - Paris Road to South Pass.	Dec 1972			Document available at: https://ipet.wes.army.mil
Budget justification, FY 1974	1973		This budget justification reports that the New Orleans East Unit is 28% complete (expected completion in 1982), New Orleans West Unit is 0% complete (expected completion in 1982), and Chalmette Unit is 30% complete (expected completion in 1982).	19730000

Event Name	Start Date	End Date	Notes	Source
GDM #2 LP Barrier Plan, Supplement #9, N.O. East Levee from South Point to GIWW	May 1973			Document available at: https://ipet.wes.army.mil
Sea level datum of 1929 renamed NGVD	May 7, 1973		Since the 1929 datum was based on average sea level at 26 tide stations, it did not necessarily reflect local mean sea level at any location. "In order to avoid confusion and the costly errors that may result through a failure to consider local sea level when engineering projects are undertaken, it is proposed to change the present name of the vertical control datum from Sea level Datum of 1929 to National Geodetic Vertical Datum of 1929."	Referenced in: 19730507
OLD supplemental assurances	Sep 21, 1973		Adds the assurance that OLD can and will comply with requirements of the "Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970."	Referenced in: 19760121
Budget justification, FY 1975	1974		This budget justification reports that the New Orleans East Unit is 33% complete (expected completion in 1983), New Orleans West Unit is 0% complete (expected completion is documented as indefinite), and Chalmette Unit is 40% complete (expected completion in 1985).	19740000
OLD mil levy increase approved	Mar 5, 1974		The OLD mil levee increase from 2.5 to 5.5 is approved by voters for an eleven year period. The revenue increase of $200 million is to be directed to all project work excluding the barrier complexes. Subsequently, the Times Picayune reports in an editorial that the OLD, contrary to voter expectations, had found a way to use the funds for the barriers.	Referenced in: 19770714 and 19830919
Water Resource Development Act (WRDA) of 1974	Mar 7, 1974		PL 93-251. In response to concerns about local sponsors' ability to make cost-share payments in a timely fashion, Congress authorizes future balloon payments for local sponsor cost-sharing obligations. Section 92 of the act states, "non-Federal public bodies may agree to	19740307

Event Name	Start Date	End Date	Notes	Source
			pay the unpaid balance of the cash payment due, with interest, in yearly installments .. initiated when the Secretary determines that the project is complete .. but not more than 10 years after initiation of construction .. each payment not less than 4% of remaining balance plus interest."	
St Charles Parish Police Jury resolution to conduct meeting with officials on LPVHPP	Apr 15, 1974		Documents indicate concern for the ecological study and status of the project in St Charles Parish	19740321, 19740404 and 19740415
Budget justification, FY 1976	1975		This budget justification reports that the New Orleans East Unit is 37% complete (expected completion in 1983), New Orleans West Unit is 0% complete (expected completion: indefinite), and Chalmette Unit is 40% complete (expected completion in 1986).	19750000
Draft environmental impact statement (EIS) for Barrier Plan	Jan 1975		LP&VHPP EIS filed with Council on Environmental Quality.	19740800
Public hearing on draft EIS for Barrier Plan	Feb 22, 1975		Local opposition to the proposed surge barriers is expressed by many participants on more than environmental grounds. The District in testimony argues for the need to move forward with the barrier complex, and indicates that the EIS shows that the barriers will have no significant environmental impacts.	19750222
St. Bernard Parish and Lake Borgne Basin Levee District supplemental assurances	Feb 28, 1975		Accepted by the U.S. on March 17, 1975.	Referenced in: 19800128
Assurances issue for the Lake Borgne Basin Level District (LBBLD)	Sep 1975		The LBBLD did not have money to purchase borrow area for construction of levee system in St Bernard Parish that they were required "by law" to buy. Letters between the District and the Regional	Bundled in: 19751003

Event Name	Start Date	End Date	Notes	Source
			Planning Commission, and a Times Picayune editorial, address the financial difficulties of the LBBLD.	
U.S. EPA opposes the St. Charles portion of the LP&VHPP	Oct 1, 1975		The EPA supports other portions of the project already constructed, but opposes the St Charles levees as they would lead to the loss of undeveloped wetlands.	19751001
District clarifies local responsibilities	Oct 3, 1975		A letter from District Engineer to Chairman Hurricane Protection Committee Regional Planning Commission states, "Public Law 298, 89th Congress, 1st session, approved 27 October 1965, authorized the total Lake Pontchartrain, Louisiana and Vicinity hurricane protection project. As you know, the Chalmette unit is a part of this hurricane protection project. One provision of the law specifies that the local assuring agency must provide all lands, easements, and right-of-way, including borrow and disposal areas, necessary for the construction of the project. The Government cannot assume any of the responsibilities which are assigned by law to the local assuring agency...The Government and the assuring agency, to the best of my knowledge, fully intends to complete the subject project."	19751003
Save Our Wetlands, Inc. (SOWL) contests the project plan in federal court	Dec 8, 1975		SOWL files suit in the U.S. District Court for the Eastern District of Louisiana against the District Engineer, the Secretary of the Army, the Administrator of the EPA, and the President of the Orleans Levee District (OLD). The Cilo Sportsman's League joins the suit on June 21, 1976. The suit alleges that a regional cumulative EIS should be accomplished prior to proceeding with the project; that the Corps had not complied with conditions of final approval by the EPA; and that the Corps had not completely eliminated the St. Charles lakefront levee as required by the EPA. The suit is modified by SOWL on February 4, 1976 and March 8, 1976 to include allegations about the inadequacy of economic analysis and the incapability of the OLD to provide local assurances. St. Tammany Parish files a similar suit on March 30, 1977.	19760204, 19760308, 19760319, and 19770401

Event Name	Start Date	End Date	Notes	Source
Budget justification, FY 1977	1976		This budget justification reports that the New Orleans East Unit is 43% complete (expected completion in 1985), New Orleans West Unit is 6% complete (expected completion is documented as indefinite), and Chalmette Unit is 45% complete (expected completion in 1989).	19760121
OLD amended assurances	Mar 30, 1976		New assurances executed by the OLD for the barrier complexes covering all requirements of local cooperation and a deferred payment plan for the cash contribution portion of the OLD share as authorized by WRDA of 1974. Total project cost now estimated to be $352 million and OLD's cost-share is $67,086,140. This agreement still pertains to the Barrier Plan. Assurances are accepted by the U.S. on December 7, 1977.	Referenced in: 19800128
St Bernard Parish and Lake Borgne Basin Levee District amended assurances	Apr 2, 1976		New joint assurances covering all project costs and deferred payment plan as authorized by WRDA of 1974. Assurances accepted by the U.S. on December 7, 1977.	Referenced in: 19800128
GDM#2 Supplement 5A - Citrus Lakefront Levee IHNC to Paris Road.	May 1976			Document available at: https://ipet.wes.army.mil
Government Accounting Office Report	Aug 31, 1976		The report, "Cost, Schedule, And Performance Problems of the Lake Pontchartrain And Vicinity, Louisiana, Hurricane Protection Project," reports that estimated project cost has increased from $85M to $352M, and that the expected completion date has moved from 1978 to 1991. States that project delays were not caused by funding shortfalls, but rather were more the result of other factors such as the refusal by local entities to provide necessary rights-of-way for construction of the tidal barriers. The report also notes that, due to higher estimated hurricane surges caused by wind, as learned from Hurricane Betsy, levees would	19760831

Event Name	**Start Date**	**End Date**	**Notes**	**Source**
			have to be higher, and the outfall canals would require project protection. The report raises questions about repayment ability of local sponsors in consideration of rapidly escalating overall project cost, and speculates that locals may be unable to make balloon payments under WRDA 1974.	
Pontchartrain Levee District assurances	Sep 20, 1976		PLD and the LA Department of Public Works (LADPW) assure that LADPW will lend PLD funds as necessary after PLD's expenditure of the first $100,000 due to PLD's limited financial capability. Assurances accepted by the U.S. on December 7, 1977.	Referenced in: 19800128
LA Governor executes instrument to lend financial assistance to local sponsors	Oct 19, 1976	Nov 8, 1976	The LA Department of Public Works (LADPW) is designated to provide financial assistance to the PLD and St. Tammany Parish. LADPW provides financial assistance for the Pontchartrain Levee District's cost-share obligations above $100,000 for the portion of the Barrier Plan which is responsibility of the PLD, and agrees to fulfill all local cooperation agreements for that portion of the project in St. Tammany Parish. Assurances accepted by the U.S. on November 8, 1976.	Referenced in: 19800128
Budget justification, FY 1978	Jan 17, 1977		This budget justification reports that the New Orleans East Unit is 47% complete (expected completion in 1985), New Orleans West Unit is 5% complete (expected completion is documented as indefinite), and Chalmette Unit is 46% complete (expected completion in 1989).	19770117
State Rep. Edward Scogin opposes the Barrier Plan	Feb 27, 1977		Letter to District Engineer states, "Local funding for the project was defeated three times, two of the three times it was defeated by the residents of Orleans Parish, resoundingly! … Municipal Associations, as well as Parish Governments are opposed, and have or will, in fact, file suit." Scogin's opposition is to the barrier portion of the plan only and not the project in its entirety.	19770227

Event Name	Start Date	End Date	Notes	Source
Times Picayune editorial opposes barriers	Jul 14, 1977		This editorial argues that the barriers do not have the support of the public and never did, and claims that the OLD tricked the public, urging them to vote for a 3 mill tax while assuring them no portion of the tax would be used on the barrier structures. Shortly after the tax was approved, it was learned that OLD had found a way to use the money for the barriers. Notes that lawsuits against the project have been filed by St. Tammany Parish and Save Our Wetlands Inc.	19770714
District Engineer responds to the Times-Picayune editorial board	Jul 18, 1977		In a letter to The Times-Picayune editorial board, the District Engineer challenges the statement in the editorial that "There is no proof that the barriers will work to reduce hurricane damage…" Several sites are listed where barriers have been used successfully for surge protection.	19770718
Outfall canal alternatives identified	Aug 19, 1977		The District determines that alternatives analysis is needed prior to preparation of GDM No. 2 for the Orleans Parish outfall canals. This would consist of preliminary designs and costs for seven listed alternatives, including floodgates at the mouths of the canals, and the parallel protection plan with either levees and/or a combination of levees, I-walls and T-walls to eliminate the relocation of homes.	19770819
Analysis of soils along the outfall canals	Sep 16, 1977		An internal District memo notes that analysis of soil and geodetic data "indicate the presence of a buried beach sand deposit that underlies the outfall canals. This sand deposit approaches the bottom of each outfall canal, creating the potential for excessive and dangerous hydrostatic uplift pressures during high stages in the canals. Additionally, there are reaches in each of the outfall canals that presently do not meet minimum stability requirements even during normal stages. Therefore, no matter which alternative is selected for the GDM, if return levees are part of federal hurricane protection, we anticipate some modification of existing levees."	19770916

Event Name	Start Date	End Date	Notes	Source
OLD opposes 1-year moratorium on project work	Oct 19, 1977		The OLD states its opposition to proposed 1-year project construction moratorium. That opposition is seconded by the Lake Borgne Basin Levee District.	19771028
The Sewerage & Water Board (SWB) expresses support for the Barrier Plan	Nov 23, 1977		The Executive Director of SWB in a letter to Mr. August Perez, III, states, "I certainly cannot agree with your conclusion that we should abandon the barrier plan…[and]… high level levees around the entire Shoreline of Lake Pontchartrain, as well as in other contiguous waterway areas where this high level levee would be needed would be almost ludicrous."	19771123
Q&A meeting held at OLD	Nov 30, 1977		Technical questions concerning the barrier plan are asked and answered by the District and the OLD. At the meeting the OLD President states, "If this project is delayed then it is dead because we will not have the money to do it."	19771130
Federal court injunction against the Barrier Plan	Dec 30, 1977		Based on a lawsuit filed by Save Our Wetlands Inc. and others, the injunction stops project implementation based on an inadequate EIS, including analysis of the surge barriers effects on salinity regimes and habitat, and an inadequate alternatives analysis. The injunction also addresses questions about the project economic analysis and the ability of the OLD to meet its cost-sharing requirement for O&M of the barrier structures. While there are many sources of opposition to the barriers, non-compliance with NEPA analytical requirements is cited by the court as the basis for halting project construction.	19771230

Event Name	Start Date	End Date	Notes	Source
Implicit Flood Model used for surge modeling	1978	1980	The Waterways Experiment Station (WES) Implicit Flood Model (WIFM) computer model is developed by WES and applied to estimate SPH surges for the barrier complexes. An analytical byproduct of that effort indicates that the 1962-era surge estimates for the lakefront may have been too high, and original surge estimates may have been too low along the Chalmette Unit, the Citrus Back Levee, and the IHNC and GIWW.	19780000
OLD expresses concerns about project delays and costs	Jan 4, 1978		The OLD President writes to the LA Department of Transportation and Development to express concerns about local sponsors' ability to meet rising project costs. After listing the financing problems faced by other local sponsors, the OLD President notes, "The Orleans Levee Board's share of the project approximates 67% of local participation. As of this date, if there are no further delays in the project, we estimate that we will have just enough money to pay our share…Any delay which will inflate the cost of the project in excess of the $400 million now estimated will place the cost beyond our ability to pay."	19780104
Project hearing held by H.R. Subcommittee on Water Resources	Jan 5, 1978		Hearing is held in New Orleans.	19780315
Budget justification, FY 1979	Jan 23, 1978		This budget justification reports that total project cost has increased from $65M to $378M, with the non-federal share at $110M, of which $88M is cash. The New Orleans East Unit is reported to be 47% complete and the Chalmette Unit 46% complete. Project work has just started in the New Orleans West Unit. This justification sheet continues to argue that storms more severe than hurricanes of record are possible, and that the barrier plan will protect against such storms. Notes the need to move forward with the Seabrook lock for storm protection as well as navigation and environmental reasons.	19780123

Event Name	Start Date	End Date	Notes	Source
District Engineer responds to Rep. Livingston's questions	Jan 27, 1978		The District Engineer in a letter to Rep. Livingston answers questions raised by Livingston in the January 5, 1978 hearing on the project held by the House Subcommittee on Water Resources. One question posed by Rep. Livingston is whether the Corps favored project construction in uninhabited areas as opposed to more critical inhabited areas.	19780127
Congressman Livingston urges Corps response to court injunction against the project	Feb 15, 1978		In a letter to the Chief of Engineers, Rep. Livingston expresses concerns about project delays and encourages Corps to accelerate project study, design, and construction.	19780215
Times-Picayune article after hearing	Mar 3, 1978		Asserts that Congress authorized the project without knowing if it was viable, and that Rep. John Breaux says that if the barriers are dropped, then project will be "back to ground zero," requiring first a new feasibility study then new authorization.	19780303
Senator Johnston expresses opposition to Barrier Plan	Mar 9, 1978		In a letter to David Levy, a vocal opponent of the Barrier Plan, Senator Johnston states that he would not support a plan that degrades the environment.	19780309
Court injunction lifted on non-barrier project features	Mar 1978		On March 8, 10, and 29, Judge Schwartz lifts the injunction on all features of the project plan except the barrier structures at Chef Menteur and the Rigolets, and the Seabrook lock.	Referenced in: 19800128
DM#2, Supplement 5D Orleans Parish	Apr 1978			Document available at: https://ipet.wes.army.mil

Event Name	**Start Date**	**End Date**	**Notes**	**Source**
Lakefront Levees - Orleans Marina.				
District Chief of Engineering comments on the SPH	Apr 4, 1978		In a letter to David Pierce, the District Chief of Engineering provides an explanation of the SPH as the design hurricane, why it was chosen, and what it means. He states, "The use of this hurricane (SPH) for design purposes, when hazard to human life inheres in a failure of the protective system, is standard with the US Army Corps of Engineers."	19780404
District Engineer submits proposed schedule for project restudy to the Division	Apr 14, 1978		The District Engineer submits a schedule to address deficiencies cited by the court. Three items are a concern: (1) the EIS does not describe what the Corps proposed to build; (2) the alternatives to the barrier are not adequately described and evaluated; and, (3) the impactson the surrounding wetlands and on movement of aquatic organisms through the passes have not been adequately assessed. The memorandum notes that economic reanalysis is necessary for compliance with the court and engineering, model, and environmental studies must be conducted.	Bundled in: 19780424
Division Engineer approves the District restudy plan and schedule	Apr 24, 1978		The Division Engineer approves the District restudy plan and states that it is imperative to correct the legal inadequacies of the EIS in the shortest time possible. A 36 month timeline is mandated and a February 1980 deadline for alternatives analysis and economic documentation is established	19780424
District activities related to restudy	May 16, 1978		The District Economics and Social Branch provides an update on restudy activities and remarks about the urgency and special nature of the analytical work.	19780516

Event Name	**Start Date**	**End Date**	**Notes**	**Source**
Division Engineer communicates with LA Governor	Jun 1978	Jul 1978	Article in the Times Picayune reports that Governor Edwards has retracted his support for the Barrier Plan. This leads to a telephone conversation between the Governor and the Division Engineer. The Division Engineer reports to the Governor that it is important for the project to move forward and that any loss of local sponsor assurances would bring a halt to further work that could be advancing in spite of the court injunction. This leads to a Division briefing for the Governor on July 7, 1978	19780608 and 19780707
Headquarters issues engineer technical letter on NGVD	Oct 31, 1978		Engineer Technical Letter No. 1110-1-97 informs staff of the change in name of the Sea Level Datum of 1929 to the National Geodetic Vertical Datum (NGVD).	19781031
Preliminary alternatives analysis for the outfall canals	Nov 16, 1978		District internal memo reports on the incomplete status of preparation of survey scope designs and cost estimates for the seven outfall canal alternatives.	19781116
Budget justification, FY 1980	Jan 22, 1979		This budget justification reports that the New Orleans East Unit is 46% complete (expected completion in 1986), the New Orleans West Unit is 5% complete (expected completion is indefinite), and the Chalmette Unit is 47% complete (expected completion in 1990).	19790122
East Jefferson Levee District formed	Jan 1, 1979		The State of Louisiana forms the East Jefferson Parish Levee District and assigns it responsibility for levees on the east bank of the Mississippi River in Jefferson Parish, which were previously the responsibility of the Pontchartrain Levee District. Revised assurances are required for the St. Charles portion of the project from the Pontchartrain Levee District, and new assurances are required from the	Referenced in: 19840201

Event Name	Start Date	End Date	Notes	Source
			East Jefferson Levee District.	
Division forwards Corps engineering technical letter on NGVD to the District	Feb 9, 1979		The ETL on datum name change is forwarded by the Division to the four districts in its jurisdiction, including the New Orleans District.	19790209
National Weather Service Report 23 provides revised SPH and PMH parameters	Sep 1979		"Meteorological Criteria for SPH and PMH Windfields, Gulf and East Coasts of the United States." Major new analysis of storm events. Continues enveloping methodology and leaves out major storm events from SPH. Events such as Camille are not included within the SPH envelope. SPH cpi for New Orleans area are lowered to 27.35 from 27.6 as in 1962 document. No changes in wind speed estimates for SPH. However, the PMH calculations for wind speed and cpi were changed dramatically, since the PMH was affected by the inclusion of Camille data. There is an increased divergence between the SPH and PMH when the 1959 and 1979 results are compared.	19790900
District meeting on alternative plans analysis for the outfall canals	Nov 28, 1979		District memo from the Chief of Design Memo branch to Chiefs of Design and other branches requests them to bring this program into their overall work load and advise of any priority conflicts. Representatives from the various branch offices agree that "it would be more desirable to complete work on subject Alternative Plans Investigation in-house since so much of the work had already been accomplished."	19791128

Event Name	Start Date	End Date	Notes	Source
Budget justification, FY 1981	Jan 28, 1980		This budget justification reports that the New Orleans East Unit is 38% complete (expected completion in 1987), the New Orleans West Unit is 3% complete (expected completion is indefinite), and the Chalmette Unit is 37% complete (expected completion in 1991).	19800128
District draft “LP&VHPP Alternative Plans Study”	Feb 1980		The document describes a variety of engineering alternatives for the LP&VHPP. Numerous levee alignments and approaches are presented in order to calculate costs. The Barrier Plan providing SPH protection, a High Level Plan providing SPH protection, and a High Level Plan providing 100-year protection are given priority analysis; altogether, ten alternative plans are identified and analyzed. The identification of alternatives assumes that the existing condition represents all project components in place as of October 1979.	Bundled in 19800600
District draft "Preliminary Formulation of Alternative Plans for the LP&VHPP"	Jun 1980		This is the consolidated plan of alternatives for the LP&VHPP that establishes justification for the switch to the High Level Plan. It includes the engineering alternatives identified in the February 1980 plans study and subjects them to economic and environmental assessment. It states that for analysis, "[The] study used a "zero-based budgeting approach," that is, sunk costs or costs of common features were not of interest, nor were the impacts associated with these features; only differences between the plans were analyzed and displayed." The assessment concludes that the High Level Plan providing SPH protection is less costly, less damaging to the environment, and more acceptable than the Barrier Plan. Moreover, there are no operations costs with levees as there would be with barriers.	19800600
Briefing for local interests on alternative	Aug 22, 1980		The purpose of the meeting is to brief local interests on the District’s alternative plans study and to solicit their input and recommendations	19800825

Event Name	Start Date	End Date	Notes	Source
plans study			for a preferred alternative. District representatives state that the District planned to prepare a letter report to its higher authority which would present alternative plans and recommend a plan of action. Input from the local sponsor would be included in the report. At the meeting, a representative of the OLD states that a plan that would allow abandonment of existing lateral levees would, from OLD viewpoint, be highly desirable since the levees constituted a considerable maintenance problem.	
Budget justification, FY 1982	Jan 15, 1981		Despite the injunction, this justification still presumes that the barriers will be built, but as modified to accommodate the salinity constraint. To meet this constraint, and for other reasons, total project cost have increased from $65 M to $900M, with the non-federal share at $277M, of which $147M is cash. This budget justification reports that the New Orleans East Unit is 44% complete (expected completion in 1987), the New Orleans West Unit is 2% complete (expected completion is indefinite), and the Chalmette Unit is 33% complete (expected completion in 1991).	19810115
Internal Division note on subsidence	Nov 30, 1981		Identifies factors that influence subsidence in coastal LA and settlement of benchmarks. Suggests that these factors be included in any ongoing studies of coastal LA which address the present or projected future amount or condition of coastal resources affected by subsidence.	19811130
Government Accounting Office report	Aug 17, 1982		GAO reports sponsors concerns that Corps is moving too slowly to provide required protection, and project costs are escalating rapidly. As of March 1982, $171M had been made available ($131M federal and $40M local). Expected completion date is 2008 and expected total cost is $924M. States that the OLD considers Corps standards "too high for what is really needed for adequate protection and for what is affordable by local sponsors." OLD "recommended that the Corps lower its design standards (to) … more realistic … 100 years rather than … 200 to 300-	19820817

Event Name	Start Date	End Date	Notes	Source
			year." Includes additional information about relationship between the Corps and the OLD Board with regard to the outfall canals. States that the Corps was uncertain about authority to do "this work as part of the project."	
District response to GAO report submitted to the Division	Sep 10, 1982		Regarding the GAO suggestion that the Corps has not prosecuted the project with the vigor and effectiveness that it deserves, the District writes, "While we regret that progress has not been faster, and view with deep concern the residual threat to the area after 17 years of work on the project, we don't believe the report—or more importantly the record, supports such findings. The project was authorized and funded for design in the same fiscal year (1966), a rarity among civil works projects. Designs were pressed with vigor and expedition, and the system was exploited, bent, twisted, and innovatively interpreted to permit the earliest practicable completion of design and start of construction."	19820908 and 19820910
ASA(CW) requests briefing on the LP&VHPP	Oct 8, 1982		In order to respond to the 1982 GAO report, the ASA(CW) requests a briefing from the Chief on the project. In a letter to the GAO, the ASA(CW) states that he will respond to report recommendations after he learns about the status of the project.	19821008
ASA(CW) receives briefing on the LP&VHPP	Nov 4, 1982		District and Division leaders brief the ASA(CW) on the project and its status. They report that the High level Plan is less costly and less damaging to the environment than the Barrier Plan.	19821022 and 19830819
ASA(CW) expresses reservations about the Chief's discretionary authority to adopt the High Level Plan	Nov 17, 1982		In a memorandum to the Chief of Engineers, the ASA(CW) expresses concerns about use of the Chief's discretionary authority to switch to the High Level Plan, requests a copy of the draft EIS, and directs that documents pertaining to the proposal to abandon the Barrier Plan be retained in the District office pending the ASA(CW) review of the	19821117

Event Name	Start Date	End Date	Notes	Source
			project and issuance of further guidance.	
Chief sends draft project restudy and EIS to ASA(CW)	Nov 24, 1982		The Chief also promises the ASA(CW) a position paper on the Chief's discretionary authority to switch to the High Level Plan, which will be forthcoming from the Division.	19821123 and 19821124
SWB informs District of planned pumping capability for the outfall canals	Dec 7, 1982		In a letter to the District, the SWB indicates its planned pumping capability at pumping station No. 6 and its position that the choice of protection alternatives for the outfall canals must preserve the capability to pump interior drainage into the canals under all conditions.	19821207
Division position paper on discretionary authority forwarded to the Chief	Dec 16, 1982		The Division position paper argues that the switch to the High Level Plan falls under the discretionary authority of the Chief because the associated work would not change the scope and function of the project or legal relationships with local sponsors.	Bundled in: 19830106
Adjusted benchmark elevations in Gulf Coast area	1983		National Geodetic Survey publishes adjustments to vertical datum benchmark elevations in Gulf Coast area.	19830000
Budget justification, FY 1984	Jan 31, 1983		This budget justification reports that the New Orleans East Unit is 70% complete (expected completion in 1988), the New Orleans West Unit is 0% complete (expected completion is indefinite), and the Chalmette Unit is 63% complete (expected completion in 1991).	19830131
Corps Chief Counsel provides opinion that switch to High Level Plan can be made under the Chief's discretionary authority	Mar 2, 1983		The Chief Counsel presents a legal opinion that a change from the Barrier Plan to the High Level Plan falls under the discretionary authority of the Chief of Engineers. The issue had been raised by the ASA(CW). The memorandum provides background information and rationale. The Counsel finds that the change would not involve: "a). a material alteration of the function of the project; b). a material change	19830302

Event Name	Start Date	End Date	Notes	Source
			in the scope of the authorized plan of improvement; and c). a change in legal relationships." Counsel states that this is a departure from earlier views on the need for reauthorization and that the rationale should be communicated to Congress.	
Chief furnishes ASA(CW) position paper on Chief's discretionary authority to switch to the High Level Plan	Mar 31, 1983		Drawing heavily on the Division position paper and the opinion of the Corps Chief Counsel, the Chief recommends that the High Level Plan be undertaken under his discretionary authority. He states there is no change in project purposes, scope, or legal relationships.	19830331
Cost estimates requested for outfall canal alternatives	Jun 6, 1983		District internal memo requests cost estimates for outfall canal alternatives for GDM. Plans to be considered include: 1) parallel protection, 2) gravity drainage structure with auxiliary pumping at lakefront, 3) gravity drainage structure as fronting protection--vertical lift gates, and 4) gravity drainage structure as fronting protection--vertically pinned gate. Notes that alternative 4 is considerably cheaper that alternatives 1 and 2, and has certain advantages over alternative 3 that may make it more acceptable to SWB. Accordingly, in assessing E&D requirements, alternative 4 should be viewed as the "tentatively" recommended plan, and assume that detailed design effort will be focused on that plan.	19830606
District meets with Waterways Experiment Station (WES) on proposed model study of butterfly gates	Jun 24, 1983		WES concurs that a model study would be beneficial in providing design and operating guidance for the proposed butterfly valve gated structures.	19830624

Event Name	Start Date	End Date	Notes	Source
Division Engineer urges Chief to get the project "off of dead center" and talk to the ASA(CW)	Aug 4, 1983		The Division Engineer expresses his concern for further delays in project construction. The document includes a project timeline with key decisions to that point.	19830804
District request for authorization of model study of butterfly gates	Oct 1, 1983		Letter to the Division requests authority and funding to conduct model study of butterfly gates plan for the outfall canals. Says that existing lateral levees do not meet design height or design sectional stability required for either the Barrier Plan or the High Level Plan. The District writes, "Finding a solution has been made difficult because, on the one hand, raising and strengthening the levees would be extremely expensive and disruptive of existing developments along the canals, while on the other hand, solutions which would eliminate the need to raise the levees are acceptable to SWB only if they preserve the ability of the Board to pump into the canals under all conditions. With the exception of the vertically pinned butterfly control valves, all plans proved either excessive in cost, unacceptable to the Board, and/or presented intractable operational problems."	19831001
ASA(CW) responds to the 1982 GAO report	Nov 9, 1983		The ASA(CW) provides the official DOD response to the GAO Report. Although it concurs with most GAO findings, it explains that delays have come about due to serious engineering issues, such as soft foundation soils requiring multiple levee lifts, and recalculation of the SPH storm surges based on new hurricane parameters from the NWS. It does not concur with the GAO finding regarding the local sponsors' potential inability to pay for the project.	19831109
Division replies to the District on the request for model study of	Nov 28, 1983		Division letter to the District notes, "impossible situation in that a scheme must be developed for keeping hurricane surges out of the drainage canal while preserving for SWB the option to pump at all	19831128

Event Name	Start Date	End Date	Notes	Source
butterfly gates			times...The argument NOD presented has not been convincing from the standpoint that a significant increase in pumping time will result if the butterfly gate is selected over a vertical lift, or other standard gate...It appears that there is no compelling reason to invest from $340K to $547K and 1.5 years in model studies in butterfly control...NOD should furnish additional supporting documentation to include an economic analysis reasonably demonstrating that the butterfly valve solution would provide greater net benefits than the roller gate solution."	
District replies to Division comments on proposed model study of butterfly gates	Dec 12, 1983		District letter to the Division Engineer reiterates that any plan that uses fronting protection must also satisfy to the fullest extent possible operational drainage requirements of SWB. It states, "The District would not recommend an expensive model test of a plan that it did not believe enjoyed a high probability of satisfying design objectives for the Lake Pontchartrain project and operational constraints of the SWB...We do not agree that the situation presented is impossible...Also, the SWB is of the opinion that regardless of whether or not gated structures are placed at the Lake end of the outfall canals, that they must provide sufficient freeboard to allow them to pump throughout the design storm...local interests are for the 17th St. Canal currently attempting, through the permit process to meet our hurricane protection design criteria for their proposed upgrade of the canal and levees. This office has been working closely with SWB in an effort to insure that their designs are compatible with the Lake Pontchartrain project...We remain cautiously optimistic that these designs may be incorporated into the project. However, independent study conducted by the District leave us with sufficient doubt about the economic feasibility of the SWB plan when compared to fronting protection...It is important to understand that if the project ultimately adopts a fronting protection plan, the responsibility of the lateral parallel levees along the outfall canals is solely the responsibility of the SWB."	19831212

Event Name	Start Date	End Date	Notes	Source
Budget justification, FY 1985	Feb 1, 1984		This budget justification reports that the New Orleans East Unit is 72% complete (expected completion in 1988), the New Orleans West Unit is 0% complete (expected completion is indefinite), and the Chalmette Unit is 73% complete (expected completion in 1991).	19840201
LA legislature orders OLD to return Bohemia Spillway property to original owners	1984		The state legislature orders the OLD to return property rights in the Bohemia Spillway area to the original owners. This has a major impact on the financial status of the OLD. Ensuing distribution of royalties from mineral rights (oil company leases) to former owners, and legal costs (over 45,000 claims were filed with the Department of Natural Resources), place an administrative and financial burden on OLD. The story of the Bohemia Spillway began in 1923. It is located in Plaquemines Parish. The state saw the area as favorable to use as a spillway to protect against flooding upstream in New Orleans. Landowners in the rural town of Ostrica, 60% of whom were black, were bought out cheaply or forced out. In 1924, drilling rights were given to Shell, Gulf, Chevron, and Bass Oil. In 1929, large amounts of Oil were discovered. Legal battles began in 1948 to return land rights to original owners.	Referenced in: 19901121 and 20010521
District request to OLD for right of entry	Mar 13, 1984		District letter to the President of the OLD Board proposes to perform surveys and soil borings for design studies for the High Level Plan at various locations along the Orleans Parish outfall canals. The District requests right of entry to conduct surveys and soil borings for a period of one year. The OLD grants right of entry on March 15, 1984.	19840313a
Division and District staff meet with National Geodetic Survey staff on 1983 benchmark adjustments	Apr 10, 1984		Agenda includes a briefing for Division and District staff by a representative of the National Geodetic Survey on 1983 leveling and datum adjustment work in the Gulf Coast area. Agenda also includes a presentation by a District representative on specific problems in the District relating to datum benchmark adjustments.	19840410

Event Name	Start Date	End Date	Notes	Source
District grants permit for dredging of the 17th Street Outfall Canal	Jun 13, 1984		In 1983, the SWB applied to the District regulatory branch for a permit to dredge and enlarge the 17th St. Canal and install sheet pile walls along its existing levees to improve drainage capacity of the canal. The dredging project is a joint venture of the SWB, the OLD, and the East Jefferson Levee District. The District engineering branch evaluates the proposed work for its possible effects on the existing federal levee on the west bank of the canal, and provides numerous technical comments to the applicant on required additional data needs and studies. District engineers work with SWB consulting engineers to resolve their concerns, and the permit is granted after those concerns had been resolved.	19840613
LP&VHPP Reevaluation Report recommends switch to the High Level Plan	Jul 1984		The report recommends abandonment of the Barrier Plan in favor of the High-Level Plan providing SPH protection. The 1984 reevaluation determines that the High Level Plan is more cost effective than the Barrier Plan based on a remaining cost - remaining benefit calculation. The recommended plan would involve higher levees along all areas exposed to tidal action along the shores of Lake Pontchartrain as they would no longer be protected by the barrier structures that were to have been built as part of the Barrier Plan. Internal levee heights along the lakeshore alignment are adjusted upward to take into account higher lakefront surges without the barriers, but designs are not adjusted for new SPH calculations provided by the NWS in 1979. The new SPH parameters are reported in the document but not used for redesign of project structures. No changes in stillwater surge estimates or wave runup calculations when compared to 1962 planning report. The report states that the outfall canals are an "unresolved issue" and describes five alternatives developed by the District and their estimated costs: 1) raise and strengthen the existing canal levees without concern for the number of house relocations necessary ($200 million); 2) same as alternative one except house relocations would be avoided ($250 million); 3)	19840700

Event Name	Start Date	End Date	Notes	Source
			floodgates at the mouths of the canals ($20 million); 4) same as alternative three but with added auxiliary pumping stations at the lakefront to allow pumping to continue when the gates were closed ($124 million), and; 5) relocate existing pumping stations to the canal mouths at the lakefront (presumed to be prohibitively expensive).	
Post Authorization Change Report - High Level Plan	Aug 8, 1984		The District forwards the Final Reevaluation Report and Final Supplement to the Environmental Impact Statement to the Division. The High Level Plan is recommended. The report provides information on changes in local cooperation requirements, project location, design changes, project costs, benefits, environmental considerations, cost apportionment, and methodological revisions.	Bundled in: 19840808
Division provides Corps Headquarters with post authorization change report	Aug 15, 1984		Provides copies of report materials and informs of Division review.	Bundled in: 19840808
Chief informs ASA (CW) of switch to the High Level Plan.	Aug 29, 1984		The Chief informs the ASA(CW) that it is his opinion that the change to the High Level Plan is within the discretionary authority of the Chief of Engineers and urges the ASA(CW) to provide further guidance as to be able to process the necessary decision documents for the project.	19840829
First meeting on E-99 sheet pile wall field load test	Sep 18, 1984		Meeting includes Division and District staff. Minutes or notes are not available from this meeting, but reference to the meeting is provided in an October 10, 1984 letter from the Division to the District.	19841029
E-99 sheet pile wall field load test initiated by Division	Oct 29, 1984		Letter from the Division to the District Engineer states that the proposed sheet pile test is justified and suggests contract alternatives. The letter states that the current method of designing and determining optimum depth for sheet pile has been the subject of discussion among design engineers for many years. Over the next few years I-wall projects with an estimated cost of over $100M will be constructed in	19841029

Event Name	Start Date	End Date	Notes	Source
			the District for the Mississippi and Atchafalaya Rivers and for hurricane protection. Considering the high cost of sheet pile I-walls, it is felt appropriate and advisable to reevaluate procedures for determining depth of penetration for stability with consideration for duration of loading on those walls.	
Briefing on subsidence plan for LA Gulf Coast	Nov 1984		National Geodetic Survey staff briefs District staff and the Greater New Orleans Planning Council on “Geodastre,” a subsidence monitoring plan for the Gulf Coast similar to the one developed for Houston, TX.	19841100
District requests meeting with NGS on use of 1983 benchmark adjustments.	Nov 2, 1984		District letter to the Division Commander notes "Before we begin to use the 1983 adjustments, we believe a discussion with NGS...would be useful. In particular, we would like to better understand the NGS methodology and its implications.”	19841102
District concurs with Division plan for E-99 sheet pile wall field test	Nov 13, 1984		Letter from the District to the Division notes the plan to design the test wall penetration for a 1.3 safety factor in the Q-case based upon current information available.	19841113
OLD bond sale	Nov 27, 1984	1985	In November 1984, a $50 Million bond sale is approved for project levees as part of the OLD “Interim Hurricane and Flood Protection and Capital Improvement Project.” The bond sale proceeds in 1985.	19841127
Budget justification, FY 1986	Feb 4, 1985		This budget justification reports that the New Orleans East Unit is 72% complete (expected completion in 1988), the New Orleans West Unit is 0% complete (expected completion is indefinite), and the Chalmette Unit is 89% complete (expected completion in 1991).	19850204
Record of Decision for post authorization change to the High Level Plan	Feb 7, 1985		Memorandum from the Director of Civil Works to the Division affirms that the High Level Plan is less costly to complete and environmentally superior to the Barrier Plan, and involves no basic differences in local cooperation agreements. Record of decision concurs with District recommendation to switch to the High Level Plan.	19850207

Event Name	Start Date	End Date	Notes	Source
Division inquires about 1983 benchmark adjustments	Mar 5, 1985		Division letter to the National Geodetic Survey notes, "In view of the implications [of the 1983 adjustments] to existing facilities and possible changes to projects in the planning and design stage, we would appreciate...any information you could give us concerning the level of confidence that can be expected from the 1983 adjustments before we begin using this new elevation data in current projects and before initiating any modifications to existing projects.”	19850305
National Geodetic Survey (NGS) expresses confidence in 1983 benchmark adjustments	Mar 29, 1985		NGS letter to the Division Chief of Engineering expresses "very high level of confidence in the 1983 Gulf Coast area adjustment results" even though it relied on leveling data observed from 1968 to 1982 which necessitated the assumption that no significant movement occurred between surveys. "In conclusion, the major problem in the area is that the Gulf Coast vertical network is not intended to provide detailed crustal motion information. However, we still believe the heights from the 1983 Gulf Coast area adjustment are the best obtainable at this time.” The Division forwards the NGS letter to the District on April 12, 1985.	19850329 and 19850412
E-99 sheet pile wall field load test	May 1985	Sep 1985	Performed between May and September in Atchafalaya basin south of Morgan city using PZ-27 sheet pile. The test was initiated by the Division after consultation with the District out of a general sense that existing sheet pile penetration criteria for I-type floodwalls (I-walls) was too conservative for hurricane protection applications, and interest in determining whether cost savings might be realized without compromising stability by modifying the sheet pile penetration requirements for I-wall structures where loading is short term as would be the case during a hurricane. This test ultimately leads to new guidance on sheet pile penetration requirements for non-sustained loading scenarios when soil conditions are poor or uncertain.	Referenced in: 19880600
Division requests	May 1,		Division letter to the District Engineer states, “In view of the potential	19850501

Event Name	**Start Date**	**End Date**	**Notes**	**Source**
District plan for use of updated benchmark elevations	1985		significant consequences of elevation changes on project in your District, we request that you reexamine the information in Rear Admiral Bossler's [NGS] letter and then after any consultation with the NOAA staff which you consider necessary, propose a course of action for incorporating the changes in elevation into your projects and studies and for defining in a more reliable manner the subsidence in your area. Your action plan should include a schedule and cost estimate and is requested by May 31, 1985.”	
District response to Division request for plan for use of updated benchmark elevations	May 24, 1985		District letter informs the Division that the Regional Planning Commission representing Jefferson, Orleans, St. Bernard and St. Tammany parishes met with NOAA/NGS and are contributing funds to rerun portions of the control net in their jurisdictions. Notes that the District will meet with NGS on June 12, 1985 to present their estimate of overall needs to predict subsidence and to obtain a more reliable network for the District. "After the meeting with NOAA, we will develop a recommended plan of action with a schedule and cost estimate."	19850524
OLD amended assurances	May 29, 1985		Provides assurance that the OLD has authority and capability to furnish the non-federal cooperation required by the Corps for the High Level Plan. OLD agrees to comply with all the required conditions and provisions of local cooperation listed in Assurances dated 9/30/66, 3/29/74, 4/2/74, 7/8/75, and 12/7/77. The local share of the cost to complete the High Level Plan is estimated to be $108M. Requirement to pay for capitalized cost of Rigolets Navigation Lock and Channel is deleted. Assurances accepted by the U.S. on June 21, 1985.	Referenced in: 19900129
District proposes policy on use of updated benchmark elevations	Aug 7, 1985		Letter from the District Chief of Eng. to the Division Engineer proposes a policy that says, “1) Modification of projects which have already been completed will not be considered. The level of precision in the current data, and the practical difficulty and cost of changing such projects	19850807

Event Name	Start Date	End Date	Notes	Source
			combine to mandate this course of action at least for the foreseeable future, 2) Hurricane protection projects which are partially complete will use the NGS benchmarks current at the time of construction of the first increment of the project. To shift to the later NGS data without altering the heights of previously constructed portions would make fuseplugs of those portions and thus impose a gratuitous servitude on the lands and facilities they protect. And altering previously constructed works would not be practicable, 3) New hurricane protection projects will be constructed using the latest available NGS benchmark data, and 4) We plan to respond affirmatively to NOAA's invitation to participate in the 'cadastre' program to better evaluate subsidence...We do not, at this time, anticipate providing any direct funding."	
Division approves District policy on use of updated benchmark elevations	Sep 16, 1985		Division letter to the District Engineer approves the District's proposed policy plan for dealing with subsidence. It notes, "We concur in general with this position; however, you should conscientiously review your flood control works and structures to ensure there are no exceptions that should be individually analyzed with an independent decision made on the specifics of that case...Consideration should be given to reanalyzing and modifying (if needed) hurricane protection work in high density urban areas where the datum changes will drastically reduce the level of protection."	19850916
Budget justification, FY 1987	Feb 4, 1986		This budget justification reports that the New Orleans East Unit is 81% complete (expected completion in 1993), the New Orleans West Unit is 0% complete (expected completion in 2006), and the Chalmette Unit is 89% complete (expected completion in 1991).	19860204
Corps initiates risk & uncertainty research program	1986		At request of the ASA(CW), a new Corps research program on risk and uncertainty (R&U) analysis is begun. A series of letters document early progress to include research, workshops and planning guidance. R&U analysis will not become required practice in the Corps until the 1990s,	19860416, 19861104, and 19861208

Event Name	Start Date	End Date	Notes	Source
			however.	
Headquarters memo on relative sea level change	Mar 21, 1986		Transmitted to District by Division. It states, "Prudence may require an allowance in a project design for the continuation over the project design life of an established significant long-term trend in relative sea level rise. Consideration must be given to the relative magnitude of the suggested allowance and the confidence band of the data the designer is using and the tolerance allowed in constructing the project."	19860321
OLD sponsored design memorandum for the London Avenue Canal	Apr 1986		I-walls for parallel protection are designed by Burk and Associates, Inc. under contract issued by the OLD. The designs conform to existing Division design criteria for I-walls, and are estimated to cost $38-44 million. The OLD deems this cost to be too high and cancels further work on the design.	19860400
Revised Corps engineering manual provides updated criteria for calculating SPH parameters	Apr 15, 1986		The revised EM 1110-2-1412 presents new criteria for determining SPH central pressure based on an improved database. The EM also gives guidelines for using statistical procedures which make use of a longer storm history. (A 1993 report by the Corps Coastal Engineering Research Center uses the new EM approach to conclude that an updated understanding of SPH central pressure would be 27.3 as opposed to 27.35 as reported by the NWS in 1979.)	19860415
Water Resource Development Act of 1986	Nov 17, 1986		This is the first WRDA passed since 1976 and includes major reform of national cost-sharing requirements. For the LP&VHPP, the Act authorizes modification in Jefferson Parish for floodwall and sluice gates to accommodate pumping station constructed by local interests.	19861117
Budget justification, FY 1988	Jan 5, 1987		Reports that total project cost have decreased from the last year of the Barrier Plan to $900M, with the non-federal share at $207M, of which $115 is cash. The New Orleans East Unit is reported to be 83% complete (big change from 4 years earlier) and Chalmette is 89% complete (big change from 4 years earlier). The New Orleans West	19870105

Event Name	Start Date	End Date	Notes	Source
			Unit is reported to be 0% complete.	
East Jefferson Levee District supplemental assurances	Jan 16, 1987		Supplemental assurances for High Level Plan pertaining to the Jefferson Parish portion of the plan. A financial plan was received on November 25, 1987. Accepted by the U.S. on December 21, 1987.	Referenced in: 19900129
Pontchartrain Levee District supplemental assurances	Apr 20, 1987		Supplemental assurances for the High level Plan pertaining to the St. Charles portion of the plan. This supplements the agreement between Corps and PLD entered into on February 15, 1977. Accepted by the U.S. on August 7, 1987.	Referenced in: 19900129
GDM#17, Jefferson Parish Lakefront Levee	Aug 1987		This part of the project is to increase the height of federal levees previously authorized (in 1946) and built as part of MR&T. Under that previous project, the levees were built to 10 feet in 1965, and later increased to 13-14 feet by locals in the late 1960s.	Document available at: https://ipet.wes.army.mil
Division issues draft revised sheet pile wall design criteria	Dec 23, 1987		Division letter to the District provides draft revised sheet pile wall design criteria. The guidance states that based on the E-99 test and the related finite element study, the attached revised criteria should be followed to determine the required penetration for sheet pile floodwalls founded in soft clays. The draft guidance states, "for sheet pile wall driven into a levee founded on very soft to soft clays, the majority of lateral sheet pile movement during flood loading will likely be due to deep seated foundation movement and not due to sheet pile flexoral deflection. Driving the sheet pile deeper has little effect on overall levee stability, or after some limiting depth, on flexoral deflection at the top of the wall. ... The primary intent of the revised criteria is to prevent excessive sheet pile penetrations which do not improve either sheet pile or overall levee stability.” This draft sheet pile wall design criteria mirrors the final guidance criteria issued by the Division on July 24, 1989 and that is used by the District for project design purposes.	19871223
District and Division	Jan 6,		Representatives from the District and Division meet and approve the	19880126

Event Name	Start Date	End Date	Notes	Source
staff meet to plan phase-in of new design criteria for I-walls	1988		use of the new December 23, 1987 draft design criteria for floodwalls along the 17th Street, Orleans Avenue, and London Avenue outfall canals because of the "high potential for savings." Minutes of the meeting are approved by the Division on February 22, 1988.	
Budget justification, FY 1989	Feb 18, 1988		This budget justification reports that the New Orleans East Unit is 86% complete (expected completion in 1993), the New Orleans West Unit is 0% complete (expected completion in 2006), and the Chalmette Unit is 95% complete (expected completion in 1991).	19880218
E-99 sheet pile wall field load test report	Jun 1988		Background section of the report states that many miles of I-type walls are to be constructed over the next few years for hurricane protection and flood protection at an estimated cost of over $100M, and "the cost of these walls is obviously highly dependent on the sheet pile penetration required for stability." States that the method of analysis currently used in the Division to determine sheet pile penetration has minimum factor of safety of 1.5 and is "somewhat conservative in order to account for uncertainties in sheet pile and soil behavior." The test found that S-case analysis for long term loading (FS = 1.5 @ 44 foot penetration) was too conservative for design with short loading periods. Found no significant decrease in deflection from penetration beyond 28 feet (FS = 1.2 @ 28 feet penetration).	19880600

Event Name	**Start Date**	**End Date**	**Notes**	**Source**
GDM#19 - Orleans Avenue Outfall Canal	Aug 1988		Includes a detailed description of alternative plans and recommends fronting protection with butterfly gates based on cost-effectiveness/least cost analysis (at a cost of $15.1M). It describes the alternative locally-preferred parallel protection plan, with a cost of $43.8M. The document states the facts of the disagreement between the District and OLD (August 11, 1988 letter from District Chief of Engineering to OLD indicated that the parallel protection plan is a "betterment.") and asserts that design work done under contract for the locals on the parallel protection plan had been coordinated with the District and met Corps standards. Moreover, it states that the federal contribution to the parallel protection plan, if implemented, would be limited to 70% of the cost of the recommended fronting protection plan.	19880800, 19880800a, and 19880800b
District and Division staff meet to discuss I-wall deflection	Oct 28, 1988		Representatives from the District and Division meet to discuss a variety of issues related to the new 1987 draft I-wall design criteria and their application to floodwalls in New Orleans. It is reported that the new criteria result in a substantial reduction of sheet pile penetration, and that sheet pile thickness does not affect deflection in soft clay soils.	19881118
General Design Memorandum #19A - London Avenue Outfall Canal	Jan 1989		This DM is prepared by the District and reviewed by the Division. It recommends the frontage protection (butterfly gates) plan as the least cost alternative. However, Volume 2 describes an alternative parallel protection plan with I-wall designs based on draft revisions to Division guidance criteria for I-wall design.	19890100 and 19890100a
Budget justification, FY 1990	Jan 9, 1989		This budget justification reports that the New Orleans East Unit is 86% complete (expected completion in 1993), the New Orleans West Unit is 0% complete (expected completion in 2006), and the Chalmette Unit is 95% complete (expected completion in 1997).	19890109

Event Name	Start Date	End Date	Notes	Source
Design Memorandum #18, St. Charles – High Level Plan, North of Airline Highway describes logic for maintaining original SPH parameters	Feb 1989		The hydrology section (Appendix A) of Volume I provides an explanation for the use of pre-Hurricane Camille SPH parameters for design purposes. The document states, “For design of the LP&VHPP High Level Plan, the SPH, as defined after Hurricane Betsy, was used. To assure that all the segments of the project would be compatible, SPH parameters have not been changed since construction began. Modifications and adjustments of these parameters, subsequent to Hurricane Betsy, have not significantly changed the characteristics of the SPH.”	19890200
Final revised sheet pile wall design criteria	Jul 24, 1989		Letter from the Division to the District presents the final guidance on revised sheet pile wall design criteria. It references the December 1987 draft guidance, associated follow-up guidance, and the WES final report entitled, "Development of Finite Element-Based Design Procedures for Sheet Pile Walls" It provides background information on the E-99 test and WES model application to the data derived from the test. It states, "Due to sensitivity of the computed and actual deflections of soil stiffness, the actual deflections experienced in the field can only be estimated with limited accuracy…[and]…Engineering judgment should be exercised in selecting appropriate loading cases and penetration to head ratios." These criteria are applied to outfall canal design memoranda for project floodwalls after 1987.	19890724
Technical Report GL-894	Sep 1989		WES report, "Development of Finite-Element-Based Design Procedure for Sheet-pile Walls" developed as part of the E-99 sheet pile wall field load test.	19890900

Event Name	Start Date	End Date	Notes	Source
St. Charles Parish Council adopts resolution for project protection	Dec 4, 1989		The resolution states that the Parish Council “do hereby demand that the US Army Corps of Engineers and other respective parties take emergency action to initiate immediate construction of the Lake Pontchartrain Hurricane Protection Levee in St. Charles Parish to prevent flooding from hurricane surges as well as flooding from periodic rainfall…”	19891204
Budget justification, FY 1991	Jan 29, 1990		This budget justification reports that the New Orleans East Unit is 89% complete (expected completion in 1995), the New Orleans West Unit is 5% complete (expected completion in 2006), and the Chalmette Unit was 95% complete (expected completion in 1997).	19900129
Parcels comprising Bohemia Spillway relinquished by OLD	1990	1995	The return of these parcels pursuant to state law results in OLD losing annual royalty income plus retroactive payments of prior years royalties amounting to $26M.	19901121
General Design Memorandum #20 - 17th St. Outfall Canal	Mar 1990		This design memoranda prepared by the District recommends a parallel protection plan for the 17th St. Canal since the cost difference between this alternative and the frontage protection (butterfly gates) alternative for this canal is minimal, and the local sponsor (OLD) prefers the parallel protection plan. Parallel protection designs for the west side of the 17th St Canal include I-wall specifications similar those included in DM#19A for the London Avenue Canal.	19900300 and 19900300a
OLD sponsored London Avenue Canal Interim Plan	May 1990		This design memorandum prepared by Burk and Associates for OLD is for 100-year ("interim") protection along the canal. The document references that the previous plan developed for OLD to provide SPH (300-year) protection was deemed too expensive by OLD	19900500
OLD engineering committee meeting	Jul 31, 1990		Detailed discussion between OLD, the District, and OLD’s contractor on the design and funding of protection works for three outfall canals.	19900731

Event Name	Start Date	End Date	Notes	Source
First Endorsement of DM#20 - 17th St. Outfall Canal	Aug 8, 1990		The Division Chief of the Engineering Division states due to the close proximity of the adjacent canal, a minimum penetration to head ratio of 3 to 1 be used. It is noted that the 3 to 1 minimum ratio has been used in less critical projects in the New Orleans area. Also, the letter states that to ensure adequate bulkhead stability toward the flood side, the sheet pile bulkheads should be analyzed using the "S" case soil strengths and a factor of safety of 1.5. The sheet pile penetration in the DM should be increased as necessary and that if there is a potential for erosion at the flood side toe of the bulkheads, stone protection should be considered. The Division Engineer also states that the construction contract that had already been awarded for sheet pile work on the east side, "results in an undesirable situation for the office and the Corps."	Bundled in: 19900300
Joint meeting of OLD, SWB, District and others on the District's proposed butterfly valve alternative for the outfall canals	Aug 15, 1990		Meeting documented in the minutes of a September 1990 Committee meeting of the Orleans Levee District.	19900919
OLD resolution in favor of parallel protection for the outfall canals	Oct 17, 1990		At an OLD Committee meeting, the OLD Board expresses its commitment to parallel protection, encourages the Corps to support parallel protection, and empowers the President of the Board to take necessary steps to bring this to the attention of government officials at all levels. The meeting minutes explain the financial stakes involved for OLD of the choice of protection alternative for the outfall canals. Potential net additional cost to the OLD from raising the internal levees on their own and cost-sharing the frontage protection plan may reach $45M. A District representative is present at the meeting	19901017
District Response to First Endorsement of	Oct 22, 1990		The District Chief of the Engineering does not concur with the First Endorsement prepared by the Division. He states that new guidance	Bundled in: 19900300.pdf

Event Name	Start Date	End Date	Notes	Source
DM #20 – 17th St. Outfall Canal			criteria for sheet pile penetration (July 24, 1989 Division guidance) allows for a 2.5 to 1 penetration ratio. The factors that would "cause the tip elevation to be arbitrarily increased by a penetration to head ratio are unknown variations in surface elevations and soil conditions." The District used the 2.5 ratio because (1) ground surface elevations are based on surveys at 100 foot intervals, (2) two surveys were done in the last ten years, (3) the velocities of the canal are too low to cause scour, (4) borings were taken at 350 ft. intervals by contractors on both sides of the canal and were supplemented by USACE check borings, the point being that "no other project has had the level of borings or surveys."	
Division reply to District response comments to First Endorsement, DM #20	Nov 26, 1990		The Division concurs with District non-concurrence regarding application of Q-case for sheet pile penetration.	Bundled in: 19900300
Water Resource Development Act of 1990	Nov 28, 1990		PL 101-640 requires a restudy of and report on project benefits to determine whether or not local sponsors have received expected benefits and whether or not there should be a reallocation of costs as a result of any unrealized expected benefits. No non-federal payment for St. Bernard Parish portion of the project is required during the study period (November 1990 to November 1991). Conference report language accompanying the Act seeks to resolve the choice of protection alternative for the outfall canals. It states, “"The conferees do not believe it was the intent of Congress in authorizing this project to compound flooding or drainage problems in the City of New Orleans. Therefore, the conferees direct 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	19901027 and 19901221

Event Name	Start Date	End Date	Notes	Source
			confine the standard project hurricane with costs to be borne by both Federal and local assuring authorities.”	
Budget justification, FY 1992	Feb 5, 1991		This budget justification reports that the New Orleans East Unit is 90% complete (expected completion in 2000), the New Orleans West Unit is 10% complete (expected completion in 2013), and the Chalmette Unit is 97% complete (expected completion in 1997).	19910205
1992 Energy and Water Development Appropriations Act	Aug 17, 1991		PL 102-104. Congress finally resolves issue regarding the choice between parallel protection and frontage protection for the outfall canals by mandating construction of parallel protection. The legislation states, "…the Secretary of the Army is authorized and directed to provide parallel hurricane protection along the entire lengths of the Orleans Avenue and London Avenue Outfall Canals by raising levees and improving flood protection works along and parallel to 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.” Committee report language addresses local repayment and extends the reimbursement date for the Lake Borgne Basin Levee District.	19910612 and 19910817
District informs OLD that the District is taking over design work for the outfall canals	Nov 8, 1991		The District Engineer in a letter to the OLD declares that since parallel protection at the outfall canals is now a federally funded project feature, the District will take over design work with in-house personnel or District-selected design contractors.	Referenced in: 19930319
District memorandum to	Dec 10,		In 1991, the following ratings for required maintenance of completed	19911210

Event Name	Start Date	End Date	Notes	Source
Division on annual inspection of completed works	1991		project features are given to local levee districts: Orleans - OUTSTANDING; Lake Borgne Basin - OUTSTANDING ; East Jefferson - OUTSTANDING; Pontchartrain - OUTSTANDING .	
Financial role reversal for federal and local sponsors regarding funding of project work at the outfall canals	1992		Prior to the congressional directive to the Corps to implement and pay 70% of parallel protection at the London Avenue and Orleans Avenue Canals, the District estimated that it would budget about $14M for frontage protection gates at the two canals. Following the congressional directive, the District will have to spend in excess of $45M for the parallel protection plan, while the OLD's expected costs to implement parallel protection are reduced by the same amount. This estimate was made by the study authors based on information contained in the minutes of OLD Board meetings and other sources.	19901017
Budget justification, FY 1993	Jan 29, 1992		This justification reports that the New Orleans East Unit is 90% complete (expected completion in January 2000), the New Orleans West Unit is 10% complete (expected completion in November 2013), and the Chalmette Unit is 97% complete (expected completion in January 1997).	19920129
ASA(CW) states administration policy on funding parallel protection plan	Jan 29, 1992		In a response to a letter from Congressman Livingston regarding federal funding the outfall canals, the ASA(CW) states that the parallel protection plans for the outfall canals, "provide interior drainage which normally is a non-federal responsibility." Consequently, funding for project work at the canals is not in the President's budget request. This establishes a budget precedent regarding outfall canals. In subsequent years, project work at the outfall canals is not included in the annual administration budget requests, and the work is instead funded by Congressional adds to the administration's requested appropriations, which the District uses to implement the work.	19920129a
SWB requests time	May 27,		The SWB had completed work on some project phases by 1989, but it	19920527

Event Name	**Start Date**	**End Date**	**Notes**	**Source**
extension for permit to dredge the 17th St. Canal	1992		was not until 1990 that it entered into an agreement with the OLD for combined dredging and flood protection works for the canal east bank. With work proceeding on that side of the canal, the SWB in 1991 signed an agreement with the East Jefferson Levee District for combined dredging and floodwall work on the canal west bank. With the timeframe for the SWB about to expire, SWB requests that the District grant a permit time extension to complete the work.	
District grants time extension for SWB permit to dredge the 17th St. Canal	Jun 22, 1992		The District grants a permit time extension until June 1977 and informs SWB that no more extensions will be forthcoming.	19920622
District memorandum to Division on annual inspection of completed works	Dec 14, 1992		In 1992, the following ratings for required maintenance of completed project features are given to local levee districts: Orleans-OUTSTANDING; Lake Borgne-OUTSTANDING ; East Jefferson-OUTSTANDING; Pontchartrain-OUTSTANDING .	19921214
Corps Coastal Engineering Research Center (CERC) conducts storm surge model study	1993		The District contracts with CERC to perform a model pilot study to assess the impacts of changes in SHP parameters on design stages, and the effects of changes in the relationship between local mean sea level (MSL) and the datum used for construction (NGVD) with respect to the required elevations of structures designed to prevent overtopping form a SPH surge derived in the MSL frame of reference. The CERC study uses an early version of the more sophisticated Advanced Circulation (ADCIRC) surge model to validate the original surge estimates for project under the original SPH parameters. That application of the ADCIRC model reinforces the 1980s-era WIFM modeling findings that the 1962-era surge estimates may have overestimated the surge for the lakeshore, and underestimated the SPH surge along the IHNC corridor and the eastern boundary of Chalmette. With respect to the latest 1979 SPH parameters, CERC uses the ADCIRC model to conclude that the	19930000

Event Name	Start Date	End Date	Notes	Source
			changes produce an increase in surge heights of 1-2 feet for certain storm tracks under one set of assumptions, while under another set of assumptions the new SPH parameters produce little change in the 1962-era surge estimates. The CERC study also concludes that local MSL had increased with respect to NGVD by approximately one foot since 1929. Based on these findings, CERC recommends pursuing a thorough hydrodynamic modeling of the basin and reevaluation of the project using ADCIRC and a statistical procedure using the full database on historical storms within a joint probability approach or empirical simulation technique.	
Budget justification, FY 1994	Apr 5, 1993		This budget justification reports that the New Orleans East Unit is 90% complete (expected completion in 2000), the New Orleans West Unit is 12% complete (expected completion in 2013), and the Chalmette Unit is 98% complete (expected completion in 1997).	19930405
District informs OLD that the District is taking over design work for the outfall canals	Jan 15, 1993		The District Engineer in a letter informs OLD that the District is reassigning $5.5M of the $12M appropriated by Congress for work at the outfall canals in FY 93 because the OLD design firm is behind schedule, and that the District is taking over parallel protection design work because the local sponsor design experiment failed.	Referenced in: 19930203 and 19930319
Meeting of OLD Board to consider performance of its contractor for design work at outfall canals	Feb 3, 1993		Board members consider the contractual performance, or lack thereof, of Design Engineering, Inc. (DEI), its consulting engineer, in connection with various Levee Board projects and to take appropriate action. DEI was under contract for eight separate projects, including hurricane protection projects and their coordination. These contracts were executed between 1985 and 1987. DEI had been paid $9.5M to date. A major contract was for coordination of flood protection projects was dated October 21, 1987. Orleans Ave Canal project delays are the subject of a January 15, 1993 letter from the District Engineer to the OLD. No action is taken because the District Engineer is unable to	19930203

Event Name	Start Date	End Date	Notes	Source
			attend the meeting.	
Meeting of the OLD Board to terminate contract with its contractor for design work at outfall canals	Mar 19, 1993		Special meeting to consider termination of certain contracts with its consultant (DEI) that cover LP&VHPP work. The District Engineer attends the meeting and states that issue is timely work performance and quality. The resolution to terminate is adopted. The minutes of this meeting provide background information regarding tension between the District and the OLD regarding management of the parallel protection plan.	19930319
Change to North American Vertical Datum of 1988 (NAVD88)	Jun 24, 1993		Federal Register, Vol. 58, No. 120 (June 24, 1993) reports decision by federal Geodetic Control Subcommittee to affirm NAVD88 as the official civilian vertical datum for surveying and mapping activities in U.S. performed or financed by the federal government.	19930624
OLD requests datum adjustment for outfall canals	Aug 13, 1993		OLD letter to the District Chief Engineering notes that construction plans for the Orleans Avenue Canal parallel protection are based on a 1983 datum benchmark levels, while plans for the London Avenue Canal are based on 1964 benchmark levels. The OLD writes, “According to our records there is an adjustment required between these two datums. The adjustment required makes elevation of flood protection for the Orleans canal higher than that for the London canal. This appears to be an intolerable situation. Please adjust as may be required so as to provide maximum protection for both canals.”	19930813
Plans and specifications - Contract #3, London Avenue Canal	Nov 1993		For the two areas of the canal floodwalls that breached during Hurricane Katrina, specifications included PZ-22 sheet pile to tip elevation -16 and top of wall at elevation 14.4 feet.	19931100

Event Name	Start Date	End Date	Notes	Source
District memorandum to Division on annual inspection of completed works	Dec 22, 1993		In 1993, the following ratings for required maintenance of completed project features are given to local levee districts: Orleans-OUTSTANDING; Lake Borgne-OUTSTANDING; East Jefferson-OUTSTANDING; Pontchartrain-OUTSTANDING.	19931222
Budget justification, FY 1995	1994		This budget justification reports that the New Orleans East Unit is 90% complete (expected completion in 2000), the New Orleans West Unit is 12% complete (expected completion in 2013), and the Chalmette Unit is 98% complete (expected completion in 1997).	19940000
Headquarters guidance on NAVD88	Jan 1, 1994		Engineer Technical Letter 1110-1-152 provides technical advice for implementation procedures to convert from the National Geodetic Vertical Datum of 1929 (NGVD29) to the North American Vertical Datum of 1988 (NAVD88). Says that the transition to NAVD88 will result in more accurate vertical reference datum that has removed leveling errors, and accounts for subsidence and other changes in elevation.	19940101
District request to conduct a model study to reevaluate existing degree of protection	Sep 20, 1994		Memorandum from the District to the Division cites the CERC pilot surge study results and recommendations as well as earlier 1980s-era WIFM modeling. It requests authority from the Division to conduct a numerical model study of project protection using the ADCIRC model and modern data. The District notes that the restudy would be conducted with a view towards insuring that the authorized degree of protection is uniformly designed and constructed throughout the protection network.	19940920
District memorandum to Division on annual inspection of completed works	Dec 19, 1994		In 1994, the following ratings for required maintenance of completed project features are given to local levee districts: Orleans-OUTSTANDING; Lake Borgne-OUTSTANDING; East Jefferson-OUTSTANDING; Pontchartrain-OUTSTANDING.	19941219

Event Name	Start Date	End Date	Notes	Source
Budget justification, FY 1996	1995		This justification reports that the New Orleans East Unit is 90% complete (expected completion in 2000), the New Orleans West Unit is 12% complete (expected completion in 2013), and the Chalmette Unit is 98% complete (expected completion in 1997).	19950000
ADCIRC surge model refinement and testing	1995	2004	The District, noting problems with the ADCIRC model associated in part with its inability to mimic known events, decides to pursue further model refinement and testing before applying the model to reevaluate project protection. An effort to improve the model is undertaken from 1995 to 2004, and the model is subjected to independent technical review in 2003-2004 timeframe.	19950000a
District memorandum to Division on annual inspection of completed works	Dec 12, 1995		In 1995, the following ratings for required maintenance of completed project features are given to local levee districts: Orleans-OUTSTANDING; Lake Borgne-OUTSTANDING; East Jefferson-OUTSTANDING; Pontchartrain-OUTSTANDING.	19951212
Budget justification, FY 1997	Mar 18, 1996		This budget justification reports that the New Orleans East Unit is 90% complete (expected completion not given), the New Orleans West Unit is 12% complete (expected completion not given), and the Chalmette is 98% complete (expected completion not given).	19960318
Water Resource Development Act of 1996	Oct 12, 1996		PL 109-843. Includes a modification of the project to provide that St. Bernard Parish and the Lake Borgne Basin Levee District shall not be required to pay the unpaid balance, including interest, of their cost-share for the project	19961012
District memorandum to Division on annual inspection of completed works	Dec 13, 1996		In 1996, the following ratings for required maintenance of completed project features are given to local levee districts: Orleans-OUTSTANDING; Lake Borgne-OUTSTANDING; East Jefferson-OUTSTANDING; Pontchartrain-OUTSTANDING.	19961213

Event Name	Start Date	End Date	Notes	Source
Budget justification, FY 1998	Feb 10, 1997		This budget justification reports that the New Orleans East Unit is 90% complete (expected completion in 2013), the New Orleans West Unit is 12% complete (expected completion in 2013), and the Chalmette Unit is 98% complete (expected completion in 2006).	19970210
Supplemental agreement between OLD, East Jefferson Levee District (EJLD), SWB, and the District.	Feb 18, 1997		The EJLD agrees to cost-share the frontal protection for pump no 6 at the 17th St. Canal. The OLD and the EJLD will share the local cost on a 76.5%- /23.5% basis, respectively. This arrangement is being made because the 17th St. Canal pumping station drains part of Jefferson Parish. The agreement provides the necessary assurances from the SWB, the EJLD, and the OLD for this arrangement.	19970218
Supplemental agreement between OLD, SWB and the District	Feb 18, 1997		Part of the work remaining on the High Level Plan is to provide frontal protection for the pumping stations on the three canals. The pumping stations are on property under control of the SWB and they want to maintain the protection after completion of the project. The OLD concurs with this arrangement. The SWB wants to become a local sponsor for the fronting protection since it must provide rights of way and operation and maintenance. The OLD wishes to remain local sponsor for all other purposes previously agreed to, and to retain ownership of the fronting protection improvements subject to the right and obligation of SWB to operate and maintain. The agreement provides the necessary assurances and reassurances from the SWB and the OLD for this arrangement.	19970218a
District memorandum to Division on annual inspection of completed works	Dec 24, 1997		In 1997, the following ratings for required maintenance of completed project features are given to local levee districts: Orleans-OUTSTANDING; Lake Borgne-OUTSTANDING; East Jefferson-OUTSTANDING; Pontchartrain-OUTSTANDING.	19971224
Budget justification, FY	Feb 2,		This budget justification reports that the New Orleans East Unit is 90%	19980202

Event Name	Start Date	End Date	Notes	Source
1999	1998		complete (expected completion in 2013), the New Orleans West Unit is 50% complete (expected completion in 2013), and the Chalmette Unit is 98% complete (expected completion in 2009).	
Hurricane Georges	Sep 18, 1998		This hurricane passes over the Florida Keys and eventually veers away from New Orleans into southern Mississippi. Hurricane damage estimates in the United States exceed $5 billion.	19990800
District memorandum to Division on annual inspection of completed works	Dec 15, 1998		In 1998, the following ratings for required maintenance of completed project features are given to local levee districts: Orleans-OUTSTANDING; Lake Borgne-OUTSTANDING; East Jefferson-OUTSTANDING; Pontchartrain-OUTSTANDING.	19981215
Budget justification, FY 2000	Feb 1, 1999		This budget justification reports that the New Orleans East Unit is 90% complete (expected completion to be determined), the New Orleans West Unit is 50% complete (expected completion to be determined), and the Chalmette Unit is 98% complete (expected completion to be determined)	19990201
Governor requests Corps help in securing Cat 4/5 recon study	Apr 21, 1999		Alarmed by the near miss of Hurricane Georges, the LA Governor writes to the Chief of Engineers seeking help in getting funding and authority to develop a plan for protection against a category 5 storm for all of Southeast LA. He states, "In my opinion, expeditious achievement of this goal depends on the federal government, through the Corps, taking the lead in developing a comprehensive plan and providing the bulk of the funding..."	19990421
Cat 4/5 recon study authorized by Congress	Apr 22, 1999		Study authorized by resolution adopted by the H.R. Committee on Transportation and Infrastructure. It directs the Corps to review the Chief's reports for several LA hurricane protection projects, including LP&VHPP, New Orleans to Venice, Grand Isle & Vicinity, as well as "other pertinent reports with a view to determining whether any modifications of the recommendations contained therein are	Referenced in: 20020628

Event Name	Start Date	End Date	Notes	Source
			advisable...to provide a higher level of hurricane protection for category 4 or 5 storms."	
Budget justification, FY 2001	Feb 7, 2000		This budget justification reports that the New Orleans East Unit is 90% complete (expected completion to be determined), the New Orleans West Unit is 50% complete (expected completion to be determined), and the Chalmette Unit is 98% complete (expected completion to be determined).	20000207
Initial appropriations for Cat 4/5 recon study	2000		The 2001 Energy & Water Appropriations Act includes $100K added by Congress to initiate a General Reconnaissance Study specifically for the Hurricane Protection, LA area.	Referenced in: 20020628
District proposes to adopt NAVD88	Oct 26, 2000		District memorandum to Division Chief of Engineering states, "In the 15 years since adopting [the 1985 District policy on benchmarks], the NGS has no longer performed the surveying of our reference benchmarks to publish new epochs and, most assuredly, we have witnessed continued subsidence. Until recently there has been very little alternative for maintaining accurate vertical control...It is becoming increasingly untenable to maintain the existing policy. We are proposing to use the NAVD88 for future work on all projects. All of our partners are using this datum for their work, and the existing policy is causing great confusion. We propose to abandon the 1985 policy and request your concurrence." Further notes District proposal to implement GPS Continuously Operating Reference Stations (CORS) to measure and accommodate subsidence in the area.	20001026
District memorandum to Division on annual inspection of completed works	Dec 12, 2000		In 2000, the following ratings for required maintenance of completed project features are given to local levee districts: Orleans-ACCEPTABLE; Lake Borgne-NOT DOCUMENTED; East Jefferson-ACCEPTABLE; Pontchartrain- NOT DOCUMENTED.	20001212
District requests	Jan 30,		District letter to the Division Engineer notes that because the study	20010130

Event Name	Start Date	End Date	Notes	Source
increase in Cat 4/5 recon study funding & duration.	2001		encompasses 5 projects, an extensive area, and requires coordination with many local interests, reconnaissance study funding and duration limits are not sufficient. Requests a minimum of $500,000 and duration of 18 months for the study.	
Division approves District switch to NAVD88	Jan 31, 2001		Division memorandum to the District Engineer concurs with the District proposal to use NAVD88 for future work on all projects. It notes, "Hurricane protection projects under construction or to be constructed in the future will use the NAVD88 benchmark data," and that if the CORS system proves accurate for determining benchmark elevations, "MVD and NOD should re-evaluate the above policy to consider use of the CORS benchmark information in lieu of the NAVD88 benchmark information. Further, the NOD should at that time begin evaluation of completed projects to determine whether or not modifications are necessary to achieve authorized levels of protection."	20010131
Division endorses District request for increased Cat 4/5 recon study funding and duration	Feb 2001		Letter from Division Director of Planning & Programs Management to Headquarters endorses District request for more study money and time. It notes, "We see the key to the District's request in their statement that the geographic and hydrodynamic complexity of the area necessitates consideration of alternatives other than simply raising elevations of existing structures."	20010200
Headquarters approves increase in Cat 4/5 recon study funding and duration.	Mar 9, 2001		Letter from Headquarters Chief of Planning to the Division Engineer approves increase in the cost and duration of the reconnaissance study to $500,000 and 18 months.	20010309
Budget justification, FY 2002	Apr 3, 2001		This budget justification reports that the New Orleans East Unit is 90% complete (expected completion to be determined), the New Orleans West Unit is 50% complete (expected completion to be determined), and the Chalmette Unit is 98% complete (expected completion to be	20010403

Event Name	Start Date	End Date	Notes	Source
			determined).	
District memorandum to Division on annual inspection of completed works	Dec 2001		In 2001, the following ratings for required maintenance of completed project features are given to local levee districts: Orleans-OUTSTANDING; Lake Borgne-OUTSTANDING; East Jefferson-OUTSTANDING; Pontchartrain-OUTSTANDING.	20011200
Budget justification, FY 2003	Feb 4, 2002		This budget justification reports that the New Orleans East Unit is 90% complete (expected completion in 2013), the New Orleans West Unit is 60% complete (expected completion in 2013), and the Chalmette Unit is 98% complete (expected completion in 2008).	20020204
Congressional appropriations for Cat 4/5 recon phase	2002	2006	Congressional adds for recon phase provide $300K for FY02, $250K for FY03, $100K for FY04, and $100K for FY05. The Corps trys to get local sponsor to cost-share a feasibility study through FY05. The FY06 budget submission includes new start feasibility study, but it is known to have issues related to securing a local sponsor, and is given a low HQ ranking and not recommended to OMB. The 3rd Supplemental Act morphed the study into the current study at full federal cost (the current study is referred to in the 4th Supplemental Act as "Louisiana coastal protection and restoration plan").	Personal communication with Harry Kitch, Corps Headquaters
District direction on NAVD88	Apr 11, 2002		District internal memorandum from Chief of Engineering to other branch chiefs states, "It is the policy of Engineering Division to use those benchmarks that best define vertical control with respect to the NAVD88 datum...Survey section personnel...will visit District benchmarks as they are needed to update their vertical elevations through use of the Continuously Operating Reference Stations (CORS) associated with LSU's GULFNET system. This system allows us to more accurately define vertical elevations and will provide information to predict subsidence."	20020411

Event Name	Start Date	End Date	Notes	Source
Times Picayune articles on hurricane risk	Jun 2002		Five-part series ("Washing Away") published in New Orleans Times Picayune. One of several published reports on hurricane dangers in New Orleans.	
State letter of intent for Cat 4/5 feasibility study	Jun 19, 2002		Letter from the LA Department of Development and Transportation to the District Project Manger acknowledges receipt of draft recon study and announces intent to sponsor feasibility study. "The state of LA strongly supports the concept of providing higher levels of hurricane protection in southeast LA and supports moving forward into the feasibility phase. The satisfactory completion of negotiations related to the Project Management Plan and the costs contained therein are critical to the execution of a feasibility study cost-sharing agreement with the Corps. This Department intends to form a coalition of affected southeast LA communities in order to provide the financial resources to go forward with the project."	20020619
Cat 4/5 recon study letter report	Jun 28, 2002		The study seeks to determine whether detailed studies are warranted to investigate increased levels of hurricane protection in an extensive area of Southeast Louisiana. The study developes 4 plans for east of the Mississippi River, and 5 plans for west of the river. Due to limited resources, the analysis focuses on one structural plan providing increased protection for the East Jefferson Basin. Among other structures, that plan includes butterfly valve gates for the 17th St. Canal. Estimated average annual costs for the E. Jefferson plan are $2.5 million, and estimated annual benefits are $15.2 million. Based on this preliminary finding of net benefits, the District Engineer recommends that the Hurricane Protection Study, LA proceed into the feasibility phase contingent upon the availability of funds and execution of a cost-sharing agreement with a local sponsor.	20020628

Event Name	Start Date	End Date	Notes	Source
District requests Division approval of Cat 4/5 recon report & state letter of intent for feasibility phase	Jul 1, 2002		The District notes, "Because extensive coordination is underway with the State of LA, levee boards and local governments in the study area, a final Project Management Plan is not yet available... The total estimated cost of the feasibility study is $9.4 million, and the duration of the study is estimated at 6 years." Requests approval of analysis, state letter of intent, and approval to execute feasibility report cost-sharing agreement upon completion of negotiations. Notes that similar memo sent to Headquarters for concurrent review.	20020701
Division comment on local sponsor financing of Cat 4/5 feasibility study	Aug 5, 2002		Letter from Division Management Director to the District Engineer comments, "The potential magnitude of this project, in addition to all the projects already being sponsored by the State of LA, brings into question whether the State of LA has the resources to fully participate in increasing the protection. A good financial plan to ensure that adequate resources are available should be part of the feasibility effort."	20020805
Headquarters approves Cat 4/5 recon study and State letter of intent for feasibility phase	Aug 16, 2002		Letter from the HQ Chief of Planning to the Division Engineer approves the reconnaissance study analysis and state letter of intent for proceeding into the feasibility phase of planning.	20020816
Public meeting on Cat 4/5 recon & feasibility studies	Oct 9, 2002		District staff meet with state and local officials in Metarie to present recon study results and review the content, cost, and duration of the proposed feasibility study, and solicit local sponsors for that study. State and local officials express the need for enhanced protection but also raise serious concerns about funding project implementation. State and local officials note that they can't even get enough funding to complete existing projects and studies. Many participants said that existing projects should first be finished before moving forward with projects providing greater protection. The final speaker notes that Cat 4/5 protection could be implemented only if Congress provided 100% federal financing for project design and construction.	Audio tapes of the meeting provided by Mervin Morehiser of the Corps New Orleans District

Event Name	Start Date	End Date	Notes	Source
District memorandum to Division on annual inspection of completed works	Dec 2002		In 2002, the following ratings for required maintenance of completed project features are given to local levee districts: Orleans- ACCEPTABLE; Lake Borgne- ACCEPTABLE; East Jefferson- ACCEPTABLE; Pontchartrain- ACCEPTABLE.	20021200
District internal memorandum affirms new datum policy	Dec 20, 2002		District memorandum from the Chief of Eng. to other branch chiefs, section chiefs, functional team leaders, and technical managers states, "It is the policy of Engineering Division to use the NAVD88 datum for all vertical control and for gages...No meaningful conversion between old datums [NGVD29] is possible without proper field investigations and even then could result in an approximation at best...It is the intent of this policy that the assigned benchmark elevations represent a snapshot, and may change on future contracts depending on benchmark movement. Engineers must use sound engineering judgment in employing the NAVD88 datum, recognizing that projects have already been designed and/or constructed using the NGVD29 datum against various epochs and that projects may require a significant number of years from conception to completion, and therefore allowances must be made for vertical movement."	20021220
Budget justification, FY 2004	Feb 3, 2003		This budget justification reports that the percent complete and expected completion dates for all project units is “to be determined”	20030203
Article on hurricane risks in New Orleans	Jun 2003		Detailed article (“The Creeping Storm”) on recent modeling of growing hurricane protection risks in Southeast LA. Notes that efforts to protect New Orleans from category 4 or 5 storms would take 30 years to complete, and the feasibility study alone would cost as much as $8M.	Civil Engineering Magazine
District memorandum to Division on annual inspection of completed works	Dec 8, 2003		In 2003, the following ratings for required maintenance of completed project features are given to local levee districts: Orleans- ACCEPTABLE; Lake Borgne- ACCEPTABLE; East Jefferson- ACCEPTABLE; Pontchartrain- ACCEPTABLE.	20031208

Event Name	Start Date	End Date	Notes	Source
Budget justification, FY 2005	Feb 2, 2004		This budget justification reports that the New Orleans East Unit is 91% complete (expected completion to be determined), the New Orleans West Unit is 65% complete (expected completion to be determined), and the Chalmette Unit is 98% complete (expected completion to be determined).	20040202
Independent technical review of ADCIRC surge model development	Jan 31, 2004		"Review of the Application of the Numerical model ADCIRC for Storm Surge Prediction in the New Orleans, LA, Vicinity." The document explains the four-year effort to evaluate the ability of the model to determine the adequacy of existing levees and protective works.	20040131
Hurricane Pam emergency planning exercise	Jul 2004		Emergency officials from 50 parish, state, federal, and volunteer organizations participate in a hurricane simulation exercise to help officials develop joint response plans for a catastrophic hurricanes in LA. The exercise uses realistic weather and damage information developed by the NWS, the Corps, the LSU Hurricane Center and other state and federal agencies.	20040723
District memorandum to Division on annual inspection of completed works	Dec 20, 2004		In 2004, the following ratings for required maintenance of completed project features are given to local levee districts: Orleans- ACCEPTABLE; Lake Borgne- ACCEPTABLE; East Jefferson- ACCEPTABLE; Pontchartrain- ACCEPTABLE.	20041220
Budget justification, FY 2006	Feb 7, 2005		This budget justification reports that the New Orleans East Unit is 92% complete (expected completion date to be determined), the New Orleans West Unit is 65% complete (expected completion date to be determined), and the Chalmette Unit is 97% complete (expected completion date to be determined).	20050207
Hurricane Katrina	Aug 29, 2005			

Appendix B. Glossary of Terms

Act of Assurances – (Also known as Local Cooperation Agreement and presently as Project Cooperation Agreement) A document signed by a non-federal project sponsor that expresses the sponsor's willingness to comply with cost-sharing and all other requirements set forth in project authorization. It includes a financial plan for verification of ability to pay and must be approved by the federal government.

Advanced Circulation Model (ADCIRC) – Sophisticated computer model developed in the 1990s and in use today to calculate detailed estimates of hurricane tidal surges by location based on specified hurricane parameters.

Apparent Subsidence (relative sea level rise) – Lowering of the land relative to local water surface levels due to the combination of geologic subsidence and rising sea level.

Appropriation – The provision of funds, through an annual appropriations act or a permanent law, for federal agencies to make payments out of the Treasury for specified purposes. The formal federal spending process consists of two sequential steps: congressional authorization and then appropriation. Typically set forth in the annual Energy and Water Development Appropriations Acts.

Authorization - A statutory provision that obligates funding for a program or agency. An authorization may be effective for one year, a fixed number of years, or an indefinite period. An authorization may be for a definite amount of money or for "such sums as may be necessary." The formal federal spending process consists of two sequential steps: congressional authorization and then appropriation. Authorizations are established by Congress in Public Law.

Barrier Plan – The plan alternative for the LP&VHPP recommended in the 1962 Interim Survey Report for the provision of SPH surge protection. As authorized in 1965, it included levees for the Chalmette unit, barrier gates at Chef Monteur Pass and the Rigolets, and low levees along the urban lakefront of south Lake Pontchartrain.

Benchmarks – Spatially distributed, marked vertical control points that are referenced to vertical datums. Local benchmarks serve as the reference or starting elevation when measuring levee and floodwall heights and their relationships to local water surface.

Budget Justification Sheet (BJS) – Document that provides background information to Congress in support of the budget request. It is prepared annually for each authorized project by all Corps districts and is reviewed by the Division and Headquarters, after consultation with the administration budget office. It includes historical financial data, project status, including percent complete, citation of relevant authorization, and Acts of Assurance signed by the non-federal project sponsors.

Central Pressure – The minimum level of atmospheric pressure within a hurricane at a specific time.

Citrus – A term used to refer to part of the LP&VHPP area. It includes Orleans Parish east of the Inner Harbor Navigation Channel (IHNC) and north of the Gulf Intracoastal Waterway (GIWW).

Chalmette – A term used to refer to part of the LP&VHPP area. It includes St. Bernard Parish and the Lower Ninth Ward of Orleans Parish.

Chiefs Report- (See Feasibility Report) **–** A final recommendation on a civil works project signed by the Chief of Engineers. Congress uses a favorable Chief's report as the basis for authorizing projects.

Coastal Engineering Research Center (CERC) – This Corps research center, which is presently called the Coastal and Hydraulics Laboratory, conducts research in the area of coastal development. It is part of the Corps Engineer Research and Development Center and is located in Vicksburg, MS.

Cost-Sharing – The allocation of cost for Corps of Engineers projects among non-federal sponsors and the federal government for both construction, and operations and maintenance. Cost-sharing percentages vary by project purpose. Local sponsor's requirements are accepted in the form of cash or in-kind contributions such as lands, easements or rights-of-way.

Data for Testifying Officers (DTO) – A document that provides background information for Corps officers testifying before Congress during budget hearings. It was prepared annually by the District and reviewed by the Division, until recent years. It comes in two parts. The first part is much like the BJS for that year. The second part provides more detailed background information in anticipation of issues and/or questions raised during the budget process.

Degree of Protection – Project performance standard based on normative policy guidance. For example, the degree of protection might be expressed as for the worst storm "reasonably possible" for the region, the "worst possible storm." or a storm/flood event of a given recurrence interval. Such expressions of intended protection against specific design events form the basis of project authorization.

Design Elevation (Design Grade) **–** A term denoting the height of levee and floodwall structures, expressed in feet relative to local mean sea level. Design elevation includes the sum of the stillwater surge elevation and either runup, in the case of interaction with wind-induced wave action, or freeboard. Design elevations for project structures are provided in the various project Design Memoranda.

Design Hurricane – The set of hurricane parameters selected by the reporting office as a basis for design of the proposed plan of improvement.

Design Memorandum – Detailed engineering and design document prepared for different project reaches by the District after project authorization. It presents final plans for the project and is reviewed by the Division, which registers formal feedback to the District in the form of endorsements. Copies of the document including endorsements are sent to Headquarters.

District – (See Reporting Office) **–** The decentralized or local level within the organizational structure of the U.S. Army Corps of Engineers. Districts carry the primary workload of the organization for planning and construction of projects.

Division – The mid-management organizational level of the U.S. Army Corps of Engineers. There are eight divisions in the United States, defined by watershed boundaries within the United States. Each division has subordinate district offices.

Headquarters – The highest organizational level of the U.S. Army Corps of Engineers. Located in Washington D.C., the executive office creates policy and plans future direction of all the other Corps organizations. The Chief of Engineers and the Director of Civil Works are located at Headquarters.

Economic Analysis – The formal quantification of project benefits and costs, which for the LP&VHPP was done by the District Economics and Social Branch. Since 1983, all reasonable alternative project plans are subject to systematic evaluation during the feasibility stage of planning with the purpose of maximizing national economic development with the proposed project.

Endorsement – Documented review of planned project technical or engineering features by higher authority. Design memoranda prepared by the district for an authorized project receive endorsements by the division office. The district office makes formal response to all endorsements, and this correspondence is published as part of the formal record.

Engineering Circular (EC) – Corps guidance document that sets out policy, and is parallel to an Engineering Regulation (ER), i.e. directive in nature, with the difference that applicability is transitory (one-time occurrence or otherwise temporary). Circulars remain active for no more than two years from the date of issuance. If after two years the guidance of a circular is still valid, then it is published as a regulation.

Engineering Manual- (EM) – Corps guidance documents that sets out technical guidance and directive/non-directive instruction and criteria of a continuing nature concerned primarily with engineering and design type projects.

Engineering Regulation (ER) – A Corps guidance document that sets out policies, responsibilities, and procedures of a continuing nature, prescribed exclusively for the Corps of Engineers mission.

Engineering Technical Letter (ETL) – A Corps document that sets out advance information on design, engineering, and construction matters. Technical letters are considered intermediary publications that will eventually be republished in more permanent media. They remain active for no more than five years from the date of issuance.

Feasibility Report – This represents the second phase of preauthorization project planning after a reconnaissance report. It describes the purposes for the proposed project and recommends an alternative to secure those purposes. The equivalent report for the LP&VHPP was the 1965 letter report of the Secretary of the Army. This is also known as the Chiefs report.

Fetch – The continuous area of water which the wind from a fixed direction may have unobstructed contact with the water surface.

Freeboard – The difference between the stillwater elevation levels of the design hurricane at a particular location and the design elevation of project structures at that location. For the LP&VHPP, it applies to project structures located where wave runup is not expected. Freeboard provides a margin of safety for settlement, subsidence, and other factors of uncertainty.

High Level Plan – The recommended plan for the LP&VHPP included in the 1984 Reevaluation Report. It replaced the Barrier Plan, eliminating the barrier gates at Chef Monteur Pass and the Rigolets, and included high levees along the urban lakeshore of south Lake Pontchartrain.

Hurricane Speed – The rate of forward movement of a hurricane.

Hurricane Surge – The mass of water causing an increase in elevation of the water surface at the time of a hurricane.

Hurricane Path (or Track) – The line connecting successive locations of central pressure of the hurricane.

Hurricane Tide – The elevation of the stillwater surge level at a given point during a hurricane. In inland lakes it is the sum of hurricane surge heights and additional local wind setup, but does not include wave setup.

In-kind Contribution – Non-cash contributions of project work by non-federal sponsors. It includes the fair market value of project related work completed by the sponsor according to Corps specifications. It also includes the value of lands, easements, and rights-of-ways.

Interim Survey Report – The original planning document for the LP&VHPP published in 1962. It included the recommendations of the reporting office and formed the basis for project authorization by Congress in 1965. (See Feasibility report and Chiefs report)

I-Wall – A floodwall structure in which sheet pile is often driven into an existing levee to achieve greater protection elevation within existing rights-of-way. Generally, exposed wall metal is capped with concrete.

Inspection of Completed Works – An Operations and Management (O&M) program that provides for Corps of Engineers annual inspections of flood control and hurricane protection project features constructed by the federal government and turned over to the local sponsor, who is then responsible for operation, maintenance and rehabilitation. The annual inspections involve visual evaluation of non-federal sponsors' compliance with required maintenance of completed project features.

Landfall – The arrival of a hurricane center on the coastline.

Levee – A protective structure built from earth. Design is based on quality and nature of available material (return frequency). Levees are built in a sequence of lifts to accommodate expected settlement.

Level of Protection – Project performance standard based on probability statistics for the design event. It is expressed in the form of a recurrence interval. Economic benefits are calculated on the basis of flood damages prevented from storms of higher probability using stage damage curves.

Local Mean Sea Level (MSL) – The average hourly height of the sea surface for all stages of the tide at specific locations, covering a period of at least 19 years. It is constantly changing at varying rates at different locations.

Local Sponsor – A non-federal entity (typically a government unit or association of such units) that enters into a legal partnership with the federal government for the planning, constructing, and funding of a Corps of Engineers project. Projects can not proceed beyond the reconnaissance level of planning without a local sponsor

National Environmental Policy Act – The National Environmental Policy Act (NEPA) [42 U.S.C. 4321 et seq.] was signed into law on January 1, 1970. The act establishes national environmental policy and goals for the protection, maintenance, and enhancement of the environment and it provides a process for implementing these goals within the federal agencies. The Act also establishes the Council on Environmental Quality (CEQ). All federal agencies are to prepare detailed statements assessing the environmental impact of and alternatives to major federal actions significantly affecting the environment. Such a statement is commonly referred to as an Environmental Impact Statements (EIS).

National Geodetic Vertical Datum of 1929 (NGVD) – This was the first of only two official national vertical geodetic datums that have been established to date. It was based on MSL as measured in 1929 at 21 locations in the U.S. and five in Canada. This datum did not match MSL at all locations when it was first established and did not change with sea level rise, although adjustments were made over time to reflect geologic subsidence as newer and more accurate leveling data were acquired.

North American Vertical Datum of 1988 (NAVD88) – This was the second official national vertical datum that replaced NGVD in 1993. It was based on MSL at only one location on the US-Canada border, and does not purport to represent local MSL at other locations. It works with Global Positioning System (GPS) satellites and offers improved stability and repeatability. The NOAA National Geodetic Survey in 2005 developed a new time-stamped, vertical reference framework for Southeast Louisiana, termed NAVD88(2004.65). This new reference framework provides an improved means to monitor regional and local subsidence and sea level rise, and for more accurately relating vertical datums to the design elevations of protective structures based on hydraulic assessments.

Outfall Canal – A drainage canal that carries pumped storm water from the interior of metro New Orleans to Lake Pontchartrain.

Overtopping – The amount of water passing over the top of a project structure as a result of wave runup or surge action.

Percent Complete – Information category included in the project annual Budget Justification Sheet that indicates progress toward the construction of individual project units as well as the entire project.

Plans and Specifications (P&S) – The detailed design of project components for the purpose of soliciting bids from private construction contractors.

Post Authorization Change (PAC) – Modification to an authorized project, at the discretion of the Chief of Engineers, for engineering or construction reasons to serve the project purposes authorized by Congress.

Pre-Katrina Protection Elevation – The actual elevation of project structures when Hurricane Katrina made landfall as measured against NAVD88 2004.65. Along most sections of the project, Pre-Katrina protection elevations of structures were below intended design elevations due to datum errors at the time of construction, and settlement and subsidence since construction.

Probable Maximum Hurricane – The hurricane that may be expected from the most severe combination of meteorological conditions that are reasonably possible in some region.

Reconnaissance Report – A project planning report prepared in the first stage of the Corps of Engineers project planning process. It is of limited scope, is fully-funded by the federal government, and forms the basis for seeking a local sponsor for the more detailed feasibility stage of the planning process, which is cost-shared.

Reevaluation Report – Reevaluation of the LP&VHPP plan published in 1984 in response to the court injunction of 1977. It recommends the High Level Plan in place of the Barrier Plan, and was approved at the discretion of the Chief of Engineers as a Post Authorization Change (PAC) in 1985.

Re-leveling – Periodic survey adjustments to benchmark elevations within the vertical control network to conform to the applicable geodetic vertical datum. These adjustments are used to account for local subsidence and other surface changes over time and are referred to as datum "epochs" associated with the year in which they were made.

Reporting Office – The originators of all planning activity for the LP&VHPP, which was the New Orleans District of the U.S. Army Corps of Engineers. (See District)

Runup – The vertical elevation above the stillwater surge level to which water rises on the face of a project structure as a result of wave action.

Settlement – Occurs when soils and other foundation materials under a project structure become compressed by the weight of the structure. It can lower the protection elevation of a structure over time.

Setup – The vertical rise in the stillwater surge level, above that which would occur without wind action caused by wind stresses on the surface of the water.

Significant Wave – A statistical term denoting waves having the average height and period of the highest one-third waves of a given wave train.

Standard Project Hurricane – A hurricane that may be expected from the most severe combination of meteorological conditions that are considered characteristic of some region.

Stillwater Level – The surge elevation of the water surface if all wave action were to cease.

Subsidence – The general decrease in the elevation of land throughout a region. It can lower the protection elevation of structures over time.

T-Wall – Concrete floodwall with lateral reinforcement for stability.

Vertical Datum – Reference system whereby geospatial coordinates (such as the elevations of hurricane protection structures) are consistently determined with respect to some reference surface.

Waterways Experiment Station (WES) – During the period of LP&VHPP planning and design, it was the principal research, testing and development facility of the U.S. Army Corps of Engineers. The facility is now known as the Engineer Research and Development Center (ERDC), which is located in Vicksburg, MS.

Wave Setup – The super elevation of the water surface above the hurricane tide height due to wave action alone**.**

Wave Train – A series of waves from the same direction.

WES Implicit Flood Model (WIFM) – A two-dimensional computer model developed in 1978 by the Waterways Experiment Station, which was used in the early 1980s to forecast storm surges by location based on specified hurricane parameters.

Wind Setup – The vertical rise in the stillwater surge level above that which would occur without wind action, caused by wind stresses on the surface of the water. Wind setup is a component of the hurricane surge height, and of hurricane tide in inland lakes.

Appendix C. Persons Interviewed

HQ = Corps Headquarters
MVD = Corps Mississippi Valley Division
MVN = Corps New Orleans District
IWR = Corps Institute for Water Resources

1. Current Corps Staff

Donald Basham, HQ
Walter Baumy, MVN
Carol Burdine, MVN
Ron Conner, IWR
Jerry Colletti, MVN
Marsha Demma, MVN
Gary Hawkins, MVN
Dan Hitchings, MVD
Janis Hote, MVN
Harry Kitch, HQ
Edwin Lyon, MVN
David Moser, IWR
M.K. Miles, HQ
Mervin Morehiser, MVN
Al Naomi, MVN
Nancy Powell, MVN
Dave Pezza, HQ
Norm Starler, IWR
Van Stutts, MVN
Leslie Waguespack, MVD
Harley Winer, MVN

2. Former Corps Staff

Fred Bayley, MVD
Ken Brown, MVN
Fred Caver, MVD
Lloyd Duscha, HQ
Les Edelmen, HQ
Roger Harris, MVD
Vald Heiberg III, MVN
Cecil Soileau, MVN
Eugene Tickner, MVN
Frank Weaver, MVD

Wayne Weiser, MVN
Tony Young, MVD

3. Others

Glenda Beudreaux, Orleans Levee District
Walter Baudier, Orleans Levee District and Design Engineering, Inc
Jim Huey, Orleans Levee District
Mike Jackson, Burk-Kleinpeter, Inc.
Vic Landry, Orleans Levee District/New Orleans Sewerage & Water Board
Shelby La Salle, Krebs, LaSalle, LeMieux Consultants, Inc.
Mona Nosari, Pontchartrain Levee District
Ed Preau, LA Department of Transportation & Development
Stephen Spencer, Orleans Levee District
Robert Turner, Lake Borgne Basin Levee District

Appendix D. Biographies of Report Authors

Douglas Woolley is a Professor Emeritus from Radford University where he taught for 30 years and served as the Director of the University's Center for Economic Education. Dr. Woolley received his PhD. in economics from the University of Connecticut.

Dr. Woolley was the Scientific Advisor to the Assistant Secretary of the Army for Civil Works [ASA(CW)] from 1983 to 1984, and as a planning and budget consultant to the ASA(CW) from 1985 to 2000. He prepared capital investment plans and other studies for the Arlington National Cemetery between 2000 and 2005. In 1999, he served as a member of the Committee to Assess the U.S. Army Corp of Engineers Water Resource Planning Procedures for the National Research Council. His research includes papers and presentations on community development, higher education, public investment analysis, and the use premise sets to expose risk and uncertainty for decision makers.

Leonard Shabman became a Resident Scholar in the Energy and Natural Resources Division of Resources for the Future on July 1, 2002. Prior to that time he was for 30 years on the faculty in the Department of Agricultural and Applied Economics at Virginia Tech. He also served as the Director of the Virginia Water Resources Research Center from 1995 until 2002. Dr. Shabman received his Ph.D. in economics from Cornell University.

Dr. Shabman has served as a Staff Economist at the United States Water Resources Council (October 1977-October 1978), as Scientific Advisor to the ASA(CW)(1984-1985), and as Visiting Scholar at the National Academy of Sciences National Research Council (2001). Dr. Shabman served as the Arthur Maass-Gilbert White Scholar at the Corps Institute for Water Resources from 2004 to 2006.

Dr. Shabman is currently a member of the National Academy of Sciences, National Research Council, Water Science and Technology Board and has been appointed to several Academies Committees including the committees on the Restoration of Aquatic Ecosystems, Flood Control for the American River, and Corps of Engineers Planning and Technical Review Procedures (Chair).

Dr. Shabman's research and publications includes papers and presentations on natural hazard management, wetlands management, public investment analysis, and the role of economic analysts in public policy formulation. Dr. Shabman has provided consultation and advice to a wide array of governmental and non-governmental organizations.