DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P.O. BOX 60267
NEW ORLEANS, LOUISIANA 70160-0267

REPLY TO
ATTENTION OF:

CELMN-ED-HC 20 Sep 94

SUBJECT: Lake Pontchartrain, La. and Vicinity Hurricane Protection Project - Model Study, Request for Authorization

Commander, Lower Mississippi Valley Division, ATTN: LMVED-WH

1. **Purpose.** We request authority to conduct a numerical model study of the Lake Pontchartrain and Vicinity Hurricane Protection Project. In your LMVED-TS 1st endorsement dated 19 Sep 85, subject NGS Benchmarks, you recommended reanalyzing hurricane protection works in high density urban areas where datum changes drastically reduce the level of protection, copy at Enclosure 1. With this in mind and in view of the lengthy period of construction of the Lake Pontchartrain Hurricane Protection Project, we recommend this model study. The model study will optimize all elements of the design and determine the existing degree of protection using the latest numerical techniques. We will establish the basis for this model study in this letter.

2. **Physical Setting.** The Lake Pontchartrain Hurricane Protection Project protects the New Orleans metropolitan area from storm surges originating in the Gulf of Mexico. The project protects the lives and property of about 1 million residents of the area. It insures protection from storm surge events up to and including the Standard Project Hurricane. The protected area is situated as much as 8 to 10 feet below sea level and must be protected from inundation with an extensive levee and pumping system. The SPH storm surge can raise the surface of surrounding water bodies adjacent to project levees as much as 12 feet above normal. In addition, high winds accompanying hurricanes can cause large waves to impinge on the project levees. Levees were designed to prevent overtopping from wave runup and hurricane surge. The levees and floodwalls exposed to hurricane surge, but not wave runup, were designed and constructed with freeboard, some with as little as 1 foot of freeboard. Enclosure 2 gives a brief description of the project area and illustrates SPH stillwater levels as well as designed and existing levee and floodwall heights.

3. **Background.**

a. The project was formulated in the 1950's and 1960's 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 in the project are nearing completion. Because of the extensive use of project 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. A brief history of the this hurricane protection design and its associated problems is at Enclosure 3.

b. During the early 1980's when the Lake Pontchartrain project was being reevaluated because of litigation, one of the more ambitious undertakings was an attempt by WES to restudy the hurricane surge using the 2-D WIFM model. The study was formulated by the District to answer questions about the influence of the proposed barrier plan structures on the hurricane surge. Significant spin-off findings from this numerical model study can be summarized by saying that water levels forecasted by the WIFM model suggest that some reaches of the project appear to provide protection against a storm greater than the SPH while other reaches seem to provide a lesser degree of protection; a summary is at Enclosure 4. We suspect that some levee reaches are over-designed, while others are under-designed. If this model study confirms our suspicions, then a wiser course of investment will be in raising deficient reaches.

c. In 1993 the New Orleans District contracted with CERC to perform a pilot model study to assess the impacts of changes in SPH hurricane parameters on design stages. The study also assessed the effects of changes in the relationship between Mean Sea Level (MSL) and NGVD with respect to the required elevation of levees designed to prevent overtopping from a storm surge derived in MSL frame of reference. As a result of their investigations CERC concluded that the changes in the SPH parameters had little effect on storm surge elevations; but that MSL had increased with respect to NGVD by approximately 1 foot since 1929. As a result of their study CERC recommended a thorough hydrodynamic modeling of the basin and reevaluation of the protection system using a statistical procedure which would make use of the full data base of historical storms such as the joint probability approach or the empirical simulation technique. Their report is at Enclosure 5.

CELMN-ED-HC
SUBJECT: Lake Pontchartrain and Vicinity Hurricane Protection Project - Model Study, Request for Authorization

4. **Plan Under Consideration.**

a. 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 protection 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 rigorous effort. A scope of work and estimate of time and cost for such a study were prepared by CERC in response to a request from NOD. (See Enclosure 6.)

b. Results from the numerical model will produce a grid of storm surge magnitudes for the 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.

5. **Recommendations.** We recommend the model study as outlined herein. Your comments and concurrence are requested.

FOR THE COMMANDER:

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as

W. EUGENE TICKNER
Chief, Engineering Division

9.28.94

CF: CERC
(wo/encls)

Background. The Lake Pontchartrain Hurricane Protection Project protects the New Orleans metropolitan area from high water levels in Lakes Pontchartrain and Borgne. The project protects the lives and property of about 1 million residents of the area. It insures protection for storm surge events up to and including the Standard Project Hurricane.

The project was formulated in the 1950's and 1960's using the technology available at that time. Hurricane parameters were provided by the National Weather Service and standard 1-D equations were used to route the hurricane storm surge into the shallow water bodies surrounding the project area and compute wind setup. Standard methodologies outlined in Technical Report No. 4 and nomographs provided by the Coastal Engineering Research Center (CERC) were used to determine wave heights and wave runup for design of levee heights and cross sections. Recorded gage data and historic high water marks were used to calibrate the 1-D hurricane surge models and analyze the frequency of occurrence.

Many reaches in the project are nearing completion, but almost 40 years have elapsed since the project's inception. In the intervening years more precise numerical techniques have been developed and many advances in the "State of the Art" of coastal engineering design have occurred. Observed phenomena such as sea level rise, deltaic subsidence and datum changes were not accounted for in the project formulation and could detrimentally affect the performance of the project. We have in the past attempted to quantify the combined magnitudes of these phenomena by revisiting the various datum plane adjustments for the several survey epochs that have been accomplished over the years. We can say with some degree of certainty that the combined effects of these phenomena approach a net change in the order of 1 foot over the past 30 year period of construction. 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.

A policy matter established in subsequent years after project construction began required that all future construction work done under the authorized Lake Pontchartrain project would use NGS's 1964 epoch benchmark that was in place when project construction was first initiated in 1966. This policy decision was formalized and justified in the mid-1980's when questions concerning differences in benchmarks from one survey epoch to the next produced problems in reporting to Congress the percentage of MR&T levee completed from one year to the next. When reporting using the 1983 benchmark data it appeared that the miles of MR&T levee remaining to be completed during the fiscal year was greater than the amount that was remaining in the previous fiscal year when an earlier epoch's benchmark was used. This of course was only one of the problems that changing benchmarks produced. The entire chain of correspondence formalizing the benchmark policy is attached as Enclosure 1. Significant to the issue at hand is that the benchmark policy for construction of the Lake

Encl 3

Pontchartrain project is yet another factor that exacerbates the problems associated with sea level rise, deltaic subsidence and datum changes. We draw your attention to paragraph c on page 4 of this enclosure which states "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."

Historic measured gage data was used to calibrate the original 1-D hurricane surge model. In the intervening years the amount of available stage records has doubled, with the newer data probably more accurate than the older records. Water levels approaching SPH design stages have been experienced at the western end of Lake Pontchartrain at Frenier, 12.1 feet during Hurricane Betsy and 13.0 feet during the 1915 Hurricane; and along the MRGO at Yscloskey, 11.7 feet during Hurricane Betsy and 11.6 feet during the 1915 Hurricane. But on the south shore of Lake Pontchartrain at the West End gage, stages of 5.4 feet were experienced in Hurricane Betsy and 6.7 feet in 1915; these stages are nowhere near the 11.5 foot SPH stage. West End has the longest period of record of any of the recording stations in the area. Data at West End from the early 1900's indicates that stages near SPH level occurred in 1893 and 1901, but have not been experienced in recent history. This indicates that some physical changes may have affected the hurricane stage relationship on the south shore of Lake Pontchartrain.

During the early 1980's when the Lake Pontchartrain project was being reevaluated because of litigation on the project, many simultaneous study efforts were undertaken to answer questions about the advisability of proceeding with the barrier plan as originally authorized by Congress or recommending moving to a high level plan which would necessitate raising the heights of the levees along the Lake Pontchartrain lakefront. One of the more ambitious undertakings was an attempt to restudy the hurricane surge phenomena using the 2-D WIFM model. The Study was formulated by the District to answer questions about the influence of the proposed barrier plan structures on the hurricane surge and their potential impact to the north shore in the Slidell, La. area. The numerical modeling was conducted by WES. Significant spin-off findings from this numerical model study that relate to the issue of confidence about our water level predictions and degree of protection provided by the project, can best be summarized by saying that water levels forecasted by the WIFM model suggest that the project as originally formulated may not afford the same degree of protection throughout its various separable areas and reaches. Some reaches appear to provide protection against a storm greater than the SPH while other reaches seem to provide a lesser degree of protection. To illustrate this point we have extracted snapshots of the maximum water levels forecasted by the WIFM model for an SPH intensity hurricane on a track critical to the Rigolets - Chef Menteur area for pre-Hurricane Betsy levee heights and high level plan levee heights; these are included

with Enclosure 4. These plots indicate that the extent and height of the project levee system has affected the design stillwater levels. However, some of these levees will require future lifts to maintain their design grades and decisions to do these lifts or not to do the lifts can best be answered by a comprehensive reanalysis of this project. We suspect that some levee reaches are over-designed, while others are under-designed. If this model study confirms our suspicions then a wiser course of investment will be in raising deficient reaches.

In 1993 the New Orleans District contracted with CERC to perform a pilot model study to assess the effects of two factors on the degree of protection afforded the project area by the old project design levee heights and cross sections. CERC was requested to assess the impacts of the change in SPH hurricane parameters and also the impacts of the relative changes in the Mean Sea Level with respect to NGVD on the actual elevation of the levees with respect to a MSL related storm surge. As a result of their investigations CERC concluded that the changes in the SPH parameters had little effect on storm surge elevations; but that MSL had increased with respect to NGVD by approximately 1 foot since 1929. As a result of their study CERC recommended a thorough hydrodynamic modeling of the basin and reevaluation of the protection system using a statistical procedure which would make use of the full data base of historical storms such as the joint probability approach or the empirical simulation technique, see Enclosure 5.

A model restudy will determine if the authorized degree of protection is uniformly designed and constructed throughout the project. A scope of work and estimate of time and cost for such a comprehensive model study were prepared by CERC in response to a request from NOD. Briefly, the tasks outlined for study are:

a. Develop a 2-D wave generation model of Lakes Pontchartrain and Borgne.

b. Develop a modified version of the ADCIRC model to predict storm surge in Lakes Pontchartrain and Borgne which includes wetting and drying. This task will include the capability for analyzing storm surge elevations along the open coast of Louisiana.

c. Develop a statistical analysis of the degree of protection afforded by various elements of the protective levee system surrounding Lakes Pontchartrain and Borgne.

A detailed cost estimate is Enclosure 6. As outlined the model restudy will be a joint effort with NOD and CERC sharing some modeling duties. The purchase of some computer equipment for the district will be required to perform their portion of the study in partnership with CERC.

Results from the numerical model will produce a grid of SPH storm surge magnitudes for the project area based on existing topography referenced to a consistent datum. The wave analysis will yield proper wave heights for design of each project reach. The statistical analysis will indicate the appropriate frequency of the SPH Hurricane as well as lower flood stage frequency relationships.

DRAFT

CEWES-CR-O 21 March 1994

A Proposal to Conduct
Modeling Studies of Storm Surge Effects
for Lake Pontchartrain, LA

by

U.S. Army Engineer Waterways Experiment Station
Coastal Engineering Research Center

Summary

This scope of work and estimate of time and cost were prepared in response to a request by the U.S. Army Engineer District, New Orleans (CELMN) for assistance in performing various tasks associated with storm surge impacts along the Lake Pontchartrain and Lake Borgne areas as well as along the open coast of Louisiana. This proposed work unit is a cooperative effort which will involve personnel of the Coastal Engineering Research Center (CERC) providing CELMN with the numerical models necessary for CELMN to conduct an in-house storm surge study over Lakes Pontchartrain and Borgne and the Louisiana coastline. Included in this proposal is the purchase of a high-resolution work station to allow CELMN to perform future surge analyses. CELMN and CERC engineers will work together to complete the proposed scope of work. The following proposal itemizes the total costs (billed at CERC rates) associated with each task of the proposal with a cost separation of proposed CERC costs and costs which will be performed by CELMN.

The primary objectives of this effort are to provide CELMN a numerical capability to perform accurate and detailed calculations of hurricane propagation, assist in the statistical frequency-of-occurrence analysis of maximum storm surge elevations, and train CELMN engineers on the application of the numerical procedures for applying the technology for future engineering studies. Storm surge elevations will be computed via the ADCIRC hydrodynamic model modified to allow for wetting and drying. Although the wetting/drying algorithm will be developed by CERC; shoreline data, levee location information, bathymetric data, and historic storm surge records necessary for model verification will be supplied to CERC by CELMN.

A modeling package will be developed which will permit District personnel the capability of selecting/constructing and generating hurricanes, computing the associated wind and pressure field, computing storm surge, and performing a frequency analysis of storm surge elevations. These capabilities will be initially performed on a mainframe computer (CRAY Y-MP) and transferred to a work station which will be purchased by CERC and transferred to the District. Training will be provided to CELMN personnel on the use and implementation of the analysis package on both the mainframe and work station environment. All software required for the analysis and visualization on the work station will be supplied to and installed at CELMN. Details of the tasks required to complete the scope of work follow.

Introduction

The CERC preformed a pilot study for hurricane surge elevations in the Lake Pontchartrain and Lake Borgne vicinity. The pilot study addressed coastal datums and evaluated the maximum storm surge in the study area as a function of critical hurricane tracks A and C using both the ADCIRC model and the PBL wind model. Conclusions of the study recommended a thorough hydrodynamic modeling and statistical stage-frequency study of the Lake Pontchartrain and Lake Borgne area. Follow-up meetings were held between personnel of CELMN and CERC to discuss other potential aspects of the study. As a result of the

Encl 6

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pilot study and subsequent meetings, CELMN requested a time and cost estimate for the following tasks:

a. Assistance in developing a 2-D wave generation model for Lakes Pontchartrain and Borgne and instruction in the use of the model.

b. Development of a modified version of the ADCIRC model to include wetting and drying. Assistance to CELMN to develop an in-house modeling capability to reanalyze the Lakes Pontchartrain and Borgne storm surge pilot study. Assistance will include the capability for analyzing storm surge elevations along the open coast of Louisiana.

c. Assist CELMN with development and execution of a statistical analysis of the degrees of protection afforded by various elements of the protective levee system surrounding Lakes Pontchartrain and Borgne.

d. Assist in the selection of a high resolution work station, purchase the selected hardware, install necessary software, and transfer the package to CELMN.

A scope of work to complete all of the above tasks is given below. CERC cost estimates for key task elements assume CELMN engineers will be working with CERC in the completion of the project, therefore, the proposal itemizes the total costs associated with each task of the proposal with a cost separation of CERC costs and CELMN costs (reflecting the cost if CERC performed the work).

The surge model, PBL hurricane model, wave model, frequency analysis model, and visualization software will be provided and installed at CELMN on the high-speed, high-resolution work station terminal selected by CERC in coordination with District staff. This transfer of software/hardware will include the training necessary to provide District engineers and scientists the in-house ability to fully investigate, analyze, and evaluate the impact of various storm surge related phenomena affecting District coastal areas. The following sections briefly describe the tasks required to complete the objectives of this proposal.

Task a. Development of 2-D Wave Generation Model

a.1 An existing 2-D wave model will be used to evaluate hurricane waves on Lake Pontchartrain and Lake Borgne. We propose to use a two dimensional, time dependent, second generation, shallow water, spectral wave model (WISWAVE 2.0) in combination with a planetary boundary layer (PBL) hurricane wind model to obtain estimates of wave conditions on Lakes Pontchartrain and Borgne. We are unaware of measured wave data for either lake. In the absence of measured data for Lake Pontchartrain, it is important to verify the model application to another small, shallow lake, to test whether the model results are reasonable for a different location with similar geometry. Comparisons will be made to hindcast and measured data from Lakes St. Clair and Okeechobee which may be used to verify wave estimates for Lakes Pontchartrain and Borgne under storm conditions. Other elements under this task are; set up the wind and wave models, test response to expected conditions, create a "user friendly" environment to run the models, and train of District personnel in use of the system.

Depending on the resolution of the WISWAVE grid and techniques used by CELMN to estimate run up and overtopping, it may be necessary to transform waves to points closer to shore. If this is the case, a combined wave refraction-diffraction model (REFDIF) will be used to calculate input for the run-up and over topping estimates.

The following time and cost estimates for element of Task a are proposed. The time represents the man-months of effort. Total time reflects the period of performance. Costs associated with item a.6 are those required to generate wave fields corresponding to the 25-30 hurricane events selected for the statistical training set.

Task Components		Time (months)	Total Cost-(CERC/CELMN) ($K)
a.1	WISWAVE and PBL model set up, verification and testing.	4	30 (30/0)
a.2	WISWAVE and PBL model system configuration.	1	10 (10/0)
a.3	REFDIF model set up, test, and include in system.	2	10 (10/0)
a.4	Training on system use.	1	15 (5/10)
a.5	Preparation of letter report documenting study.	1	5 (5/0)
a.6	Generation/verification of storm event associated wave fields	3	20 (5/15)
	Total	8	90 (65/25)

Task b. Development of 2-D Storm Surge Model

The development of a 2-D storm surge model for Lakes Pontchartrain and Borgne will necessitate the development of a wetting and drying capability for the existing 2-D ADCIRC model. In conjunction with this phase of the study, appropriate algorithms will be developed for computing storm surge over a grid which reflects the fact that as the surge rises, computational cells become inundated, thus increasing the spatial area of inundation. Because this task is essential to all other tasks of the storm surge study, it will be performed by CERC. Engineers at CERC will also develop the high resolution grid required for this task. An ASCII formatted database of bathymetry and shoreline location in latitude and longitude, as well as locations of the protective levee system, will be provided CERC by CELMN for CERC's incorporation into the high resolution grid. CELMN will provide direct assistance in the verification step (Task b.2) by providing surge elevation data for the two selected tropical storms.

An important component of this cooperative effort is the development of user oriented interfaces between the selected storm event, the PBL hurricane model, and the ADCIRC model. These interfaces will be developed and installed on the work station. CERC will then provide assistance to the District in applying this software, however, detailed documentation in the form of a users guide will be prepared by CELMN. Task b will be performed during the first year of the project. A time and cost estimate for Task b follow:

Task Components	Time (months)	Total Cost-(CERC/CELMN) ($K)
b.1 Development of high resolution grid	3	50 (20/30)
b.2 Develop wetting and drying and verify to surge data for hurricanes Juan and Betsy (or two other events selected by CELMN)	9	150 (125/25)
b.3 Develop user interface of between PBL, ADCIRC, and visualization software	1	10 (10/0)

b.4 Provide assistance and training on use of the models	2	45 (10/35)
Total	12	255 (165/90)

Task c. Perform Statistical Analysis of Protective System

A statistical analysis procedure for evaluating the degree of protection afforded by a levee system will be developed by CELMN with assistance from CERC. The necessary training set of storms will also be developed by CELMN with CERC assistance from the existing Dredging Research Program's (DRP) data base of tropical storm events. These data will be used by CELMN to develop input to the PBL model via the user interface software, to generate input to ADCIRC via the software of Task b. Production run ADCIRC simulations will be conducted by CELMN, with CERC assistance, to produce spatial distributions of peak storm surge under prescribed configurations of the protective system.

The spatial distribution of storm surge elevation will represent the input data base for the Empirical Simulation Technique (EST) based frequency model. Application of the EST and subsequent frequency computations necessary to quantify degrees of protection for the various elements comprising the protective system will be performed by CELMN with assistance by CERC. Results of the simulations will be interpreted by CERC and CELMN and incorporated into a final report. Primary production of the report will be done by CELMN, however, publication will be done at CERC. Task c will be performed during the second year of the project. CERC will provide 20 man days of assistance to the District for this task. The time and cost estimate for Task c shown below reflects the fact that CELMN will perform the majority of the work, with minimal assistance from CERC.

Task Components	Time (months)	Total Cost-(CERC/CELMN) (SK)
c.1 Development of storm event training set, perform PBL and ADCIRC simulations, and develop surge response vector data set.	3	20 (5/15)
c.2 Development of statistical approach for quantifying effectiveness of various degrees of surge protection.	6	50 (5/45)
c.3 Perform statistical analysis and prepare final report.	3	30 (10/20)
Total	12	100 (20/80)

Task d. Purchase of Work station and Software Installation/Verification

d.2 All numerical modeling and visualization components of this study will be made operational on an appropriate work station such that all future storm surge modeling efforts can be performed in-house by CELMN. This task will install and verify the necessary linkages and will develop training and documentation necessary use the system. The WS will be purchased under this task and will be delivered to CELMN at the conclusion of the project.

Task Components	Time (months)	Total Cost-(CERC/CELMN) ($K)
d.1.1 Purchase high resolution, Silicon Graphics (SGI) WS.	2.5	40 (40/0)
d.1.2 Install all numerical models on work station and verify proper execution	.5	10 (5/5)
d.1.3 Prepare documentation for input to Task a.1	.5	10 (5/5)
Total	3.5	60 (50/10)

SUMMARY OF COSTS	Total Cost-(CERC/CELMN)
SUMMARY OF COSTS:	K $
Task a. Development of 2-D Wave Generation Model	90 (65/25)
Task b. Development of 2-D Storm Surge Model	255 (165/90)
Task c. Statistical analysis of Protective System	100 (20/80)
Task d. Work Station Purchase and Tech Transfer	60 (50/10)
Total	505 (300/205)

The above proposal will provide CELMN a numerical capability and expertise for performing inhouse analyses of tropical storm propagation for all coastal areas of the State of Louisiana, including storm surge and associated wave propagation. The total cost for CERC's involvement is 300 K. This figure reflects a cooperative involvement between CERC and CELMN in which the total project cost of 505 K (if performed entirely by CERC) reflects a 300K CERC effort and a 205K CELMN effort.